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## Ecological functions and environmental fate of exopolymers of Acidobacteria

Costa, O.Y.A.

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# References

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**A**

- Abbas AS & Edwards C (1990) Effects of metals on *Streptomyces coelicolor* growth and actinorhodin production. *Appl Environ Microbiol* **56**: 675-680.
- Alami Y, Achouak W, Marol C & Heulin T (2000) Rhizosphere soil aggregation and plant growth promotion of sunflowers by an exopolysaccharide-producing *Rhizobium* sp strain isolated from sunflower roots. *Appl Environ Microbiol* **66**: 3393-3398.
- Alneberg J, Bjarnason BS, de Bruijn I, Schirmer M, Quick J, Ijaz UZ, Lahti L, Loman NJ, Andersson AF & Quince C (2014) Binning metagenomic contigs by coverage and composition. *Nat Methods* **11**: 1144-1146.
- Amellal N, Burtin G, Bartoli F & Heulin T (1998) Colonization of wheat roots by an exopolysaccharide-producing *Pantoea agglomerans* strain and its effect on rhizosphere soil aggregation. *Appl Environ Microbiol* **64**: 3740-3747.
- Amellal N, Bartoli F, Villemin G, Talouizte A & Heulin T (1999) Effects of inoculation of EPS-producing *Pantoea agglomerans* on wheat rhizosphere aggregation. *Plant Soil* **211**: 93-101.
- Amézketa E (1999) Soil Aggregate Stability: A Review. *J Sustain Agr* **14**: 83-151.
- Angers DA & Mehruys GR (1989) Effects of Cropping on Carbohydrate Content and Water-Stable Aggregation of a Clay Soil. *Can J Soil Sci* **69**: 373-380.
- Anwar MA, Kralj S, Pique AV, Leemhuis H, van der Maarel MJEC & Dijkhuizen L (2010) Inulin and levan synthesis by probiotic *Lactobacillus gasseri* strains: characterization of three novel fructansucrase enzymes and their fructan products. *Microbiology* **156**: 1264-1274.
- Ashraf M, Hasnain S, Berge O & Mahmood T (2004) Inoculating wheat seedlings with exopolysaccharide-producing bacteria restricts sodium uptake and stimulates plant growth under salt stress. *Biol Fertil Soils* **40**.
- Aspiras RB, Allen ON, Harris RF & Chesters G (1971) Aggregate stabilization by filamentous microorganisms. *Soil Sci* **112**: 3.
- Atlas RM (2010) *Handbook of microbiological media*. CRC Press c2004., Boca Raton, Florida.
- Ayeldeen M, Negm A, El-Sawwaf M & Kitazume M (2017) Enhancing mechanical behaviors of collapsible soil using two biopolymers. *J Rock Mech Geotech Eng* **9**: 329-339.
- Azeredo J & Oliveira R (2000) The role of exopolymers in the attachment of *Sphingomonas paucimobilis*. *Biofouling* **16**: 59-67.
- Aziz RK, Bartels D, Best AA, et al. (2008) The RAST Server: Rapid Annotations using Subsystems Technology. *BMC Genomics* **9**.

**B**

- Bae J, Oh E & Jeon B (2014) Enhanced transmission of antibiotic resistance in *Campylobacter jejuni* biofilms by natural transformation. *Antimicrob Agents Chemother* **58**: 7573-7575.
- Baldock JA (2002) Interactions of organic materials and microorganisms with minerals in the stabilization of soil structure. *Interactions between soil particles and microorganisms*, Vol. 8 (Huang PM, Bollag J-M & Senesi N, eds.), John Wiley & Sons, Ltd, England.
- Banerjee D, Jana M & Mahapatra S (2009) Production of exopolysaccharide by endophytic *Stemphylium* sp. *Micol Appl Int* **21**: 6.
- Bao Y, Dolfin J, Wang B, Chen R, Huang M, Li Z, Lin X & Feng Y (2019) Bacterial communities involved directly or indirectly in the anaerobic degradation of cellulose. *Biol Fertil Soils* **55**: 201-211.
- Barboza NR, Morais MMCA, Queiroz PS, Amorim SS, Guerra-Sá R & Leão VA (2017) High manganese tolerance and biooxidation ability of *Serratia marcescens* isolated from manganese mine water in Minas Gerais, Brazil. *Front Microbiol* **8**.
- Barns SM, Takala SL & Kuske CR (1999) Wide distribution and diversity of members of the bacterial kingdom Acidobacterium in the environment. *Appl Environ Microbiol* **65**: 1731-1737.
- Beare MH, Hendrix PF, Cabrera ML & Coleman DC (1994) Aggregate-protected and unprotected organic matter pools in conventional- and no-tillage soils. *Soil Sci Soc Am J* **58**: 787.
- Becker A, Katzen F, Pühler A & Ielpi L (1998) Xanthan gum biosynthesis and application: a biochemical/genetic perspective. *Appl Microbiol Biotechnol* **50**: 145-152.

- Belova SE, Ravin NV, Pankratov TA, Rakitin AL, Ivanova AA, Beletsky AV, Mardanov AV, Sinnenhe Damsté JS & Dedysh SN (2018) Hydrolytic Capabilities as a Key to Environmental Success: Chitinolytic and Cellulolytic *Acidobacteria* From Acidic Sub-arctic Soils and Boreal Peatlands. *Front Microbiol* **9**.
- Bengtsson-Palme J, Ryberg M, Hartmann M, et al. (2013) Improved software detection and extraction of ITS1 and ITS2 from ribosomal ITS sequences of fungi and other eukaryotes for analysis of environmental sequencing data. *Methods Ecol Evol* **4**.
- Bergmann GT, Bates ST, Eilers KG, Lauber CL, Caporaso JG, Walters WA, Knight R & Fierer N (2011) The under-recognized dominance of Verrucomicrobia in soil bacterial communities. *Soil Biol Biochem* **43**: 1450-1455.
- Berini F, Casciello C, Marcone GL & Marinelli F (2017) Metagenomics: novel enzymes from non-culturable microbes. *FEMS Microbiol Lett* **364**.
- Berne C, Ducret A, Brun YV & Hardy GG (2015) Adhesins involved in attachment to abiotic surfaces by gram-negative bacteria. *Microbiol Spectr* **3**.
- Bezzate S, Aymerich S, Chambert R, Czarnes S, Berge O & Heulin T (2000) Disruption of the *Paenibacillus polymyxa* levensucrase gene impairs its ability to aggregate soil in the wheat rhizosphere. *Environ Microbiol* **2**: 333-342.
- Bhatnagar M, Pareek S, Bhatnagar A & Ganguly J (2014) Rheology and characterization of a low viscosity emulsifying exopolymer from desert borne *Nostoc calcicola*. *Indian J Biotechnol* **13**: 241-246.
- Bianchetti CM, Elsen NL, Fox BG & Phillips GN (2011) Structure of cellobiose phosphorylase from *Clostridium thermocellum* in complex with phosphate. *Acta Crystallogr Sect F Struct Biol Cryst Commun* **67**: 1345-1349.
- Blanchette RA (1984) Manganese accumulation in wood decayed by white rot fungi. *Phytopathology* **74**.
- Blaud A, Lerch TZ, Chevallier T, Nunan N, Chenu C & Brauman A (2012) Dynamics of bacterial communities in relation to soil aggregate formation during the decomposition of 13C-labelled rice straw. *Appl Soil Eco* **53**: 1-9.
- Bleriot C, Effantin G, Lagarde F, Mandrand-Berthelot MA & Rodrigue A (2011) RcnB is a periplasmic protein essential for maintaining intracellular Ni and Co concentrations in *Escherichia coli*. *J Bacteriol* **193**: 3785-3793.
- Bödeker ITM, Nygren CMR, Taylor AFS, Olson Å & Lindahl BD (2009) ClassII peroxidase-encoding genes are present in a phylogenetically wide range of ectomycorrhizal fungi. *ISME J* **3**: 1387-1395.
- Boer Wd, Folman LB, Summerbell RC & Boddy L (2005) Living in a fungal world: impact of fungi on soil bacterial niche development. *FEMS Microbiol Rev* **29**: 795-811.
- Bolger AM, Lohse M & Usadel B (2014) Trimmomatic: a flexible trimmer for Illumina sequence data. *Bioinformatics* **30**: 2114-2120.
- Bolla K, Gopinath BV, Shaheen SZ & Charya MAS (2010) Optimization of carbon and nitrogen sources of submerged culture process for the production of mycelial biomass and exopolysaccharides by *Trametes versicolor*. *Int Biotechnol Mol Biol Res* **1**: 7.
- Boonchai R, Kaewsuk J & Seo G (2014) Effect of nutrient starvation on nutrient uptake and extracellular polymeric substance for microalgae cultivation and separation. *Desalin Water Treat* **55**: 360-367.
- Bosmans L, De Brujin I, De Mot R, Rediers H & Lievens B (2016) Agar composition affects in vitro screening of biocontrol activity of antagonistic microorganisms. *J Microbiol Methods* **127**: 7-9.
- Braak CJFt & Smilauer P (2012) *Canoco reference manual and user's guide: software for ordination, version 5.0*. Microcomputer Power, Ithaca USA.
- Bronick CJ & Lal R (2005) Soil structure and management: a review. *Geoderma* **124**: 3-22.
- Buchfink B, Xie C & Huson DH (2014) Fast and sensitive protein alignment using DIAMOND. *Nat Methods* **12**: 59-60.
- Burke DJ, Smemo KA & Hewins CR (2014) Ectomycorrhizal fungi isolated from old-growth northern hardwood forest display variability in extracellular enzyme activity in the presence of plant litter. *Soil Biol Biochem* **68**: 219-222.
- Bushnell B (2015) BBMap.
- C**
- Caesar-TonThat T-C & Cochran VL (2000) Soil aggregate stabilization by a saprophytic lignin-decomposing basidiomycete fungus I. Microbiological aspects. *Biol Fertil Soils* **32**: 6.
- Caesar-TonThat TC, Caesar AJ, Gaskin JF, Sainju UM & Busscher WJ (2007) Taxonomic diversity of predominant culturable bacteria associated with microaggregates from two different agroecosystems and their ability to

- aggregate soil in vitro. *Appl Soil Ecol* **36**: 10-21.
- Caesar-TonThat TC, Stevens WB, Sainju UM, Caesar AJ, West M & Gaskin JF (2014) Soil-Aggregating Bacterial Community as Affected by Irrigation, Tillage, and Cropping System in the Northern Great Plains. *Soil Sci* **179**: 11-20.
- Campanharo JC, Kielak AM, Castellane TCL, Kuramae EE & Lemos EGdM (2016) Optimized medium culture for *Acidobacteria* subdivision 1 strains. *FEMS Microbiol Lett* **363**: fnw245.
- Caravaca F, Hernández T, García C & Roldán A (2002) Improvement of rhizosphere aggregate stability of afforested semiarid plant species subjected to mycorrhizal inoculation and compost addition. *Geoderma* **108**: 133-144.
- Cardman Z, Arnosti C, Durbin A, Zervogel K, Cox C, Steen AD, Teske A & Spormann AM (2014) *Verrucomicrobia* are candidates for polysaccharide-degrading bacterioplankton in an arctic fjord of Svalbard. *Appl Environ Microbiol* **80**: 3749-3756.
- Carini P, Marsden PJ, Leff JW, Morgan EE, Strickland MS & Fierer N (2016) Relic DNA is abundant in soil and obscures estimates of soil microbial diversity. *Nat Microbiol* **2**.
- Carzaniga T, Antoniani D, Dehò G, Briani F & Landini P (2012) The RNA processing enzyme polynucleotide phosphorylase negatively controls biofilm formation by repressing poly-N-acetylglucosamine (PNAG) production in *Escherichia coli* C. *BMC Microbiol* **12**: 270.
- Chamizo S, Cantón Y, Miralles I & Domingo F (2012) Biological soil crust development affects physicochemical characteristics of soil surface in semiarid ecosystems. *Soil Biol Biochem* **49**: 96-105.
- Chandrangs P, Rensing C & Helmann JD (2017) Metal homeostasis and resistance in bacteria. *Nat Rev Microbiol* **15**: 338-350.
- Chang I & Cho G-C (2012) Strengthening of Korean residual soil with  $\beta$ -1,3/1,6-glucan biopolymer. *Constr Build Mater* **30**: 30-35.
- Chang I, Im J, Prasidhi AK & Cho G-C (2015) Effects of Xanthan gum biopolymer on soil strengthening. *Constr Build Mater* **74**: 65-72.
- Chang I, Im J, Lee S-W & Cho G-C (2017) Strength durability of gellan gum biopolymer-treated Korean sand with cyclic wetting and drying. *Constr Build Mater* **143**: 210-221.
- Chen Y, Pu G, Lian B, Pei X, Huang G, Wang Q & Lv Y (2018) Interactions between Two Fungi Strains during Litter Decomposition through a Microcosm Experiment: Different Degradative Enzyme Activities. *Adv Enzyme Res* **06**: 1-9.
- Cheng HP & Walker GC (1998) Succinoglycan is required for initiation and elongation of infection threads during nodulation of alfalfa by *Rhizobium meliloti*. *J Bacteriol* **180**: 5183-5191.
- Chenu C (1995) Extracellular polysaccharides : an interface between microorganisms and soil constituents. *Environmental impact of soil component interactions Natural and Anthropogenic organics*,(Huang PM, Berthelin J, Bollag JM, McGill WB & Page AL, eds.), CRC Lewis Publishers, Boca Raton, USA.
- Chenu C & Roberson EB (1996) Diffusion of glucose in microbial extracellular polysaccharide as affected by water potential. *Soil Biol Biochem* **28**: 877-884.
- Chenu C & Cosentino D (2011) Microbial regulation of soil structural dynamics. *The Architecture and Biology of Soils: Life in Inner Space*,(Ritz K & Young I, eds.), 37-70. CABI, Wallingford, Oxfordshire, UK.
- Chin C-S, Alexander DH, Marks P, et al. (2013) Nonhybrid, finished microbial genome assemblies from long-read SMRT sequencing data. *Nat Methods* **10**: 563-569.
- Christensen-Dalsgaard M, Jørgensen MG & Gerdes K (2010) Three new RelE-homologous mRNA interferases of *Escherichia coli* differentially induced by environmental stresses. *Mol Microbiol* **75**: 333-348.
- Christensen SK, Mikkelsen M, Pedersen K & Gerdes K (2001) RelE, a global inhibitor of translation, is activated during nutritional stress. *Proc Natl Acad Sci U S A* **98**: 14328-14333.
- Coates JD, Ellis DJ, Gaw CV & Lovley DR (1999) Geothrix fermentans gen. nov., sp. nov., a novel Fe(III)-reducing bacterium from a hydrocarbon-contaminated aquifer. *Int J Syst Bacteriol* **49 Pt 4**: 1615-1622.
- Cole JR, Wang Q, Fish JA, Chai B, McGarrell DM, Sun Y, Brown CT, Porras-Alfaro A, Kuske CR & Tiedje JM (2014) Ribosomal Database Project: data and tools for high throughput rRNA analysis. *Nucleic Acids Res* **42**: D633-D642.
- Costa OYA, Raaijmakers JM & Kuramae EE (2018) Microbial extracellular polymeric substances: ecological function

- and impact on soil aggregation. *Front Microbiol* **9**: 1636.
- Coughlan LM, Cotter PD, Hill C & Alvarez-Ordóñez A (2015) Biotechnological applications of functional metagenomics in the food and pharmaceutical industries. *Front Microbiol* **6**.
- Craigie B (2011) The Use of Commercially Available Alpha-Amylase Compounds to Inhibit and Remove *Staphylococcus aureus* Biofilms. *Open Microbiol J* **5**: 21-31.
- Crowe MA, Power JF, Morgan XC, et al. (2013) *Pyrinomonas methylaliphatogenes* gen. nov., sp. nov., a novel group 4 thermophilic member of the phylum *Acidobacteria* from geothermal soils. *Int J Syst Evol Microbiol* **64**: 220-227.
- Crowley JD, Traynor DA & Weatherburn DC (2000) Enzymes and proteins containing manganese: an overview. *Met Ions Biol Syst*, Vol. 37 209-278.
- Cuthbertson L, Mainprize IL, Naismith JH & Whitfield C (2009) Pivotal roles of the outer membrane polysaccharide export and polysaccharide copolymerase protein families in export of extracellular polysaccharides in gram-negative bacteria. *Microbiol Mol Biol Rev* **73**: 155-177.
- Cvetkovic A, Menon AL, Thorgersen MP, et al. (2010) Microbial metalloproteomes are largely uncharacterized. *Nature* **466**: 779-782.
- Czarnes S, Hallett PD, Bengough AG & Young IM (2000) Root- and microbial-derived mucilages affect soil structure and water transport. *Eur J Soil Sci* **51**: 435-443.
- D**
- Dahiya N, Tewari R, Tiwari RP & Hoondal GS (2005) Chitinase Production in Solid-State Fermentation by Enterobacter sp. NRG4 Using Statistical Experimental Design. *Curr Microbiol* **51**: 222-228.
- Davenport EK, Call DR & Beyenal H (2014) Differential protection from tobramycin by extracellular polymeric substances from *Acinetobacter baumannii* and *Staphylococcus aureus* biofilms. *Antimicrob Agents Chemother* **58**: 4755-4761.
- de Castro VHL (2011) Identificação, isolamento e caracterização de bactérias de solo de cerrado pertencentes ao filo *Acidobacteria*. Dissertation Thesis, Universidade Católica de Brasília, Brasília.
- de Castro VHL, Schroeder LF, Quirino BF, Kruger RH & Barreto CC (2013) *Acidobacteria* from oligotrophic soil from the Cerrado can grow in a wide range of carbon source concentrations. *Can J Microbiol* **59**: 746-753.
- De Vuyst, Vanderveken, Van de V & Degeest (1998) Production by and isolation of exopolysaccharides from *Streptococcus thermophilus* grown in a milk medium and evidence for their growth-associated biosynthesis. *J Appl Microbiol* **84**: 1059-1068.
- Dedysh S, Kulichevskaya I, Huber K & Overmann J (2017) Defining the taxonomic status of described subdivision 3 Acidobacteria: proposal of Bryobacteraceae fam. nov. *Int J Syst Evol Microbiol* **67**: 498-501.
- Dedysh SN & Yilmaz P (2018) Refining the taxonomic structure of the phylum *Acidobacteria*. *Int J Syst Evol Microbiol* **68**: 3796-3806.
- Dedysh SN, Kulichevskaya IS, Serkebaeva YM, Mityaeva MA, Sorokin VV, Suzina NE, Rijpstra WIC & Damste JSS (2012) *Bryocella elongata* gen. nov., sp nov., a member of subdivision 1 of the Acidobacteria isolated from a methanotrophic enrichment culture, and emended description of *Edaphobacter aggregans* Koch et al. 2008. *Int J Syst Evol Microbiol* **62**: 654-664.
- Dimitrov MR, Veraart AJ, de Hollander M, Smidt H, van Veen JA & Kuramae EE (2017) Successive DNA extractions improve characterization of soil microbial communities. *PeerJ* **5**: e2915.
- Dinel H, Lévesque PEM, Jambu P & Righi D (1992) Microbial activity and long-chain aliphatics in the formation of stable soil aggregates. *Soil Sci Soc Am J* **56**: 1455.
- Dominguez-Ferreras A, Perez-Arnedo R, Becker A, Olivares J, Soto MJ & Sanjuan J (2006) Transcriptome profiling reveals the importance of plasmid pSymB for osmoadaptation of *Sinorhizobium meliloti*. *J Bacteriol* **188**: 7617-7625.
- Doncheva NT, Assenov Y, Domingues FS & Albrecht M (2012) Topological analysis and interactive visualization of biological networks and protein structures. *Nat Protoc* **7**: 670-685.
- Dray S & Dufour A-B (2007) The ade4 Package: implementing the duality diagram for ecologists. *J Stat Softw* **22**.
- Druzhinina IS, Seidl-Seiboth V, Herrera-Estrella A, Horwitz BA, Kenlerley CM, Monte E, Mukherjee PK, Zeilingher S, Grigoriev IV & Kubicek CP (2011) *Trichoderma*: the genomics of opportunistic success. *Nat Rev Microbiol* **9**: 749-

- 759.
- DuBois M, Gilles KA, Hamilton JK, Rebers PA & Smith F (1956) Colorimetric method for determination of sugars and related substances. *Anal Chem* **28**: 350-356.
- Dumitriu S (2005) *Polysaccharides: structural diversity and functional versatility*. Marcel Dekker, New York.
- E**
- Edgar RC (2010) Search and clustering orders of magnitude faster than BLAST. *Bioinformatics* **26**: 2460-2461.
- Edgar RC, Haas BJ, Clemente JC, Quince C & Knight R (2011) UCHIME improves sensitivity and speed of chimaera detection. *Bioinformatics* **27**: 2194-2200.
- Eichorst SA, Breznak JA & Schmidt TM (2007) Isolation and characterization of soil bacteria that define *Terriglobus* gen. nov., in the phylum Acidobacteria. *Appl Environ Microbiol* **73**: 2708-2717.
- Eichorst SA, Kuske CR & Schmidt TM (2011) Influence of plant polymers on the distribution and cultivation of bacteria in the phylum Acidobacteria. *Appl Environ Microbiol* **77**: 586-596.
- Eichorst SA, Trojan D, Roux S, Herbold C, Rattei T & Woebken D (2018) Genomic insights into the Acidobacteria reveal strategies for their success in terrestrial environments. *Environ Microbiol* **20**: 1041-1063.
- Ekkers DM, Cretoiu MS, Kielak AM & van Elsas JD (2011) The great screen anomaly—a new frontier in product discovery through functional metagenomics. *Appl Microbiol Biotechnol* **93**: 1005-1020.
- El-Naggar AH, Omar HH, Osman MEH & Ismail GA (2008) Heavy metal binding capacity of Exopolysaccharides produced by *Anabaena variabilis* and *Nostoc muscorum*. *Egypt J Exp Biol* **4**: 6.
- Elisashvili VI, Kachlishvili ET & Wasser SP (2009) Carbon and nitrogen source effects on basidiomycetes exopolysaccharide production. *Appl Biochem Micro* **45**: 531-535.
- Entcheva-Dimitrov P & Spormann AM (2004) Dynamics and Control of Biofilms of the Oligotrophic Bacterium *Caulobacter crescentus*. *J Bacteriol* **186**: 8254-8266.
- Everett JA & Rumbaugh KP (2015) Biofilms, quorum sensing and crosstalk in medically important microbes. *Molecular Medical Microbiology*, (Tang Y-W, Sussman M, Liu D, Poxton I & Schwartzman J, eds.), 235-247. Academic Press, Massachussets.
- Ezeilo UR, Zakaria II, Huyop F & Wahab RA (2017) Enzymatic breakdown of lignocellulosic biomass: the role of glycosyl hydrolases and lytic polysaccharide monooxygenases. *Biotechnol Biotechnol Equip* 1-16.
- F**
- Falagán C, Foesel B & Johnson B (2017) *Acidicapsa ferrireducens* sp. nov., *Acidicapsa acidiphila* sp. nov., and *Granulicella acidiphila* sp. nov.: novel acidobacteria isolated from metal-rich acidic waters. *Extremophiles* **21**: 459-469.
- Farber BF, Kaplan MH & Clogston AG (1990) *Staphylococcus epidermidis* extracted slime inhibits the antimicrobial action of glycopeptide antibiotics. *Int J Infect Dis* **161**: 37-40.
- Faria M, Bordin N, Kizina J, Harder J, Devos D & Lage OM (2018) Planctomycetes attached to algal surfaces: Insight into their genomes. *Genomics* **110**: 231-238.
- Farrés J, Caminal G & López-Santín J (1997) Influence of phosphate on rhamnose-containing exopolysaccharide rheology and production by *Klebsiella* I-714. *Appl Microbiol Biotechnol* **48**: 522-527.
- Federici L, Du D, Walas F, Matsumura H, Fernandez-Recio J, McKeegan KS, Borges-Walmsley MI, Luisi BF & Walmsley AR (2005) The Crystal Structure of the Outer Membrane Protein VceC from the Bacterial Pathogen *Vibrio cholerae* at 1.8 Å Resolution. *J Biol Chem* **280**: 15307-15314.
- Fierer N, Morse JL, Berthrong ST, Bernhardt ES & Jackson RB (2007) Environmental Controls on the Landscape-Scale Biogeography of Stream Bacterial Communities. *Ecology* **88**: 2162-2173.
- Figueras MJ, Beaz-Hidalgo R, Hossain MJ & Liles MR (2014) Taxonomic affiliation of new genomes should be verified using average nucleotide identity and multilocus phylogenetic analysis. *Genome Announc* **2**.
- Fitzpatrick JJ, Ahrens M & Smith S (2001) Effect of manganese on *Lactobacillus casei* fermentation to produce lactic acid from whey permeate. *Process Biochem* **36**: 671-675.
- Fleming D, Chahin L & Rumbaugh K (2016) Glycoside Hydrolases Degrade Polymicrobial Bacterial Biofilms in Wounds. *Antimicrob Agents Chemother*.

- Flemming H-C & Wingender J (2010) The biofilm matrix. *Nat Rev Microbiol* 6:23-63.
- Flemming H-C, Neu TR & Wozniak DJ (2007) The EPS matrix: the “house of biofilm cells”. *J Bacteriol* 189: 7945-7947.
- Flemming H-C, Wingender J, Mayer C, Korstgens V & Borchard W (2000) Cohesiveness in biofilm matrix polymers. *Symposium of the Society for General Microbiology* 59th: 87-105.
- Flemming H-C, Wingender J, Szewzyk U, Steinberg P, Rice SA & Kjelleberg S (2016) Biofilms: an emergent form of bacterial life. *Nat Rev Microbiol* 14: 563-575.
- Foesel BU, Rohde M & Overmann J (2013) *Blastocatella fastidiosa* gen. nov., sp. nov., isolated from semiarid savanna soil—The first described species of Acidobacteria subdivision 4. *Syst Appl Microbiol* 36: 82-89.
- Foesel BU, Wanner G, Mayer S, Rohde M, Overmann J & Luckner M (2016) Occallatibacter riparius gen. nov., sp. nov. and Occallatibacter savannae sp. nov., acidobacteria isolated from Namibian soils, and emended description of the family Acidobacteriaceae. *Int J Syst Evol Microbiol* 66: 219-229.
- Foesel BU, Nägele V, Naether A, et al. (2014) Determinants of Acidobacteria activity inferred from the relative abundances of 16S rRNA transcripts in German grassland and forest soils. *Environ Microbiol* 16: 658-675.
- Forster SM (1979) Microbial aggregation of sand in an embryo dune system. *Soil Biol Biochem* 11: 537-543.
- Forster SM & Nicolson TH (1981) Aggregation of sand from a maritime embryo sand dune by microorganisms and higher plants. *Soil Biol Biochem* 13: 199-203.
- Friedman J & Alm EJ (2012) Inferring Correlation Networks from Genomic Survey Data. *PLoS Comput Biol* 8.
- Fu XT & Kim SM (2010) Agarase: Review of Major Sources, Categories, Purification Method, Enzyme Characteristics and Applications. *Mar Drugs* 8: 200-218.
- Fuchs EL, Brutinel ED, Klem ER, Fehr AR, Yahr TL & Wolfgang MC (2010) In vitro and in vivo characterization of the *Pseudomonas aeruginosa* Cyclic AMP (cAMP) Phosphodiesterase CpdA, required for cAMP homeostasis and virulence factor regulation. *J Bacteriol* 192: 2779-2790.
- Fujita Y (2014) Carbon Catabolite Control of the Metabolic Network in *Bacillus subtilis*. *Biosci Biotechnol Biochem* 73: 245-259.
- Fukunaga Y, Kurahashi M, Yanagi K, Yokota A & Harayama S (2008) Acanthopleuribacter pedis gen. nov., sp. nov., a marine bacterium isolated from a chiton, and description of Acanthopleuribacteraceae fam. nov., Acanthopleuribacterales ord. nov., Holophagaceae fam. nov., Holophagales ord. nov. and Holophagae classis nov. in the phylum ‘Acidobacteria’. *Int J Syst Evol Microbiol* 58: 2597-2601.
- G**
- Galperin MY, Makarova KS, Wolf YI & Koonin EV (2015) Expanded microbial genome coverage and improved protein family annotation in the COG database. *Nucleic Acids Res* 43: D261-D269.
- Gamar-Nourani L, Blondeau K & Simonet JM (1998) Influence of culture conditions on exopolysaccharide production by *Lactobacillus rhamnosus* strain C83. *J Appl Microbiol* 85: 664-672.
- Gandhi HP, Ray RM & Patel RM (1997) Exopolymer production by *Bacillus* species. *Carbohydr Polym* 34: 323-327.
- García-Fraile P, Benada O, Cajthaml T, Baldrian P, Lladó S & Löffler FE (2016) Terracidiphilus gabretensis gen. nov., sp. nov., an Abundant and Active Forest Soil Acidobacterium Important in Organic Matter Transformation. *Appl Environ Microbiol* 82: 560-569.
- Gasperi-Mago RR & Troeh FR (1979) Microbial Effects on Soil Erodibility1. *Soil Sci Soc Am J* 43.
- Geoghegan MJ & Brian RC (1948) Aggregate formation in soil. 1. Influence of some bacterial polysaccharides on the binding of soil particles. *Biochem J* 43: 5-13.
- Gillard B, Chatzivangelou D, Thomsen L & Ullrich MS (2019) Heavy-metal-resistant microorganisms in deep-sea sediments disturbed by mining activity: an application toward the development of experimental in vitro systems. *Front Mar Sci* 6.
- Ginige MP, Hugenholtz P, Daims H, Wagner M, Keller J & Blackall LL (2004) Use of stable-isotope probing, full-cycle rRNA analysis, and fluorescence in situ hybridization-microautoradiography to study a methanol-fed denitrifying microbial community. *Appl Environ Microbiol* 70: 588-596.
- Givry S & Duchiron F (2008) Optimization of culture medium and growth conditions for production of L-arabinose isomerase and D-xylose isomerase by *Lactobacillus bifermentans*. *Microbiology* 77: 281-287.

- Godinho AL & Bhosle S (2009) Sand aggregation by exopolysaccharide-producing *Microbacterium arborescens*--AGSB. *Curr Microbiol* **58**: 616-621.
- González-García Y, Heredia A, Meza-Contreras JC, Escalante FME, Camacho-Ruiz RM & Córdova J (2015) Biosynthesis of extracellular polymeric substances by the marine bacterium *Saccharophagus degradans* under different nutritional conditions. *Int J Polym Sci* **2015**: 1-7.
- Gorla P, Plocinska R, Sarva K, Satsangi AT, Pandeeti E, Donnelly R, Dziadek J, Rajagopalan M & Madiraju MV (2018) MtrA response regulator controls cell division and cell wall metabolism and affects susceptibility of mycobacteria to the first line antituberculosis drugs. *Front Microbiol* **9**.
- Grainge I & Sherratt DJ (1999) Xer Site-specific Recombination. *J Biol Chem* **274**: 6763-6769.
- Gremion F, Chatzinotas A & Harms H (2003) Comparative 16S rDNA and 16S rRNA sequence analysis indicates that Actinobacteria might be a dominant part of the metabolically active bacteria in heavy metal-contaminated bulk and rhizosphere soil. *Environ Microbiol* **5**: 896-907.
- Grobe S, Wingender J & Flemming H-C (2001) Capability of mucoid *Pseudomonas aeruginosa* to survive in chlorinated water. *Int J Hyg Environ Health* **204**: 139-142.
- Grube M, Cernava T, Soh J, et al. (2014) Exploring functional contexts of symbiotic sustain within lichen-associated bacteria by comparative omics. *ISME J* **9**: 412-424.
- Guedon E, Moore CM, Que Q, Wang T, Ye RW & Helmann JD (2003) The global transcriptional response of *Bacillus subtilis* to manganese involves the MntR, Fur, TnrA and σB regulons. *Mol Microbiol* **49**: 1477-1491.
- Guldinmann C, Boor KJ, Wiedmann M, Guariglia-Oropeza V & Schaffner DW (2016) Resilience in the face of uncertainty: sigma factor B fine-tunes gene expression to support homeostasis in gram-positive bacteria. *Appl Environ Microbiol* **82**: 4456-4469.
- Guo H, Nasir M, Lv J, Dai Y & Gao J (2017) Understanding the variation of microbial community in heavy metals contaminated soil using high throughput sequencing. *Ecotox Environ Safe* **144**: 300-306.
- Guo Y, Zhao H, Zuo X, Drake S & Zhao X (2007) Biological soil crust development and its topsoil properties in the process of dune stabilization, Inner Mongolia, China. *Environ Geol* **54**: 653-662.
- Gvakharia BO, Permina EA, Gelfand MS, Bottomley PJ, Sayavedra-Soto LA & Arp DJ (2007) Global Transcriptional Response of *Nitrosomonas europaea* to Chloroform and Chloromethane. *Appl Environ Microbiol* **73**: 3440-3445.
- H**
- Haichar FeZ, Achouak W, Christen R, Heulin T, Marol C, Marais M-F, Mougel C, Ranjard L, Balesdent J & Berge O (2007) Identification of cellulolytic bacteria in soil by stable isotope probing. *Environ Microbiol* **9**: 625-634.
- Hantke K (2001) Iron and metal regulation in bacteria. *Curr Opin Microbiol* **4**: 5.
- Harkes P, Suleiman A, van den Elsen S, de Haan J, Holterman M, Kuramae E & Helder J (2019) Mapping of long-term impact of conventional and organic soil management on resident and active fractions of rhizosphere communities of barley (*Hordeum vulgare*). *bioRxiv* 546192.
- Hausmann B, Pelikan C, Herbold CW, et al. (2018) Peatland Acidobacteria with a dissimilatory sulfur metabolism. *ISME J* **12**: 1729-1742.
- Hausner M & Wuertz S (1999) High rates of conjugation in bacterial biofilms as determined by quantitative in situ analysis. *Appl Environ Microbiol* **65**: 3710-3713.
- Hayes CS & Low DA (2009) Signals of growth regulation in bacteria. *Curr Opin Microbiol* **12**: 667-673.
- Helmann JD (2016) *Bacillus subtilis* extracytoplasmic function (ECF) sigma factors and defense of the cell envelope. *Curr Opin Microbiol* **30**: 122-132.
- Hendrickx L, Hausner M & Wuertz S (2003) Natural genetic transformation in monoculture *Acinetobacter* sp. strain BD413 biofilms. *Appl Environ Microbiol* **69**: 1721-1727.
- Herve M, Boniface A, Gobec S, Blanot D & Mengin-Lecreux D (2007) Biochemical characterization and physiological properties of *Escherichia coli* UDP-N-Acetylglucosamine: L-Alanyl-D-Glutamyl-meso-Diaminopimelate Ligase. *J Bacteriol* **189**: 3987-3995.
- Hess M, Sczyrba A, Egan R, et al. (2011) Metagenomic Discovery of Biomass-Degrading Genes and Genomes from Cow Rumen. *Science* **331**: 463-467.
- Ho A, Lonardo DPD & Bodelier PLE (2017) Revisiting life strategy concepts in environmental microbial ecology. *FEMS*

- Microbiol Ecol.*
- Hollander MD (2017) Nioo-Knaw/Hydra: 1.3.3.
- Houssin C, Eynard N, Shechter E & Ghazi A (1991) Effect of osmotic pressure on membrane energy-linked functions in *Escherichia coli*. *Biochim Biophys Acta Bioenerg* **1056**: 76-84.
- Hubbard C, McNamara JT, Azumaya C, Patel MS & Zimmer J (2012) The hyaluronan synthase catalyzes the synthesis and membrane translocation of hyaluronan. *J Mol Biol* **418**: 21-31.
- Huber KJ & Overmann J (2018) Vicinamibacteraceae fam. nov., the first described family within the subdivision 6 Acidobacteria. *Int J Syst Evol Microbiol* **68**: 2331-2334.
- Huber KJ, Wüst PK, Rhode M, Overmann J & Fösel BU (2014) Aridibacter famidurans and Aridibacter kavangonensis, 2 novel species of Acidobacteria subdivision 4 isolated from semiarid savanna soil. *Int J Syst Evol Microbiol ijs*. 0.060236-060230.
- Huber KJ, Geppert AM, Wanner G, Fösel BU, Wüst PK & Overmann J (2016) The first representative of the globally widespread subdivision 6 Acidobacteria, *Vicinamibacter silvestris* gen. nov., sp. nov., isolated from subtropical savannah soil. *Int J Syst Evol Microbiol* **66**: 2971-2979.
- Huerta-Cepas J, Forslund K, Coelho LP, Szklarczyk D, Jensen LJ, von Mering C & Bork P (2017) Fast Genome-Wide functional annotation through Orthology Assignment by eggNOG-Mapper. *Mol Biol Evol* **34**: 2115-2122.
- Huerta-Cepas J, Szklarczyk D, Forslund K, et al. (2016) eggNOG 4.5: a hierarchical orthology framework with improved functional annotations for eukaryotic, prokaryotic and viral sequences. *Nucleic Acids Res* **44**: D286-D293.
- Hugenholtz P, Goebel BM & Pace NR (1998) Impact of culture-independent studies on the emerging phylogenetic view of bacterial diversity. *J Bacteriol* **180**: 4765-4774.
- HuiXia P, ZhengMing C, XueMei Z, ShuYong M, XiaoLing Q & Fang W (2007) A study on an oligotrophic bacteria and its ecological characteristics in an arid desert area. *Sci China D Earth Sci* **50**: 128-134.
- Hukić M, Seljmo D, Ramovic A, Ibrićimović MA, Dogan S, Hukic J & Bojic EF (2018) The Effect of Lysozyme on Reducing Biofilms by *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Gardnerella vaginalis*: An In Vitro Examination. *Microb Drug Resist* **24**: 353-358.
- Hunter P (2008) The mob response. The importance of biofilm research for combating chronic diseases and tackling contamination. *EMBO Rep* **9**: 314-317.
- Hwang HJ, Kim SW, Xu CP, Choi JW & Yun JW (2004) Morphological and rheological properties of the three different species of basidiomycetes *Phellinus* in submerged cultures. *J Appl Microbiol* **96**: 1296-1305.
- Hyatt D, Chen G-L, LoCascio PF, Land ML, Larimer FW & Hauser LJ (2010) Prodigal: prokaryotic gene recognition and translation initiation site identification. *BMC Bioinformatics* **11**.
- I
- Ianova AA, Wegner C-E, Kim Y, Liesack W & Dedysh SN (2016) Identification of microbial populations driving biopolymer degradation in acidic peatlands by metatranscriptomic analysis. *Mol Ecol* **25**: 4818-4835.
- Ianova AA, Wegner C-E, Kim Y, Liesack W & Dedysh SN (2017) Metatranscriptomics reveals the hydrolytic potential of peat-inhabiting *Planctomycetes*. *Antonie Van Leeuwenhoek* **111**: 801-809.
- Ianova AA, Naumoff DG, Miroshnikov KK, Liesack W & Dedysh SN (2017) Comparative genomics of four *Isosphaeraeaceae Planctomycetes*: a common pool of plasmids and glycoside hydrolase genes shared by *Paludisphaera borealis* PX4T, *Isosphaera pallida* IS1BT, *Singulisphaera acidiphila* DSM 18658T, and strain SH-PL62. *Front Microbiol* **8**: 801-809.
- Ianova AO & Dedysh SN (2012) Abundance, diversity, and depth distribution of *Planctomycetes* in Acidic Northern Wetlands. *Front Microbiol* **3**: 9.
- Izano EA, Amarante MA, Kher WB & Kaplan JB (2007) Differential roles of poly-N-acetylglucosamine surface polysaccharide and extracellular DNA in *Staphylococcus aureus* and *Staphylococcus epidermidis* biofilms. *Appl Environ Microbiol* **74**: 470-476.
- Izumi H, Nunoura T, Miyazaki M, Mino S, Toki T, Takai K, Sako Y, Sawabe T & Nakagawa S (2012) Thermotomaculum hydrothermale gen. nov., sp. nov., a novel heterotrophic thermophile within the phylum Acidobacteria from a deep-sea hydrothermal vent chimney in the Southern Okinawa Trough. *Extremophiles* **16**: 245-253.
- J

- Jain R, Raghukumar S, Tharanathan R & Bhosle NB (2005) Extracellular polysaccharide production by Thraustochytrid protists. *Mar Biotechnol* **7**: 184-192.
- Jakubovics NS & Jenkinson HF (2001) Out of the iron age: new insights into the critical role of manganese homeostasis in bacteria. *Microbiology* **147**: 1709-1718.
- Janczarek M (2011) Environmental signals and regulatory pathways that influence exopolysaccharide production in *Rhizobia*. *Int J Mol Sci* **12**: 7898-7933.
- Jankovic I & Bruckner R (2002) Carbon catabolite repression by the catabolite control protein CcpA in *Staphylococcus xylosus*. *J Mol Microbiol Biotechnol* **4**: 309-314.
- Janssen PH (2006) Identifying the dominant soil bacterial taxa in libraries of 16S rRNA and 16S rRNA genes. *Appl Environ Microbiol* **72**: 1719-1728.
- Janssen PH, Yates PS, Grinton BE, Taylor PM & Sait M (2002) Improved culturability of soil bacteria and isolation in pure culture of novel members of the divisions *Acidobacteria*, *Actinobacteria*, *Proteobacteria*, and *Verrucomicrobia*. *Appl Environ Microbiol* **68**: 2391-2396.
- Jeffries P (1999) Scleroderma. *Ectomycorrhizal Fungi Key Genera in Profile*, 187-200.
- Jensen AN & Jensen LT (2014) CHAPTER 1. Manganese transport, trafficking and function in invertebrates. 1-33.
- Johnson JM, Ludwig A, Furch A, Mithöfer A, Scholz SS, Reichelt M & Oelmüller R (2018) The beneficial root-colonizing fungus *Mortierella hyalina* promotes the aerial growth of *Arabidopsis* and activates calcium-dependent responses which restrict *Alternaria brassicae*-induced disease development in roots. *Mol Plant Microbe Interact* **31**: 351-363.
- Jorgensen MG, Pandey DP, Jaskolska M & Gerdes K (2008) HicA of *Escherichia coli* defines a novel family of translation-independent mRNA interferases in *Bacteria* and *Archaea*. *J Bacteriol* **191**: 1191-1199.
- Joshi PA, Singh N & Shekhawat DB (2015) Effect of metal ions on growth and biosurfactant production by halophilic bacteria *Adv Appl Sci Res* **6**: 4.
- Joubert LM, Wolfaardt GM & Botha A (2006) Microbial exopolymers link predator and prey in a model yeast biofilm system. *Microb Ecol* **52**: 187-197.
- K**
- Kaci Y, Heyraud A, Barakat M & Heulin T (2005) Isolation and identification of an EPS-producing *Rhizobium* strain from arid soil (Algeria): characterization of its EPS and the effect of inoculation on wheat rhizosphere soil structure. *Res Microbiol* **156**: 522-531.
- Kalogiannis S, Iakovidou G, Liakopoulou-Kyriakides M, Kyriakidis DA & Skaracis GN (2003) Optimization of xanthan gum production by *Xanthomonas campestris* grown in molasses. *Process Biochem* **39**: 249-256.
- Kambourova M, Mandeva R, Dimova D, Poli A, Nicolaus B & Tommonaro G (2009) Production and characterization of a microbial glucan, synthesized by *Geobacillus tepidamans* V264 isolated from Bulgarian hot spring. *Carbohydr Polym* **77**: 338-343.
- Kanehisa M (2000) KEGG: Kyoto Encyclopedia of Genes and Genomes. *Nucleic Acids Res* **28**: 27-30.
- Kang DD, Froula J, Egan R & Wang Z (2015) MetaBAT, an efficient tool for accurately reconstructing single genomes from complex microbial communities. *PeerJ* **3**.
- Kawaharada Y, Kelly S, Nielsen MW, et al. (2015) Receptor-mediated exopolysaccharide perception controls bacterial infection. *Nature* **523**: 308-312.
- Kehr J-C & Dittmann E (2015) Biosynthesis and function of extracellular glycans in Cyanobacteria. *Life* **5**: 164-180.
- Kehres DG & Maguire ME (2003) Emerging themes in manganese transport, biochemistry and pathogenesis in bacteria. *FEMS Microbiol Rev* **27**: 263-290.
- Keiski C-L, Harwich M, Jain S, et al. (2010) AlgK is a TPR-containing protein and the periplasmic component of a novel exopolysaccharide secretin. *Structure* **18**: 265-273.
- Khan RH, Du L, Pang H, Wang Z, Lu J, Wei Y & Huang R (2013) Characterization of an Invertase with pH Tolerance and Truncation of Its N-Terminal to Shift Optimum Activity toward Neutral pH. *PLoS One* **8**.
- Khani M, Bahrami A, Chegeni A, Ghafari MD & Mansouran Zadeh A (2016) Optimization of carbon and nitrogen sources for extracellular polymeric substances production by *Chryseobacterium indologenes* MUT.2. *Iran J Biotechnol* **14**: 13-18.

- Kielak AM, Cipriano MAP & Kuramae EE (2016) Acidobacteria strains from subdivision 1 act as plant growth-promoting bacteria. *Arch Microbiol.*
- Kielak AM, Barreto CC, Kowalchuk GA, van Veen JA & Kuramae EE (2016) The ecology of acidobacteria: moving beyond genes and genomes. *Front Microbiol* **7**: 16.
- Kielak AM, Scheublin TR, Mendes LW, van Veen JA & Kuramae EE (2016) Bacterial community succession in pine-wood decomposition. *Front Microbiol* **7**.
- Kielak AM, Castellane TCL, Campanharo JC, Colnago LA, Costa OYA, Corradi da Silva ML, van Veen JA, Lemos EGM & Kuramae EE (2017) Characterization of novel *Acidobacteria* exopolysaccharides with potential industrial and ecological applications. *Sci Rep* **7**: 41193.
- Kim D & Robyt JF (1994) Production and selection of mutants of *Leuconostoc mesenteroides* constitutive for glucansucrases. *Enzyme Microb Technol* **16**: 659-664.
- Kim HS, Nagore D & Nikaido H (2009) Multidrug Efflux Pump MdtBC of *Escherichia coli* Is active only as a B2C heterotrimer. *J Bacteriol* **192**: 1377-1386.
- Király Z, El-Zahaby HM & Klement Z (1997) Role of extracellular polysaccharide (EPS) slime of plant pathogenic bacteria in protecting cells to reactive oxygen species. *J Phytopathol* **145**: 59-68.
- Kishimoto N, Kosako Y & Tano T (1991) *Acidobacterium capsulatum* gen. nov., sp. nov.: an acidophilic chemoorganotrophic bacterium containing menaquinone from acidic mineral environment. *Curr Microbiol* **22**: 1-7.
- Koch IH, Gich F, Dunfield PF & Overmann J (2008) Edaphobacter modestus gen. nov., sp. nov., and Edaphobacter aggregans sp. nov., acidobacteria isolated from alpine and forest soils. *Int J Syst Evol Microbiol* **58**: 1114-1122.
- Koczan JM, McGrath MJ, Zhao Y & Sundin GW (2009) Contribution of *Erwinia amylovora* exopolysaccharides Amylovoran and Levan to biofilm formation: implications in pathogenicity. *Phytopathology* **99**: 1237-1244.
- Kohler J, Caravaca F, Carrasco L & Roldán A (2006) Contribution of *Pseudomonas mendocina* and *Glomus intraradices* to aggregate stabilization and promotion of biological fertility in rhizosphere soil of lettuce plants under field conditions. *Soil Use Manage* **22**: 298-304.
- Kolde R (2019) pheatmap: Pretty Heatmaps. R package version 1.0.12.
- Köljalg U, Nilsson RH, Abarenkov K, et al. (2013) Towards a unified paradigm for sequence-based identification of fungi. *Mol Ecol* **22**: 5271-5277.
- Konan HK, Yapi D, Bi CY, Koné TFM, Kouadio PEJN & Patrice K (2016) Biochemical characterization of two acid phosphatases purified from breadfruit (*Artocarpus communis*) seeds. *J Adv Biol Biotechnol* **43**: 1102-1113.
- Koster J & Rahmann S (2012) Snakemake—a scalable bioinformatics workflow engine. *Bioinformatics* **28**: 2520-2522.
- Kravchenko AN, Negassa WC, Guber AK, Hildebrandt B, Marsh TL & Rivers ML (2014) Intra-aggregate Pore Structure Influences Phylogenetic Composition of Bacterial Community in Macroaggregates. *Soil Sci Soc Am J* **78**: 1924-1939.
- Krembs C, Eicken H & Deming JW (2011) Exopolymer alteration of physical properties of sea ice and implications for ice habitability and biogeochemistry in a warmer Arctic. *Proc Natl Acad Sci U S A* **108**: 3653-3658.
- Krembs C, Eicken H, Junge K & Deming JW (2002) High concentrations of exopolymeric substances in Arctic winter sea ice: implications for the polar ocean carbon cycle and cryoprotection of diatoms. *Deep-Sea Res Pt I* **49**: 2163-2181.
- Küçük Ç & Kivanç M (2009) Extracellular polysaccharide production by *Rhizobium ciceri* from Turkey. *Ann Microbiol* **59**: 141-144.
- Kulichevskaya IS, Suzina NE, Liesack W & Dedysh SN (2010) Bryobacter aggregatus gen. nov., sp. nov., a peat-inhabiting, aerobic chemo-organotroph from subdivision 3 of the Acidobacteria. *Int J Syst Evol Microbiol* **60**: 301-306.
- Kulichevskaya IS, Suzina NE, Rijpstra WIC, Damste JSS & Dedysh SN (2014) Paludibaculum fermentans gen. nov., sp. nov., a facultative anaerobe capable of dissimilatory iron reduction from subdivision 3 of the Acidobacteria. *Int J Syst Evol Microbiol* **64**: 2857-2864.
- Kulichevskaya IS, Ivanova AO, Baulina OI, Bodelier PLE, Damste JSS & Dedysh SN (2008) *Singulisphaera acidiphila* gen. nov., sp. nov., a non-filamentous, *Isosphaera*-like planctomycete from acidic northern wetlands. *Int J Syst*

- Evol Microbiol* **58**: 1186-1193.
- Kulichevskaya IS, Kostina LA, Valaskova V, Rijpstra WI, Damste JS, de Boer W & Dedysh SN (2012) *Acidicapsa borealis* gen. nov., sp. nov. and *Acidicapsa ligni* sp. nov., subdivision 1 Acidobacteria from Sphagnum peat and decaying wood. *Int J Syst Evol Microbiol* **62**: 1512-1520.
- Kullik I & Giachino P (1997) The alternative sigma factor σ B in *Staphylococcus aureus*: regulation of the sigB operon in response to growth phase and heat shock. *Arch Microbiol* **167**: 151-159.
- Kumar AS, Mody K & Jha B (2007) Bacterial exopolysaccharides – a perception. *J Basic Microbiol* **47**: 103-117.
- Kumar GK & Ram MR (2014) Effect of carbon and nitrogen sources on exopolysaccharide production by rhizobial isolates from root nodules of *Vigna trilobata*. *Afr J Microbiol Res* **8**: 2255-2260.
- Kumar R, Rawat KS, Singh J, Singh A & Rai A (2013) Soil aggregation dynamics and carbon sequestration. *J Nat Appl Sci* **5**: 250-267.
- Kuramae EE, Yergeau E, Wong LC, Pijl AS, Veen JA & Kowalchuk GA (2012) Soil characteristics more strongly influence soil bacterial communities than land-use type. *FEMS Microbiol Ecol* **79**: 12-24.
- Kuramae EE, Hillekens RHE, de Hollander M, van der Heijden MGA, van den Berg M, van Straalen NM & Kowalchuk GA (2013) Tracking Fungal Community Responses to Maize Plants by DNA- and RNA-Based Pyrosequencing. *PLoS One* **8**: e69973.
- Kursa MB & Rudnicki WR (2010) Feature Selection with the Boruta Package. *J Stat Softw* **36**.
- Kuske CR, Barns SM & Busch JD (1997) Diverse uncultivated bacterial groups from soils of the arid southwestern United States that are present in many geographic regions. *Appl Environ Microbiol* **63**: 3614-3621.
- Kuznetsova A, Brockhoff PB & Christensen RHB (2017) lmerTest package: tests in Linear Mixed Effects Models. *J Stat Softw* **82**.
- L**
- Labes A, Karlsson EN, Fridjonsson OH, Turner P, Hreggvidson GO, Kristjansson JK, Holst O & Schonheit P (2008) Novel Members of Glycoside Hydrolase Family 13 Derived from Environmental DNA. *Appl Environ Microbiol* **74**: 1914-1921.
- Lacombe-Harvey M-È, Brzezinski R & Beaulieu C (2018) Chitinolytic functions in actinobacteria: ecology, enzymes, and evolution. *Appl Microbiol Biotechnol* **102**: 7219-7230.
- Lairson LL, Henrissat B, Davies GJ & Withers SG (2008) Glycosyltransferases: Structures, Functions, and Mechanisms. *Annu Rev Biochem* **77**: 521-555.
- Langmead B & Salzberg SL (2012) Fast gapped-read alignment with Bowtie 2. *Nat Methods* **9**: 357-359.
- Lau TC, Wu XA, Chua H, Qian P & Wong PK (2005) Effect of exopolysaccharides on the adsorption of metal ions by *Pseudomonas* sp CU-1. *Water Sci Technol* **52**: 6.
- Lee TK, Lee J, Sul WJ, Iwai S, Chai B, Tiedje JM & Park J (2011) Novel Biphenyl-Oxidizing Bacteria and Dioxygenase Genes from a Korean Tidal Mudflat. *Appl Environ Microbiol* **77**: 3888-3891.
- Legendre P & Gallagher ED (2001) Ecologically meaningful transformations for ordination of species data. *Oecol* **129**: 271-280.
- Legin E, Ladrat C, Godfroy A, Barbier G & Duchiron F (1997) Thermostable amylolytic enzymes of thermophilic microorganisms from deep-sea hydrothermal vents. *Comptes Rendus Acad Sci* **320**: 893-898.
- Lehman AP & Long SR (2013) Exopolysaccharides from *Sinorhizobium meliloti* can protect against H<sub>2</sub>O<sub>2</sub>-Dependent Damage. *J Bacteriol* **195**: 5362-5369.
- Leutner BF, Reineking B, Müller J, Bachmann M, Beierkuhnlein C, Dech S & Wegmann M (2012) Modelling Forest α-Diversity and Floristic Composition — On the Added Value of LiDAR plus Hyperspectral Remote Sensing. *Remote Sens* **4**: 2818-2845.
- Lew LC, Liang MT & Gan CY (2013) Growth optimization of *Lactobacillus rhamnosus* FTDC 8313 and the production of putative dermal bioactives in the presence of manganese and magnesium ions. *J Appl Microbiol* **114**: 526-535.
- Li B & Dewey CN (2011) RSEM: accurate transcript quantification from RNA-Seq data with or without a reference genome. *BMC Bioinformatics* **12**.
- Li D, Liu C-M, Luo R, Sadakane K & Lam T-W (2015) MEGAHIT: an ultra-fast single-node solution for large and complex

- metagenomics assembly via succinct de Bruijn graph. *Bioinformatics* **31**: 1674-1676.
- Li Y & Zhou H (2009) tRNAs as regulators in gene expression. *Sci China C Life Sci* **52**: 245-252.
- Li Z, Gao Y, Nakanishi H, Gao X & Cai L (2013) Biosynthesis of rare hexoses using microorganisms and related enzymes. *Beilstein J Org Chem* **9**: 2434-2445.
- Liang D-M, Liu J-H, Wu H, Wang B-B, Zhu H-J & Qiao J-J (2015) Glycosyltransferases: mechanisms and applications in natural product development. *Chem Soc Rev* **44**: 8350-8374.
- Liao B, Yan X, Zhang J, Chen M, Li Y, Huang J, Lei M, He H & Wang J (2019) Microbial community composition in alpine lake sediments from the Hengduan Mountains. *Microbiologyopen* **8**.
- Liesack W, Bak F, Kreft JU & Stackebrandt E (1994) Holophaga Foetida Gen-Nov, Sp-Nov, a New, Homoacetogenic Bacterium Degrading Methoxylated Aromatic-Compounds. *Arch Microbiol* **162**: 85-90.
- Liu H & Fang HH (2002) Extraction of extracellular polymeric substances (EPS) of sludges. *J Biotechnol* **95**: 249-256.
- Liu QP, Sulzenbacher G, Yuan H, et al. (2007) Bacterial glycosidases for the production of universal red blood cells. *Nature Biotechnol* **25**: 454-464.
- Liu X & Kokare C (2017) Microbial Enzymes of Use in Industry. *Biotechnology of Microbial Enzymes*, 267-298.
- Lladó S, Benada O, Cajthaml T, Baldrian P & García-Fraile P (2016) *Silvibacterium bohemicum* gen. nov. sp. nov., an acidobacterium isolated from coniferous soil in the Bohemian Forest National Park. *Syst Appl Microbiol* **39**: 14-19.
- Lloret J, Wulff BB, Rubio JM, Downie JA, Bonilla I & Rivilla R (1998) Exopolysaccharide II production is regulated by salt in the halotolerant strain *Rhizobium meliloti* EFB1. *Appl Environ Microbiol* **64**: 1024-1028.
- Locatelli FM, Goo KS & Ulanova D (2016) Effects of trace metal ions on secondary metabolism and the morphological development of streptomycetes. *Metalomics* **8**: 469-480.
- Lombard V, Golaconda Ramulu H, Drula E, Coutinho PM & Henrissat B (2014) The carbohydrate-active enzymes database (CAZy) in 2013. *Nucleic Acids Res* **42**: D490-D495.
- López-López O, Knapik K, Cerdán M-E & González-Siso M-I (2015) Metagenomics of an Alkaline Hot Spring in Galicia (Spain): Microbial Diversity Analysis and Screening for Novel Lipolytic Enzymes. *Front Microbiol* **6**.
- Losey NA, Stevenson BS, Busse HJ, Sinnighe Damste JS, Rijpstra WI, Rudd S & Lawson PA (2013) Thermoanaerobaculum aquaticum gen. nov., sp. nov., the first cultivated member of Acidobacteria subdivision 23, isolated from a hot spring. *Int J Syst Evol Microbiol* **63**: 4149-4157.
- Ludwig W, Bauer SH, Bauer M, Held I, Kirchhof G, Schulze R, Huber I, Spring S, Hartmann A & Schleifer KH (1997) Detection and in situ identification of representatives of a widely distributed new bacterial phylum. *FEMS Microbiol Lett* **153**: 181-190.
- Lupatini M, Suleiman AKA, Jacques RJS, Lemos LN, Pylro VS, Van Veen JA, Kuramae EE & Roesch LFW (2019) Moisture Is More Important than Temperature for Assembly of Both Potentially Active and Whole Prokaryotic Communities in Subtropical Grassland. *Microb Ecol*.
- Lynch JM (1981) Promotion and inhibition of soil aggregate stabilization by micro-organisms. *J Gen Microbiol* **126**: 4.
- M**
- Mader U, Homuth G, Scharf C, Buttner K, Bode R & Hecker M (2002) Transcriptome and proteome analysis of *Bacillus subtilis* gene expression modulated by amino acid availability. *J Bacteriol* **184**: 4288-4295.
- Madsen EL (2006) The use of stable isotope probing techniques in bioreactor and field studies on bioremediation. *Curr Opin Biotechnol* **17**: 92-97.
- Makowski D (2018) The psycho package: an efficient and publishing-oriented workflow for psychological science. *J Open Source Softw* **3**.
- Malam Issa O, Trichet J, Défarge C, Couté A & Valentin C (1999) Morphology and microstructure of microbiotic soil crusts on a tiger bush sequence (Niger, Sahel). *Catena* **37**: 175-196.
- Malam Issa O, Défarge C, Le Bissonnais Y, Marin B, Duval O, Bruand A, D'Acqui LP, Nordenberg S & Annerman M (2006) Effects of the inoculation of cyanobacteria on the microstructure and the structural stability of a tropical soil. *Plant Soil* **290**: 209-219.
- Mallela K, Talens-Perales D, Górska A, Huson DH, Polaina J & Marín-Navarro J (2016) Analysis of Domain Architecture and Phylogenetics of Family 2 Glycoside Hydrolases (GH2). *PLoS One* **11**.

- Manca MC, Lama L, Improta R, Esposito E, Gambacorta A & Nicolaus B (1996) Chemical composition of two exopolysaccharides from *Bacillus thermoantarcticus*. *Appl Environ Microbiol* **62**: 3265-3269.
- Mannisto MK, Rawat S, Starovoytov V & Haggblom MM (2012) *Granulicella arctica* sp. nov., *Granulicella mallensis* sp. nov., *Granulicella tundricola* sp. nov. and *Granulicella sapimiensis* sp. nov., novel acidobacteria from tundra soil. *Int J Syst Evol Microbiol* **62**: 2097-2106.
- Martin JP (1971) Decomposition and binding action of polysaccharides in soil. *Soil Biol Biochem* **3**: 33-41.
- Martin JP & Richards SJ (1963) Decomposition and binding action of a polysaccharide from *Chromobacterium violaceum* in soil. *J Bacteriol* **85**: 1288-1294.
- Martinez-Garcia M, Brazel DM, Swan BK, et al. (2012) Capturing single cell genomes of active polysaccharide degraders: an unexpected contribution of *Verrucomicrobia*. *PLoS One* **7**: e35314.
- Martinez D, Berka RM, Henrissat B, et al. (2008) Genome sequencing and analysis of the biomass-degrading fungus *Trichoderma reesei* (syn. *Hypocrea jecorina*). *Nature Biotechnol* **26**: 553-560.
- Marx JG, Carpenter SD & Deming JW (2009) Production of cryoprotectant extracellular polysaccharide substances (EPS) by the marine psychrophilic bacterium *Colwellia psychrerythraea* strain 34H under extreme conditions. *Can J Microbiol* **55**: 63-72.
- Masuko T, Minami A, Iwasaki N, Majima T, Nishimura S-I & Lee YC (2005) Carbohydrate analysis by a phenol-sulfuric acid method in microplate format. *Anal Biochem* **339**: 69-72.
- Matsutani M, Ito K, Azuma Y, Ogino H, Shirai M, Yakushi T & Matsushita K (2015) Adaptive mutation related to cellulose producibility in *Komagataeibacter medellinensis* (*Gluconacetobacter xylinus*) NBRC 3288. *Appl Microbiol Biotechnol* **99**: 7229-7240.
- McCalla TM, Haskins FA & Curley RD (1958) Soil aggregation by microorganisms following soil fumigation. *Agr Hortic*.
- McDonald D, Clemente JC, Kuczynski J, et al. (2012) The Biological Observation Matrix (BIOM) format or: how I learned to stop worrying and love the ome-ome. *GigaScience* **1**.
- McKee LS, Sunner H, Anasontzis GE, Toriz G, Gatenholm P, Bulone V, Vilaplana F & Olsson L (2016) A GH115 α-glucuronidase from *Schizophyllum commune* contributes to the synergistic enzymatic deconstruction of softwood glucuronoarabinoxylan. *Biotechnol Biofuels* **9**.
- McMurdie PJ & Holmes S (2013) phyloseq: An r package for reproducible interactive analysis and graphics of microbiome census data. *PLoS One* **8**.
- Mehta NC, Streuli H, Müller M & Deuel H (1960) Role of polysaccharides in soil aggregation. *J Sci Food Agric* **11**: 40-47.
- Mendiburu Fd (2017) Statistical procedures for agricultural research.
- Menzel P, Ng KL & Krogh A (2016) Fast and sensitive taxonomic classification for metagenomics with Kaiju. *Nat Commun* **7**.
- Merchant SS & Helmann JD (2012) Elemental economy. *Advances in Microbial Physiology*, Vol. 60 91-210.
- Minh Tran T, MacIntyre A, Khokhani D, Hawes M & Allen C (2016) Extracellular DNases of *Ralstonia solanacearum* modulate biofilms and facilitate bacterial wilt virulence. *Environ Microbiol* **18**: 4103-4117.
- Mishra A & Jha B (2013) Microbial Exopolysaccharides. *The Prokaryotes*, (Rosemburg E, ed.) 179-192. Springer-Verlag New York, New York.
- Mitchell AL, Scheremetjew M, Denise H, et al. (2017) EBI Metagenomics in 2017: enriching the analysis of microbial communities, from sequence reads to assemblies. *Nucleic Acids Res* **46**: D726-D735.
- Mohan A, Flora B & Girdhar M (2018) Inulinase: An Important Microbial Enzyme in Food Industry. *Microbial Bioprospecting for Sustainable Development*, 237-248.
- Moncrieffe MC, Fernandez M-J, Spiteller D, Matsumura H, Gay NJ, Luisi BF & Leadlay PF (2012) Structure of the Glycosyltransferase EryCIII in Complex with its Activating P450 Homologue EryCII. *J Mol Biol* **415**: 92-101.
- Moore EK, Villanueva L, Hopmans EC, Rijpstra WIC, Mets A, Dedysh SN, Sinninghe Damsté JS & Schloss PD (2015) Abundant trimethylornithine lipids and specific gene sequences are indicative of *Planctomyces* importance at the oxic/anoxic interface in sphagnum-dominated Northern Wetlands. *Appl Environ Microbiol* **81**: 6333-6344.
- More TT, Yadav JSS, Yan S, Tyagi RD & Surampalli RY (2014) Extracellular polymeric substances of bacteria and their potential environmental applications. *J Environ Manage* **144**: 1-25.

- Morgenstern A, Paetz C, Behrend A & Spiteller D (2015) Divalent transition-metal-ion stress induces prodigiosin biosynthesis in *Streptomyces coelicolor* m145: formation of coeligosins. *Chem: Eur J* **21**: 6027-6032.
- Morillo Pérez JA, García-Ribera R, Quesada T, Aguilera M, Ramos-Cormenzana A & Monteoliva-Sánchez M (2008) Biosorption of heavy metals by the exopolysaccharide produced by *Paenibacillus jamilae*. *World J Microbiol Biotechnol* **24**: 2699-2704.
- Mugnai G, Rossi F, Felde VJML, Colesie C, Büdel B, Peth S, Kaplan A & De Philippis R (2017) Development of the polysaccharidic matrix in biocrusts induced by a cyanobacterium inoculated in sand microcosms. *Biol Fertil Soils* **54**: 27-40.
- Mulichak AM, Lu W, Losey HC, Walsh CT & Garavito RM (2004) Crystal structure of vancosaminyltransferase GtfD from the vancomycin biosynthetic pathway: interactions with acceptor and nucleotide ligands. *Biochemistry* **43**: 5170-5180.
- Mulichak AM, Losey HC, Lu W, Wawrzak Z, Walsh CT & Garavito RM (2003) Structure of the TDP-epi-vancosaminyltransferase GtfA from the chloroeremomycin biosynthetic pathway. *Proc Natl Acad Sci U S A* **100**: 9238-9243.
- Mummey DL & Stahl PD (2004) Analysis of Soil Whole- and Inner-Microaggregate Bacterial Communities. *Microb Ecol* **48**: 41-50.
- Murray LE, Rowley N, Dawes IW, Johnston GC & Singer RA (1998) A yeast glutamine tRNA signals nitrogen status for regulation of dimorphic growth and sporulation. *Proc Natl Acad Sci U S A* **95**: 8619-8624.
- N**
- Nagler M, Podmirseg SM, Griffith GW, Insam H & Ascher-Jenull J (2018) The use of extracellular DNA as a proxy for specific microbial activity. *Appl Microbiol Biotechnol* **102**: 2885-2898.
- Nahar S, Mizan MFR, Ha AJ-w & Ha S-D (2018) Advances and Future Prospects of Enzyme-Based Biofilm Prevention Approaches in the Food Industry. *Compr Rev Food Sci Food Saf* **17**: 1484-1502.
- Nalin R, Simonet P, Vogel TM & Normand P (1999) *Rhodanobacter lindaniclasticus* gen. nov., sp. nov., a lindane-degrading bacterium. *Int J Syst Bacteriol* **49**: 19-23.
- Nampoothiri KM, Singhania RR, Sabarinath C & Pandey A (2003) Fermentative production of gellan using *Sphingomonas paucimobilis*. *Process Biochem* **38**: 1513-1519.
- Navarrete AA, Barreto CC, Arnaldo M & Tsai SM (2013) Molecular detection on culture medium of Acidobacteria from Amazon soils. *Microbiol Discov* **1**.
- Navarrete AA, Kuramae EE, de Hollander M, Pijl AS, van Veen JA & Tsai SM (2013) Acidobacterial community responses to agricultural management of soybean in Amazon forest soils. *FEMS Microbiol Ecol* **83**: 607-621.
- NCBI Resource Coordinators (2016) Database resources of the National Center for Biotechnology Information. *Nucleic Acids Res* **44**: D7-D19.
- Negrea A, Bjur E, Puia S, Ygberg SE, Aslund F & Rhen M (2009) Thioredoxin 1 participates in the activity of the *Salmonella enterica* aerovar *Typhimurium* pathogenicity island 2 type III secretion system. *J Bacteriol* **191**: 6918-6927.
- Neufeld JD, Vohra J, Dumont MG, Lueders T, Manefield M, Friedrich MW & Murrell JC (2007) DNA stable-isotope probing. *Nat Protoc* **2**: 860-866.
- Nguyen NH, Song Z, Bates ST, Branco S, Tedersoo L, Menke J, Schilling JS & Kennedy PG (2016) FUNGuild: An open annotation tool for parsing fungal community datasets by ecological guild. *Fungal Ecol* **20**: 241-248.
- Nichols CM, Bowman JP & Guezennec J (2005) Effects of incubation temperature on growth and production of exopolysaccharides by an antarctic sea ice bacterium grown in batch culture. *Appl Environ Microbiol* **71**: 3519-3523.
- Nicolaus B, Moriello VS, Lama L, Poli A & Gambacorta A (2004) Polysaccharides from extremophilic microorganisms. *Orig Life Evol Biosph* **34**: 159-169.
- Nicolaus B, Panico A, Manca MC, Lama L, Gambacorta A, Maugeri T, Gugliandolo C & Caccamo D (2000) A thermophilic *Bacillus* isolated from an eolian shallow hydrothermal vent able to produce exopolysaccharides. *Syst Appl Microbiol* **23**: 426-432.
- Nidetzky B, Fürlinger M, Gollhofer D, Scopes RK, Haltrich D & Kulbe KD (1997) Improved operational stability of cell-

- free glucose-fructose oxidoreductase from *Zymomonas mobilis* for the efficient synthesis of sorbitol and gluconic acid in a continuous ultrafiltration membrane reactor. *Biotechnol Bioeng* **53**: 623-629.
- Nielsen PH & Jahn A (1999) Extraction of EPS. *Microbial Extracellular Polymeric Substances*, (Wingender J, Neu TR & Flemming H-C, eds.), 49-72. Springer Berlin Heidelberg, Berlin.
- Nikaido H (1996) Multidrug efflux pumps of gram-negative bacteria. *J Bacteriol* **178**: 5853-5859.
- O**
- Oh HN, Park D, Seong HJ, Kim D & Sul WJ (2019) Antarctic tundra soil metagenome as useful natural resources of cold-active lignocellolytic enzymes. *J Microbiol* **57**: 865-873.
- Okada K, Minehira M, Zhu X, Suzuki K, Nakagawa T, Matsuda H & Kawamukai M (1997) The *ispB* gene encoding octaprenyl diphosphate synthase is essential for growth of *Escherichia coli*. *J Bacteriol* **179**: 3058-3060.
- Okamura K, Kawai A, Yamada T & Hiraishi A (2011) Acidipila rosea gen. nov., sp. nov., an acidophilic chemoorganotrophic bacterium belonging to the phylum Acidobacteria. *FEMS Microbiol Lett* **317**: 138-142.
- Oksanen J, Blanchet FG, Friendly M, et al. (2018) vegan: community ecology package. R package version 2.4-6.
- Okshevsky M & Meyer RL (2013) The role of extracellular DNA in the establishment, maintenance and perpetuation of bacterial biofilms. *Crit Rev Microbiol* **41**: 341-352.
- Olm MR, Brown CT, Brooks B & Banfield JF (2017) dRep: a tool for fast and accurate genomic comparisons that enables improved genome recovery from metagenomes through de-replication. *ISME J* **11**: 2864-2868.
- Oshkin IY, Kulichevskaya IS, Rijpstra WIC, Sinninghe Damsté JS, Rakitin AL, Ravin NV & Dedysh SN (2019) Granulicella sibirica sp. nov., a psychrotolerant acidobacterium isolated from an organic soil layer in forested tundra, West Siberia. *Int J Syst Evol Microbiol* **69**: 1195-1201.
- Oussenko IA, Abe T, Ujiiie H, Muto A & Bechhofer DH (2005) Participation of 3'-to-5' exoribonucleases in the turnover of *Bacillus subtilis* mRNA. *J Bacteriol* **187**: 2758-2767.
- P**
- Padilla-Benavides T, Long JE, Raimunda D, Sasetti CM & Argüello JM (2013) A Novel P1B-type Mn<sup>2+</sup>-transporting ATPase Is required for secreted protein metallation in mycobacteria. *J Biol Chem* **288**: 11334-11347.
- Padmanabhan P, Padmanabhan S, DeRito C, Gray A, Gannon D, Snape JR, Tsai CS, Park W, Jeon C & Madsen EL (2003) Respiration of 13C-labeled substrates added to soil in the field and subsequent 16S rRNA gene analysis of 13C-labeled soil DNA. *Appl Environ Microbiol* **69**: 1614-1622.
- Pal C, Bengtsson-Palme J, Rensing C, Kristiansson E & Larsson DGJ (2014) BacMet: antibacterial biocide and metal resistance genes database. *Nucleic Acids Res* **42**: D737-D743.
- Pan Y, Cassman N, de Hollander M, Mendes LW, Korevaar H, Geerts RHEM, van Veen JA & Kuramae EE (2014) Impact of long-term N, P, K, and NPK fertilization on the composition and potential functions of the bacterial community in grassland soil. *FEMS Microbiol Ecol* **90**: 195-205.
- Pan Y, Cassman N, de Hollander M, Mendes LW, Korevaar H, Geerts R, van Veen JA & Kuramae EE (2014) Impact of long-term N, P, K, and NPK fertilization on the composition and potential functions of the bacterial community in grassland soil. *FEMS Microbiol Ecol* **90**: 195-205.
- Pankratov TA & Dedysh SN (2010) *Granulicella paludicola* gen. nov., sp nov., *Granulicella pectinivora* sp nov., *Granulicella aggregans* sp nov and *Granulicella rosea* sp nov., acidophilic, polymer-degrading acidobacteria from Sphagnum peat bogs. *Int J Syst Evol Microbiol* **60**: 2951-2959.
- Pankratov TA, Serkebaeva YM, Kulichevskaya IS, Liesack W & Dedysh SN (2008) Substrate-induced growth and isolation of *Acidobacteria* from acidic Sphagnum peat. *ISME J* **2**: 551-560.
- Pankratov TA, Kiranova LA, Kaparullina EN, Kevbrin VV & Dedysh SN (2012) Telmatobacter bradus gen. nov., sp nov., a cellulolytic facultative anaerobe from subdivision 1 of the Acidobacteria, and emended description of Acidobacterium capsulatum Kishimoto et al. 1991. *Int J Syst Evol Microbiol* **62**: 430-437.
- Papp-Wallace KM & Maguire ME (2006) Manganese transport and the role of manganese in virulence. *Annu Rev Microbiol* **60**: 187-209.
- Parikh A & Madamwar D (2006) Partial characterization of extracellular polysaccharides from cyanobacteria. *Bioresour Technol* **97**: 1822-1827.
- Parks DH, Imelfort M, Skennerton CT, Hugenholtz P & Tyson GW (2015) CheckM: assessing the quality of microbial

- genomes recovered from isolates, single cells, and metagenomes. *Genome Res* **25**: 1043-1055.
- Pascual J, Wüst PK, Geppert A, Foesel BU, Huber KJ & Overmann J (2015) Novel isolates double the number of chemotrophic species and allow the first description of higher taxa in Acidobacteria subdivision 4. *Syst Appl Microbiol* **38**: 534-544.
- Patel JJ & Gerson T (1974) Formation and utilisation of carbon reserves by *Rhizobium*. *Arch Microbiol* **101**: 211-220.
- Patel K & Golemi-Kotra D (2016) Signaling mechanism by the *Staphylococcus aureus* two-component system LytSR: role of acetyl phosphate in bypassing the cell membrane electrical potential sensor LytS. *F1000Res* **4**.
- Paterson GK, Cone DB, Northen H, Peters SE & Maskell DJ (2009) Deletion of the gene encoding the glycolytic enzyme triosephosphate isomerase (*Tpi*) alters morphology of *Salmonella enterica* serovar *typhimurium* and decreases fitness in mice. *FEMS Microbiol Lett* **294**: 45-51.
- Paul D, Pandey G, Meier C, van der Meer JR & Jain RK (2006) Bacterial community structure of a pesticide-contaminated site and assessment of changes induced in community structure during bioremediation. *FEMS Microbiol Ecol* **57**: 116-127.
- Pavlova K & Grigorova D (1999) Production and properties of exopolysaccharide by *Rhodotorula acheniorum* MC. *Food Res Int* **32**: 473-477.
- Pereira de Castro A, Sartori da Silva MRS, Quirino BF, da Cunha Bustamante MM & Krüger RH (2016) Microbial diversity in cerrado biome (neotropical savanna) soils. *PLoS One* **11**.
- Perez-Riverol Y, Csordas A, Bai J, et al. (2019) The PRIDE database and related tools and resources in 2019: improving support for quantification data. *Nucleic Acids Res* **47**: D442-D450.
- Petry S, Furlan S, Crepeau MJ, Cerning J & Desmazeaud M (2000) Factors affecting exocellular polysaccharide production by *Lactobacillus delbrueckii* subsp. *bulgaricus* grown in a chemically defined medium. *Appl Environ Microbiol* **66**: 3427-3431.
- Pinnell LJ, Dunford E, Ronan P, Hausner M & Neufeld JD (2014) Recovering glycoside hydrolase genes from active tundra cellulolytic bacteria. *Can J Microbiol* **60**: 469-476.
- Poli A, Moriello VS, Esposito E, Lama L, Gambacorta A & Nicolaus B (2004) Exopolysaccharide production by a new *Halomonas* strain CRSS isolated from saline lake Cape Russell in Antarctica growing on complex and defined media. *Biotechnol Lett* **26**: 1635-1638.
- Porcheron G, Garenaux A, Proulx J, Sabri M & Dozois CM (2013) Iron, copper, zinc, and manganese transport and regulation in pathogenic Enterobacteria: correlations between strains, site of infection and the relative importance of the different metal transport systems for virulence. *Front Cell Infect Microbiol* **3**: 90.
- Pruesse E, Peplies J & Glöckner FO (2012) SINA: Accurate high-throughput multiple sequence alignment of ribosomal RNA genes. *Bioinformatics* **28**: 1823-1829.
- Puri S, Hohle TH & O'Brian MR (2010) Control of bacterial iron homeostasis by manganese. *Proc Natl Acad Sci U S A* **107**: 10691-10695.
- Q**
- Queiroz PS, Ruas FAD, Barboza NR, de Castro Borges W & Guerra-Sá R (2018) Alterations in the proteomic composition of *Serratia marcescens* in response to manganese (II). *BMC Biotechnol* **18**.
- Qurashi AW & Sabri AN (2012) Bacterial exopolysaccharide and biofilm formation stimulate chickpea growth and soil aggregation under salt stress. *Braz J Microbiol* **43**: 1183-1191.
- R**
- R Core Team (2015) *R: A Language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna.
- Rashid MI, Mujawar LH, Shahzad T, Almeelbi T, Ismail IMI & Oves M (2016) Bacteria and fungi can contribute to nutrients bioavailability and aggregate formation in degraded soils. *Microbiol Res* **183**: 26-41.
- Rawat SR, Männistö MK, Starovoytov V, Goodwin L, Nolan M, Hauser L, Land M, Davenport KW, Woyke T & Häggblom MM (2013) Complete genome sequence of *Granulicella tundricola* type strain MP5ACTX9T, an Acidobacteria from tundra soil. *Stand Genomic Sci* **9**: 449-461.
- Rawat SR, Männistö MK, Starovoytov V, Goodwin L, Nolan M, Hauser LJ, Land M, Davenport KW, Woyke T & Häggblom MM (2013) Complete genome sequence of *Granulicella mallensis* type strain MP5ACTX8T, an acidobacterium

- from tundra soil. *Stand Genomic Sci* **9**: 71-82.
- Rehm BHA (2010) Bacterial polymers: biosynthesis, modifications and applications. *Nat Rev Microbiol* **8**: 578-592.
- Remminghorst U & Rehm BHA (2006) Bacterial alginates: from biosynthesis to applications. *Biotechnol Lett* **28**: 1701-1712.
- Reuber TL & Walker GC (1993) Biosynthesis of succinoglycan, a symbiotically important exopolysaccharide of *Rhizobium meliloti*. *Cell* **74**: 269-280.
- Richardson AR, Somerville GA & Sonenshein AL (2015) Regulating the Intersection of Metabolism and Pathogenesis in Gram-positive Bacteria. *Microbiol Spectr* **3**.
- Roberson EB & Firestone MK (1992) Relationship between desiccation and exopolysaccharide production in a soil *Pseudomonas* sp. *Appl Environ Microbiol* **58**: 1284-1291.
- Roberson EB, Chenu C & Firestone MK (1993) Microstructural changes in bacterial exopolysaccharides during desiccation. *Soil Biol Biochem* **25**: 1299-1301.
- Roberson EB, Shennan C, Firestone MK & Sarig S (1995) Nutritional Management of Microbial Polysaccharide Production and Aggregation in an Agricultural Soil. *Soil Sci Soc Am J* **59**.
- Robinson MD, McCarthy DJ & Smyth GK (2009) edgeR: A Bioconductor package for differential expression analysis of digital gene expression data. *Bioinformatics* **26**: 139-140.
- Roca C, Alves VD, Freitas F & Reis MAM (2015) Exopolysaccharides enriched in rare sugars: bacterial sources, production, and applications. *Front Microbiol* **6**.
- Rogers SL & Burns RG (1994) Changes in aggregate stability, nutrient status, indigenous microbial populations, and seedling emergence, following inoculation of soil with *Nostoc muscorum*. *Biol Fertil Soils* **18**: 209-215.
- Rognes T, Mahé F & xflouris (2015) vsearch: VSEARCH version 1.0.16.
- Romaní AM, Fischer H, Mille-Lindblom C & Tranvik LJ (2006) Interactions of bacteria and fungi on decomposing litter: differential extracellular enzyme activities. *Ecology* **87**: 2559-2569.
- Rosenzweig R, Shavit U & Furman A (2012) Water Retention Curves of Biofilm-Affected Soils using Xanthan as an Analogue. *Soil Sci Soc Am J* **76**.
- Rosner JL & Martin RG (2009) An Excretory function for the *Escherichia coli* outer membrane pore TolC: upregulation of marA and soxS transcription and rob activity due to metabolites accumulated in tolC mutants. *J Bacteriol* **191**: 5283-5292.
- Rossi F & De Philippis R (2015) Role of Cyanobacterial Exopolysaccharides in Phototrophic Biofilms and in Complex Microbial Mats. *Life* **5**: 1218-1238.
- Rossi F, Mugnai G & De Philippis R (2017) Complex role of the polymeric matrix in biological soil crusts. *Plant Soil*.
- Ruhal R, Kataria R & Choudhury B (2013) Trends in bacterial trehalose metabolism and significant nodes of metabolic pathway in the direction of trehalose accumulation. *Microb Biotechnol* **6**: 493-502.
- Ryder C, Byrd M & Wozniak DJ (2007) Role of polysaccharides in *Pseudomonas aeruginosa* biofilm development. *Curr Opin Microbiol* **10**: 644-648.
- S**
- Sá-Correia I, Fialho AM, Videira P, Moreira LM, Marques AR & Albano H (2002) Gellan gum biosynthesis in *Sphingomonas paucimobilis* ATCC 31461: genes, enzymes and exopolysaccharide production engineering. *J Ind Microbiol Biotechnol* **29**: 170-176.
- Sacheti P, Patil R, Dube A, et al. (2014) Proteomics of arsenic stress in the gram-positive organism *Exiguobacterium* sp. PS NCIM 5463. *Appl Microbiol Biotechnol* **98**: 6761-6773.
- Sadeghi SH, Kheirfam H, Homaei M, Darki BZ & Vafakhah M (2017) Improving runoff behavior resulting from direct inoculation of soil micro-organisms. *Soil Tillage Res* **171**: 35-41.
- Saeed AI, Sharov V, White J, et al. (2003) TM4: A free, open-source system for microarray data management and analysis. *Biotechniques* **34**: 374-378.
- Sakurai K, Arai H, Ishii M & Igashira Y (2010) Transcriptome response to different carbon sources in *Acetobacter aceti*. *Microbiology* **157**: 899-910.
- Sanchez-Peinado MD, Gonzalez-Lopez J, Martinez-Toledo MV, Pozo C & Rodelas B (2010) Influence of linear

- alkylbenzene sulfonate (LAS) on the structure of Alphaproteobacteria, Actinobacteria, and Acidobacteria communities in a soil microcosm. *Environ Sci Pollut Res* **17**: 779-790.
- Schabereiter-Gurtner C, Saiz-Jimenez C, Pinar G, Lubitz W & Rolleke S (2002) Altamira cave Paleolithic paintings harbor partly unknown bacterial communities. *FEMS Microbiol Lett*.
- Schellenberger S, Kolb S & Drake HL (2009) Metabolic responses of novel cellulolytic and saccharolytic agricultural soil Bacteria to oxygen. *Environ Microbiol* **12**: 845-861.
- Schlemper TR, van Veen JA & Kuramae EE (2017) Co-variation of bacterial and fungal communities in different sorghum cultivars and growth stages is soil dependent. *Microb Ecol* **76**: 205-214.
- Schlener H (1994) The development of media suitable for the microorganisms morphologically resembling *Planctomyces* spp., *Pirellula* spp., and other *Planctomycetales* from various aquatic habitats using dilute media. *Syst Appl Microbiol* **17**: 135-145.
- Schmid J, Sieber V & Rehm B (2015) Bacterial exopolysaccharides: biosynthesis pathways and engineering strategies. *Front Microbiol* **6**.
- Schmid J, Heider D, Wendel NJ, Sperl N & Sieber V (2016) Bacterial Glycosyltransferases: Challenges and Opportunities of a Highly Diverse Enzyme Class Toward Tailoring Natural Products. *Front Microbiol* **7**.
- Schneider T, Schmid E, de Castro JV, Cardinale M, Eberl L, Grube M, Berg G & Riedel K (2011) Structure and function of the symbiosis partners of the lung lichen (*Lobaria pulmonaria* L. Hoffm.) analyzed by metaproteomics. *Proteomics* **11**: 2752-2756.
- Schneider T, Keiblinger KM, Schmid E, Sterflinger-Gleixner K, Ellersdorfer G, Roschitzki B, Richter A, Eberl L, Zechmeister-Boltenstern S & Riedel K (2012) Who is who in litter decomposition? Metaproteomics reveals major microbial players and their biogeochemical functions. *ISME J* **6**: 1749-1762.
- Schön A (1999) Ribonuclease P: the diversity of a ubiquitous RNA processing enzyme. *FEMS Microbiol Rev* **23**: 391-406.
- Schwab C, Walter J, Tannock GW, Vogel RF & Gänzle MG (2007) Sucrose utilization and impact of sucrose on glycosyltransferase expression in *Lactobacillus reuteri*. *Syst Appl Microbiol* **30**: 433-443.
- Scieglińska D & Krawczyk Z (2014) Expression, function, and regulation of the testis-enriched heat shock HSPA2 gene in rodents and humans. *Cell Stress Chaperon* **20**: 221-235.
- Seemann T (2014) Prokka: rapid prokaryotic genome annotation. *Bioinformatics* **30**: 2068-2069.
- Seemann T (2018) BAsic Rapid Ribosomal RNA Predictor 0.9.
- Sessitsch A, Weiharter A, Gerzabek MH, Kirchmann H & Kandeler E (2001) Microbial Population Structures in Soil Particle Size Fractions of a Long-Term Fertilizer Field Experiment. *Appl Environ Microbiol* **67**: 4215-4224.
- Shannon P (2003) Cytoscape: a software environment for integrated models of biomolecular interaction networks. *Genome Res* **13**: 2498-2504.
- Sheng GP, Yu HQ & Yue Z (2006) Factors influencing the production of extracellular polymeric substances by *Rhodopseudomonas acidophila*. *Int Biodegrad Biodegr* **58**: 89-93.
- Shih I-L, Yu J-Y, Hsieh C & Wu J-Y (2009) Production and characterization of curdlan by *Agrobacterium* sp. *Biochem Eng J* **43**: 33-40.
- Shu C-H & Lung M-Y (2004) Effect of pH on the production and molecular weight distribution of exopolysaccharide by *Antrodia camphorata* in batch cultures. *Process Biochem* **39**: 931-937.
- Sieber CMK, Probst AJ, Sharrar A, Thomas BC, Hess M, Tringe SG & Banfield JF (2018) Recovery of genomes from metagenomes via a dereplication, aggregation and scoring strategy. *Nat Microbiol* **3**: 836-843.
- Singh V, Maniar K, Bhattacharyya R & Banerjee D (2018) A novel insight in favor of structure-function relationship for 16S rRNA. *Mol Biol Rep* **45**: 1569-1573.
- Singleton DR, Powell SN, Sangaiah R, Gold A, Ball LM & Aitken MD (2005) Stable-isotope probing of bacteria capable of degrading salicylate, naphthalene, or phenanthrene in a bioreactor treating contaminated soil. *Appl Environ Microbiol* **71**: 1202-1209.
- Sokolov M, Lu L, Tucker W, Gao F, Gegenheimer PA & Richter ML (1999) The 20 C-terminal amino acid residues of the chloroplast ATP synthase γ subunit are not essential for activity. *J Biol Chem* **274**: 13824-13829.
- Song M, Jiang L, Zhang D, Luo C, Wang Y, Yu Z, Yin H & Zhang G (2016) Bacteria capable of degrading anthracene, phenanthrene, and fluoranthene as revealed by DNA based stable-isotope probing in a forest soil. *J Hazard Mater*

- 308: 50-57.
- Souli M & Giamarellou H (1998) Effects of slime produced by clinical isolates of coagulase-negative staphylococci on activities of various antimicrobial agents. *Antimicrob Agents Chemother* **42**: 939-941.
- Sparling GP & Cheshire MV (1985) Effect of periodate oxidation on the polysaccharide content and microaggregate stability of rhizosphere and non-rhizosphere soils. *Plant Soil* **88**: 113-122.
- Spring S, Bunk B, Spröer C, Schumann P, Rohde M, Tindall BJ & Klenk H-P (2016) Characterization of the first cultured representative of *Verrucomicrobia* subdivision 5 indicates the proposal of a novel phylum. *ISME J* **10**: 2801-2816.
- Srikanth R, Reddy CHSSS, Siddartha G, Ramaiah MJ & Uppuluri KB (2015) Review on production, characterization and applications of microbial levan. *Carbohydr Polym* **120**: 102-114.
- Staley JT & Konopka A (1985) Measurement of in Situ Activities of Nonphotosynthetic Microorganisms in Aquatic and Terrestrial Habitats. *Annu Rev Microbiol* **39**: 321-346.
- Stasinopoulos SJ, Fisher PR, Stone BA & Stanisich VA (1999) Detection of two loci involved in (1 → 3)-beta-glucan (curdlan) biosynthesis by *Agrobacterium* sp. ATCC31749, and comparative sequence analysis of the putative curdlan synthase gene. *Glycobiology* **9**: 31-41.
- Staudt AK, Wolfe LG & Shroud JD (2011) Variations in exopolysaccharide production by *Rhizobium tropici*. *Arch Microbiol* **194**: 197-206.
- Stevenson BS, Eichorst SA, Wertz JT, Schmidt TM & Breznak JA (2004) New strategies for cultivation and detection of previously uncultured microbes. *Appl Environ Microbiol* **70**: 4748-4755.
- Stopnisek N, Zühlke D, Carlier A, Barberán A, Fierer N, Becher D, Riedel K, Eberl L & Weisskopf L (2016) Molecular mechanisms underlying the close association between soil *Burkholderia* and fungi. *ISME J* **10**: 253-264.
- Stothard P & Wishart DS (2004) Circular genome visualization and exploration using CGView. *Bioinformatics* **21**: 537-539.
- Štursová M, Žifčáková L, Leigh MB, Burgess R & Baldrian P (2012) Cellulose utilization in forest litter and soil: identification of bacterial and fungal decomposers. *FEMS Microbiol Ecol* **80**: 735-746.
- Sutherland IW (2001) Microbial polysaccharides from Gram-negative bacteria. *Int Dairy J* **11**: 663-674.
- Sutherland IW (2004) Microbial Exopolysaccharides. *Polysaccharides: Structural Diversity and Functional Versatility*, (Dumitriu S, ed.) CRC Press, Florida.
- Swaby RJ (1949) The relationship between micro-organisms and soil aggregation. *J Gen Microbiol* **3**: 236-254.
- T**
- Tachdjian S & Kelly RM (2006) Dynamic metabolic adjustments and genome plasticity are implicated in the heat shock response of the extremely thermoacidophilic archaeon *Sulfolobus solfataricus*. *J Bacteriol* **188**: 4553-4559.
- Tamames J & Puente-Sánchez F (2019) SqueezeMeta, A Highly Portable, Fully Automatic Metagenomic Analysis Pipeline. *Front Microbiol* **9**.
- Tamura K & Nei M (1993) Estimation of the Number of Nucleotide Substitutions in the Control Region of Mitochondrial DNA in Humans and Chimpanzees. *Mol Biol Evol* **10**: 512-526.
- Tang J, Mo Y, Zhang J & Zhang R (2011) Influence of biological aggregating agents associated with microbial population on soil aggregate stability. *Appl Soil Ecol* **47**: 153-159.
- Tank M & Bryant DA (2015) Nutrient requirements and growth physiology of the photoheterotrophic Acidobacterium, *Chloracidobacterium thermophilum*. *Front Microbiol* **06**.
- Tebar AR, Ballesteros A & Soria J (1977) Mn<sup>2+</sup> electron spin resonance studies on ATP phosphoribosyltransferase from *E. coli*. *Experientia* **33**: 1292-1294.
- Thoma R, Hennig M, Sterner R & Kirschner K (2000) Structure and function of mutationally generated monomers of dimeric phosphoribosylanthranilate isomerase from *Thermotoga maritima*. *Structure* **8**: 265-276.
- Thrash JC & Coates Jd (2014) Phylum XVII. Acidobacteria phyl. nov. *Bergey's Manual of Systematic Bacteriology*, (Krieg NR, Ludwig W, Whitman WB, Hedlund BP, Paster BJ, Staley JT, Ward N & Brown D, eds.).
- Tieking M, Ehrmann MA, Vogel RF & Gänzle MG (2004) Molecular and functional characterization of a levensucrase from the sourdough isolate *Lactobacillus sanfranciscensis* TMW 1.392. *Appl Microbiol Biotechnol* **66**: 655-663.
- Tisdall JM & Oades JM (1982) Organic matter and water-stable aggregates in soils. *J Soil Sci* **33**: 141-163.

- Torrent M, Chalancón G, de Groot NS, Wuster A & Madan Babu M (2018) Cells alter their tRNA abundance to selectively regulate protein synthesis during stress conditions. *Sci Signal* **11**.
- Torres CAV, Antunes S, Ricardo AR, Grandfils C, Alves VD, Freitas F & Reis MAM (2012) Study of the interactive effect of temperature and pH on exopolysaccharide production by *Enterobacter* A47 using multivariate statistical analysis. *Bioresour Technol* **119**: 148-156.
- Trchounian K, Poladyan A & Trchounian A (2016) Optimizing strategy for *Escherichia coli* growth and hydrogen production during glycerol fermentation in batch culture: effects of some heavy metal ions and their mixtures. *Appl Energy* **177**: 335-340.
- Tsuneda S, Aikawa H, Hayashi H, Yuasa A & Hirata A (2003) Extracellular polymeric substances responsible for bacterial adhesion onto solid surface. *FEMS Microbiol Lett* **223**: 287-292.
- U**
- Uhlik O, Wald J, Strejcek M, Musilova L, Ridl J, Hroudova M, Vlcek C, Cardenas E, Mackova M & Macek T (2012) Identification of bacteria utilizing biphenyl, benzoate, and naphthalene in long-term contaminated soil. *PLoS One* **7**: e40653.
- Umer MI & Rajab SM (2012) Correlation between aggregate stability and microbiological activity in two Russian soil types. *Eurasian J Soil Sci* **1**: 5.
- Upadhyay A, Kochar M, Rajam MV & Srivastava S (2017) Players over the Surface: Unraveling the Role of Exopolysaccharides in Zinc Biosorption by Fluorescent Pseudomonas Strain Psd. *Front Microbiol* **8**.
- Upadhyay SK, Singh JS & Singh DP (2011) Exopolysaccharide-producing plant growth-promoting rhizobacteria under salinity condition. *Pedosphere* **21**: 214-222.
- Urbanová M, Šnajdr J & Baldrian P (2015) Composition of fungal and bacterial communities in forest litter and soil is largely determined by dominant trees. *Soil Biol Biochem* **84**: 53-64.
- V**
- Valášková V, de Boer W, Klein Gunnewiek PJA, Pospíšek M & Baldrian P (2009) Phylogenetic composition and properties of bacteria coexisting with the fungus *Hypholoma fasciculare* in decaying wood. *ISME J* **3**: 1218-1221.
- Valdivia-Anistro JA, Eguiarte-Fruns LE, Delgado-Sapién G, Márquez-Zacarías P, Gasca-Pineda J, Learned J, Elser JJ, Olmedo-Alvarez G & Souza V (2016) Variability of rRNA Operon Copy Number and Growth Rate Dynamics of *Bacillus* Isolated from an Extremely Oligotrophic Aquatic Ecosystem. *Front Microbiol* **6**.
- Valepyn E, Berezina N & Paquot M (2012) Optimization of production and preliminary characterization of new exopolysaccharides from *Gluconacetobacter hansenii* LMG1524. *Adv Microbiol* **02**: 488-496.
- van Bueren AL, Saraf A, Martens EC, Dijkhuizen L & Drake HL (2015) Differential metabolism of exopolysaccharides from probiotic *Lactobacilli* by the human gut symbiont *Bacteroides thetaiotaomicron*. *Appl Environ Microbiol* **81**: 3973-3983.
- Vardharajula S & Ali SZ (2014) Exopolysaccharide production by drought tolerant *Bacillus* spp. and effect on soil aggregation under drought stress. *J Microbiol Biotechnol Food Sci* **4**: 51-57.
- Vardharajula S & Ali SZ (2015) The production of exopolysaccharide by *Pseudomonas putida* GAP-P45 under various abiotic stress conditions and its role in soil aggregation. *Microbiology* **84**: 512-519.
- Vardharajula S, Sk. Z A, Grover M, Reddy G & Venkateswarlu B (2009) Alleviation of drought stress effects in sunflower seedlings by the exopolysaccharides producing *Pseudomonas putida* strain GAP-P45. *Biol Fertil Soils* **46**: 17-26.
- Velasco Ayuso S, Giraldo Silva A, Nelson C, Barger NN, Garcia-Pichel F & Stams AJ (2017) Microbial Nursery Production of High-Quality Biological Soil Crust Biomass for Restoration of Degraded Dryland Soils. *Appl Environ Microbiol* **83**.
- Verastegui Y, Cheng J, Engel K, et al. (2014) Multisubstrate isotope labeling and metagenomic analysis of active soil bacterial communities. *mBio* **5**: e01157-01114.
- Vester JK, Glaring MA & Stougaard P (2015) Improved cultivation and metagenomics as new tools for bioprospecting in cold environments. *Extremophiles* **19**: 17-29.
- Vicente-García V, Ríos-Leal E, Calderón-Domínguez G, Cañizares-Villanueva RO & Olvera-Ramírez R (2004) Detection, isolation, and characterization of exopolysaccharide produced by a strain of *Phormidium* 94a isolated from an arid zone of Mexico. *Biotechnol Bioeng* **85**: 306-310.

- Vieira S, Luckner M, Wanner G & Overmann J (2017) Luteitalea pratensis gen. nov., sp. nov. a new member of subdivision 6 Acidobacteria isolated from temperate grassland soil. *Int J Syst Evol Microbiol* **67**: 1408-1414.
- Vilain S, Pretorius JM, Theron J & Brozel VS (2009) DNA as an adhesin: *Bacillus cereus* requires extracellular DNA to form biofilms. *Appl Environ Microbiol* **75**: 2861-2868.
- Vivanco L, Rascovan N & Austin AT (2018) Plant, fungal, bacterial, and nitrogen interactions in the litter layer of a native Patagonian forest. *PeerJ* **6**.
- Vorhölter F-J, Schneiker S, Goessmann A, et al. (2008) The genome of *Xanthomonas campestris* pv. *campestris* B100 and its use for the reconstruction of metabolic pathways involved in xanthan biosynthesis. *J Biotechnol* **134**: 33-45.
- W**
- Walker BJ, Abeel T, Shea T, et al. (2014) Pilon: an integrated tool for comprehensive microbial variant detection and genome assembly improvement. *PLoS One* **9**.
- Wan Z, Brown PJB, Elliott EN & Brun YV (2013) The adhesive and cohesive properties of a bacterial polysaccharide adhesin are modulated by a deacetylase. *Mol Microbiol* **88**: 486-500.
- Wang J, Jenkins C, Webb RI & Fuerst JA (2002) Isolation of *Gemmata*-like and *Isosphaera*-like *Planctomycete* bacteria from soil and freshwater. *Appl Environ Microbiol* **68**: 417-422.
- Wang N, Zhang S & He M (2016) Bacterial community profile of contaminated soils in a typical antimony mining site. *Environ Sci Pollut Res* **25**: 141-152.
- Wang Q, Garrity GM, Tiedje JM & Cole JR (2007) Naive Bayesian Classifier for Rapid Assignment of rRNA Sequences into the New Bacterial Taxonomy. *Appl Environ Microbiol* **73**: 5261-5267.
- Wang X, Sharp CE, Jones GM, Grasby SE, Brady AL, Dunfield PF & Nojiri H (2015) Stable-isotope probing identifies uncultured *Planctomycetes* as primary degraders of a complex heteropolysaccharide in soil. *Appl Environ Microbiol* **81**: 4607-4615.
- Wang X, Xu P, Yuan Y, Liu C, Zhang D, Yang Z, Yang C & Ma C (2006) Modeling for gellan gum production by *Sphingomonas paucimobilis* ATCC 31461 in a simplified medium. *Appl Environ Microbiol* **72**: 3367-3374.
- Ward NL, Challacombe JF, Janssen PH, et al. (2009) Three genomes from the phylum Acidobacteria provide insight into the lifestyles of these microorganisms in soils. *Appl Environ Microbiol* **75**: 2046-2056.
- Warnecke F, Lugibühl P, Ivanova N, et al. (2007) Metagenomic and functional analysis of hindgut microbiota of a wood-feeding higher termite. *Nature* **450**: 560-565.
- Warner JB & Lolkema JS (2003) CcpA-Dependent carbon catabolite repression in bacteria. *Microbiol Mol Biol Rev* **67**: 475-490.
- Wegner C-E & Liesack W (2017) Unexpected Dominance of Elusive Acidobacteria in Early Industrial Soft Coal Slags. *Front Microbiol* **8**.
- Whang KS, Lee JC, Lee HR, Han SI & Chung SH (2014) *Terriglobus tenax* sp. nov., an exopolysaccharide-producing acidobacterium isolated from rhizosphere soil of a medicinal plant. *Int J Syst Evol Microbiol* **64**: 431-437.
- Whitchurch CB, Tolker-Nielsen T, Ragas PC & Mattick JS (2002) Extracellular DNA required for bacterial biofilm formation. *Science* **295**: 1487-1487.
- White, Bruns T, Lee S & Taylor J (1990) Amplification and direct sequencing of fungal ribosomal RNA Genes for phylogenetics. *PCR - Protocols and Applications - A Laboratory Manual*, 315-322. Academic Press.
- White III RA, Brown J, Colby S, Overall CC, Lee J-Y, Zucker J, Glaesemann KR, Jansson C & Jansson JK (2017) ATLAS (Automatic Tool for Local Assembly Structures) - a comprehensive infrastructure for assembly, annotation, and genomic binning of metagenomic and metatranscriptomic data. *PeerJ* **1**.
- Whitney JC & Howell PL (2013) Synthase-dependent exopolysaccharide secretion in gram-negative Bacteria. *Trends Microbiol* **21**: 63-72.
- Wiater A, Szczodrak J, Pleszczynska M & Próchniak K (2005) Production and use of mutanase from *Trichoderma harzianum* for effective degradation of streptococcal mutans. *Braz J Microbiol* **36**.
- Wickham H (2016) ggplot2. Use R!
- Wiegand S, Jogler M & Jogler C (2018) On the maverick *Planctomycetes*. *FEMS Microbiol Rev* 739-760.

- Williams A, Wilkinson A, Krehenbrink M, Russo DM, Zorreguieta A & Downie JA (2008) Glucomannan-mediated attachment of *Rhizobium leguminosarum* to pea root hairs is required for competitive nodule infection. *J Bacteriol* **190**: 4706-4715.
- Wingender J, Neu TR & Flemming H-C (1999) What are bacterial extracellular polymeric substances? *Microbial Extracellular Polymeric Substances: Characterization, Structure and Function*, (Wingender J, Neu TR & Flemming H-C, eds.), 1-19. Springer Berlin Heidelberg, Berlin.
- Wingender J, Jaeger K-E & Flemming H-C (1999) Interaction Between Extracellular Polysaccharides and Enzymes. *Microbial Extracellular Polymeric Substances* 231-251. Springer Berlin Heidelberg, Berlin.
- Wingender J, Jaeger K-E & Flemming H-C (1999) Interaction between extracellular polysaccharides and enzymes. *Microbial extracellular polymeric substances*, 231-251. Springer.
- Wintsche B, Glaser K, Sträuber H, Centler F, Liebetrau J, Harms H & Kleinstuber S (2016) Trace elements induce predominance among methanogenic activity in anaerobic digestion. *Front Microbiol* **7**.
- Wolfaardt GM, Lawrence JR & Korber DR (1999) Function of EPS. *Microbial Extracellular Polymeric Substances* 171-200. Springer Berlin Heidelberg, Berlin.
- Wu N, Pan H-X, Qiu D & Zhang Y-M (2014) Feasibility of EPS-producing bacterial inoculation to speed up the sand aggregation in the Gurbantüngüt Desert, Northwestern China. *J Basic Microbiol* **54**: 1378-1386.
- Wu Y-W, Tang Y-H, Tringe SG, Simmons BA & Singer SW (2014) MaxBin: an automated binning method to recover individual genomes from metagenomes using an expectation-maximization algorithm. *Microbiome* **2**.
- Wüst PK, Foesel BU, Geppert A, Huber KJ, Luckner M, Wanner G & Overmann J (2016) *Brevitalea aridisoli*, *B. deliciosa* and *Arenimicrobium luteum*, three novel species of Acidobacteria subdivision 4 (class Blastocatellia) isolated from savanna soil and description of the novel family Pyrinomonadaceae. *Int J Syst Evol Microbiol* **66**: 3355-3366.
- Y**
- Yamada K, Okuno Y, Meng X-Y, Tamaki H, Kamagata Y & Hanada S (2014) *Granulicella cerasi* sp. nov., an acidophilic bacterium isolated from cherry bark. *Int J Syst Evol Microbiol* **64**: 2781-2785.
- Yin Y, Mao X, Yang J, Chen X, Mao F & Xu Y (2012) dbCAN: a web resource for automated carbohydrate-active enzyme annotation. *Nucleic Acids Res* **40**: W445-W451.
- Yoon S-H, Ha S-m, Lim J, Kwon S & Chun J (2017) A large-scale evaluation of algorithms to calculate average nucleotide identity. *Antonie Van Leeuwenhoek* **110**: 1281-1286.
- Yu H, Rao X & Zhang K (2017) Nucleoside diphosphate kinase (Ndk): A pleiotropic effector manipulating bacterial virulence and adaptive responses. *Microbiol Res* **205**: 125-134.
- Yu X, Zhang C, Yang L, Zhao L, Lin C, Liu Z & Mao Z (2015) CrdR function in a curdlan-producing *Agrobacterium* sp. ATCC31749 strain. *BMC Microbiol* **15**: 25.
- Yuan S, Yin S, Liu M & Kong J-Q (2018) Isolation and characterization of a multifunctional flavonoid glycosyltransferase from *Ornithogalum caudatum* with glycosidase activity. *Sci Rep* **8**.
- Yuksekdag ZN & Aslim B (2008) Influence of different carbon sources on exopolysaccharide production by *Lactobacillus delbrueckii* subsp. *bulgaricus* (B3, G12) and *Streptococcus thermophilus* (W22). *Braz Arch Biol Technol* **51**: 581-585.
- Z**
- Zgurskaya HI, Krishnamoorthy G, Ntreh A & Lu S (2011) Mechanism and Function of the Outer Membrane Channel TolC in Multidrug Resistance and Physiology of Enterobacteria. *Front Microbiol* **2**.
- Zhang H, Yohe T, Huang L, Entwistle S, Wu P, Yang Z, Busk PK, Xu Y & Yin Y (2018) dbCAN2: a meta server for automated carbohydrate-active enzyme annotation. *Nucleic Acids Res* **46**: W95-W101.
- Zhang X, Xin X, Zhu A, Yang W, Zhang J, Ding S, Mu L & Shao L (2018) Linking macroaggregation to soil microbial community and organic carbon accumulation under different tillage and residue managements. *Soil Tillage Res* **178**: 99-107.
- Zhang Y, Rodionov DA, Gelfand MS & Gladyshev VN (2009) Comparative genomic analyses of nickel, cobalt and vitamin B12 utilization. *BMC genomics* **10**: 78.
- Zhang Y, Wen Z, Washburn MP & Florens L (2010) Refinements to label free proteome quantitation: how to deal with peptides shared by multiple proteins. *Anal Chem* **82**: 2272-2281.

References

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- Zhang Y, Deng W, Xie X & Jiao N (2016) Differential incorporation of carbon substrates among microbial populations identified by field-based, DNA stable-isotope probing in South China sea. *PLoS One* **11**: e0157178.
- Zimmermann J, Gonzalez JM, Saiz-Jimenez C & Ludwig W (2005) Detection and phylogenetic relationships of highly diverse uncultured acidobacterial communities in altamira cave using 23S rRNA sequence analyses. *Geomicrobiol J* **22**: 379-388.
- Zweers JC, Nicolas P, Wiegert T, van Dijl JM & Denham EL (2012) Definition of the oW Regulon of *Bacillus subtilis* in the Absence of Stress. *PLoS One* **7**.s