



Universiteit
Leiden
The Netherlands

Ecological functions and environmental fate of exopolymers of *Acidobacteria*

Costa, O.Y.A.

Citation

Costa, O. Y. A. (2020, July 9). *Ecological functions and environmental fate of exopolymers of Acidobacteria*. Retrieved from <https://hdl.handle.net/1887/123274>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/123274>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/123274> holds various files of this Leiden University dissertation.

Author: Costa, O.Y.A.

Title: Ecological functions and environmental fate of exopolymers of Acidobacteria

Issue Date: 2020-07-09

References

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.
- Amézqueta E (1999) Soil Aggregate Stability: A Review. *J Sustain Agr* **14**: 83-151.
- Angers DA & Mehuys 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 Apl Int* **21**: 6.
- Bao Y, Dolfing 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, Sinninghe 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* levansucrase 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 Ecol* **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 J 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 Bruijn 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) BMAP.
- 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, Ziervogel 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.
- Chandrangsu 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 β -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**.
- Craig 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, Kenerley CM, Monte E, Mukherjee PK, Zeilinger 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 chimera 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 & Woeckel 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, Massachusetts.

Ezeilo UR, Zakaria II, Huyop F & Wahab RA (2017) Enzymatic breakdown of lignocellulosic biomass: the role of glycosyl hydrolases and lytic polysaccharide monoxygenases. *Biotechnol Biotechnol Equip* 1-16.

F

Falagán C, Foessel 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* **623**:633.
- 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., *Acanthopleuribacteriales* 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, Chatzievangelou 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 bif fermentans*. *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 Envir 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 σ B regulons. *Mol Microbiol* **49**: 1477-1491.
- Guldimann 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, Mougél 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 & Wuerzt 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 & Wuerzt 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-Lecreulx D (2007) Biochemical characterization and physiological properties of *Escherichia coli* UDP-N-Acetylmuramate: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 & Foesel 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, Ibršimović 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

- Ivanova 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.
- Ivanova 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.
- Ivanova AA, Naumoff DG, Miroshnikov KK, Liesack W & Dedysh SN (2017) Comparative genomics of four *Isosphaeraceae* *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.
- Ivanova 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, Raghu Kumar 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* 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 CYY, 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 H₂O₂-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, Liong 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. *Metallomics* **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, Sinninghe Damste JS, Rijpstra WJ, 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 & Annernman 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 sapmiensis* 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 Hort*.
- 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*, (Rosemberg 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 *Planctomycete* 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 coeligiosins. *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 VJMN, 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.
- Mulchak 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.
- Mulchak 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, Singhanian 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, Puigac 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, Furlinger 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 lignocellulolytic 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, Rijpsma WIC, Sinninghe Damsté JS, Rakitin AL, Ravin NV & Dedys 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, Ujiie H, Muto A & Bechhofer DH (2005) Participation of 3'-to-5' exonucleases in the turnover of *Bacillus subtilis* mRNA. *J Bacteriol* **187**: 2758-2767.
- P**
- Padilla-Benavides T, Long JE, Raimunda D, Sassetti CM & Argüello JM (2013) A Novel P1B-type Mn²⁺-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 & Dedys SN (2010) *Granulicella paludicola* gen. nov., sp. nov., *Granulicella pectinivorans* 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 & Dedys SN (2008) Substrate-induced growth and isolation of *Acidobacteria* from acidic Sphagnum peat. *ISME J* **2**: 551-560.
- Pankratov TA, Kirsanova LA, Kaparullina EN, Kevbrin VV & Dedys 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*.
- Ruhel 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 & Igarashi 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 & Rolfe 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.
- Schlesner 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, Weilharter 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 *Rhodospseudomonas acidophila*. *Int Biodeter 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 CHSS, Siddhartha 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 & Shrout 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) Mn²⁺ 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 levansucrase 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, Chalancon 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, Eguarte-Frutos 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, Goesmann 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, Luginbühl 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, Pleszczyńska 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 & Kleinstaub 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 Gurbantünggüt 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 curdian-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, Ntrel 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.

- 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 Dijk JM & Denham EL (2012) Definition of the σ^W Regulon of *Bacillus subtilis* in the Absence of Stress. *PLoS One* **7**:s