

# [Editorial: actinobacteria , a source of biocatalytic tools](https://assignbuster.com/editorial-actinobacteria-a-source-of-biocatalytic-tools/)

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Editorial on the Research Topic
[*Actinobacteria* , a Source of Biocatalytic Tools](https://www.frontiersin.org/research-topics/5513/actinobacteria-a-source-of-biocatalytic-tools)

## Actinobacteria: Ancient Phylum With Large Biotechnological Potential Still to be Uncovered

Actinobacteria (Actinomycetes) represent one of the largest and most diverse phyla among the Bacteria. The characteristics and phylogeny of actinobacteria have been well-described throughout the years ( [Anteneh and Franco](https://doi.org/10.3389/fmicb.2019.00077) ; [Embley et al., 1994](#B7) ; [Stackebrandt et al., 1997a](#B51) , [b](#B53) ; [Stach and Bull, 2005](#B50) ; [Stackebrandt and Schumann, 2006](#B52) ; [Ventura et al., 2007](#B58) ; [Gao and Gupta, 2012](#B8) ; [Goodfellow, 2012a](#B9) , [b](#B10) ; [Schrempf, 2013](#B45) ; [Lawson, 2018](#B19) ; [Lewin et al., 2016](#B20) ). Still actinobacteria are hotspots for discovery of new biomolecules and enzyme activities, fueling an active field of research. The remarkable diversity is displayed by various lifestyles, distinct morphologies, a wide spectrum of physiological and metabolic activities, as well as genetics.

Most actinobacteria have a high GC-content (ranging from 51% to over 70%) and belong to Gram-positive or Gram-variable type microbes ( [Stackebrandt and Schumann, 2006](#B52) ; [Ventura et al., 2007](#B58) ; [Lawson, 2018](#B19) ). Many species are well-known for their large genomes, which may be of linear style, as in case of rhodococci, or circular ( [Ventura et al., 2007](#B58) ; [Sen et al., 2014](#B47) ; [Lewin et al., 2016](#B20) ). Many also harbor linear megaplasmids as a kind of genetic storage device ( [König et al., 2004](#B17) ; [Medema et al., 2010](#B23) ; [Wagenknecht et al., 2010](#B59) ; [Bottacini et al., 2015](#B2) ). These plasmids often encode special metabolic features such as secondary metabolite synthetic machineries or alternative degradation pathways. However, a number of representatives comprise smaller genomes such as some *Bifidobacteria, Corynebacteria, Mycobacteria* , and *Propionibacteria* species ( [Ventura et al., 2007](#B58) ; [Lewin et al., 2016](#B20) ). Interestingly, smaller genomes are often encountered in pathogens or in those, which live in ecological niches. The smallest actinobacterial genomes can be found among *Tropheryma* , which is known as the Whipple's disease microbe ( [Bentley et al., 2003](#B1) ; [Raoult et al., 2003](#B35) ). Gene redundancy or genes encoding for closely related enzymes are frequently reported and in most cases the evolutionary history or a functional role remains enigmatic ( [McLeod et al., 2006](#B22) ; [Tischler et al., 2009](#B55) , [2010](#B56) , [2013](#B57) ; [Roberts et al., 2011](#B42) ; [Riebel et al., 2012](#B39) ; [Gröning et al., 2014](#B12) ; [Riedel et al., 2015a](#B40) , [b](#B41) ; [Nguyen et al., 2017](#B26) ; [Chen et al., 2018](#B3) ; [Gran-Scheuch et al.](https://doi.org/10.3389/fmicb.2018.01609) ). In this context horizontal gene transfer was found to play a major role in the genome fluidity of actinobacteria ( [Ventura et al., 2007](#B58) ). However, this seems not to be true for all actinobacteria or limited to some features such as secondary metabolism as discussed for *Streptomyces* and *Rhodococcus* , respectively ( [McLeod et al., 2006](#B22) ; [Lewin et al., 2016](#B20) ).

The large actinobacterial genomes and megaplasmids provide access to an impressive number of potential biocatalysts and pathways ( [Lewin et al., 2016](#B20) ). A few examples of novel biocatalysts linked to gene redundancy are cited above, but still more truly novel enzymes or pathways await elucidation. Actinobacteria are well-known for their biotechnological potential which is exemplarily described for amino acid producing *Corynebacteria* ( [Poetsch et al., 2011](#B32) ; [Goldbeck et al.](https://doi.org/10.3389/fmicb.2018.02564) ; [Pérez-García et al.](https://doi.org/10.3389/fmicb.2018.02589) ), secondary metabolite producing *Streptomyces* ( [Niu et al., 2016](#B28) ; [Senges et al., 2018](#B48) ), pathogenic targets as *Nocardia* and *Mycobacteria* ( [Cosma et al., 2003](#B4) ; [Wilson, 2012](#B60) ), carotenoid building *Micrococcus* strains ( [Rostami et al., 2016](#B43) ), acid fermenting *Propionibacteria* ( [Rabah et al., 2017](#B33) ), health and food related *Bifidobacterium* strains ( [Lawson, 2018](#B19) ), rubber degrading *Gordonia* species ( [Linos et al., 1999](#B21) ; [Heine et al., 2018](#B14) ), and organic pollutant degrading rhodococci ( [McLeod et al., 2006](#B22) ; [Kim et al., 2018](#B16) ) among others.

In many cases individual pathways can be exploited for the production of valuable products, or enzymes can be recombinantly produced and exploited for biocatalysis. Even some genetic tools to work directly in actinobacteria have been successfully used as for example in *Corynebacterium* ( [Nešvera and Pátek, 2011](#B25) ). Recently some additional systems have been established to create e. g., *Kocuria* and *Rhodococcus* hosts ( [Montersino et al.](https://doi.org/10.3389/fmicb.2017.01110) ; [Toda and Itoh](https://doi.org/10.3389/fmicb.2017.02313) ). The first system allowed actually to express genes of various origins in *Kocuria* , whereas the *Rhodococcus* system was used for identification of the natural phospholipid ligand of a monooxygenase. During the last decade more and more genomes have been sequenced and made available for data mining and become accessible by state-of-the-art genomic manipulation methods. Novel pathways and enzymes are frequently described from actinobacteria as a result of the progress in various omics approaches and high-throughput methods. Except for novel pathways or enzymes, genome analyses have revealed that actinobacteria also employ rather unique cofactors, such as the F 420 cofactor ( [Selengut and Haft, 2010](#B46) ; [Greening et al., 2016](#B11) ; [Nguyen et al., 2017](#B26) ; [Ney et al.](https://doi.org/10.3389/fmicb.2017.01902) ). With respect to biocatalysis and derived applications a number of recent studies can be mentioned. These comprise whole-cell systems ( [Oelschlägel et al., 2015](#B29) ; [Okamoto et al., 2017](#B30) ; [de Carvalho, 2017](#B5) ; [Goldbeck et al.](https://doi.org/10.3389/fmicb.2018.02564) ; [Yin et al.](https://doi.org/10.3389/fmicb.2018.03149) ) enzymatic cascades ( [Kara et al., 2015](#B15) ; [Ni et al., 2016](#B27) ; [Zimmerling et al., 2017](#B62) ), structure-function relationships ( [Riebel et al., 2012](#B39) ; [Montersino et al., 2013](#B24) ; [Riedel et al., 2015a](#B40) , [b](#B41) ; [Sucharitakul et al., 2016](#B54) ; [Scholtissek et al., 2017](#B44) ; [Scholtissek et al.](https://doi.org/10.3389/fmicb.2018.02410) ) as well as mechanistic insights ( [Greening et al.](https://doi.org/10.3389/fmicb.2017.01000) ; [Ney et al.](https://doi.org/10.3389/fmicb.2017.01902) ; [Westphal et al.](https://doi.org/10.3389/fmicb.2018.03050) ).

Secondary metabolite production is of industrial interest and here especially *Streptomyces* has to be mentioned which provides access to antibiotics as well as siderophores ( [Medema et al., 2010](#B23) ; [Čihák et al.](https://doi.org/10.3389/fmicb.2017.02495) ; [Botas et al.](https://doi.org/10.3389/fmicb.2018.00361) ; [López-García et al](https://doi.org/10.3389/fmicb.2018.00312) .; [Senges et al., 2018](#B48) ; [Suárez Moreno et al.](https://doi.org/10.3389/fmicb.2019.00290) ). Secondary metabolite production is frequently investigated either on a regulatory level ( [Botas et al.](https://doi.org/10.3389/fmicb.2018.00361) ) or *via* metabolomics ( [Senges et al., 2018](#B48) ) and of course within biotechnological studies. It was found that the lifestyle and the development stage seem to be crucial for secondary metabolism. Spore formation among *Streptomyces* is such a specialized development stage and of importance for cell regulatory processes, but also with respect to applications ( [Bobek et al.](https://doi.org/10.3389/fmicb.2017.02205) ). Further, some regulatory elements are solely present among actinobacteria and need to be functionally tested ( [Koepff et al](https://doi.org/10.3389/fmicb.2018.02680) .; [López-García et al.](https://doi.org/10.3389/fmicb.2018.00312) ; [Šetinová et al.](https://doi.org/10.3389/fmicb.2017.02693) ). Growth limiting conditions (Fe-, N-, S-limitations or presence of toxic compounds/elements) are often used to overproduce target compounds and among those the secondary metabolites siderophores ( [Retamal-Morales et al., 2017](#B37) , [2018b](#B38) ; [Senges et al., 2018](#B48) ) and biosurfactants ( [Kügler et al., 2015](#B18) ; [Retamal-Morales et al., 2018a](#B36) ) can be mentioned.

Actinobacteria also harbor extremophile branches, which become more and more attractive for biotechnological investigations ( [Shivlata and Satyanarayana, 2015](#B49) ). Examples include antimicrobial compound producers as many *Streptomyces* spp. ( [Radhakrishnan et al., 2007](#B34) ; [Xue et al., 2013](#B61) ), siderophore producing strains as *Thermobifida fusca* ( [Dimise et al., 2008](#B6) ) and *Thermocrispum agreste* ( [Heine et al., 2017](#B13) ), and many rhizosphere specialists with various interactions toward plants, fungi and/or other bacteria ( [Palaniyandi et al., 2013](#B31) ). Besides the above described actinobacteria mainly derived from soil, also other habitats and ecological niches are explored and successfully conquered by various actinobacteria. Among those interesting resources for biotechnology are present ( [Shivlata and Satyanarayana, 2015](#B49) ).

In conclusion, it becomes obvious that the large and diverse group of actinobacteria is of interest from different perspectives such as general microbiology, ecology, phylogeny, biochemistry, and regulation, environmental concerns, pathogenicity as well as biotechnology. Still there are new members being discovered that belong to this phylum or reclassifications occur according to new findings with respect to morphology and phylogeny. The increasing amount of data from various omics fields allows us to uncover more and more properties which can be of use for various (biotechnological) purposes. We believe that the potential of actinobacteria for biotechnology was only touched lightly thus far: there is more to be uncovered!

## Author Contributions

DT, WB, and MF drafted this editorial together and approved it prior submission.

## Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## References

Bentley, S. D., Maiwald, M., Murphy, L. D., Pallen, M. J., Yeats, C. A., Dover, L. G., et al. (2003). Sequencing and analysis of the genome of the Whipple's disease bacterium *Tropheryma whipplei* . *Lancet* 361, 637–644. doi: 10. 1016/S0140-6736(03)12597-4

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=12606174) | [CrossRef Full Text](https://doi.org/10.1016/S0140-6736%2803%2912597-4) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=S.+D.+Bentley&author=M.+Maiwald&author=L.+D.+Murphy&author=M.+J.+Pallen&author=C.+A.+Yeats&author=L.+G.+Dover+&publication_year=2003&title=Sequencing+and+analysis+of+the+genome+of+the+Whipple's+disease+bacterium+Tropheryma+whipplei&journal=Lancet&volume=361&pages=637-644)

Bottacini, F., O'Connell Motherway, M., Casey, E., McDonnell, B., Mahony, J., Ventura, M., et al. (2015). Discovery of a conjugative megaplasmid in *Bifidobacterium breve* . *Appl. Environ. Microbiol.* 81, 166–176. doi: 10. 1128/AEM. 02871-14

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=25326305) | [CrossRef Full Text](https://doi.org/10.1128/AEM.02871-14) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=F.+Bottacini&author=M.+O'Connell+Motherway&author=E.+Casey&author=B.+McDonnell&author=J.+Mahony&author=M.+Ventura+&publication_year=2015&title=Discovery+of+a+conjugative+megaplasmid+in+Bifidobacterium+breve&journal=Appl.+Environ.+Microbiol.&volume=81&pages=166-176)

Chen, B. S., Médici, R., van der Helm, M. P., van Zwet, Y., Gjonaj, L., van der Geest, R., et al. (2018). *Rhodococcus* strains as source for ene-reductase activity. *Appl. Microbiol. Biotechnol.* 102, 5545–5556. doi: 10. 1007/s00253-018-8984-7

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29705954) | [CrossRef Full Text](https://doi.org/10.1007/s00253-018-8984-7) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=B.+S.+Chen&author=R.+Médici&author=M.+P.+van+der+Helm&author=Y.+van+Zwet&author=L.+Gjonaj&author=R.+van+der+Geest+&publication_year=2018&title=Rhodococcus+strains+as+source+for+ene-reductase+activity&journal=Appl.+Microbiol.+Biotechnol.&volume=102&pages=5545-5556)

Cosma, C. L., Sherman, D. R., and Ramakrishnan, L. (2003). The secret lives of the pathogenic mycobacteria. *Annu. Rev. Microbiol.* 57, 641–676. doi: 10. 1146/annurev. micro. 57. 030502. 091033

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=14527294) | [CrossRef Full Text](https://doi.org/10.1146/annurev.micro.57.030502.091033) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=C.+L.+Cosma&author=D.+R.+Sherman&author=L.+Ramakrishnan+&publication_year=2003&title=The+secret+lives+of+the+pathogenic+mycobacteria&journal=Annu.+Rev.+Microbiol.&volume=57&pages=641-676)

de Carvalho, C. C. (2017). Whole cell biocatalysts: Essential workers from Nature to the industry. *Microb. Biotechnol.* 10, 250–263. doi: 10. 1111/1751-7915. 12363

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27145540) | [CrossRef Full Text](https://doi.org/10.1111/1751-7915.12363) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=C.+C.+de+Carvalho+&publication_year=2017&title=Whole+cell+biocatalysts%3A+Essential+workers+from+Nature+to+the+industry&journal=Microb.+Biotechnol.&volume=10&pages=250-263)

Dimise, E. J., Widboom, P. F., and Bruner, S. D. (2008). Structure elucidation and biosynthesis of fuscachelins, peptide siderophores from the moderate thermophile *Thermobifida fusca* . *Proc. Natl. Acad. Sci. U. S. A.* 105, 15311–15316. doi: 10. 1073/pnas. 0805451105

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=18832174) | [CrossRef Full Text](https://doi.org/10.1073/pnas.0805451105) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=E.+J.+Dimise&author=P.+F.+Widboom&author=S.+D.+Bruner+&publication_year=2008&title=Structure+elucidation+and+biosynthesis+of+fuscachelins,+peptide+siderophores+from+the+moderate+thermophile+Thermobifida+fusca&journal=Proc.+Natl.+Acad.+Sci.+U.S.A.&volume=105&pages=15311-15316)

Embley, T. M., Hirt, R. P., and Williams, D. M. (1994). Biodiversity at the molecular level: the domains, kingdoms and phyla of life. *Phil. Trans. R. Soc. B* 345, 21–33. doi: 10. 1098/rstb. 1994. 0083

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=7972353) | [CrossRef Full Text](https://doi.org/10.1098/rstb.1994.0083) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=T.+M.+Embley&author=R.+P.+Hirt&author=D.+M.+Williams+&publication_year=1994&title=Biodiversity+at+the+molecular+level%3A+the+domains,+kingdoms+and+phyla+of+life&journal=Phil.+Trans.+R.+Soc.+B&volume=345&pages=21-33)

Gao, B., and Gupta, R. S. (2012). Phylogenetic framework and molecular signatures for the main clades of the phylum actinobacteria. *Microbiol. Mol. Biol. Rev.* 76, 66–112. doi: 10. 1128/MMBR. 05011-11

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=22390973) | [CrossRef Full Text](https://doi.org/10.1128/MMBR.05011-11) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=B.+Gao&author=R.+S.+Gupta+&publication_year=2012&title=Phylogenetic+framework+and+molecular+signatures+for+the+main+clades+of+the+phylum+actinobacteria&journal=Microbiol.+Mol.+Biol.+Rev.&volume=76&pages=66-112)

Goodfellow, M. (2012a). “ Class I. Actinobacteria,” in *Bergey's Manual of Systematic Bacteriology* , eds M. Goodfellow, P. Kampfer, H.-J. Busse, M. E. Trujillo, K.-I. Suzuki, W. Ludwig, and B. Whitman (New York, NY: Springer), 34–45.

Goodfellow, M. (2012b). “ Phylum XXVI. Actinobacteria phyl. nov,” in *Bergey's Manual of Systematic Bacteriology* , eds M. Goodfellow, P. Kampfer, H.-J. Busse, M. E. Trujillo, K.-I. Suzuki, W. Ludwig, and B. Whitman (New York, NY: Springer), 33–2028.

Greening, C., Ahmed, F. H., Mohamed, A. E., Lee, B. M., Pandey, G., Warden, A. C., et al. (2016). Physiology, biochemistry, and applications of F420- and Fo-dependent redox reactions. *Microbiol. Mol. Biol. Rev.* 80, 451–493. doi: 10. 1128/MMBR. 00070-15

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27122598) | [CrossRef Full Text](https://doi.org/10.1128/MMBR.00070-15) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=C.+Greening&author=F.+H.+Ahmed&author=A.+E.+Mohamed&author=B.+M.+Lee&author=G.+Pandey&author=A.+C.+Warden+&publication_year=2016&title=Physiology,+biochemistry,+and+applications+of+F420-+and+Fo-dependent+redox+reactions&journal=Microbiol.+Mol.+Biol.+Rev.&volume=80&pages=451-493)

Gröning, J. A., Eulberg, D., Tischler, D., Kaschabek, S. R., and Schlömann, M. (2014). Gene redundancy of two-component (chloro)phenol hydroxylases in *Rhodococcus opacus* 1CP. *FEMS Microbiol. Lett.* 361: 68–75. doi: 10. 1111/1574-6968. 12616

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=25283988) | [CrossRef Full Text](https://doi.org/10.1111/1574-6968.12616) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+A.+Gröning&author=D.+Eulberg&author=D.+Tischler&author=S.+R.+Kaschabek&author=M.+Schlömann+&publication_year=2014&title=Gene+redundancy+of+two-component+(chloro)phenol+hydroxylases+in+Rhodococcus+opacus+1CP&journal=FEMS+Microbiol.+Lett.&volume=361&pages=68)

Heine, T., Mehnert, M., Schwabe, R., and Tischler, D. (2017). Thermochelin, a hydroxamate siderophore from *Thermocrispum agreste* DSM 44070. *Solid State Phenomena* 262, 505–508. doi: 10. 4028/www. scientific. net/SSP. 262. 501

[CrossRef Full Text](https://doi.org/10.4028/www.scientific.net/SSP.262.501) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=T.+Heine&author=M.+Mehnert&author=R.+Schwabe&author=D.+Tischler+&publication_year=2017&title=Thermochelin,+a+hydroxamate+siderophore+from+Thermocrispum+agreste+DSM+44070&journal=Solid+State+Phenomena&volume=262&pages=505-508)

Heine, T., Zimmerling, J., Ballmann, A., Kleeberg, S. B., Rückert, C., Busche, T., et al. (2018). On the enigma of glutathione-dependent styrene degradation in *Gordonia rubripertincta* CWB2. *Appl. Environ. Microbiol.* 84: e00154–e00118. doi: 10. 1128/AEM. 00154-18

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29475871) | [CrossRef Full Text](https://doi.org/10.1128/AEM.00154-18) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=T.+Heine&author=J.+Zimmerling&author=A.+Ballmann&author=S.+B.+Kleeberg&author=C.+Rückert&author=T.+Busche+&publication_year=2018&title=On+the+enigma+of+glutathione-dependent+styrene+degradation+in+Gordonia+rubripertincta+CWB2&journal=Appl.+Environ.+Microbiol.&volume=84&pages=e00154-e00118)

Kara, S., Schrittwieser, J. H., Gargiulo, S., Ni, Y., Yanase, H., Opperman, D. J., et al. (2015). Complete enzymatic oxidation of methanol to carbon dioxide: Towards more eco-efficient NAD(P)H regeneration systems. *Adv. Synth. Catal.* 357, 1687–1691. doi: 10. 1002/adsc. 201500173

[CrossRef Full Text](https://doi.org/10.1002/adsc.201500173) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=S.+Kara&author=J.+H.+Schrittwieser&author=S.+Gargiulo&author=Y.+Ni&author=H.+Yanase&author=D.+J.+Opperman+&publication_year=2015&title=Complete+enzymatic+oxidation+of+methanol+to+carbon+dioxide%3A+Towards+more+eco-efficient+NAD(P)H+regeneration+systems&journal=Adv.+Synth.+Catal.&volume=357&pages=1687-1691)

Kim, D., Choi, K. Y., Yoo, M., Zylstra, G. J., and Kim, E. (2018). Biotechnological potential of *Rhodococcus* biodegradative pathways. *J. Microbiol. Biotechnol* . 28, 1037–1051. doi: 10. 4014/jmb. 1712. 12017

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29913546) | [CrossRef Full Text](https://doi.org/10.4014/jmb.1712.12017) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+Kim&author=K.+Y.+Choi&author=M.+Yoo&author=G.+J.+Zylstra&author=E.+Kim+&publication_year=2018&title=Biotechnological+potential+of+Rhodococcus+biodegradative+pathways&journal=J.+Microbiol.+Biotechnol&volume=28&pages=1037-1051)

König, C., Eulberg, D., Gröning, J. A., Lakner, S., Seibert, V., Kaschabek, S. R., et al. (2004). A linear megaplasmid, p1CP, carrying the genes for chlorocatechol catabolism of *Rhodococcus opacus* 1CP. *Microbiology* 150, 3075–3087. doi: 10. 1099/mic. 0. 27217-0

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=15347765) | [CrossRef Full Text](https://doi.org/10.1099/mic.0.27217-0) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=C.+König&author=D.+Eulberg&author=J.+A.+Gröning&author=S.+Lakner&author=V.+Seibert&author=S.+R.+Kaschabek+&publication_year=2004&title=A+linear+megaplasmid,+p1CP,+carrying+the+genes+for+chlorocatechol+catabolism+of+Rhodococcus+opacus+1CP&journal=Microbiology&volume=150&pages=3075-3087)

Kügler, J. H., Le Roes-Hill, M., Syldatk, C., and Hausmann, R. (2015). Surfactants tailored by the class actinobacteria. *Front. Microbiol* . 6: 212. doi: 10. 3389/fmicb. 2015. 00212

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=25852670) | [CrossRef Full Text](https://doi.org/10.3389/fmicb.2015.00212) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+H.+Kügler&author=M.+Le+Roes-Hill&author=C.+Syldatk&author=R.+Hausmann+&publication_year=2015&title=Surfactants+tailored+by+the+class+actinobacteria&journal=Front.+Microbiol&volume=6&pages=212)

Lawson, P. A. (2018). “ The phylum actinobacteria,” in *The Bifidobacteria and Related Organisms. Biology, Taxonomy, Applications* , eds P. Mattarelli, B. Biavati, W. H. Holzapfel, and B. J. B Wood (London: Elsevier; Academic Press), 1–8. doi: 10. 1016/B978-0-12-805060-6. 00001-6

[CrossRef Full Text](https://doi.org/10.1016/B978-0-12-805060-6.00001-6) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=P.+A.+Lawson+&publication_year=2018&title=“ The+phylum+actinobacteria,”&journal=The+Bifidobacteria+and+Related+Organisms.+Biology,+Taxonomy,+Applications&pages=1-8)

Lewin, G. R., Carlos, C., Chevrette, M. G., Horn, H. A., McDonald, B. R., Stankey, R. J., et al. (2016). Evolution and ecology of actinobacteria and their bioenergy applications. *Annu. Rev. Microbiol.* 70, 235–254. doi: 10. 1146/annurev-micro-102215-095748

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27607553) | [CrossRef Full Text](https://doi.org/10.1146/annurev-micro-102215-095748) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=G.+R.+Lewin&author=C.+Carlos&author=M.+G.+Chevrette&author=H.+A.+Horn&author=B.+R.+McDonald&author=R.+J.+Stankey+&publication_year=2016&title=Evolution+and+ecology+of+actinobacteria+and+their+bioenergy+applications&journal=Annu.+Rev.+Microbiol.&volume=70&pages=235-254)

Linos, A., Steinbüchel, A., Spröer, C., and Kroppenstedt, R. M. (1999). *Gordonia polyisoprenivorans* sp. nov., a rubber-degrading actinomycete isolated from an automobile tyre. *Int. J. Syst. Bacteriol.* 49, 1785–1791. doi: 10. 1099/00207713-49-4-1785

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=10555361) | [CrossRef Full Text](https://doi.org/10.1099/00207713-49-4-1785) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Linos&author=A.+Steinbüchel&author=C.+Spröer&author=R.+M.+Kroppenstedt+&publication_year=1999&title=Gordonia+polyisoprenivorans+sp.+nov.,+a+rubber-degrading+actinomycete+isolated+from+an+automobile+tyre&journal=Int.+J.+Syst.+Bacteriol.&volume=49&pages=1785-1791)

McLeod, M. P., Warren, R. L., Hsiao, W. W., Araki, N., Myhre, M., Fernandes, C., et al. (2006). The complete genome of *Rhodococcus* sp. RHA1 provides insights into a catabolic powerhouse. *Proc. Natl. Acad. Sci. U. S. A.* 103, 15582–15587. doi: 10. 1073/pnas. 0607048103

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=17030794) | [CrossRef Full Text](https://doi.org/10.1073/pnas.0607048103) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=M.+P.+McLeod&author=R.+L.+Warren&author=W.+W.+Hsiao&author=N.+Araki&author=M.+Myhre&author=C.+Fernandes+&publication_year=2006&title=The+complete+genome+of+Rhodococcus+sp.+RHA1+provides+insights+into+a+catabolic+powerhouse&journal=Proc.+Natl.+Acad.+Sci.+U.S.A.&volume=103&pages=15582-15587)

Medema, M. H., Trefzer, A., Kovalchuk, A., van den Berg, M., Müller, U., Heijne, W., et al. (2010). The sequence of a 1. 8-mb bacterial linear plasmid reveals a rich evolutionary reservoir of secondary metabolic pathways. *Genome Biol. Evol.* 12, 212–224. doi: 10. 1093/gbe/evq013

[CrossRef Full Text](https://doi.org/10.1093/gbe/evq013) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=M.+H.+Medema&author=A.+Trefzer&author=A.+Kovalchuk&author=M.+van+den+Berg&author=U.+Müller&author=W.+Heijne+&publication_year=2010&title=The+sequence+of+a+1.8-mb+bacterial+linear+plasmid+reveals+a+rich+evolutionary+reservoir+of+secondary+metabolic+pathways&journal=Genome+Biol.+Evol.&volume=12&pages=212-224)

Montersino, S., Orru, R., Barendregt, A., Westphal, A. H., van Duijn, E., Mattevi, A., et al. (2013). Crystal structure of 3-hydroxybenzoate 6-hydroxylase uncovers lipid-assisted flavoprotein strategy for regioselective aromatic hydroxylation. *J. Biol. Chem.* 288, 26235–26245. doi: 10. 1074/jbc. M113. 479303

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=23864660) | [CrossRef Full Text](https://doi.org/10.1074/jbc.M113.479303) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=S.+Montersino&author=R.+Orru&author=A.+Barendregt&author=A.+H.+Westphal&author=E.+van+Duijn&author=A.+Mattevi+&publication_year=2013&title=Crystal+structure+of+3-hydroxybenzoate+6-hydroxylase+uncovers+lipid-assisted+flavoprotein+strategy+for+regioselective+aromatic+hydroxylation&journal=J.+Biol.+Chem.&volume=288&pages=26235-26245)

Nešvera, J., and Pátek, M. (2011). Tools for genetic manipulations in Corynebacterium glutamicum and their applications. *Appl. Microbiol. Biotechnol.* 90, 1641–1654. doi: 10. 1007/s00253-011-3272-9.

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=21519933) | [CrossRef Full Text](https://doi.org/10.1007/s00253-011-3272-9.) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+Nešvera&author=M.+Pátek+&publication_year=2011&title=Tools+for+genetic+manipulations+in+Corynebacterium+glutamicum+and+their+applications&journal=Appl.+Microbiol.+Biotechnol.&volume=90&pages=1641-1654)

Nguyen, Q. T., Trinco, G., Binda, C., Mattevi, A., and Fraaije, M. W. (2017). Discovery and characterization of an F420-dependent glucose-6-phosphate dehydrogenase (Rh-FGD1) from *Rhodococcus jostii* RHA1. *Appl. Microbiol. Biotechnol.* 101, 2831–2842. doi: 10. 1007/s00253-016-8038-y

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27966048) | [CrossRef Full Text](https://doi.org/10.1007/s00253-016-8038-y) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=Q.+T.+Nguyen&author=G.+Trinco&author=C.+Binda&author=A.+Mattevi&author=M.+W.+Fraaije+&publication_year=2017&title=Discovery+and+characterization+of+an+F420-dependent+glucose-6-phosphate+dehydrogenase+(Rh-FGD1)+from+Rhodococcus+jostii+RHA1&journal=Appl.+Microbiol.+Biotechnol.&volume=101&pages=2831-2842)

Ni, Y., Fernández-Fueyo, E., Gomez Baraibar, A., Ullrich, R., Hofrichter, M., Yanase, H., et al. (2016). Peroxygenase-catalyzed oxyfunctionalization reactions promoted by the complete oxidation of methanol. *Angew. Chem. Int. Ed. Engl.* 55, 798–801. doi: 10. 1002/anie. 201507881

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=26607550) | [CrossRef Full Text](https://doi.org/10.1002/anie.201507881) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=Y.+Ni&author=E.+Fernández-Fueyo&author=A.+Gomez+Baraibar&author=R.+Ullrich&author=M.+Hofrichter&author=H.+Yanase+&publication_year=2016&title=Peroxygenase-catalyzed+oxyfunctionalization+reactions+promoted+by+the+complete+oxidation+of+methanol&journal=Angew.+Chem.+Int.+Ed.+Engl.&volume=55&pages=798-801)

Niu, G., Chater, K. F., Tian, Y., Zhang, J., and Tan, H. (2016). Specialised metabolites regulating antibiotic biosynthesis in *Streptomyces* spp. *FEMS Microbiol. Rev.* 40, 554–573. doi: 10. 1093/femsre/fuw012

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27288284) | [CrossRef Full Text](https://doi.org/10.1093/femsre/fuw012) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=G.+Niu&author=K.+F.+Chater&author=Y.+Tian&author=J.+Zhang&author=H.+Tan+&publication_year=2016&title=Specialised+metabolites+regulating+antibiotic+biosynthesis+in+Streptomyces+spp&journal=FEMS+Microbiol.+Rev.&volume=40&pages=554-573)

Oelschlägel, M., Kaschabek, S. R., Zimmerling, J., Schlömann, M., and Tischler, D. (2015). Co-metabolic formation of substituted phenylacetic acids by styrene-degrading bacteria. *Biotechnol. Rep* . 6, 20–26. doi: 10. 1016/j. btre. 2015. 01. 003

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=28626693) | [CrossRef Full Text](https://doi.org/10.1016/j.btre.2015.01.003) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=M.+Oelschlägel&author=S.+R.+Kaschabek&author=J.+Zimmerling&author=M.+Schlömann&author=D.+Tischler+&publication_year=2015&title=Co-metabolic+formation+of+substituted+phenylacetic+acids+by+styrene-degrading+bacteria&journal=Biotechnol.+Rep&volume=6&pages=20-26)

Okamoto, D. N., Ferrari, V. B., Lago, J. H. G., de Melo, I. S., and Vasconcellos, S. P. (2017). Actinomycetes as tools for biotransformations of lignans. *Biomed. J. Sci. Tech. Res.* 1, 1–3. doi: 10. 26717/BJSTR. 2017. 01. 000448

[CrossRef Full Text](https://doi.org/10.26717/BJSTR.2017.01.000448) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+N.+Okamoto&author=V.+B.+Ferrari&author=J.+H.+G.+Lago&author=I.+S.+de+Melo&author=S.+P.+Vasconcellos+&publication_year=2017&title=Actinomycetes+as+tools+for+biotransformations+of+lignans&journal=Biomed.+J.+Sci.+Tech.+Res.&volume=1&pages=1-3)

Palaniyandi, S. A., Yang, S. H., Zhang, L., and Suh, J. W. (2013). Effects of actinobacteria on plant disease suppression and growth promotion. *Appl. Microbiol. Biotechnol.* 97, 9621–9636. doi: 10. 1007/s00253-013-5206-1

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=24092003) | [CrossRef Full Text](https://doi.org/10.1007/s00253-013-5206-1) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=S.+A.+Palaniyandi&author=S.+H.+Yang&author=L.+Zhang&author=J.+W.+Suh+&publication_year=2013&title=Effects+of+actinobacteria+on+plant+disease+suppression+and+growth+promotion&journal=Appl.+Microbiol.+Biotechnol.&volume=97&pages=9621-9636)

Poetsch, A., Haussmann, U., and Burkovski, A. (2011). Proteomics of corynebacteria: from biotechnology workhorses to pathogens. *Proteomics* 11, 3244–3255. doi: 10. 1002/pmic. 201000786

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=21674800) | [CrossRef Full Text](https://doi.org/10.1002/pmic.201000786) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Poetsch&author=U.+Haussmann&author=A.+Burkovski+&publication_year=2011&title=Proteomics+of+corynebacteria%3A+from+biotechnology+workhorses+to+pathogens&journal=Proteomics&volume=11&pages=3244-3255)

Rabah, H., Rosa do Carmo, F. L., and Jan, G. (2017). Dairy propionibacteria: versatile probiotics. *Microorganisms* 5: E24. doi: 10. 3390/microorganisms5020024

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=28505101) | [CrossRef Full Text](https://doi.org/10.3390/microorganisms5020024) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=H.+Rabah&author=F.+L.+Rosa+do+Carmo&author=G.+Jan+&publication_year=2017&title=Dairy+propionibacteria%3A+versatile+probiotics&journal=Microorganisms&volume=5&pages=E24)

Radhakrishnan, M., Balaji, S., and Balagurunathan, R. (2007). Thermotolerant actinomycetes from Himalayan Mountain - antagonistic potential, characterization and identification of selected strains. *Malaysian Appl. Biol.* 36, 59–65.

Raoult, D., Ogata, H., Audic, S., Robert, C., Suhre, K., Drancourt, M., et al. (2003). *Tropheryma whipplei* Twist: a human pathogenic *Actinobacteria* with a reduced genome. *Genome Res.* 13, 1800–1809. doi: 10. 1101/gr. 1474603

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=12902375) | [CrossRef Full Text](https://doi.org/10.1101/gr.1474603) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+Raoult&author=H.+Ogata&author=S.+Audic&author=C.+Robert&author=K.+Suhre&author=M.+Drancourt+&publication_year=2003&title=Tropheryma+whipplei+Twist%3A+a+human+pathogenic+Actinobacteria+with+a+reduced+genome&journal=Genome+Res.&volume=13&pages=1800-1809)

Retamal-Morales, G., Heine, T., Tischler, J. S., Erler, B., Gröning, J. A. D., Kaschabek, S. R., et al. (2018a). Draft genome sequence of *Rhodococcus erythropolis* B7g, a biosurfactant producing actinobacterium. *J. Biotechnol.* 280, 38–41. doi: 10. 1016/j. jbiotec. 2018. 06. 001

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29879458) | [CrossRef Full Text](https://doi.org/10.1016/j.jbiotec.2018.06.001) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=G.+Retamal-Morales&author=T.+Heine&author=J.+S.+Tischler&author=B.+Erler&author=J.+A.+D.+Gröning&author=S.+R.+Kaschabek+&publication_year=2018a&title=Draft+genome+sequence+of+Rhodococcus+erythropolis+B7g,+a+biosurfactant+producing+actinobacterium&journal=J.+Biotechnol.&volume=280&pages=38-41)

Retamal-Morales, G., Mehnert, M., Schwabe, R., Tischler, D., Schlömann, M., and Levicán, G. J. (2017). Genomic characterization of the arsenic-tolerant actinobacterium, *Rhodococcus erythropolis* S43. *Solid State Phenomena* 262, 660–663. doi: 10. 4028/www. scientific. net/SSP. 262. 660

[CrossRef Full Text](https://doi.org/10.4028/www.scientific.net/SSP.262.660) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=G.+Retamal-Morales&author=M.+Mehnert&author=R.+Schwabe&author=D.+Tischler&author=M.+Schlömann&author=G.+J.+Levicán+&publication_year=2017&title=Genomic+characterization+of+the+arsenic-tolerant+actinobacterium,+Rhodococcus+erythropolis+S43&journal=Solid+State+Phenomena&volume=262&pages=660-663)

Retamal-Morales, G., Mehnert, M., Schwabe, R., Tischler, D., Zapata, C., Chávez, R., et al. (2018b). Detection of arsenic-binding siderophores in arsenic-tolerating actinobacteria by a modified CAS assay. *Ecotoxicol. Environ. Saf.* 157, 176–181. doi: 10. 1016/j. ecoenv. 2018. 03. 087

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29621709) | [CrossRef Full Text](https://doi.org/10.1016/j.ecoenv.2018.03.087) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=G.+Retamal-Morales&author=M.+Mehnert&author=R.+Schwabe&author=D.+Tischler&author=C.+Zapata&author=R.+Chávez+&publication_year=2018b&title=Detection+of+arsenic-binding+siderophores+in+arsenic-tolerating+actinobacteria+by+a+modified+CAS+assay&journal=Ecotoxicol.+Environ.+Saf.&volume=157&pages=176-181)

Riebel, A., Dudek, H. M., de Gonzalo, G., Stepniak, P., Rychlewski, L., and Fraaije, M. W. (2012). Expanding the set of rhodococcal Baeyer-Villiger monooxygenases by high-throughput cloning, expression and substrate screening. *Appl. Microbiol. Biotechnol.* 95, 1479–1489. doi: 10. 1007/s00253-011-3823-0

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=22218769) | [CrossRef Full Text](https://doi.org/10.1007/s00253-011-3823-0) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Riebel&author=H.+M.+Dudek&author=G.+de+Gonzalo&author=P.+Stepniak&author=L.+Rychlewski&author=M.+W.+Fraaije+&publication_year=2012&title=Expanding+the+set+of+rhodococcal+Baeyer-Villiger+monooxygenases+by+high-throughput+cloning,+expression+and+substrate+screening&journal=Appl.+Microbiol.+Biotechnol.&volume=95&pages=1479-1489)

Riedel, A., Heine, T., Westphal, A. H., Conrad, C., Rathsack, P., van Berkel, W. J., et al. (2015a). Catalytic and hydrodynamic properties of styrene monooxygenases from *Rhodococcus opacus* 1CP are modulated by cofactor binding. *AMB Express* 5, 30. doi: 10. 1186/s13568-015-0112-9

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=26054733) | [CrossRef Full Text](https://doi.org/10.1186/s13568-015-0112-9) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Riedel&author=T.+Heine&author=A.+H.+Westphal&author=C.+Conrad&author=P.+Rathsack&author=W.+J.+van+Berkel+&publication_year=2015a&title=Catalytic+and+hydrodynamic+properties+of+styrene+monooxygenases+from+Rhodococcus+opacus+1CP+are+modulated+by+cofactor+binding&journal=AMB+Express&volume=5&pages=30)

Riedel, A., Mehnert, M., Paul, C. E., Westphal, A. H., van Berkel, W. J., and Tischler, D. (2015b). Functional characterization and stability improvement of a ‘ thermophilic-like' ene-reductase from *Rhodococcus opacus* 1CP. *Front. Microbiol.* 6: 1073. doi: 10. 3389/fmicb. 2015. 01073

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=26483784) | [CrossRef Full Text](https://doi.org/10.3389/fmicb.2015.01073) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Riedel&author=M.+Mehnert&author=C.+E.+Paul&author=A.+H.+Westphal&author=W.+J.+van+Berkel&author=D.+Tischler+&publication_year=2015b&title=Functional+characterization+and+stability+improvement+of+a+‘ thermophilic-like'+ene-reductase+from+Rhodococcus+opacus+1CP&journal=Front.+Microbiol.&volume=6&pages=1073)

Roberts, J. N., Singh, R., Grigg, J. C., Murphy, M. E., Bugg, T. D., and Eltis, L. D. (2011). Characterization of dye-decolorizing peroxidases from *Rhodococcus jostii* RHA1. *Biochemistry* 50, 5108–5119. doi: 10. 1021/bi200427h

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=21534572) | [CrossRef Full Text](https://doi.org/10.1021/bi200427h) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+N.+Roberts&author=R.+Singh&author=J.+C.+Grigg&author=M.+E.+Murphy&author=T.+D.+Bugg&author=L.+D.+Eltis+&publication_year=2011&title=Characterization+of+dye-decolorizing+peroxidases+from+Rhodococcus+jostii+RHA1&journal=Biochemistry&volume=50&pages=5108-5119)

Rostami, H., Hamedi, H., and Yolmeh, M. (2016). Some biological activities of pigments extracted from *Micrococcus roseus* (PTCC 1411) and *Rhodotorula glutinis* (PTCC 5257). *Int. J. Immunopathol. Pharmacol.* 29, 684–695. doi: 10. 1177/0394632016673846

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=27895288) | [CrossRef Full Text](https://doi.org/10.1177/0394632016673846) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=H.+Rostami&author=H.+Hamedi&author=M.+Yolmeh+&publication_year=2016&title=Some+biological+activities+of+pigments+extracted+from+Micrococcus+roseus+(PTCC+1411)+and+Rhodotorula+glutinis+(PTCC+5257)&journal=Int.+J.+Immunopathol.+Pharmacol.&volume=29&pages=684-695)

Scholtissek, A., Tischler, D., Westphal, A. H., van Berkel, W. J. H., and Paul, C. E. (2017). Old Yellow Enzyme-catalysed asymmetric hydrogenation: linking family roots with improved catalysis. *Catalysts* 7: 130. doi: 10. 3390/catal7050130

[CrossRef Full Text](https://doi.org/10.3390/catal7050130) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=A.+Scholtissek&author=D.+Tischler&author=A.+H.+Westphal&author=W.+J.+H.+van+Berkel&author=C.+E.+Paul+&publication_year=2017&title=Old+Yellow+Enzyme-catalysed+asymmetric+hydrogenation%3A+linking+family+roots+with+improved+catalysis&journal=Catalysts&volume=7&pages=130)

Schrempf, H. (2013). Actinobacteria within soils: capacities for mutualism, symbiosis and pathogenesis. *FEMS Microbiol. Lett.* 342, 77–78. doi: 10. 1111/1574-6968. 12147

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=23611473) | [CrossRef Full Text](https://doi.org/10.1111/1574-6968.12147) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=H.+Schrempf+&publication_year=2013&title=Actinobacteria+within+soils%3A+capacities+for+mutualism,+symbiosis+and+pathogenesis&journal=FEMS+Microbiol.+Lett.&volume=342&pages=77-78)

Selengut, J. D., and Haft, D. H. (2010). Unexpected abundance of coenzyme F(420)-dependent enzymes in *Mycobacterium tuberculosis* and other actinobacteria. *J. Bacteriol.* 192, 5788–5798. doi: 10. 1128/JB. 00425-10

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=20675471) | [CrossRef Full Text](https://doi.org/10.1128/JB.00425-10) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+D.+Selengut&author=D.+H.+Haft+&publication_year=2010&title=Unexpected+abundance+of+coenzyme+F(420)-dependent+enzymes+in+Mycobacterium+tuberculosis+and+other+actinobacteria&journal=J.+Bacteriol.&volume=192&pages=5788-5798)

Sen, A., Daubin, V., Abrouk, D., Gifford, I., Berry, A. M., and Normand, P. (2014). Phylogeny of the class actinobacteria revisited in the light of complete genomes. The orders ‘ Frankiales' and Micrococcales should be split into coherent entities: proposal of Frankiales ord. nov., *Geodermatophilales* ord. nov., *Acidothermales* ord. nov. and *Nakamurellales* ord. nov *. Int. J. Syst. Evol. Microbiol.* 64, 3821–3832. doi: 10. 1099/ijs. 0. 063966-0

[CrossRef Full Text](https://doi.org/10.1099/ijs.0.063966-0)

Senges, C. H. R., Al-Dilaimi, A., Marchbank, D. H., Wibberg, D., Winkler, A., Haltli, B., et al. (2018). The secreted metabolome of *Streptomyces chartreusis* and implications for bacterial chemistry. *Proc. Natl. Acad. Sci. U. S. A.* 115, 2490–2495. doi: 10. 1073/pnas. 1715713115

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=29463727) | [CrossRef Full Text](https://doi.org/10.1073/pnas.1715713115) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=C.+H.+R.+Senges&author=A.+Al-Dilaimi&author=D.+H.+Marchbank&author=D.+Wibberg&author=A.+Winkler&author=B.+Haltli+&publication_year=2018&title=The+secreted+metabolome+of+Streptomyces+chartreusis+and+implications+for+bacterial+chemistry&journal=Proc.+Natl.+Acad.+Sci.+U.S.A.&volume=115&pages=2490-2495)

Shivlata, L., and Satyanarayana, T. (2015). Thermophilic and alkaliphilic actinobacteria: biology and potential applications. *Front. Microbiol* . 6: 1014. doi: 10. 3389/fmicb. 2015. 01014

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=26441937) | [CrossRef Full Text](https://doi.org/10.3389/fmicb.2015.01014) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=L.+Shivlata&author=T.+Satyanarayana+&publication_year=2015&title=Thermophilic+and+alkaliphilic+actinobacteria%3A+biology+and+potential+applications&journal=Front.+Microbiol&volume=6&pages=1014)

Stach, J. E., and Bull, A. T. (2005). Estimating and comparing the diversity of marine actinobacteria. *Antonie Van Leeuwenhoek* 87, 3–9. doi: 10. 1007/s10482-004-6524-1

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=15726285) | [CrossRef Full Text](https://doi.org/10.1007/s10482-004-6524-1) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+E.+Stach&author=A.+T.+Bull+&publication_year=2005&title=Estimating+and+comparing+the+diversity+of+marine+actinobacteria&journal=Antonie+Van+Leeuwenhoek&volume=87&pages=3-9)

Stackebrandt, E., Rainey, F. A., and Ward-Rainey, N. L. (1997a). Proposal for a new hierarchic classification system, *Actinobacteria* classis nov. *Int. J. Syst. Evol. Microbiol.* 47, 479–491.

[Google Scholar](http://scholar.google.com/scholar_lookup?author=E.+Stackebrandt&author=F.+A.+Rainey&author=N.+L.+Ward-Rainey+&publication_year=1997a&title=Proposal+for+a+new+hierarchic+classification+system,+Actinobacteria+classis+nov&journal=Int.+J.+Syst.+Evol.+Microbiol.&volume=47&pages=479-491)

Stackebrandt, E., and Schumann, P. (2006). “ Introduction to the taxonomy of actinobacteria,” in *The Prokaryotes* , eds M. Dworkin, S. Falkow, E. Rosenberg, K.-H. Schleifer, and F. Stackebrandt (New York, NY: Springer), 297–321.

[Google Scholar](http://scholar.google.com/scholar_lookup?author=E.+Stackebrandt&author=P.+Schumann+&publication_year=2006&title=“ Introduction+to+the+taxonomy+of+actinobacteria,”&journal=The+Prokaryotes)

Stackebrandt, E., Sproer, C., Rainey, F. A., Burghardt, J., Päuker, O., and Hippe, H. (1997b). Phylogenetic analysis of the genus *Desulfotomaculum* : evidence for the misclassification of *Desulfotomaculum guttoideum* and description of *Desulfotomaculum orientis* as *Desulfosporosinus orientis* gen. nov., comb. nov. *Int. J. Syst. Evol. Microbiol.* 47, 1134–1139.

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=9336920) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=E.+Stackebrandt&author=C.+Sproer&author=F.+A.+Rainey&author=J.+Burghardt&author=O.+Päuker&author=H.+Hippe+&publication_year=1997b&title=Phylogenetic+analysis+of+the+genus+Desulfotomaculum%3A+evidence+for+the+misclassification+of+Desulfotomaculum+guttoideum+and+description+of+Desulfotomaculum+orientis+as+Desulfosporosinus+orientis+gen.+nov.,+comb.+nov&journal=Int.+J.+Syst.+Evol.+Microbiol.&volume=47&pages=1134-1139)

Sucharitakul, J., Medhanavyn, D., Pakotiprapha, D., van Berkel, W. J., and Chaiyen, P. (2016). Tyr217 and His213 are important for substrate binding and hydroxylation of 3-hydroxybenzoate 6-hydroxylase from *Rhodococcus jostii* RHA1. *FEBS J* . 283, 860–881. doi: 10. 1111/febs. 13636

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=26709612) | [CrossRef Full Text](https://doi.org/10.1111/febs.13636) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+Sucharitakul&author=D.+Medhanavyn&author=D.+Pakotiprapha&author=W.+J.+van+Berkel&author=P.+Chaiyen+&publication_year=2016&title=Tyr217+and+His213+are+important+for+substrate+binding+and+hydroxylation+of+3-hydroxybenzoate+6-hydroxylase+from+Rhodococcus+jostii+RHA1&journal=FEBS+J&volume=283&pages=860-881)

Tischler, D., Eulberg, D., Lakner, S., Kaschabek, S. R., van Berkel, W. J., and Schlömann, M. (2009). Identification of a novel self-sufficient styrene monooxygenase from *Rhodococcus opacus* 1CP. *J. Bacteriol.* 191, 4996–5009. doi: 10. 1128/JB. 00723-10

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=19482928) | [CrossRef Full Text](https://doi.org/10.1128/JB.00723-10) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+Tischler&author=D.+Eulberg&author=S.+Lakner&author=S.+R.+Kaschabek&author=W.+J.+van+Berkel&author=M.+Schlömann+&publication_year=2009&title=Identification+of+a+novel+self-sufficient+styrene+monooxygenase+from+Rhodococcus+opacus+1CP&journal=J.+Bacteriol.&volume=191&pages=4996-5009)

Tischler, D., Kermer, R., Gröning, J. A., Kaschabek, S. R., van Berkel, W. J., and Schlömann, M. (2010). StyA1 and StyA2B from *Rhodococcus opacus* 1CP: a multifunctional styrene monooxygenase system. *J. Bacteriol.* 192, 5220–5227. doi: 10. 1128/JB. 00723-10

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=20675468) | [CrossRef Full Text](https://doi.org/10.1128/JB.00723-10) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+Tischler&author=R.+Kermer&author=J.+A.+Gröning&author=S.+R.+Kaschabek&author=W.+J.+van+Berkel&author=M.+Schlömann+&publication_year=2010&title=StyA1+and+StyA2B+from+Rhodococcus+opacus+1CP%3A+a+multifunctional+styrene+monooxygenase+system&journal=J.+Bacteriol.&volume=192&pages=5220-5227)

Tischler, D., Niescher, S., Kaschabek, S. R., and Schlömann, M. (2013). Trehalose phosphate synthases otsa1 and otsa2 of *Rhodococcus opacus* 1CP. *FEMS Microbiol. Lett.* 342, 113–122. doi: 10. 1111/1574-6968. 12096

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=23398506) | [CrossRef Full Text](https://doi.org/10.1111/1574-6968.12096) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=D.+Tischler&author=S.+Niescher&author=S.+R.+Kaschabek&author=M.+Schlömann+&publication_year=2013&title=Trehalose+phosphate+synthases+otsa1+and+otsa2+of+Rhodococcus+opacus+1CP&journal=FEMS+Microbiol.+Lett.&volume=342&pages=113-122)

Ventura, M., Canchaya, C., Tauch, A., Chandra, G., Fitzgerald, G. F., Chater, K. F., et al. (2007). Genomics of actinobacteria: tracing the evolutionary history of an ancient phylum. *Microbiol. Mol. Biol. Rev.* 71, 495–548. doi: 10. 1128/MMBR. 00005-07

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=17804669) | [CrossRef Full Text](https://doi.org/10.1128/MMBR.00005-07) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=M.+Ventura&author=C.+Canchaya&author=A.+Tauch&author=G.+Chandra&author=G.+F.+Fitzgerald&author=K.+F.+Chater+&publication_year=2007&title=Genomics+of+actinobacteria%3A+tracing+the+evolutionary+history+of+an+ancient+phylum&journal=Microbiol.+Mol.+Biol.+Rev.&volume=71&pages=495-548)

Wagenknecht, M., Dib, J. R., Thürmer, A., Daniel, R., Farías, M. E., and Meinhardt, F. (2010). Structural peculiarities of linear megaplasmid, pLMA1, from *Micrococcus luteus* interfere with pyrosequencing reads assembly. *Biotechnol. Lett.* 32, 1853–1862. doi: 10. 1007/s10529-010-0357-y

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=20652620) | [CrossRef Full Text](https://doi.org/10.1007/s10529-010-0357-y) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=M.+Wagenknecht&author=J.+R.+Dib&author=A.+Thürmer&author=R.+Daniel&author=M.+E.+Farías&author=F.+Meinhardt+&publication_year=2010&title=Structural+peculiarities+of+linear+megaplasmid,+pLMA1,+from+Micrococcus+luteus+interfere+with+pyrosequencing+reads+assembly&journal=Biotechnol.+Lett.&volume=32&pages=1853-1862)

Wilson, J. W. (2012). Nocardiosis: updates and clinical overview. *Mayo Clin. Proc.* 87, 403–407. doi: 10. 1016/j. mayocp. 2011. 11. 016

[PubMed Abstract](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=ShowDetailView&TermToSearch=22469352) | [CrossRef Full Text](https://doi.org/10.1016/j.mayocp.2011.11.016) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=J.+W.+Wilson+&publication_year=2012&title=Nocardiosis%3A+updates+and+clinical+overview&journal=Mayo+Clin.+Proc.&volume=87&pages=403-407)

Xue, L., Xue, Q., Chen, Q., Lin, C., Shen, G., and Zhao, J. (2013). Isolation and evaluation of rhizosphere actinomycetes with potential application for biocontrol of *Verticillium* wilt of cotton. *Crop Prot.* 43, 231–240. doi: 10. 1016/j. cropro. 2012. 10. 002

[CrossRef Full Text](https://doi.org/10.1016/j.cropro.2012.10.002) | [Google Scholar](http://scholar.google.com/scholar_lookup?author=L.+Xue&author=Q.+Xue&author=Q.+Chen&author=C.+Lin&author=G.+Shen&author=J.+Zhao+&publication_year=2013&title=Isolation+and+evaluation+of+rhizosphere+actinomycetes+with+potential+application+for+biocontrol+of+Verticillium+wilt+of+cotton&journal=Crop+Prot.&volume=43&pages=231-240)

Zimmerling, J., Tischler, D., Großmann, C., Schlömann, M., and Oelschlägel, M. (2017) Characterization of aldehyde dehydrogenases applying an enzyme assay with *in situ* formation of phenylacetaldehydes. *Appl. Biochem. Biotechnol* . 182, 1095–1107. doi: 10. 1007/s12010-016-2384-1

[CrossRef Full Text](https://doi.org/10.1007/s12010-016-2384-1)