

DAFTAR PUSTAKA

- [APHA] American Public Health Association, American Water Works Association, & Water Environment Federation. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). APHA-AWWA-WPCF.
- Abe, I., & Morita, H. (2010). Structure and function of the chalcone synthase superfamily of plant type III polyketide synthase. *Natural Product Reports*, 27, 809–838.
- Abolola, F., Bautista, A. L., Migalang, G. M., & Naval, C. J. (2023). The role of molecular systematics in microbiological research and public health: A systematic review. *International Journal of Applied Biology*, 7(1), 123–146.
- Achkar, J., Xian, M., Zhao, H., & Frost, J. W. (2005). Biosynthesis of phloroglucinol. *Journal American Chemical Society*, 127(15), 5332–5333. <https://doi.org/10.1021/ja042340g>
- Aeny, T. N., Prasetyo, J., Suharjo, R., Dirmawati, S. R., & Saputri, M. D. (2017). *Isolation and characterization of actinomycetes from pineapple plantation potential as antagonist of Dickeya sp., the pineapple soft rot pathogen*. 1–5. <https://api.semanticscholar.org/CorpusID:261386923>
- Akihary, C., & Kolondam, B. (2020). Pemanfaatan gen 16S rRNA sebagai perangkat identifikasi bakteri untuk penelitian-penelitian di Indonesia. *Pharmacon: Jurnal Ilmiah Farmasi*, 9(1), 16–22.
- Ali, A., Junda, M., Karim, H., & Nuryani, S. R. I. (2017). Characterization and in vitro antifungal assay against *Fusarium oxysporum* f .sp. *passiflora* of endophytic actinomycetes from purple passion fruit plants of South Sulawesi, Indonesia. *Asian Journal of Microbiology, Biotechnology and Environmental Sciences*, 19(2), 344–352.
- Altschul, S. F., Gish, W., Miller, W., Myers, E. W., & Lipman, D. J. (1990). Basic local alignment search tool. *Journal of Molecular Biology*, 215(3), 403–410. [https://doi.org/10.1016/S0022-2836\(05\)80360-2](https://doi.org/10.1016/S0022-2836(05)80360-2)
- Ardila, D., Haditiar, Y., Ikhwan, M., Wafdan, R., Muhammad, Sugianto, S., & Rizal, S. (2019). Ocean eddy detection in the Andaman Sea during April 2008. *IOP Conference Series: Earth and Environmental Science*, 348(1). <https://doi.org/10.1088/1755-1315/348/1/012063>
- Asif, S., Khan, M., & Shabbir, M. I. (2021). PCR optimization for beginners: A step by step guide. *Research in Molecular Medicine*, 9(2), 81–102. <https://doi.org/10.32598/rmm.9.2.1189.1>
- Atawodi, S., Atawodi, J., & Dzikwi, A. (2011). Polymerase chain reaction: Theory, practice and application: A review. *Sahel Medical Journal*, 13(2), 54–63. <https://doi.org/10.4314/smj2.v13i2.64834>
- Ayuso-Sacido, A., & Genilloud, O. (2004). New PCR primers for the screening of NRPS and PKS-I systems in actinomycetes: Detection and distribution of

- these biosynthetic gene sequences in major taxonomic groups. *Microbial Ecology*, 49(1), 10–24. <https://doi.org/10.1007/s00248-004-0249-6>
- Azzam, F., & Malfatti, F. (2007). Microbial structuring of marine ecosystems. *Nature Reviews Microbiology*, 5, 782–791. <https://doi.org/https://doi.org/10.1038/nrmicro1747>
- Balagurunathan, R., Radhakrishnan, M., Shanmugasundaram, T., Gopikrishnan, V., & Jerrine, J. (2020). Characterization and identification of Actinobacteria. In *Protocols in Actinobacterial research* (pp. 39–64). Springer. <https://doi.org/10.1007/978-1-0716-0728-2>
- Bansal, A. K., & Meyer, T. E. (2002). Evolutionary analysis by whole genome comparisons. *Journal of Bacteriology*, 184, 2260–2272.
- Barka, E. A., Vatsa, P., Sanchez, L., Nathalie Gaveau-Vaillant, C. J., Klenk, H., Clément, C., Ouhdouch, Y., & P. van Wezeld, G. (2016). Taxonomy, physiology, and natural products of Actinobacteria. *American Society for Microbiology*, 80(1), 1–43. <https://doi.org/10.1128/MMBR.00019-15>.Address
- Beedessee, G., Hisata, K., Roy, M. C., Satoh, N., & Shoguchi, E. (2015). Multifunctional polyketide synthase genes identified by genomic survey of the symbiotic dinoflagellate, *Symbiodinium minutum*. *BMC Genomics*, 16(1), 1–11. <https://doi.org/10.1186/s12864-015-2195-8>
- Bender, C. L., N-Chaidez, F. A., & Gross, D. C. (1999). *Pseudomonas syringae* phytotoxins: Mode of action, regulation, and biosynthesis by peptide and polyketide synthetases. *Microbiology and Molecular Biology Reviews*, 63(2), 266–292. [https://doi.org/1092-2172/99/\\$04.0010](https://doi.org/1092-2172/99/$04.0010)
- Bérdy, J. (2005). Bioactive microbial metabolites. *Journal of Antibiotics. Antibiotics*, 58(1), 1–26. <https://doi.org/10.1038/ja.2005.1>
- Bérdy, J. (2012). Thoughts and facts about antibiotics: Where we are now and where we are heading. *Journal of Antibiotics*, 65, 385–395. <https://doi.org/10.1038/ja.2012.27>
- Bérubé, Y., Ritland, C., & Ritland, K. (2003). Isolation, characterization, and cross-species utility of microsatellites in yellow cedar (*Chamaecyparis nootkatensis*). *Genome*, 46(3). <https://doi.org/10.1139/G03-014>
- Bode, H. B., & Müller, R. (2005). The impact of bacterial genomics on natural product research. *Angewandte Chemie - International Edition*, 44(42), 6828–6846. <https://doi.org/10.1002/anie.200501080>
- Bowers, R. M., Kyprides, N. C., Stepanauskas, R., Harmon-Smith, M., Doud, D., Reddy, T. B. K., Schulz, F., Jarett, J., Rivers, A. R., Eloë-Fadrosh, E. A., Tringe, S. G., Ivanova, N. N., Copeland, A., Clum, A., Becroft, E. D., Malmstrom, R. R., Birren, B., Podar, M., Bork, P., ... Woyke, T. (2017). Minimum information about a single amplified genome (MISAG) and a metagenome-assembled genome (MIMAG) of bacteria and archaea. *Nature Biotechnology*, 35(8), 725–731. <https://doi.org/10.1038/nbt.3893>

- Bruns, A., Philipp, H., Cypionka, H., & Brinkhoff, T. (2003). *Aeromicrobium marinum* sp. nov., an abundant pelagic bacterium isolated from the German Wadden Sea. *International Journal of Systematic and Evolutionary Microbiology*, 53(Pt 6), 1917–1923. <https://doi.org/10.1099/ijss.0.02735-0>
- Cane, D. E., Walsh, C. T., & Khosla, C. (1998). Harnessing the biosynthetic code: Combinations, permutations, and mutations. *Science*, 282(5386), 63–68. <https://doi.org/10.1126/science.282.5386.63>
- Cao, X., Xiong, H., Fan, Y., & Xiong, L. (2024). Comparing the effects of two culture methods to determine the total heterotrophic bacterial colony count in hospital purified water. *Journal of Epidemiology and Global Health*, 14(1), 184–192. <https://doi.org/10.1007/s44197-023-00186-1>
- Chalita, M., Kim, Y. O., Park, S., Oh, H.-S., Cho, J. H., Moon, J., Baek, N., Moon, C., Lee, K., Yang, J., Nam, G. G., Jung, Y., Na, S.-I., & Bailey, M. J. (2024). Ezbiocloud: A genome-driven database and platform for microbiome identification and discovery. *International Journal of Systematic and Evolutionary Microbiology*, 74, 1–6. <https://doi.org/10.1099/ijsem.0.006421>
- Challis, G. L., & Hopwood, D. A. (2003). Synergy and contingency as driving forces for the evolution of multiple secondary metabolite production by *Streptomyces* species. *Proceedings of the National Academy of Sciences of the United States of America*, 100 Suppl(Suppl 2), 14555–14561. <https://doi.org/10.1073/pnas.1934677100>
- Chan, Y. A., Podevels, A. M., Kevany, B. M., & Thomas, M. G. (2009). Biosynthesis of polyketide synthase extender units. *Natural Product Reports*, 26(1), 90–114. <https://doi.org/10.1039/b801658p>
- Clarridge, J. E. (2004). Impact of 16S rRNA gene sequence analysis for identification of bacteria on clinical microbiology and infectious diseases. *Clinical Microbiology*, 17(4), 840–862.
- Curran, S. C., Hagen, A., Poust, S., Chan, L. J. G., Garabedian, B. M., de Rond, T., Baluyot, M.-J., Vu, J. T., Lau, A. K., Yuzawa, S., Petzold, C. J., Katz, L., & Keasling, J. D. (2018). Probing the flexibility of an iterative modular polyketide synthase with non-native substrates in vitro. *ACS Chemical Biology*, 13(8), 2261–2268. <https://doi.org/10.1021/acscchembio.8b00422>
- Daquioag, J. E. L., & Penuliar, G. M. (2021). Isolation of actinomycetes with cellulolytic and antimicrobial activities from soils collected from an urban green space in the Philippines. *International Journal of Microbiology*. <https://doi.org/10.1155/2021/6699430>
- Das, A., & Khosla, C. (2009). In vivo and in vitro analysis of the hedamycin polyketide synthase. *Chemistry & Biology*, 16(11), 1197–1207. <https://doi.org/10.1016/j.chembiol.2009.11.005>
- Dharmayanti, N. L. P. I. (2011). Filogenetika molekuler: metode taksonomi organisme berdasarkan sejarah evolusi. *WARTAZOA*, 21(1), 1-10.
- Egan, S. T., McCarthy, D. M., Patching, J. W., & Fleming, G. T. A. (2012). An

- investigation of the physiology and potential role of components of the deep ocean bacterial community (of the NE Atlantic) by enrichments carried out under minimal environmental change. *Deep-Sea Research Part I: Oceanographic Research Papers*, 61, 11–20. <https://doi.org/10.1016/j.dsr.2011.11.005>
- Elmallah, M. I. Y., Cogo, S., Constantinescu, A., Esposito, S. E. Abdelfattah, M. S., & Micheau, O. (2020). Marine actinomycetes-derived secondary metabolites overcome trail-resistance via the intrinsic pathway through down regulation of survive in and xiap. *Cells*, 9(8), 1760–1778. <https://doi.org/10.3390/cells9081760>
- Elsie, Riyana, R., & Harahap, I. (2019). Isolation of actinomycetes from mangrove soil in the Village of Sungai Rawa, Sungai Apit Sub-District, Siak Regency, Riau Province and antimicrobial test against. *Prosiding Sainstekes*, 84–91.
- Engelhardt, K. (2010). *Assesment of the antibiotic production potential of marine-derived actinomycetes via bioactivity screening and targeted genetic analysis*. Norwegian University of Science and Technology.
- Ennis, N. J., Dharumadurai, D., Sevigny, J. L., Wilmot, R., Alnaimat, S. M., Bryce, J. G., Thomas, W. K., & Tisa, L. S. (2022). Draft genomes sequences of 11 Geodermatophilaceae strains isolated from Building Stones from New England and Indian Stone Ruins found at historic sites in Tamil Nadu, India. *Journal of Genomics*, 10, 69–77. <https://doi.org/10.7150/jgen.76121>
- Faille, A., Gavalda, S., Slama, N., Lherbet, C., Maveyraud, L., Guillet, V., Laval, F., Quémard, A., Mourey, L., & Pedelacq, J.-D. (2017). Insights into substrate modification by dehydratases from type I polyketide synthases. *Journal of Molecular Biology*, 429(10), 1554–1569. <https://doi.org/10.1016/j.jmb.2017.03.026>
- Farid, W., Masud, T., & Sohail, A. (2021). Isolation, molecular characterization and preliminary screening for probiotic properties of *Lactobacillus fermentum* from indigenous dahi. *E3S Web of Conferences*, 332, 1–7. <https://doi.org/10.1051/e3sconf/202133206004>
- Fischer, C., Lipata, F., & Rohr, J. (2003). The complete gene cluster of the antitumor agent gilvocarcin V and its implication for the biosynthesis of the gilvocarcins. *Journal of the American Chemical Society*, 125(26), 7818–7819. <https://doi.org/10.1021/ja034781q>
- Fleming, J. F., Valero-Gracia, A., & Struck, T. H. (2023). Identifying and addressing methodological incongruence in phylogenomics: A review. *Evolutionary Applications*, 16, 1087–1104. <https://doi.org/10.1111/eva.13565>
- Franco-Duarte, R., Černáková, L., Kadam, S., Kaushik, K. S., Salehi, B., Bevilacqua, A., Corbo, M. R., Antolak, H., Dybka-Stępień, K., Leszczewicz, M., Tintino, S. R., de Souza, V. C. A., Sharifi-Rad, J., Coutinho, H. D. M., Martins, N., & Rodrigues, C. F. (2019). Advances in chemical and biological methods to identify microorganisms—from past to present. *Microorganisms*, 7(5), 1–32. <https://doi.org/10.3390/microorganisms7050130>

- Fritsch, R. J., & Krause, I. (2021). Electrophoresis. In L. Trugo & P. M. Finglas (Eds.), *Encyclopaedia of food science, food technology and nutrition* (2nd ed., Vol. 2, pp. 2055–2062). Academic Press. https://doi.org/10.5005/jp/books/14203_20
- Funa, N., Funabashi, M., Ohnishi, Y., & Horinouchi, S. (2005). Biosynthesis of hexahydroxyperylenequinone melanin via oxidative aryl coupling by cytochrome P-450 in *Streptomyces griseus*. *Journal of Bacteriology*, 187(23), 8149–8155. <https://doi.org/10.1128/jb.187.23.8149-8155.2005>
- Ghanem, N. B., Sabry, S. A., El-sherif, Z. M., & El-ela, G. A. A. (2000). Isolation and enumeration of marine actinomycetes from seawater and sediments in Alexandria. *Journal of General and Applied Microbiology*, 46, 105–111.
- Ghashghaei, S., Etemadifar, Z., Tavassoli, M., & Mofid, M. R. (2023). Optimization of degenerate PCR conditions for reducing error rates in detection of PKS and NRPS gene groups in actinomycetes. *Avicenna Journal of Medical Biotechnology*, 15(1), 28–37. <https://doi.org/10.18502/AJMB.V15I1.11422>
- Giu, L. O. M. G., Atmadipoera, A. S., Naulita, Y., & Nugroho, D. (2020). Struktur vertikal dan variabilitas arlindo yang masuk ke Tepi Barat Laut Banda. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, 12(2), 455–469. <https://doi.org/10.29244/jitkt.v12i2.29142>
- Gobalakrishnan, R., & Bhuvaneswari, R. (2019). Microbial fuel cells potential of marine Actinobacteria *Actinoalloteichus* sp. MHA15 from the Havelock Island of the Andamans, India. *Biotechnology Research and Innovation*, 3(1), 144–158. <https://doi.org/10.1016/j.biori.2019.01.003>
- Göltenboth, F., & Schoppe, S. (2006). Deep sea. In F. Göltenboth, K. H. Timotius, P. P. Milan, & J. Margraf (Eds.), *Ecology of insular Southeast Asia*. Elsevier.
- González, I., Ayuso-sacido, A., Anderson, A., & Genilloud, O. (2005). Actinomycetes isolated from lichens: Evaluation of their diversity and detection of biosynthetic gene sequences. *Federation of European Microbiological Societies*, 54, 401–415. <https://doi.org/10.1016/j.femsec.2005.05.004>
- Goodfellow, M., Kämpfer, P., Busse, H.-J. M. E. T., Suzuki, K., Ludwig, W., & Whitman, W. B. (2012). *Bergey's manual of systematic bacteriology volume 5: The Actinobacteria*. Springer. <https://doi.org/10.1007/978-0-387-68233-4>
- Haight, T. H., & Finland, M. (1952). The antibacterial action of erythromycin. *Proceedings of the Society for Experimental Biology and Medicine*, 81(1), 175–183. <https://doi.org/10.3181/00379727-81-19815>
- Hartline, R. (2023). *Microbiology laboratory manual*. Libretexts.
- Hatmanti, A. (2018). *Eksplorasi aktinomisetes asal sedimen Laut Selat Makassar sebagai sumber agensia antimikroba*. Universitas Gadjah Mada.
- Hatmanti, A., Lisdiyanti, P., Widada, J., & Wahyuono, S. (2018). Keragaman

- aktinomisettes yang dapat dikultur dari Dasar Laut Dalam Selat Makassar, Indonesia. *Oseanologi Dan Limnologi Di Indonesia*, 3(2), 73–93.
- Hayakawa, M., Takeuchi, T., & Yamazaki, T. (1996). Combined use of trimethoprim with nalidixic acid for the selective isolation and enumeration of actinomycetes from soil. *Actinomycetol*, 10(2), 80–90.
- He, J., & Hertweck, C. (2003). Iteration as programmed event during polyketide assembly; molecular analysis of the aureothin biosynthesis gene cluster. *Chemistry & Biology*, 10(12), 1225–1232. <https://doi.org/https://doi.org/10.1016/j.chembiol.2003.11.009>
- He, J., Kang, X., Wu, J., Shao, Z., Zhang, Z., Wu, Y., Yuan, H., Zhao, G., & Wang, J. (2023). Transcriptional self-regulation of the master nitrogen regulator GlnR in Mycobacteria. *Journal of Bacteriology*, 205(4), e00479-22. <https://doi.org/10.1128/jb.00479-22>
- Heimerl, N., Hommel, E., Westermann, M., Meichsner, D., Lohr, M., Hertweck, C., Grossman, A. R., Mittag, M., & Sasso, S. (2018). A giant type I polyketide synthase participates in zygosporangium maturation in *Chlamydomonas reinhardtii*. *The Plant Journal: For Cell and Molecular Biology*, 95(2), 268–281. <https://doi.org/10.1111/tpj.13948>
- Hertweck, C. (2015). Decoding and reprogramming complex polyketide assembly lines: Prospects for synthetic biology. *Trends in Biochemical Sciences*, 40(4), 189–199. <https://doi.org/10.1016/j.tibs.2015.02.001>.
- Hertweck, C., Luzhetsky, A., Rebets, Y., & Bechthold, A. (2007). Type II polyketide synthases: Gaining a deeper insight into enzymatic teamwork. *Natural Product Reports*, 24(1), 162–190. <https://doi.org/10.1039/b507395m>
- Hidayat, T., Hidayat, O. T., & Pancoro, A. (2008). ULASAN kajian filogenetika molekuler dan peranannya dalam menyediakan informasi dasar untuk meningkatkan kualitas sumber genetik anggrek. *Jurnal AgroBiogen*, 4(1), 35–40.
- Hutchinson, C. R. (1997). Biosynthesis studies of daunorubicin and tetracenomycin C. *Chemical Reviews*, 97(7), 2525–2536. <https://doi.org/10.1021/cr960022x>
- Ichinose, K., Ozawa, M., Itou, K., Kunieda, K., & Ebizuka, Y. (2003). Cloning, sequencing and heterologous expression of the medermycin biosynthetic gene cluster of *Streptomyces* sp. AM-7161: Towards comparative analysis of the benzoisochromanequinone gene clusters. *Microbiology (Reading, England)*, 149(Pt 7), 1633–1645. <https://doi.org/10.1099/mic.0.26310-0>
- Ilahude, A. G., & Nontji, A. (1999). *Oseanografi Indonesia dan perubahan iklim global (el nino dan la nina)*. Puslitbang Oseanografi-LIPI Jakarta.
- Imada, C. (2009). 海の微生物の利用-未知なる宝探し-. Seizando.
- Jakobi, K., & Hertweck, C. (2004). A gene cluster encoding resistomycin biosynthesis in *Streptomyces resistomycificus*; exploring polyketide cyclization beyond linear and angular patterns. *Journal of the American*

- Chemical Society, 126(8), 2298–2299. <https://doi.org/10.1021/ja0390698>*
- Johnson, J. S., Spakowicz, D. J., Hong, B. Y., Petersen, L. M., Demkowicz, P., Chen, L., Leopold, S. R., Hanson, B. M., Agresta, H. O., Gerstein, M., Sodergren, E., & Weinstock, G. M. (2019). Evaluation of 16S rRNA gene sequencing for species and strain-level microbiome analysis. *Nature Communications, 10(1), 1–11.* <https://doi.org/10.1038/s41467-019-13036-1>
- Jufri, R. F. (2020). Microbial isolation. *Journal La Lifesci, 1(1), 18–23.* <https://doi.org/10.37899/journallalifesci.v1i1.33>
- Julianto, T. S. (2019). *Fitokimia tinjauan metabolit sekunder dan skrining fitokimia.* Univeritas Islam Indonesia.
- Jusuf, M. (2001). *Genetika I: Struktur dan ekspresi gen.* IPB.
- Kai, W., Peisheng, Y., Rui, M., Wenwen, J., & Zongze, S. (2017). Diversity of culturable bacteria in deep-sea water from the South Atlantic Ocean. *Bioengineered, 8(5), 572–584.* <https://doi.org/10.1080/21655979.2017.1284711>
- Kamjam, M., Xie, Q., Deng, Z., & Hong, K. (2018). Isolation and diversity of actinomycetes from sediments of different depths between 34 m and 3.235 m in South China Sea. *Chiang Mai Journal Science, 45(4), 1595–1609.*
- Kania, D., Putri, T., Amirda, F., Muzadi, H., Carabelli, A. N., & Erlita, I. (2020). The antibacterial activity of actinomycetes against the growth of *Streptococcus mutans* and *Lactobacillus acidophilus*. *BIO Web of Conferences, 20.* <https://doi.org/10.1051/bioconf/20202003006>
- Kavitha, B., Vishnu Priyanka, N., & Khanum, Z. (2020). Screening for actinomycetes from government science college campus and study of their secondary metabolites. *International Journal of Innovative Science and Research Technology, 5(10), 574–587.*
- Keatinge-Clay, A. T. (2012). The structures of type I polyketide synthases. *Natural Product Reports, 29(10), 1050–1073.* <https://doi.org/10.1039/c2np20019h>
- Khosla, C., & Zwada, R. J. X. (1996). Generation of polyketide libraries via combinatorial biosynthesis. *Trends Biotechnology, 14, 335–341.* [https://doi.org/10.1016/0167-7799\(96\)10046-9](https://doi.org/10.1016/0167-7799(96)10046-9)
- Kiki, M. J. (2016). A new medium for the isolation and enrichment of halophilic Actinobacteria. *Life Science Journal, 13(1), 65–71.* <https://doi.org/10.7537/marslsj13011610.Keywords>
- Kim, J., & Yi, G. (2012). PKMiner: A database for exploring type II polyketide synthases. *BioMed Central Microbiology, 12(169), 1–12.* <https://doi.org/10.1186/1471-2180-12-169>
- Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution, 16(2), 111–120.* <https://doi.org/10.1007/BF01731581>

- Klau, L. J., Podell, S., Creamer, K. E., Demko, A. M., Singh, H. W., Allen, E. E., Moore, B. S., Ziemert, N., Letzel, A. C., & Jensen, P. R. (2022). The natural product domain seeker version 2 (NaPDoS2) webtool relates ketosynthase phylogeny to biosynthetic function. *Journal of Biological Chemistry*, 298(10), 102480. <https://doi.org/10.1016/j.jbc.2022.102480>
- Krysenko, S., & Wohlleben, W. (2024). Role of carbon, nitrogen, phosphate and sulfur metabolism in secondary metabolism precursor supply in *Streptomyces* spp. *Microorganisms*, 12(8). <https://doi.org/10.3390/microorganisms12081571>
- Kumar, R. R., & Jadeja, V. J. (2017). Isolation of actinomycetes : A complete approach. *International Journal of Current Microbiology and Applied Sciences*, 5(5), 606–618. <https://doi.org/10.20546/ijcmas.2016.505.062>
- Kunarso, D. H. (2011). Kajian kesuburan ekosistem Perairan Laut Sulawesi Tenggara berdasarkan aspek bakteriologi. *Jurnal Ilmu Dan Teknologi Kelautan Tropis*, 3(2), 32–47.
- Kusriyati. (2022). Kajian ENSO, hubungannya dengan suhu permukaan laut di Teluk Bone. *Journal Pusat Studi Pendidikan Rakyat*, 2(2), 36–46.
- Lal, R., Kumari, R., Kaur, H., Khanna, R., Dhingra, N., & Tuteja, D. (2000). Regulation and manipulation of the gene clusters encoding Type-I PKSs. *Trends in Biotechnology*, 18(6), 264–274. [https://doi.org/10.1016/S0167-7799\(00\)01443-8](https://doi.org/10.1016/S0167-7799(00)01443-8)
- Lechevalier, H. A., & Lechevalier, M. P. (1965). Classification des actinomycètes aérobies basée sur leur morphologie et leur composition chimique. *Ann Inst Pasteur*, 108, 662–673.
- Lestari, A., Sapa, A. R., Ananda, M., & Suwastika, I. N. (2023). Isolation and characterization of endophytic actinomycetes on onion root (*Allium ascalonicum* L.) palu cultivar. *Proceedings of the 4th International Seminar on Science and Technology (ISST 2022)*, 228–234. https://doi.org/10.2991/978-94-6463-228-6_26
- Liu, J., Piao, S., Gong, L., Zhang, M., Guo, Y., & Zhang, S. (2021). The effect of mesoscale eddy on the characteristic of sound propagation. *Journal of Marine Science and Engineering*, 9(8), 1–17. <https://doi.org/10.3390/jmse9080787>
- Liu, R., Ning, J., Jiang, Y., Wang, X., & Wu, J. (2022). A method for degenerate primer design based on artificial bee colony algorithm. *Applied Sciences*, 12(10). <https://doi.org/10.3390/app12104992>
- Lombó, F., Abdelfattah, M. S., Braña, A. F., Salas, J. A., Rohr, J., & Méndez, C. (2009). Elucidation of oxygenation steps during oviedomycin biosynthesis and generation of derivatives with increased antitumor activity. *Chembiochem : A European Journal of Chemical Biology*, 10(2), 296–303. <https://doi.org/10.1002/cbic.200800425>
- Luedemann, G. M. (1968). *Geodermatophilus*, a new genus of the Dermatophilaceae (Actinomycetales). *Journal of Bacteriology*, 96(5), 1848–

1858. <https://doi.org/10.1128/jb.96.5.1848-1858.1968>
- Magarvey, N. A., Keller, J. M., Bernan, V., Dworkin, M., & Sherman, D. H. (2004). Isolation and characterization of novel marine-derived actinomycete taxa rich in bioactive metabolites. *Applied and Environmental Microbiology*, 70(12), 7520–7529. <https://doi.org/10.1128/AEM.70.12.7520-7529.2004>
- Mahrus, H., Syukur, A., & Zulkifli, L. (2022). Morphological and molecular characters of lemuru fish (*Sardinella lemuru*) from Tanjung Luar Waters, East Lombok. *Jurnal Biologi Tropis*, 22(4), 1474 – 1482. <https://doi.org/10.29303/jbt.v22i4.4555>
- Manzoni, M., & Rollini, M. (2002). Biosynthesis and biotechnological production of statins by filamentous fungi and application of these cholesterol-lowering drugs. *Applied Microbiology and Biotechnology*, 58(5), 555–564. <https://doi.org/10.1007/s00253-002-0932-9>
- Martens, T., Gram, L., Grossart, H. P., Kessler, D., Müller, R., Simon, M., Wenzel, S. C., & Brinkhoff, T. (2007). Bacteria of the Roseobacter clade show potential for secondary metabolite production. *Microbial Ecology*, 54(1), 31–42. <https://doi.org/10.1007/s00248-006-9165-2>
- McGillicuddy, D. J. J., Anderson, L. A., Bates, N. R., Bibby, T., Buesseler, K. O., Carlson, C. A., Davis, C. S., Ewart, C., Falkowski, P. G., Goldthwait, S. A., Hansell, D. A., Jenkins, W. J., Johnson, R., Kosnyrev, V. K., Ledwell, J. R., Li, Q. P., Siegel, D. A., & Steinberg, D. K. (2007). Eddy/wind interactions stimulate extraordinary mid-ocean plankton blooms. *Science*, 316(5827), 1021–1026. <https://doi.org/10.1126/science.1136256>
- Meinarni, N. P. S. (2016). Dampak pencemaran lingkungan laut terhadap Indonesia akibat tumpahan minyak montara di Laut Timor. *Jurnal Komunikasi Hukum*, 2(2).
- Metsä-Ketälä, M., Salo, V., Halo, L., Hautala, A., Hakala, J., Mäntsälä, P., & Ylihonko, K. (1999). An efficient approach for screening minimal PKS Genes from *Streptomyces*. *FEMS Microbiology Letters*, 180(1), 1–6. <https://doi.org/10.1111/j.1574-6968.1999.tb08770.x>
- Meyer, F. M., & Bramkamp, M. (2024). Cell wall synthesizing complexes in Mycobacterales. *Current Opinion in Microbiology*, 79, 102478. <https://doi.org/https://doi.org/10.1016/j.mib.2024.102478>
- Mincer, T. J., Jensen, P. R., Kauffman, C. A., & Fenical, W. (2002). Widespread and persistent populations of a major new marine actinomycete taxon in ocean sediments. *Applied and Environmental Microbiology*, 68(10), 5005–5011. <https://doi.org/10.1128/AEM.68.10.5005-5011.2002>
- Mittal, N., Tesfu, H. H., Hogan, A. M., Cardona, S. T., & Sorensen, J. L. (2019). Synthesis and antibiotic activity of novel acylated phloroglucinol compounds against methicillin-resistant *Staphylococcus aureus*. *Journal of Antibiotics*, 72(5), 253–259. <https://doi.org/10.1038/s41429-019-0153-4>
- Mohammadipanah, F., & Dehhaghi, M. (2017). Classification and taxonomy of

- Actinobacteria. In J. Wink, F. Mohammadipanah, & J. Hamedi (Eds.), *Biology and biotechnology of Actinobacteria*. Springer Cham. <https://doi.org/10.1007/978-3-319-60339-1>
- Mohan, K. D., & Rajamanickam, U. (2018). Biodiversity of actinomycetes and secondary metabolites. *Inn Original International Journal of Sciences*, 5(1), 21–27.
- Moka, W. (2021). Pentingnya pendekatan molekuler dalam pengelolaan sumberdaya perairan. *Jurnal Pengelolaan Perairan*, 3(2).
- Morgulis, A., Coulouris, G., Raytselis, Y., Madden, T. L., Agarwala, R., & Schäffer, A. A. (2008). Database indexing for production MegaBLAST searches. *Bioinformatics (Oxford, England)*, 24(16), 1757–1764. <https://doi.org/10.1093/bioinformatics/btn322>
- Mulyadi, & Sulistyani, N. (2013). Aktivitas cairan kultur 12 isolat actinomycetes terhadap bakteri resisten. *Kes Mas: Jurnal Fakultas Kesehatan Masyarakat*, 7(2), 89–96.
- Ngamcharungchit, C., Chaimusik, N., Panbangred, W., Euanorasetr, J., & Intra, B. (2023). Bioactive metabolites from terrestrial and marine actinomycetes. *Molecules*, 28(15), 1–33. <https://doi.org/10.3390/molecules28155915>
- Nie, G.-X., Ming, H., Li, S., Zhou, E.-M., Cheng, J., Yu, T.-T., Zhang, J., Feng, H.-G., Tang, S.-K., & Li, W.-J. (2012). *Geodermatophilus nigrescens* sp. nov., isolated from a dry-hot valley. *Antonie van Leeuwenhoek*, 101(4), 811–817. <https://doi.org/10.1007/s10482-012-9696-0>
- Nilsson, W. B., & Strom, M. S. (2002). Detection and identification of bacterial pathogens of fish in kidney tissue using terminal restriction fragment length polymorphism (T-RFLP) analysis of 16S rRNA genes. *Diseases of Aquatic Organisms*, 48(3), 175–185. <https://doi.org/10.3354/dao048175>
- Noer, S. (2021). Identifikasi bakteri secara molekular menggunakan 16S rRNA. *Biological Science and Education Journal*, 1(1), 1–6.
- Normand, P., Daffonchio, D., & Gtari, M. (2014). The family Geodermatophilaceae. In E. F. DeLong, S. Lory, E. Stackebrand, & F. Thompson (Eds.), *The prokaryotes*. Springer. https://doi.org/10.1007/978-3-642-30138-4_180
- Nuzula, F., Y, L. P. S., Laksmini, M., & Purba, N. P. (2016). Variabilitas temporal eddy di Perairan Makassar – Laut Flores. *Jurnal Perikanan Kelautan*, 7(1), 130–138.
- Ortlieb, N., Klenk, E., Kulik, A., & Niedermeyer, T. H. J. (2021). Development of an agar-plug cultivation system for bioactivity assays of actinomycete strain collections. *PLOS ONE*, 16(11), 1–12. <https://doi.org/10.1371/journal.pone.0258934>
- Owen, J. G., Charlop-Powers, Z., Smith, A. G., Ternei, M. A., Calle, P. Y., Reddy, B. V. B., Montiel, D., & Brady, S. F. (2015). Multiplexed metagenome mining

- using short DNA sequence tags facilitates targeted discovery of epoxyketone proteasome inhibitors. *Proceedings of the National Academy of Sciences of the United States of America*, 112(14), 4221–4226. <https://doi.org/10.1073/pnas.1501124112>
- Owen, J. G., Reddy, B. V. B., Ternei, M. A., Charlop-Powers, Z., Calle, P. Y., Kim, J. H., & Brady, S. F. (2013). Mapping gene clusters within arrayed metagenomic libraries to expand the structural diversity of biomedically relevant natural products. *Proceedings of the National Academy of Sciences of the United States of America*, 110(29), 11797–11802. <https://doi.org/10.1073/pnas.1222159110>
- Papaiakovou, M., Pilotte, N., Baumer, B., Grant, J., Asbjornsdottir, K., Schaer, F., Hu, Y., Aroian, R., Walson, J., & Williams, S. A. (2018). A comparative analysis of preservation techniques for the optimal molecular detection of hookworm DNA in a human fecal specimen. *PLOS Neglected Tropical Diseases*, 12(1), 1–17. <https://doi.org/10.1371/journal.pntd.0006130>
- Pavelka, M. S. (2019). Snappy cell division in Actinobacteria. *Nature Chemical Biology*, 15(3), 208–209. <https://doi.org/10.1038/s41589-019-0226-5>
- Pickens, L. B., & Tang, Y. (2010). Oxytetracycline biosynthesis. *The Journal of Biological Chemistry*, 285(36), 27509–27515. <https://doi.org/10.1074/jbc.R110.130419>
- Rainey, F. A., Ray, K., Ferreira, M., Gatz, B. Z., Nobre, M. F., Bagaley, D., Rash, B. A., Park, M.-J., Earl, A. M., Shank, N. C., Small, A. M., Henk, M. C., Battista, J. R., Kämpfer, P., & da Costa, M. S. (2005). Extensive diversity of ionizing-radiation-resistant bacteria recovered from sonoran desert soil and description of nine new species of the genus *Deinococcus* obtained from a single soil sample. *Applied and Environmental Microbiology*, 71(9), 5225–5235. <https://doi.org/10.1128/AEM.71.9.5225-5235.2005>
- Rajalakshmi, S. (2017). Different types of PCR techniques and its applications. *International Journal of Pharmaceutical, Chemical, and Biological Sciences*, 7(3), 285–292. www.ijpcbs.com
- Rangkuti, A. B., Mawarni, A., & Rangkuti, R. R. (2022). Phylogenetic reconstruction of tree species on the University of North Sumatra Campus, based on the rbcL gene. *IOP Conference Series: Earth and Environmental Science*, 1–5. <https://doi.org/10.1088/1755-1315/1115/1/012030>
- Rante, H., Alam, G., Pakki, E., Usman, U., & Ali, A. (2020). Identification and antibacterial activity of actinomycetes isolated from medicinal plant *Andrographis paniculata* rhizosphere soil. *Crescent Journal of Medical and Biological Sciences*, 7(4), 2–8.
- Rawlings, B. J. (2001). Type I polyketide biosynthesis in bacteria (Part A—erythromycin biosynthesis). *Natural Product Reports*, 18(2), 190–227. <https://doi.org/10.1039/b009329g>.
- Republik Indonesia. (2002). *Peraturan Pemerintah Republik Indonesia No. 37*

- Tahun 2002 tentang hak dan kewajiban kapal dan pesawat udara asing dalam melaksanakan hak lintas alur laut kepulauan melalui alur laut kepulauan yang ditetapkan.* Pemerintah Pusat.
- Retnowati, Y., Moeljopawiro, S., & Djohan, T. S. (2018). Antimicrobial activities of actinomycete isolates from rhizospheric soils in different Mangrove Forests of Torosiaje, Gorontalo, Indonesia. *Biodiversitas*, 19(6), 2196–2203. <https://doi.org/10.13057/biodiv/d190627>
- Risdian, C., Endah, E. S., Saraswat, V., Wulansari, H. A., Diwan, A. M., Ratnaningrum, D., Hidayati, N. A., & Mozef, T. (2023). Production of antibacterial and antioxidant agents by Actinobacteria using soybean meal as a nitrogen source. *IOP Conference Series: Earth and Environmental Science*, 1201(1). <https://doi.org/10.1088/1755-1315/1201/1/012100>
- Risdian, C., Mozef, T., & Wink, J. (2019). Biosynthesis of polyketides in *Streptomyces*. *Microorganisms*, 7(5), 1–18. <https://doi.org/10.3390/microorganisms7050124>
- Rivers, M. A. J., & Lowell, A. N. (2024). Expanding the biosynthetic toolbox: The potential and challenges of in vitro type II polyketide synthase research. *SynBio*, 2(1), 85–111. <https://doi.org/10.3390/synbio2010006>
- Robbins, T., Kapilivsky, J., Cane, D. E., & Khosla, C. (2016). Roles of conserved active site residues in the ketosynthase domain of an assembly line polyketide synthase. *Biochemistry*, 55(32), 4476–4484. <https://doi.org/10.1021/acs.biochem.6b00639>
- Robbins, T., Liu, Y.-C., Cane, D. E., & Khosla, C. (2016). Structure and mechanism of assembly line polyketide synthases. *Current Opinion in Structural Biology*, 41(650), 10–18. <https://doi.org/10.1016/j.sbi.2016.05.009>
- Robinson, A. R. (1983). *Eddies in marine science*. Springer-Verlag. <https://doi.org/10.1007/978-3-642-69003-7>
- Rocha, G. T., Montalvão, S. C. L., Queiroz, P. R. M., Berçot, M. R., Gomes, A. C. M. M., & Monnerat, R. G. (2023). Morphological and biochemical characterization of bacterial species of *Bacillus*, *Lysinibacillus* and *Brevibacillus*. *Revista Ceres*, 70(3), 91–104. <https://doi.org/10.1590/0034-737X202370030010>
- Rosyidianaputri, A., Arkana, G., Maulana, H. A., & Kavitarna, S. A. (2023). Phylogenetic construction of green algae based on the rbcL gene. *Journal of Smart Bioprospecting and Technology*, 04(01), 25–31. <https://doi.org/10.21776/ub.jsmartech.2023.004.01.25>
- Rutledge, P. J., & Challis, G. L. (2015). Discovery of microbial natural products by activation of silent biosynthetic gene clusters. *Nature Publishing Group*, 13(8), 509–523. <https://doi.org/10.1038/nrmicro3496>
- Saitou, N., & Nei, M. (1987). The Neighbor-Joining Method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, 4(4), 406–425. <https://doi.org/10.1093/oxfordjournals.molbev.a040454>

- Santosa, S. F., Nazaruddin, N., Sari, W. E., & Febriani, F. (2023). Polyketide synthase gene domain exploration of marine sponge symbiont bacteria collected from Weh Island. *Biosaintifika*, 15(2), 246–254. <https://doi.org/10.15294/biosaintifika.v15i2.42980>
- Satria, G. G. A., Sulardiono, B., & Purwanti, F. (2014). Kelimpahan jenis teripang di perairan terbuka dan perairan tertutup Pulau Panjang Jepara, Jawa Tengah. *Diponegoro Journal of Maquares Management of Aquatic Resources*, 3(1), 108–115.
- Schatz, A., Bugle, E., & Waksman, S. A. (1944). Streptomycin, a substance exhibiting antibiotic activity against gram-positive and gram-negative bacteria. *Proceedings of the Society for Experimental Biology and Medicine*, 55(1), 66–69. <https://doi.org/10.3181/00379727-55-144>
- Schoch, C. L., Ciufo, S., Domrachev, M., Hotton, C. L., Kannan, S., Khovanskaya, R., Leipe, D., Mcveigh, R., O'Neill, K., Robbertse, B., Sharma, S., Soussov, V., Sullivan, J. P., Sun, L., Turner, S., & Karsch-Mizrachi, I. (2020). NCBI taxonomy: A comprehensive update on curation, resources and tools. *Database: The Journal of Biological Databases and Curation*, 2020. <https://doi.org/10.1093/database/baaa062>
- Schöppner, A., & Kindl, H. (1984). Purification and properties of a stilbene synthase from induced cell suspension cultures of peanut. *Journal of Biological Chemistry*, 259(11), 6806–6811. [https://doi.org/10.1016/S0021-9258\(17\)39799-5](https://doi.org/10.1016/S0021-9258(17)39799-5)
- Selim, M., Selim, M., Abdelhamid, S. A., & Mohamed, S. S. (2021). Secondary metabolites and biodiversity of actinomycetes. *Journal of Genetic Engineering and Biotechnology*, 9(72).
- Sheikh, M., Rathore, D. S., Gohel, S., & Singh, S. P. (2019). Cultivation and characteristics of the marine Actinobacteria from the Sea water of Alang, Bhavnagar. *Indian Journal of Geo-Marine Sciences*, 48(12), 1896–1901.
- Shelest, E., Heimerl, N., Fichtner, M., & Sasso, S. (2015). Multimodular type I polyketide synthases in algae evolve by module duplications and displacement of AT domains in trans. *BMC Genomics*, 16, 1015. <https://doi.org/10.1186/s12864-015-2222-9>
- Shirling, E. B., & Gottlieb, D. (1966). Methods for characterization of *Streptomyces* species. *International Journal of Systematic Bacteriology*, 16(3), 313–340.
- Simeis, D. De, & Serra, S. (2021). Actinomycetes: A never-ending source of bioactive compounds—an overview on antibiotics production. *Antibiotics (Basel)*, 10(5), 483. <https://doi.org/10.3390/antibiotics10050483>
- Smith, A. C., & Hussey, M. A. (2005). *Gram stain protocols*. American Society for Microbiology (ASM).
- Sogandi. (2018). *Identifikasi bakteri secara molekuler*. Universitas 17 Agustus 1945 Jakarta.

- Staunton, J., & Weissman, K. J. (2001). Polyketide biosynthesis : A millennium review. *Natural Product Reports*, 18(4), 380–416. <https://doi.org/10.1039/a909079g>
- Świecimska, M., Golińska, P., & Goodfellow, M. (2023). Generation of a high quality library of bioactive filamentous actinomycetes from extreme biomes using a culture-based bioprospecting strategy. *Frontiers in Microbiology*, 13(January). <https://doi.org/10.3389/fmicb.2022.1054384>
- Tamura, K., Stecher, G., & Kumar, S. (2021). MEGA11: Molecular evolutionary genetics analysis version 11. *Molecular Biology and Evolution*, 38(7), 3022–3027. <https://doi.org/10.1093/molbev/msab120>
- Utami, A., Apriliana, P., Kusnadi, Y., Zilda, D. S., Ilmiah, Z., Lisdiyanti, P., Setyahadi, S., & Uria, A. R. (2021). Analyzing the biosynthetic potential of antimicrobial-producing Actinobacteria originating from Indonesia. *Indonesian Journal of Biotechnology*, 26(3), 142–151. <https://doi.org/10.22146/ijbiotech.65239>
- Valenzano, C. R. (2003). *Polyketide biosynthesis: The biochemical basis for stereochemical control*. Brown University.
- Waksman, S. A. (1961). *The actinomycetes. Vol. II. classification, identification and description of genera and species*. Williams and Wilkins Co.
- Waldman, A. J., & Balskus, E. P. (2014). Lomaiviticin biosynthesis employs a new strategy for starter unit generation. *Organic Letters*, 16(2), 640–643. <https://doi.org/10.1021/ol403714g>
- Wang, H., Fewer, D. P., Holm, L., Rouhiainen, L., & Sivonen, K. (2014). Atlas of nonribosomal peptide and polyketide biosynthetic pathways reveals common occurrence of nonmodular enzymes. *Proceedings of the National Academy of Sciences of the United States of America*, 111(25), 9259–9264. <https://doi.org/10.1073/pnas.1401734111>
- Wang, J., Zhang, R., Chen, X., Sun, X., Yan, Y., Shen, X., & Yuan, Q. (2020). Biosynthesis of aromatic polyketides in microorganisms using type II polyketide synthases. *Microbial Cell Factories*, 19(110), 1–11. <https://doi.org/10.1186/s12934-020-01367-4>
- Weissman, K. J., & Leadlay, P. F. (2005). Combinatorial biosynthesis of reduced polyketides. *Nature Reviews Microbiology*, 3(12), 925–936. <https://doi.org/10.1038/nrmicro1287>
- Wolf-Baca, M., & Siedlecka, A. (2023). Community composition and antibiotic resistance of tap water bacteria retained on filtration membranes. *Diversity*, 15(3), 1–11. <https://doi.org/10.3390/d15030427>
- Xiao, X., Zhang, Y., & Wang, F. (2021). Hydrostatic pressure is the universal key driver of microbial evolution in the deep ocean and beyond. *Environmental Microbiology Reports*, 13(1), 68–72. <https://doi.org/10.1111/1758-2229.12915>

- Xu, Z., Jakobi, K., Welzel, K., & Hertweck, C. (2005). Biosynthesis of the antitumor agent chartreusin involves the oxidative rearrangement of an anthracyclic polyketide. *Chemistry & Biology*, 12(5), 579–588. <https://doi.org/10.1016/j.chembiol.2005.04.017>
- Yadav, G., Gokhale, R. S., & Mohanty, D. (2009). Towards prediction of metabolic products of polyketide synthases: An in silico analysis. *PLOS Computational Biology*, 5(4). <https://doi.org/10.1371/journal.pcbi.1000351>
- Yanti, A. H., Setyawati, T. R., & Kurniatuhadi, R. (2020). Composition and characterization of actinomycetes isolated from nipah mangrove sediment, gastrointestinal and fecal pellets of nipah worm (*Namalycastis rhodhocorde*). *IOP Conference Series: Earth and Environmental Science*, 550(1). <https://doi.org/10.1088/1755-1315/550/1/012003>
- Yu, D., Xu, F., Zeng, J., & Zhan, J. (2012). Type III polyketide synthases in natural product biosynthesis. *IUBMB Life*, 64(4), 285–295. <https://doi.org/10.1002/iub.1005>
- Yusuf, M., Maddatuang, Malik, A., & Sukri, I. (2022). Analisis trend dan variabilitas suhu permukaan laut di Perairan Indonesia WPPN-RI 713. *Jurnal Environmental Science*, 5(1), 76–82.
- Zha, W., Rubin-Pitel, S. B., & Zhao, H. (2006). Characterization of the substrate specificity of PhID, a type III polyketide synthase from *Pseudomonas fluorescens*. *Journal of Biological Chemistry*, 281(42), 32036–32047. [https://doi.org/10.1016/S0021-9258\(19\)84117-0](https://doi.org/10.1016/S0021-9258(19)84117-0)
- Zhang, J. (2011). Improvement of an isolation medium for actinomycetes. *Modern Applied Science*, 5(2), 124–127. <https://doi.org/10.5539/mas.v5n2p124>
- Zilda, D. S., Patantis, G., Sibero, M. T., & Fawzya, Y. N. (2021). Penapisan dan identifikasi bakteri penghasil agarase dari sampel sedimen Laut Bara Caddi, Sulawesi Selatan. *Jurnal Pascapanen Dan Bioteknologi Kelautan Dan Perikanan*, 16(1), 11–21. <https://doi.org/10.15578/jpbkp.v16i1.699>