



Mini review

Exploring endophytes for *in vitro* synthesis of bioactive compounds similar to metabolites produced *in vivo* by host plants

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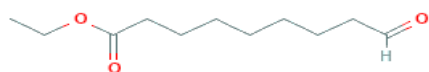
***Correspondence:** p.singh@ulster.ac.uk.

2 -D structures of compounds obtained from endophytes

1. Ethyl trans-9,10-epoxy-11-oxoundecanoate [1]



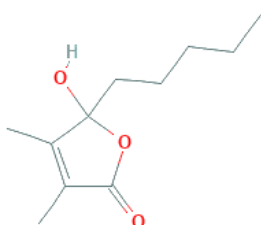
2. Ethyl 9-oxononanoate [2]



3. Ethyl zaelate [1]

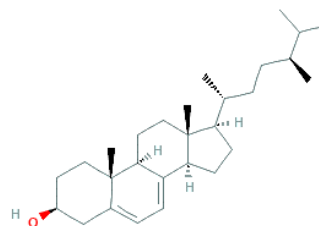


4. Hydroxydihydrobovolide [3]

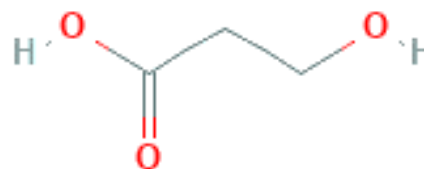


5. 8,1',5'-trihydroxy-3',4' dihydro-1'H-[2,4']binaphthalenyl-1,4,2'-trione

6. 3 β -hydroxy-ergosta-5-ene [4]



7. 3-Hydroxypropionic acid [5]

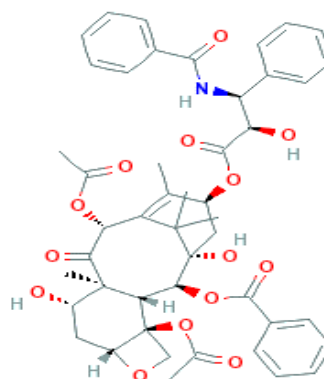


8. Leu-surfactin

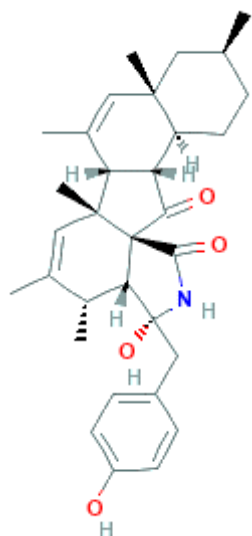
9. 1,8-cineole (monoterpene) [6]



10. Taxol [7]

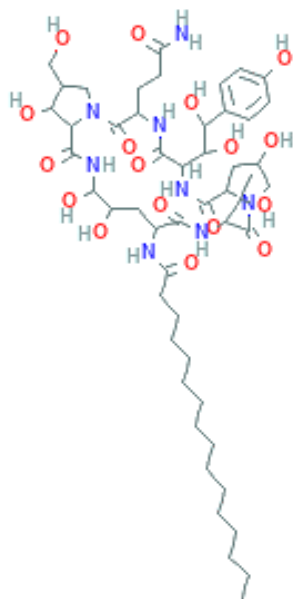


11. Phomopsichalasin [8]



12. 6-oxo-2-propenyl-3,6-dihydro-2H-pyran-3-yl ester

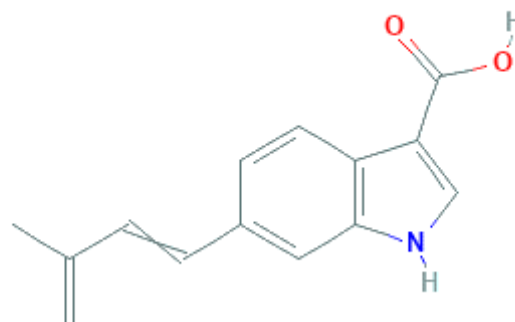
13. Cryptocandin [9]

14. 3 β ,5 α ,6 β -trihydroxyergosta-7,22-diene15. 3 β -hydroxy-ergosta-5-ene

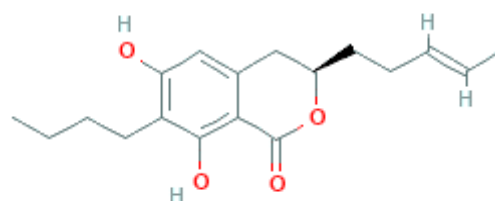
16. 3-oxo-ergosta-4,6,8(14),22-tetraene

17. 3 β -hydroxy-5 α ,8 α -epidioxy-ergosta-6,22-diene18. 3 β -hydroxy-5 α ,8 α -epidioxy-ergosta-6,9(11),22-triene, 3-oxo-ergosta-4-ene

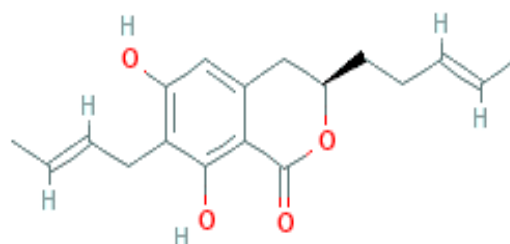
19. 6-isoprenylindole-3-carboxylic acid [10]

20. 3 β ,5 α -dihydroxy-6 β -acetoxy-ergosta-7,22-diene21. 3 β ,5 α -dihydroxy-6 β -phenylacetyloxy-ergosta-7,22-diene

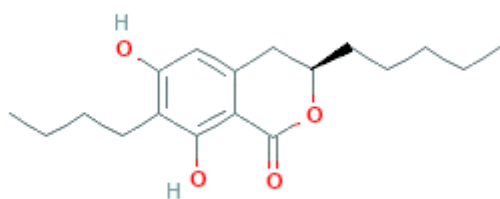
22. 7-butyl-6,8-dihydroxy-3(R)-pent-11-enylisochroman-1-one [11]



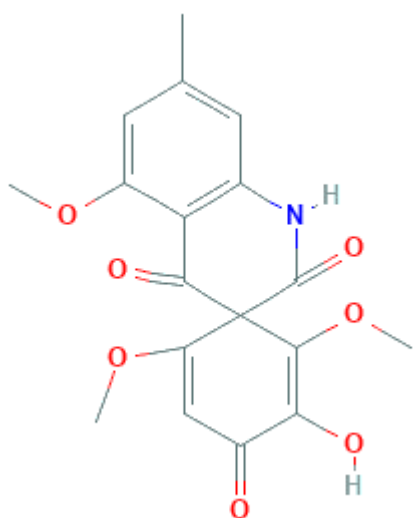
23. 7-but-15-enyl-6,8-dihydroxy-3(R)-pent-11-enylisochroman-1-one [12]



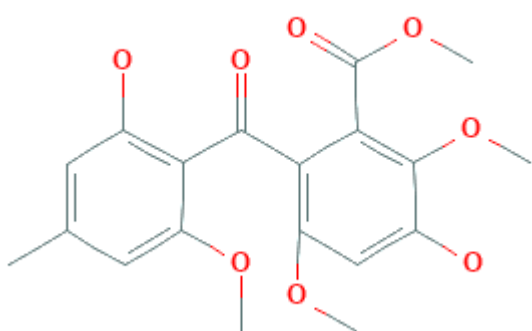
24. 7-butyl-6,8-dihydroxy-3(R)-



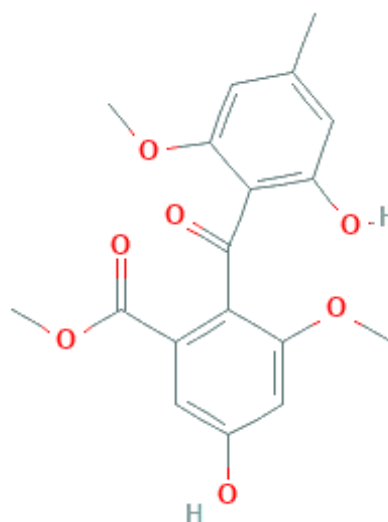
25. Asperfumoid [14]



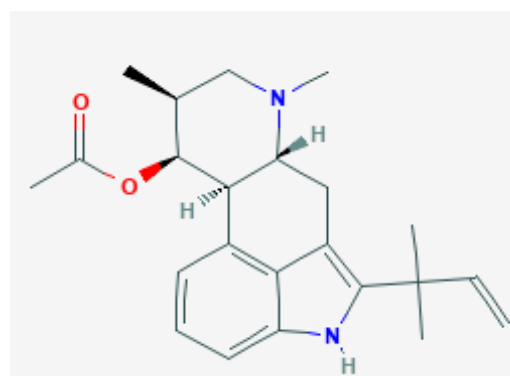
26. Asperfumin [15]



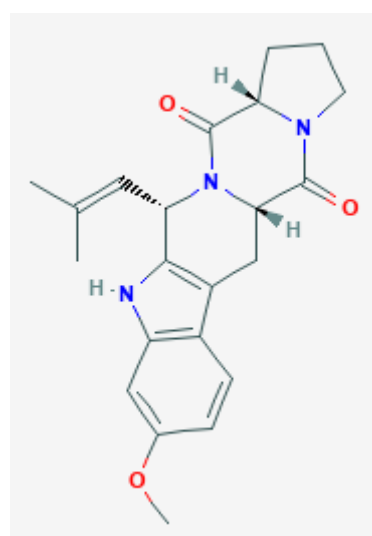
27. Monomethylsulochrin [16]



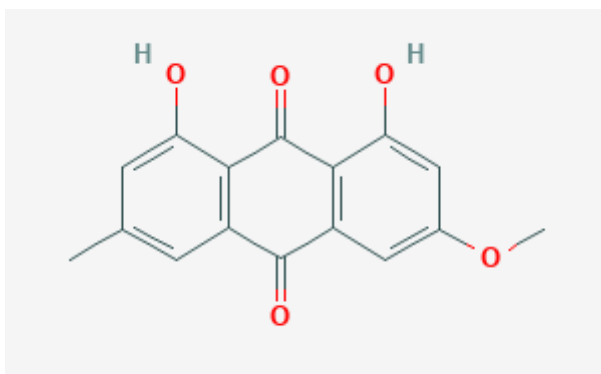
28. Fumigaclavine C [17]



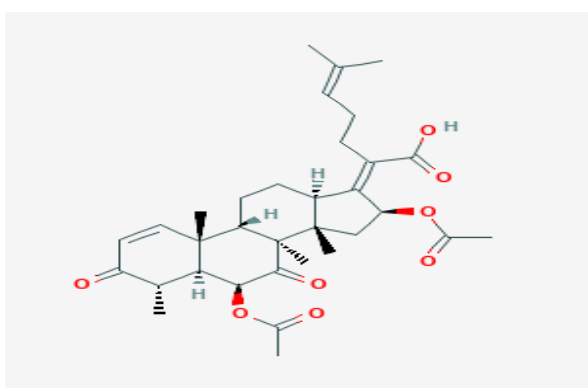
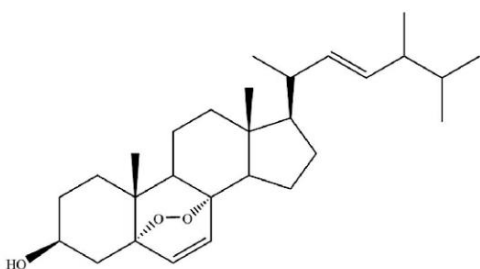
29. Fumitremorgin C [18]



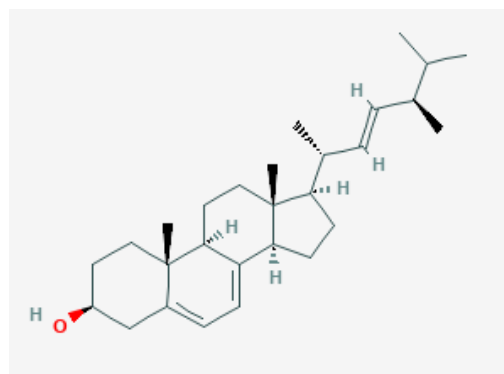
30. Physcion [19]



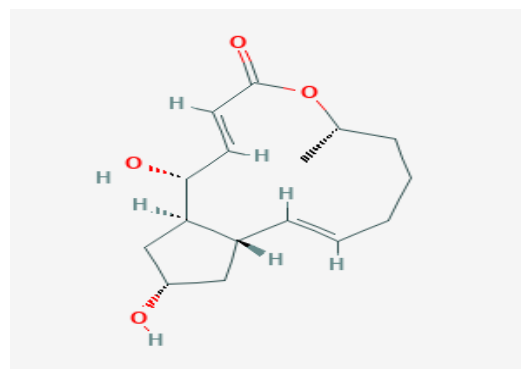
31. Helvolic acid [20]

32. $5\alpha,8\alpha$ -epidioxy-ergosta-6,22-diene- 3β -ol [21]33. Ergosta-4,22-diene- 3β -ol

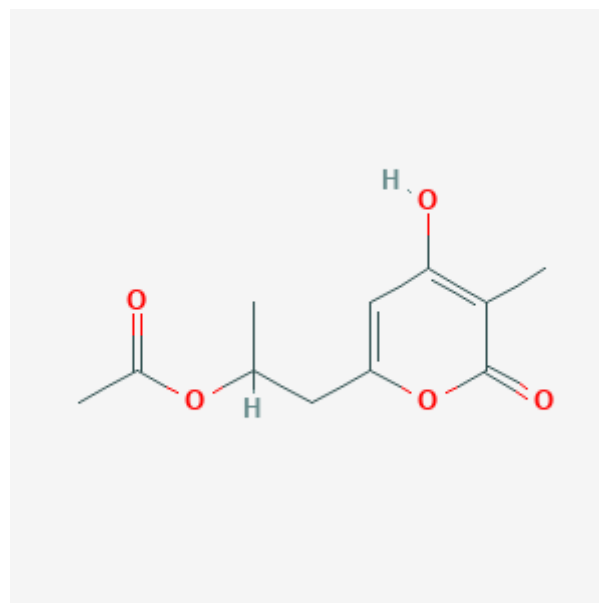
34. Ergosterol [22]

35. *Cyclo (Ala-Leu)*36. *Cyclo (Ala-Ile)*

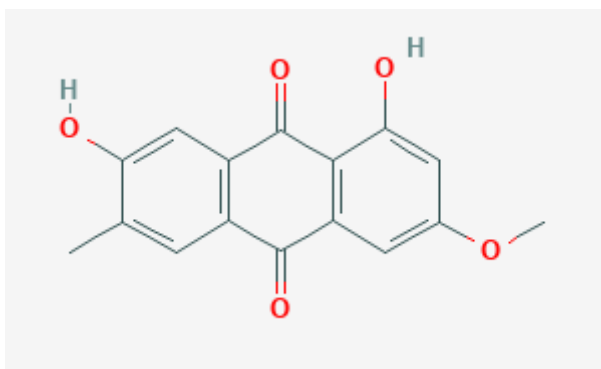
37. Brefeldin A [23]



38. Ampelopyrone [24]



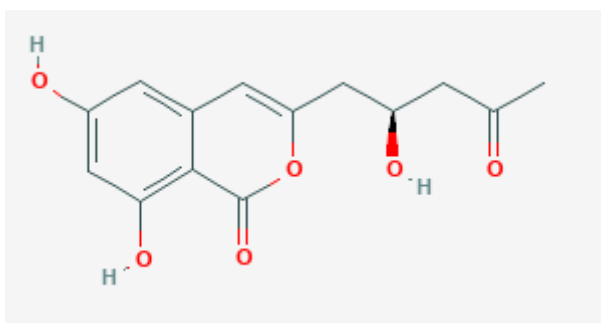
39. Macrosporin [25]



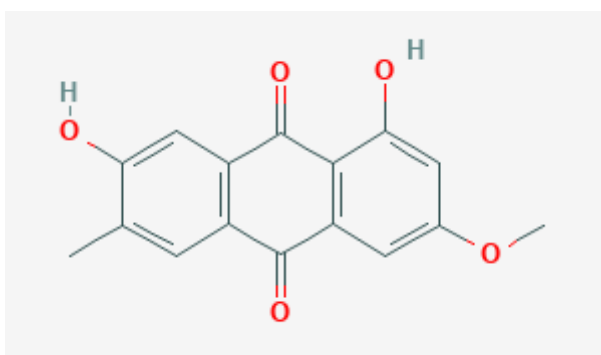
40. 3-O-methylalaternin

41. Methyltriacetic lactone

42. Citreoisocoumarin [26]

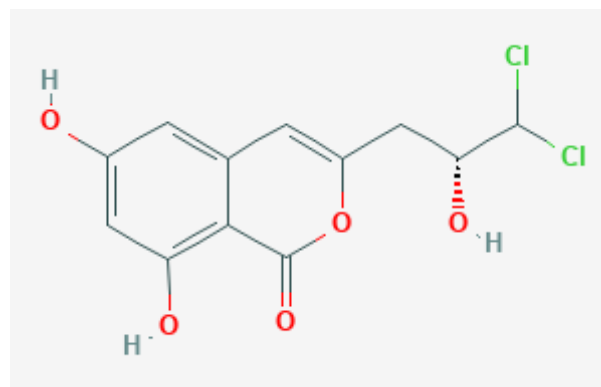


43. Macrosporin [27]

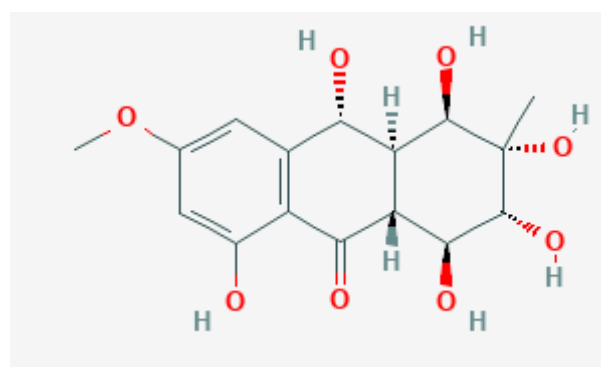


44. Desmethyldiaportino

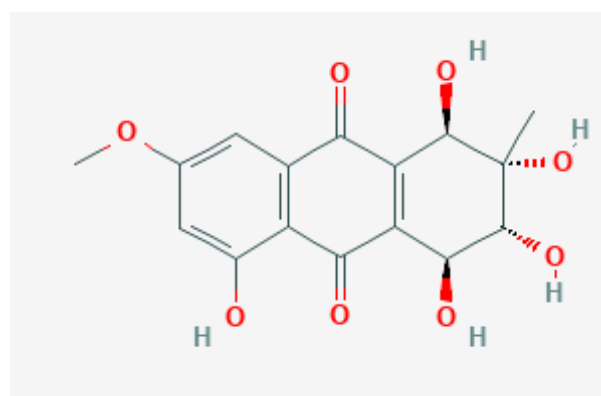
45. Desmethyldichlorodiaportin [28]



46. Ampelanol [29]

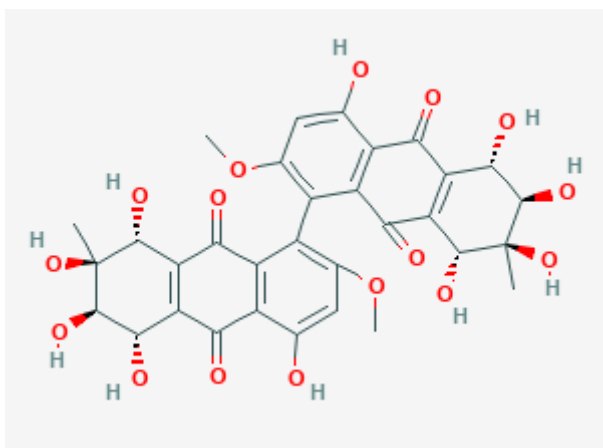


47. Altersolanol A [30]

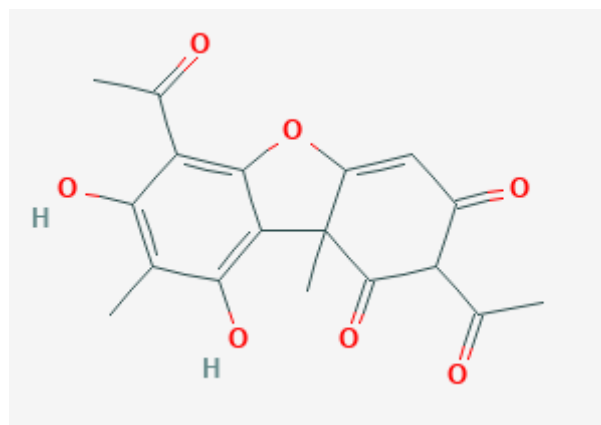


48. Alterporriols D

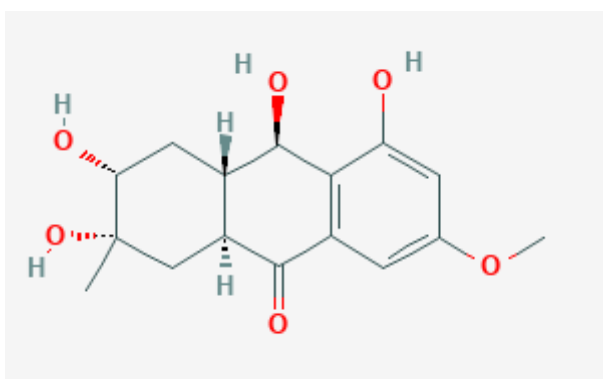
49. Alterporriols E [31]



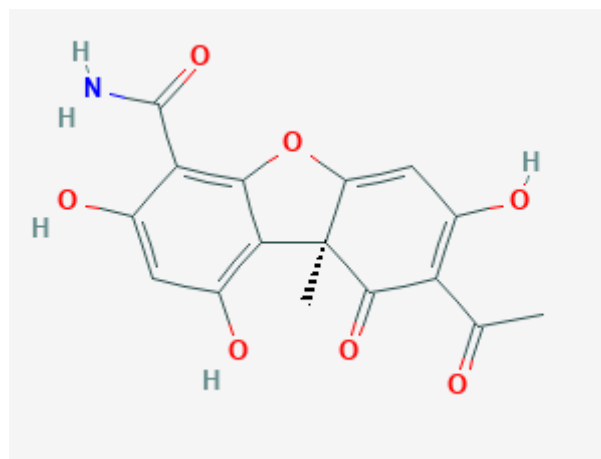
52. Usnic acid [34]



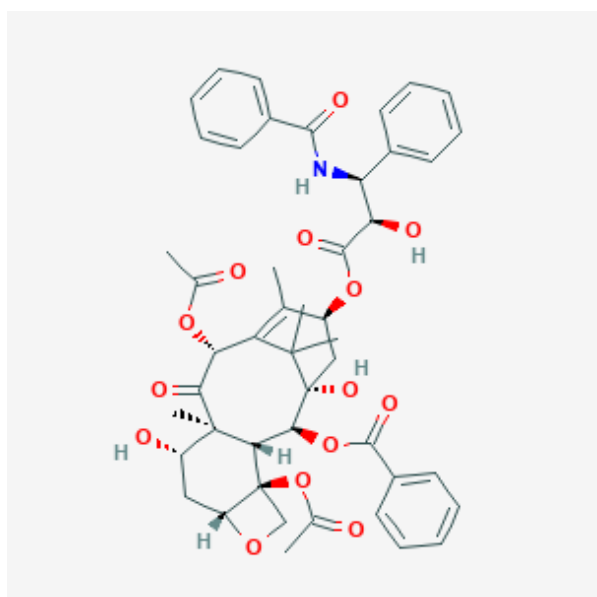
50. Altersolanol J [32]



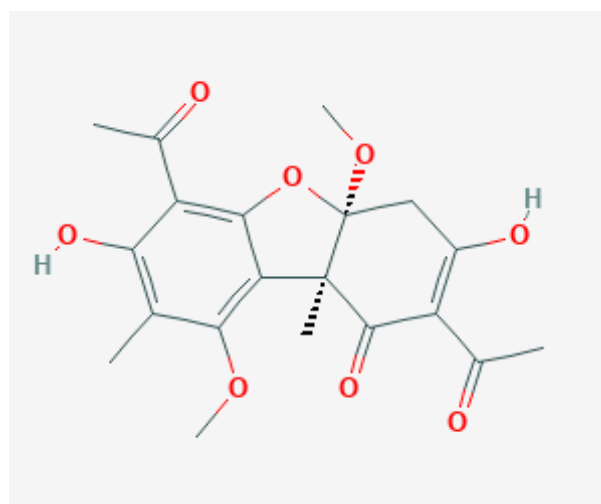
53. Cercosporamide [35]



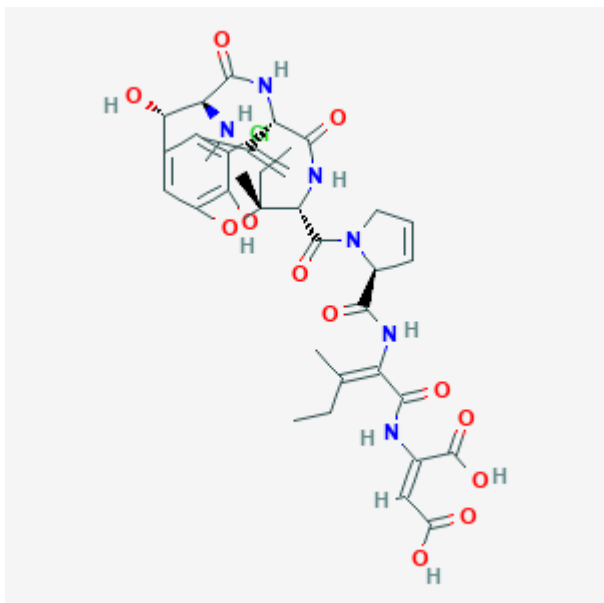
51. Paclitaxel [33]



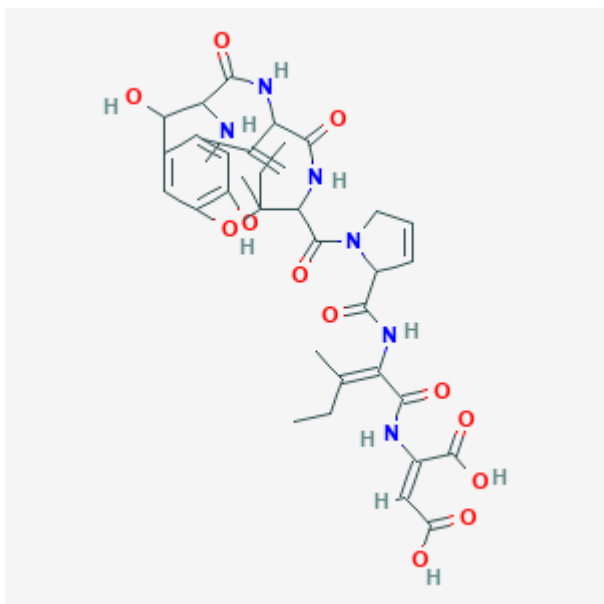
54. Phomodione [36]



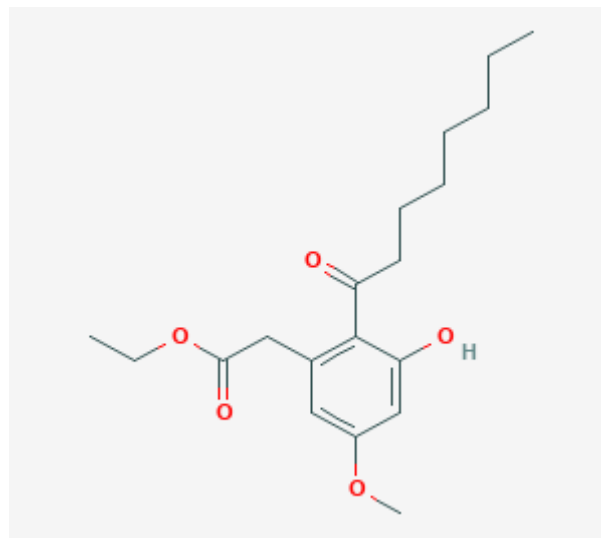
55. Phomopsin A [37]



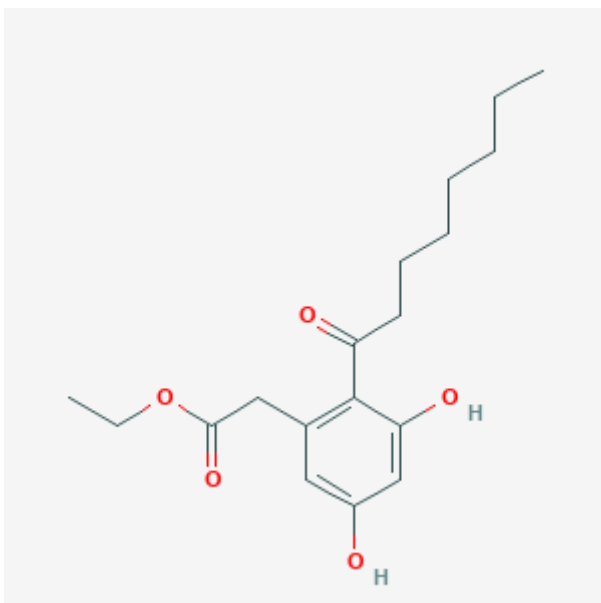
56. Phomopsin B [38]



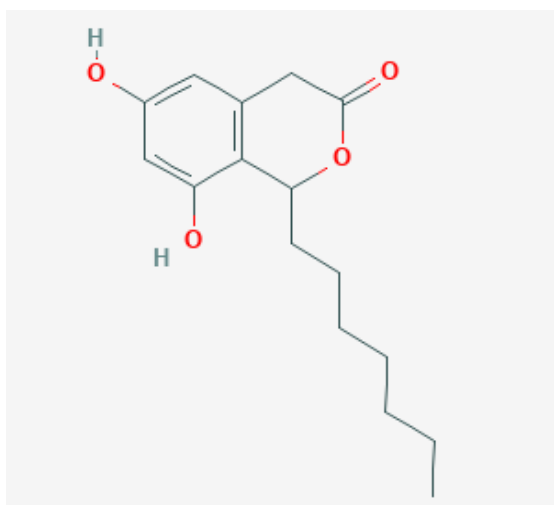
57. Phomopsin C [39]



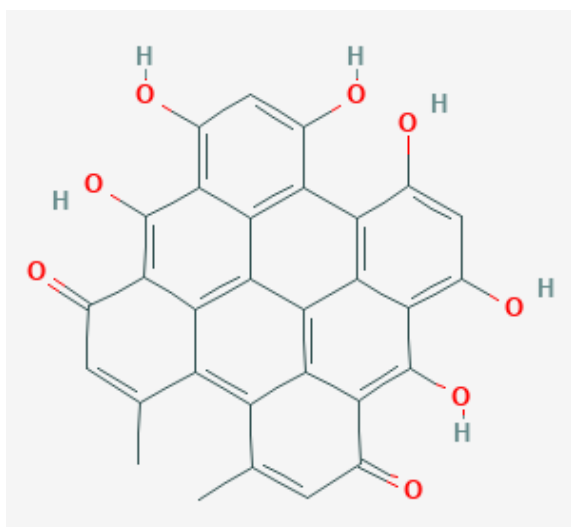
58. Cytosporone B[40]



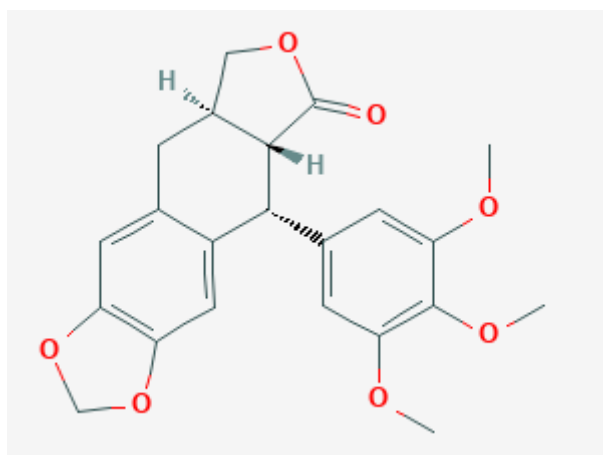
59. Cytosporone C [41]



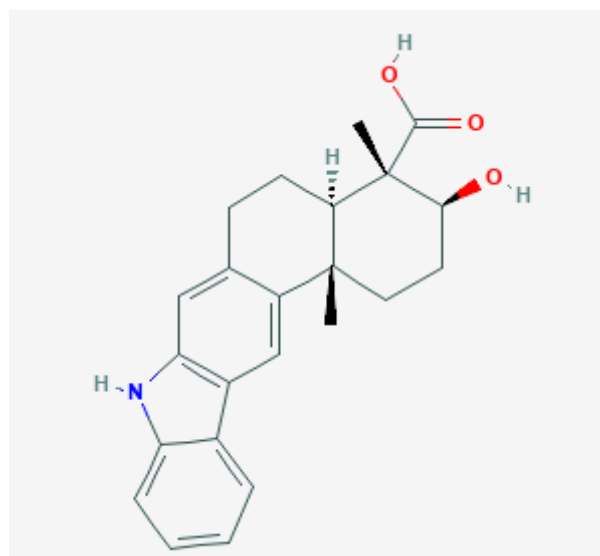
60. Hypericin [42]



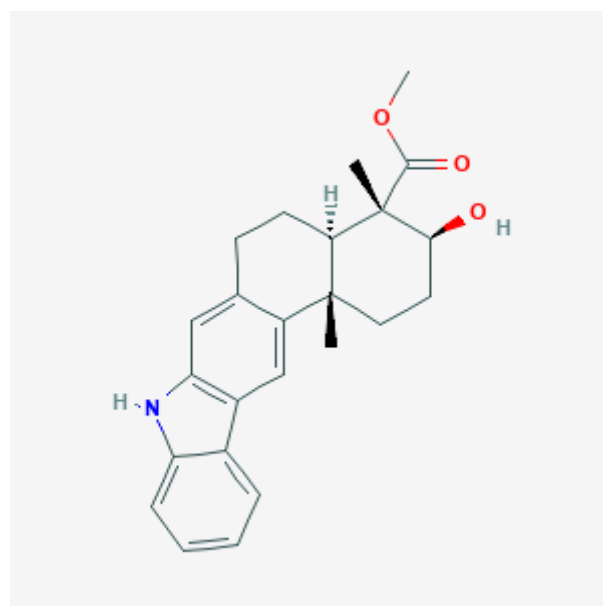
61. Deoxypodophyllotoxin [43]



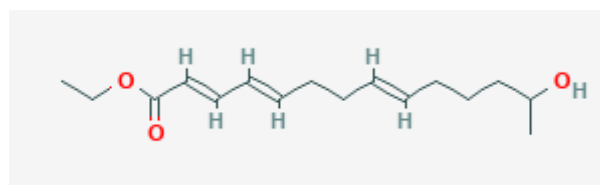
62. Xiamycin [44]



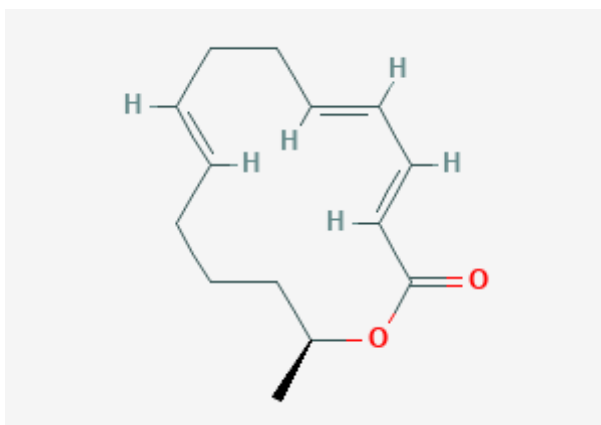
63. Methyl ester of Xiamycin [45]



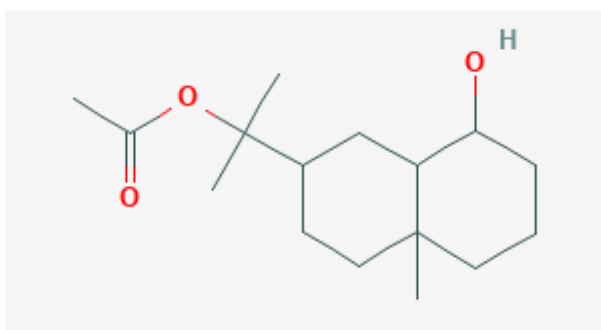
64. Benquinol [46]



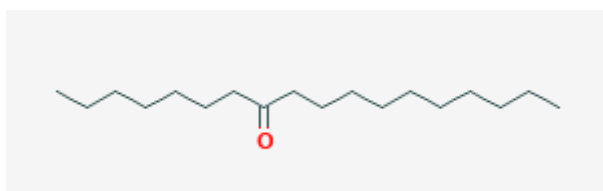
65. Benquoine [47]



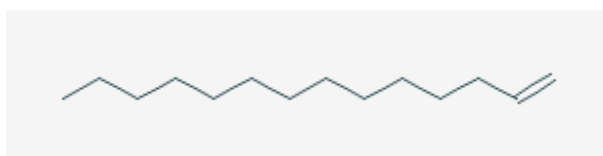
66. Terpene [48]



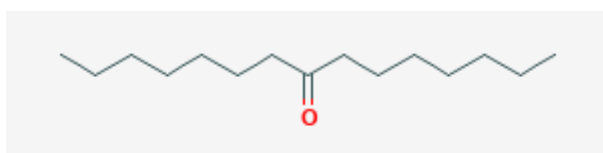
67. 8-octadecanone [49]



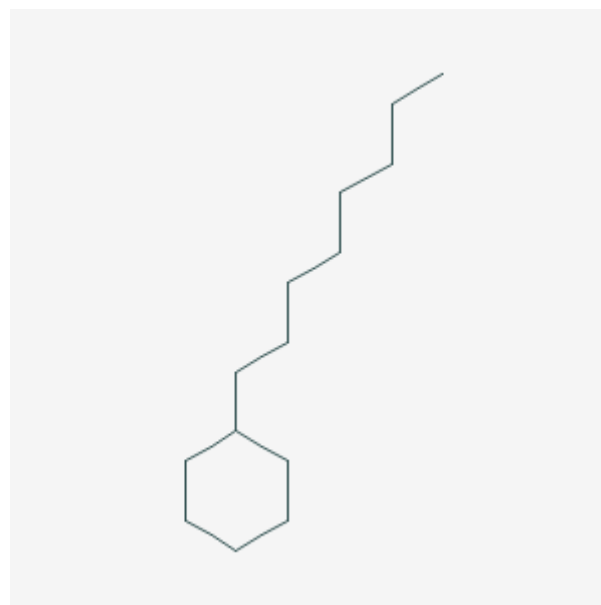
68. 1-tetradecene [50]



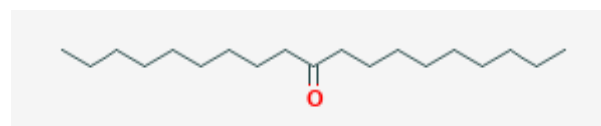
69. 8-pentadecanone [51]



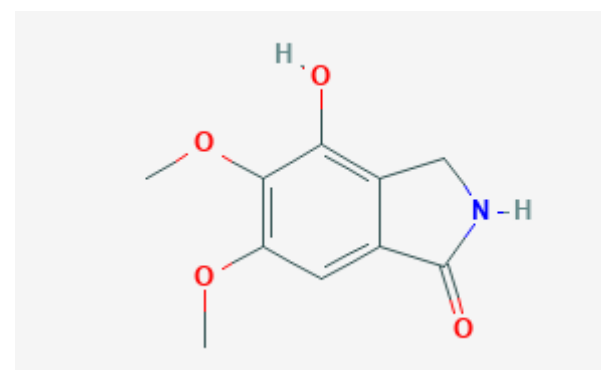
70. Octylcyclohexane [52]



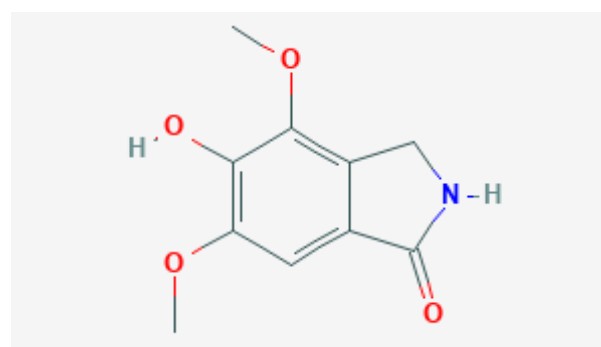
71. 10-nonadecanone [53]



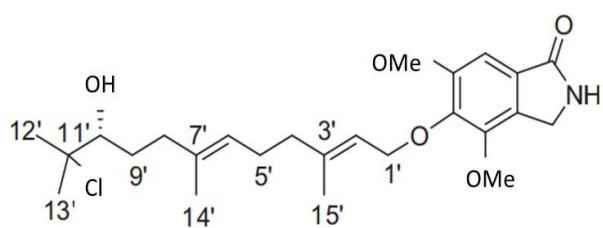
72. Emerimidine A [54]



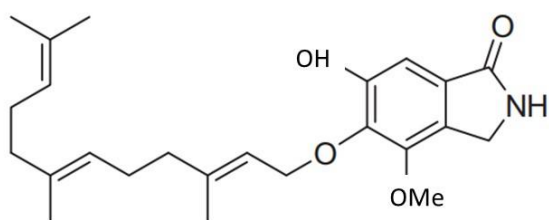
73. Emerimidine B [55]



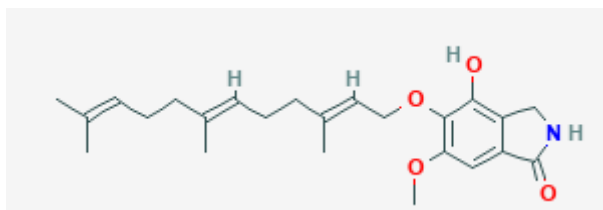
74. Emeriphenolicins A [56]



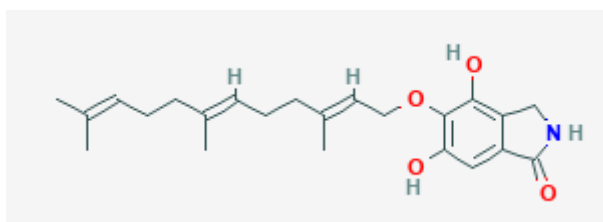
75. Emeriphenolicins A [56]



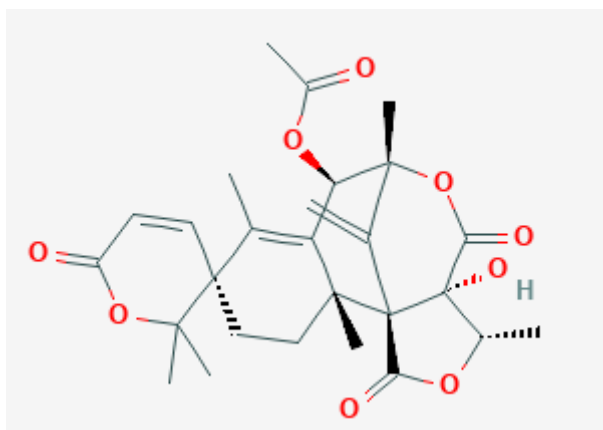
76. Aspernidine A [57]



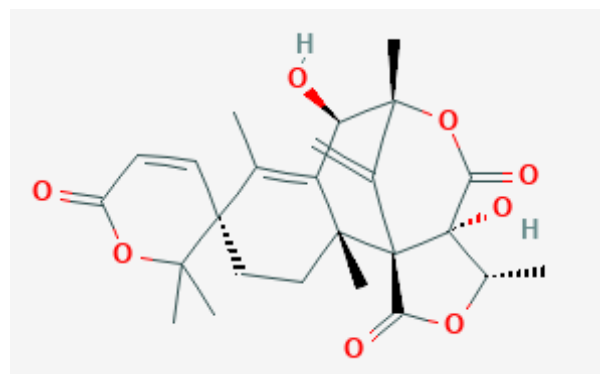
77. Aspernidine B [58]



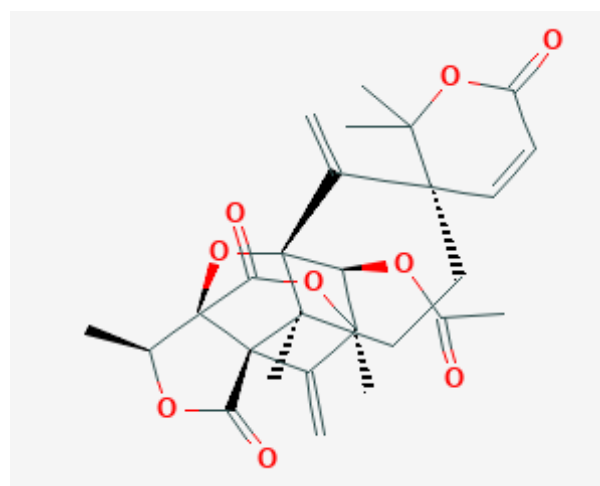
78. Austin [59]



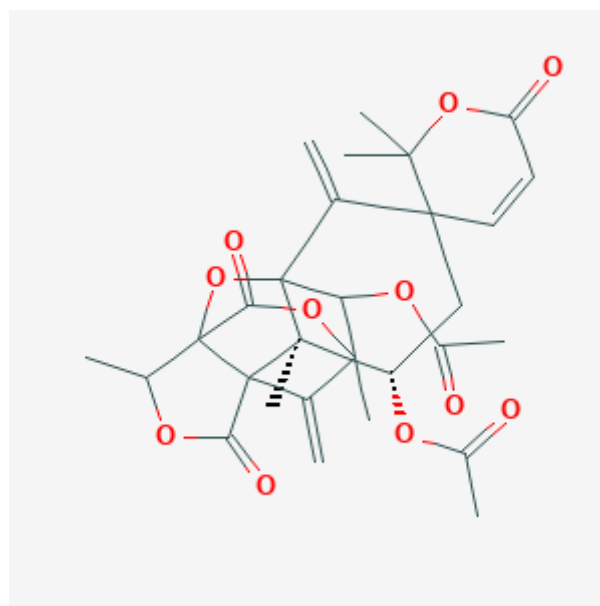
79. Austinol [60]



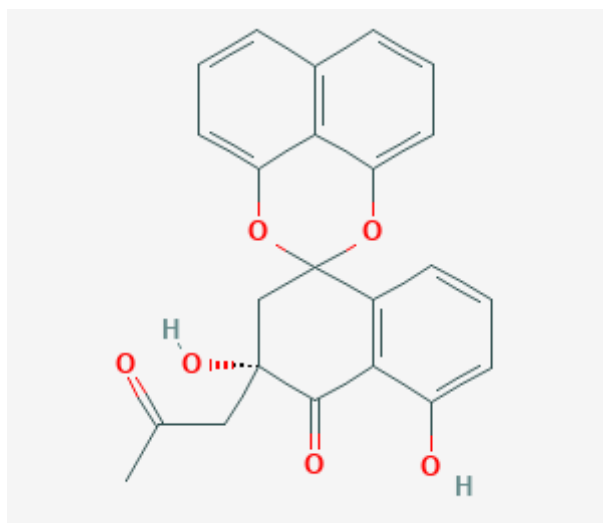
80. Dehydroaustin [61]



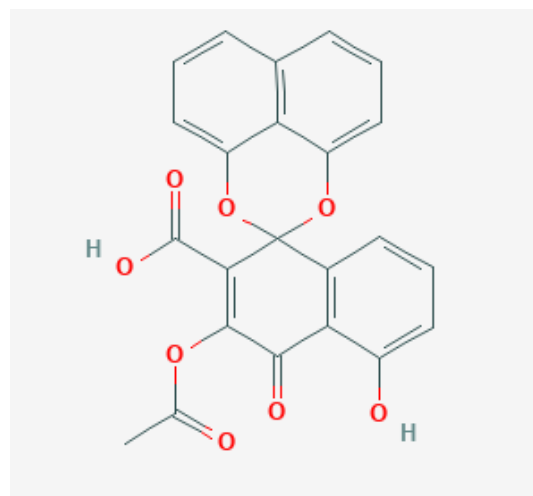
81. Acetoxydehydroaustin [62]



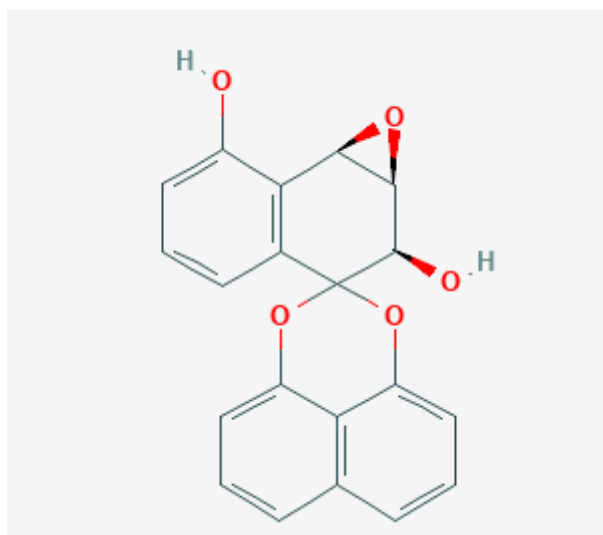
82. Guignardin A [63]



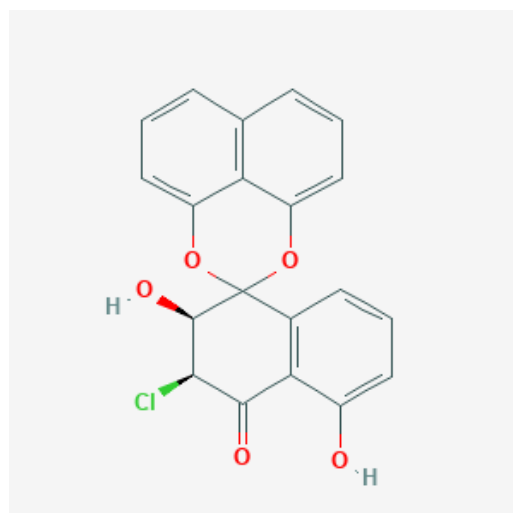
85. Guignardin D [66]



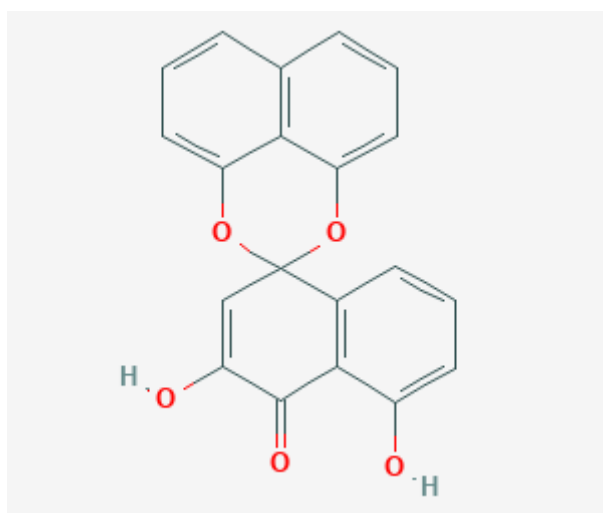
83. Guignardin B [64]



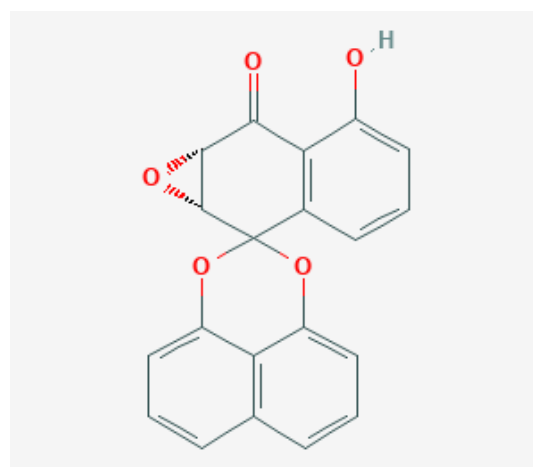
86. Guignardin E [67]



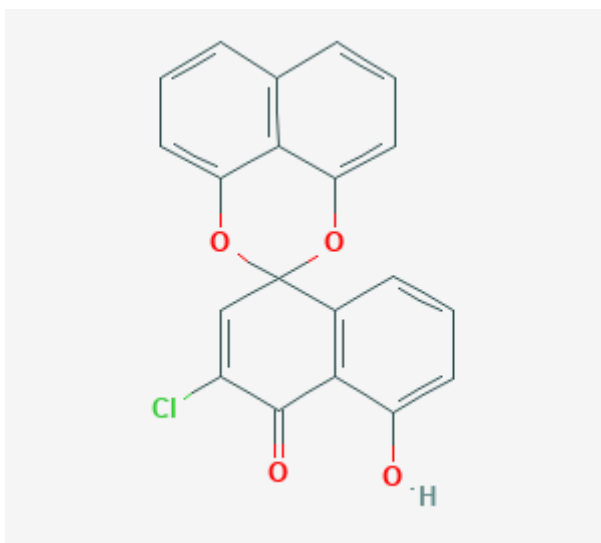
84. Guignardin C [65]



87. Guignardin F [68]

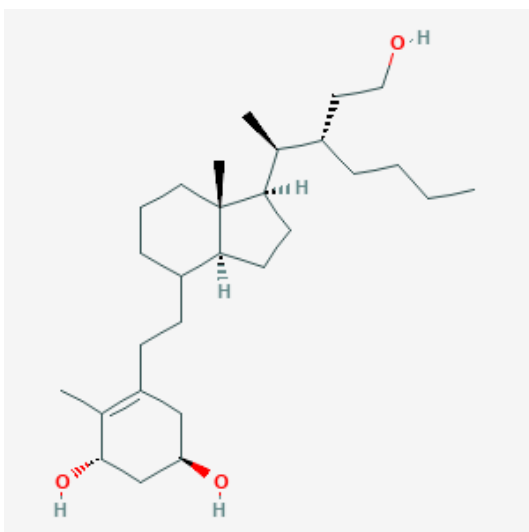


88. Palmarumycin C1 [69]

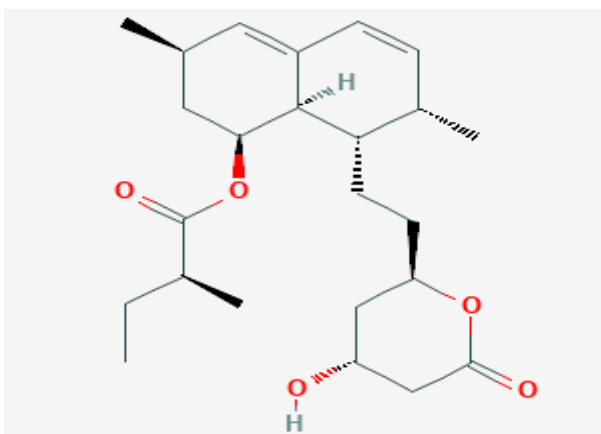


89. BG1

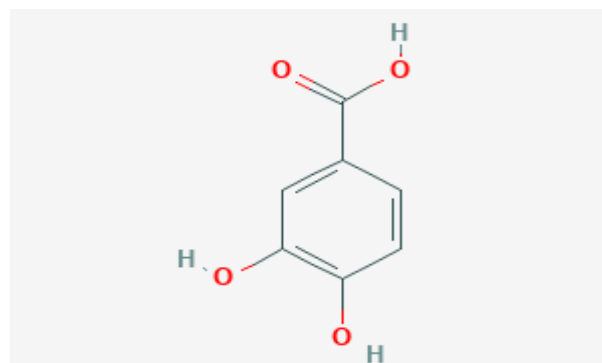
90. JC1[70]



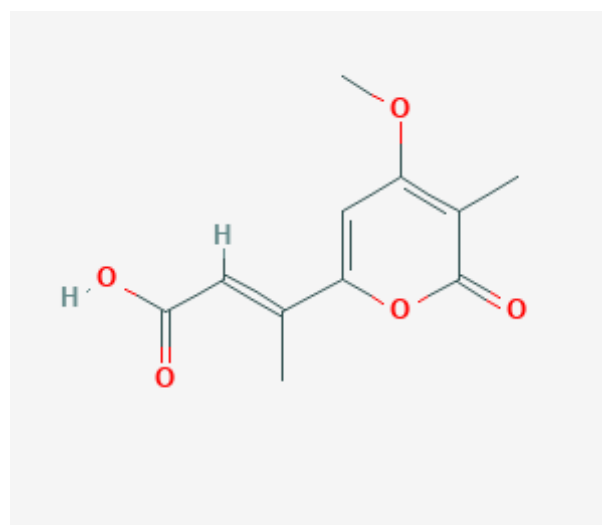
91. Lovastatin [71]



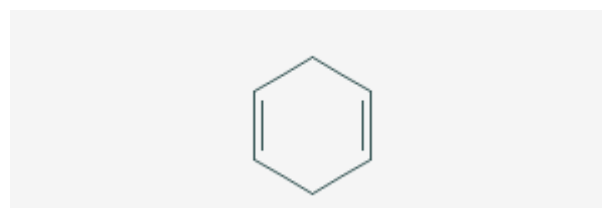
92. Protocatechuic acid [72]



93. Acropyrone [73]



94. 1,4-Cyclohexadiene [74]



References

1. Zhou L, Zhao J, Xu L, et al. (2009) Antimicrobial compounds produced by plant endophytic fungi. *Fungic Chem Environ Impact Heal Eff* 91–119
2. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 18915, Ethyl 9-oxononanoate. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Ethyl-9-oxononanoate>.
3. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 328789, 2(5H)-Furanone, 5-hydroxy-3,4-dimethyl-5-pentyl-. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/2_5H_-Furanone_-5-hydroxy-3_4-dimethyl-5-pentyl.
4. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 5326970, Ergosta-5,7-dien-3beta-ol. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/Ergosta-5_7-dien-3beta-ol.
5. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 68152, 3-Hydroxypropionic acid. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/3-Hydroxypropionic-acid>.
6. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 2758, Eucalyptol. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Eucalyptol>.
7. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 36314, Paclitaxel. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/taxol>.
8. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 139583786, Phomopsichalasin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Phomopsichalasin>.
9. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 16078330, Cryptocandin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Cryptocandin>.
10. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 71362212. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/71362212>.
11. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 11066670. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/11066670>.
12. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10935547. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/10935547>.
13. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 11012219, 7-Butyl-6,8-dihydroxy-3(R)-pentylisochroman-1-one. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/7-Butyl-6_8-dihydroxy-3_R_-pentylisochroman-1-one.
14. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101360525, Asperfumoid. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Asperfumoid>.
15. National Center for Biotechnology Information (2021). PubChem Substance Record for SID 174522689, ASPERFUMIN, Source: ChEMBL. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/substance/174522689>.

16. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 23872041, Monomethylsulochrin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Monomethylsulochrin>.
17. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 57339223, Fumigaclavine C. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Fumigaclavine-C>.
18. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 403923, Fumitremorgin C. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Fumitremorgin-C>.
19. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10639, Physcion. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Physcion>.
20. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 3002143, Helvolic acid. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Helvolic-acid>.
21. An X, Feng BM, Chen G, et al (2016) Isolation and identification of two new compounds from marine-derived fungus *Acremonium fusidioides* RZ01. *Chin J Nat Med* 14:934–938.
22. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 444679, Ergosterol. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Ergosterol>.
23. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 5287620, Brefeldin A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Brefeldin-A>.
24. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 54751220. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/54751220>.
25. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 159926, Macrosporin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Macrosporin>.
26. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 15071544, Citreoisocoumarin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Citreoisocoumarin>.
27. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 159926, Macrosporin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Macrosporin>.
28. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 24882465. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/24882465>.
29. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 24882470, Ampelanol. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Ampelanol>.
30. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 89644, Altersolanol A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Altersolanol-A>.
31. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 195315, Alterporriol E. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Alterporriol-E>.

32. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10913856, Altersolanol J. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Altersolanol-J>.
33. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 36314, Paclitaxel. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/taxol>.
34. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 5646, Usnic acid. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Usnic-acid>.
35. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 131379, Cercosporamide. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Cercosporamide>.
36. National Center for Biotechnology Information (2021). PubChem Substance Record for SID 274654506, Phomodione, Source: Japan Chemical Substance Dictionary (Nikkaji). Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/substance/274654506>.
37. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 6438581, Phomopsin A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Phomopsin-A>.
38. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 131752487, Phomopsin B. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Phomopsin-B>.
39. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 24866623, Phomopsin C. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Phomopsin-C>.
40. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10687292, Cytosporone B. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Cytosporone-B>.
41. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10778975, Cytosporone C. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Cytosporone-C>.
42. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 3663, Hypericin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Hypericin>.
43. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 345501, Deoxypodophyllotoxin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Anthricin>.
44. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 38358410, Xiamycin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Xiamycin>.
45. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 50898452, Xiamycin methyl ester. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Xiamycin-methyl-ester>.
46. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 56840153, Benquinol. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Benquinol>.

47. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 56924800, Benquoine. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Benquoine>.
48. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 23275141, Terpene-3197-12. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Terpene-3197-12..>
49. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 545574, 8-Octadecanone. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/8-Octadecanone>.
50. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 14260, 1-Tetradecene. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/1-Tetradecene>.
51. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 13162, 8-Pentadecanone. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/8-Pentadecanone>.
52. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 15712, Octylcyclohexane. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Octylcyclohexane>.
53. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 10441, 10-Nonadecanone. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/10-Nonadecanone>.
54. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 53363661. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/4-hydroxy-5_6-dimethoxy-2_3-dihydroisoindol-1-one.
55. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 53363662, Emerimidine B. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Emerimidine-B>.
56. Zhang G, Sun S, Zhu T, et al (2011) Antiviral isoindolone derivatives from an endophytic fungus *Emericella* sp. associated with *Aegiceras corniculatum*. *Phytochemistry* 72: 1436–1442.
57. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 45359507, Aspernidine A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Aspernidine-A>.
58. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 46867924, Aspernidine B. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Aspernidine-B>.
59. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 38353601, Austin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Austin>.
60. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 56955927, Austinol. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Austinol>.
61. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 122201239, Dehydroaustin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Dehydroaustin>.

62. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101660521, Acetoxydehydroaustin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Acetoxydehydroaustin>.
63. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101904185, Guignardin A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Guignardin-A>.
64. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101904186, Guignardin B. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Guignardin-B>.
65. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101904187, Guignardin C. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Guignardin-C>.
66. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101904188, Guignardin D. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Guignardin-D>.
67. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101904189, Guignardin E. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Guignardin-E>.
68. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 9905621, Deoxypreussomerin A. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Deoxypreussomerin-A>.
69. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 101672314, Palmarumycin C1. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Palmarumycin-C1>.
70. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 25150850. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/25150850>.
71. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 53232, Lovastatin. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Lovastatin>.
72. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 72, 3,4-Dihydroxybenzoic acid. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/3_4-Dihydroxybenzoic-acid.
73. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 102367304, Acropyrone. Retrieved April 4, 2021 from <https://pubchem.ncbi.nlm.nih.gov/compound/Acropyrone>.
74. National Center for Biotechnology Information (2021). PubChem Compound Summary for CID 12343, 1,4-Cyclohexadiene. Retrieved April 4, 2021 from https://pubchem.ncbi.nlm.nih.gov/compound/1_4-Cyclohexadiene.

