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著者	Wu Jing, Kawagishi Hirokazu
journal or publication title	The Journal of Antibiotics
year	2020-07-20
出版者	Springer Nature
URL	http://hdl.handle.net/10297/00027575

doi: 10.1038/s41429-020-0352-z

2 **Plant growth regulators from mushrooms**

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9 10 **Abstract**

11 Plants interact with fungi in their natural growing environments, and relationships between
12 plants and diverse fungal species impact plants in complex symbiotic, parasitic, and pathogenic
13 ways. Over the past 10 years, we have intensively investigated plant growth regulators produced
14 by mushrooms, and we succeeded in finding various regulators from mushroom-forming fungi:
15 (1) fairy chemicals as a candidate family of new plant hormones from *Lepista sordida*, (2)
16 agrocybynes A to E from fungus *Agrocybe praecox* that stimulate strawberry growth, (3)
17 armillariols A to C and sesquiterpene aryl esters from genus *Armillaria* that are allelopathic and
18 cause Arimillaria root disease, and (4) other plant growth regulators from other mushrooms, such
19 as *Stropharia rugosoannulata*, *Tricholoma flavovirens*, *Hericium erinaceus*, *Leccinum*
20 *extremiorientale*, *Russula vinosa*, *Pholiota lubrica* and *Cortinarius caperatus*.

21 22 **Introduction**

23 The fruiting body of basidiomycetes and ascomycetes is known as a “mushroom”. It produces
24 spores, and the spores germinate and create mycelium. The mycelium eventually produces a
25 primordium, which grows into a new whole mushroom, and the life cycle continues. Together with
26 their long history as a food source, mushrooms are also important for their healing capacities and
27 properties in traditional medicine. Additionally, the 14,000 species of mushrooms in the world
28 serve as important sources of bioactive compounds. In order to develop new functional compounds
29 from mushrooms, we have been screening various mushrooms for plant growth regulatory activity.

30 Interactions between plants and fungi are diverse and multileveled. Fungi can stimulate plant
31 growth in various ways, including by increasing tolerance to abiotic stress or by suppressing plant
32 diseases [1]. Plant growth regulators also serve as research tools for clarifying the mechanisms of
33 plant growth. Thus, we are interested in secondary metabolites from mushrooms that have activity
34 as plant growth regulators, and we have reported the isolation of various compounds that regulate
35 the growth of bentgrass, lettuce, and/or rice.

36

37 **Fairy chemicals from *Lepista sordida***

38 The natural phenomenon of “fairy rings”, or zones of stimulated grass growth, is due to the
39 interaction between a fungus and a plant [2–5]. In the first scientific article on fairy rings in 1675
40 and in subsequent studies reviewed in *Nature* in 1884, this phenomenon was attributed to an
41 unknown “fairy” [6]. In 2010, we discovered two plant growth regulating compounds related to
42 the formation of fairy rings, 2-azahypoxanthine (AHX, **1**) and imidazole-4-carboxamide (ICA, **2**)
43 from the culture broth of *Lepista sordida* [7, 8]. We additionally isolated a metabolite of AHX,
44 which is common in plants, 2-aza-8-oxohypoxanthine (AOH, **3**) [9] (Fig. 1). We name these three
45 compounds “fairy chemicals” (FCs) based on an article by the same title in *Nature* [10]. FCs
46 exhibited growth regulatory activity against all of the plants tested regardless of the families they
47 belong to, and conferred tolerance to various and continuous stresses (low or high temperature,
48 salt, drought stress, etc.) on the plants [7–9]. For example, when bentgrass (*Agrostis palustris*
49 Huds.) and rice (*Oryza sativa* L.) were cultivated with AHX or AOH solution, shoot and root
50 elongation of the seedlings was accelerated [7, 9]. AHX treatment of rice recovered its germination
51 rate under low-temperature stress (15°C) and shoot growth under salt stress (0.1 M NaCl).
52 Additionally, rice seedlings developed tolerance to high-temperature stress (35°C) after AHX
53 treatment. Furthermore, yields of rice, wheat (*Triticum aestivum* L.), and other crops were
54 increased by treatment with each of the FCs in greenhouse and/or field experiments. In greenhouse
55 experiments, when rice and potato (*Solanum tuberosum* L.) were cultivated with 5 or 50 µM AHX,
56 the yield per plant increased by 25% (rice), 19.3% (potato, total yield), or 40.6% (potato, esculent
57 size) [7]. When rice was cultivated with 2 µM ICA, grain yield per plant also increased by 25%
58 [8]. In field experiments, treatment with FCs drastically increased grain yields up to 20.4% and
59 9.6% (AHX), 10.6% and 10.2% (AOH), and 9.8% and 6.3% (ICA) for wheat and rice, respectively
60 [11, 12]. These results suggest the possible application of FCs in agriculture. We have also reported

61 the presence of endogenous FCs in plants and mushrooms, as well as the discovery of a new route
62 in the purine metabolic pathway through which FCs are biosynthesized [9, 13]. In addition, we
63 discovered three *N*-glucosides of AOH (4–6), an *N*-glucoside of AHX (7), and two ribosides (8,
64 9) and a ribotide (10) of ICA, as FC metabolites in rice [14, 15]. Compounds 4–7 exhibited no
65 significant activity against rice, indicating that rice regulates the activity of AHX (1) and AOH (3)
66 by converting them into their constituent glucosides. On the other hand, compounds 8 and 9
67 showed inhibition activity against the shoots of rice only at high concentration (0.1 mM) and
68 showed no significant effect on roots. Cytokinins are interconvertible to their constituent ribosides
69 and ribotides, and those glycosides are the inactive forms of the corresponding free base forms
70 [16–18]. The free base forms are usually more active than the corresponding ribosides and
71 ribotides in various bioassays, which may be related to their rapid uptake and high intrinsic activity
72 [19–21]. The inhibitory activity of 8 and 9 might be due to ICA (2), which was converted from 8
73 and 9 in rice. Many enzymes involved in cytokinin biosynthesis, interconversion, inactivation, and
74 degradation have been identified and play very important roles in the regulation of endogenous
75 cytokinin homeostasis. These findings suggest that the interconversion among ICA (2), 8 and 9
76 regulates homeostasis of ICA (2) in rice. All of these findings allow us to conclude that FCs are a
77 new family of plant hormones [22–25], and our group is currently conducting research to put FCs
78 into practical use in agriculture. We also isolated three diketopiperazines (11 to 13) from the
79 culture broth of *L. sordida* (Fig. 1) and showed that these compounds inhibited the root growth of
80 bentgrass at 0.1 and 1 $\mu\text{mol}/\text{paper}$ [26]. In our previous report, we showed that ICA (2) strongly
81 inhibited the growth of bentgrass shoot and root [8], which corroborates the finding that grass is
82 occasionally killed or damaged in fairy rings [2]. In addition to ICA (2), these diketopiperazines
83 (11 to 13) might contribute to growth inhibition by the fungus in the rings.

84

85 **Plant growth regulators from the fungus *Agrocybe praecox* that stimulate strawberry growth**

86 In 2007, abnormal enlargement of strawberries was observed along with a kind of mushroom
87 growing near the stimulated fruit in a greenhouse in Niigata Prefecture, Japan. The mushroom was
88 identified as *Agrocybe praecox* (English name, Spring Fieldcap; Japanese name, Fumizukitake),
89 which is edible and widespread in the northern temperate zone throughout the world. An earlier
90 report provided evidence of *Agrocybe* species causing stunt syndrome of strawberries [27]. These
91 widely varying phenomena related to growth stimulation and suppression suggest that *Agrocybe*

92 genus produces plant growth regulator(s). *A. praecox* is a litter degrading fungus that is able to
93 grow in forest soil and produces non-specific extracellular enzymes, which depolymerize soil
94 detritus, including cellulose, hemicellulose, and sulfur-containing compounds, to monomers and
95 oligomers, which then become available to microbes and plants [28]. The fungus has been in focus
96 for various application according to the hydrolytic and ligninolytic enzymatic activities for
97 bioremediation, however it has not yet been reported as environmental adaptation by coexisting
98 with plant [29–36]. Thus, we focused on plant growth regulators from the fungus *A. praecox*.

99 In our study to isolate the active compounds, the culture broth of *A. praecox* was partitioned
100 between EtOAc and water, followed by *n*-BuOH and water. The EtOAc-soluble part was
101 fractionated by repeated chromatography. We discovered five novel compounds (**14 to 16, 18, 19**)
102 and two known ones (**17, 20**) based on observation of the growth-regulating activity on lettuce
103 [37] (Fig. 2). Compounds **14 to 18** were named agrocybynes A to E and have triple bonds.
104 Compound **19** was a new compound and determined to be 2-formyl-3,5-dihydroxybenzyl acetate.
105 The effects of the compounds on plant growth were tested for three kinds of plants belonging to
106 different families: lettuce (*Asteraceae*), rice (*Poaceae*), and strawberry (*Rosaceae*). As a result,
107 agrocybynes A–D (**14 to 17**) inhibited hypocotyl growth, and agrocybynes A, C, and D (**14, 16,**
108 **and 17**) inhibited root growth of lettuce at 1 μ mol. Agrocybynes A and C (**14 and 16**) inhibited
109 root growth of rice at 0.1 and 1 μ M, respectively. Agrocybynes A to E (**14 to 17**) produced
110 strawberries that were dwarfed and had altered color at 1 nmol/soil-mL.

111

112 **Plant/mycelial growth regulators from the genus *Armillaria* that cause Arimillaria root** 113 **disease**

114 Genus *Armillaria* (English name, Honey fungus; Japanese name, Naratake) belonging to
115 family Physalacriaseae is a well-known group of edible mushrooms found throughout the world.
116 The mushrooms belonging to *Armillaria* spp. display a wide array of biological activities,
117 including anticancer [38, 39], anti-inflammatory [40–42], and antioxidant properties [43], and they
118 have been used in traditional Chinese medicine to treat hypertension, insomnia, and dizziness [44,
119 45]. Additionally, members of this genus have been known to be serious plant pathogens that cause
120 root rot in various plant species, which is called Arimillaria root disease [46–48]. Root rot is one
121 of the most serious diseases of plants and occurs in many broadleaf trees and conifers and several
122 herbaceous plants [49]. Furthermore, it is known that penetration of *Armillaria* mycelia to the fungi

123 *Entoloma abortivum* and *Wynnea americana* induces spherical deformity of the fruiting bodies of
124 those mushrooms [50]. These observations indicate that *Armillaria* produces allelopathic
125 substance(s). Protoilludane sesquiterpene aryl esters have been isolated from *Armillaria*
126 mushrooms and *Clitocybe illudens* [51–58]. However, there is no evidence that the compounds are
127 the principle toxic factors for *Armillaria* root disease, and the inducers of deformity in other fungi.
128 Therefore, we sought to isolate compounds with plant and mycelial growth regulatory activity
129 from the culture broth of strains of the genus.

130 Isolation of the active compounds was guided by plant growth regulatory activity on lettuce.
131 The active fractions, the hexane and EtOAc soluble parts were subjected to repeated
132 chromatography respectively to afford armillariols A to C (**21** to **23**), and nine sesquiterpene aryl
133 esters (**24** to **32**) from the culture broth of *Armillaria* sp. (Fig.3) [59, 60]. (+)- and (–)-Armillariol
134 C (**23**) and their analogues were synthesized on a gram scale using Suzuki-Miyaura cross-coupling
135 and Sharpless asymmetric dihydroxylation by Watkins’s group [61]. Compounds **24** and **25** were
136 new compounds, which were named 10-dehydroxymelleolide (**24**) and 13-hydroxymelleolide K
137 (**25**). Compounds **26** to **32** were identified as 5’-*O*-methylmelledonal (**26**), melleolide D (**27**), 13-
138 hydroxydihydromelleolide (**28**), melleolide (**29**), armillarinin (**30**), armillaridin (**31**), and
139 armillarikin (**32**). These known compounds had been isolated from the same genus *Armillaria* as
140 antimicrobial compounds [52–55, 62–64]. The plant growth regulatory activity of the isolated
141 compounds was measured using lettuce, and all compounds (**21** to **32**) showed statistically
142 significant inhibition of growth of lettuce at 1 μmol/paper, indicating that the protoilludane
143 skeleton itself was important for growth inhibition activity against lettuce. In addition, compounds
144 **24** to **32** were subjected to the mycelial growth assay against *Coprinopsis cinerea* (English name,
145 Gray shag; Japanese name, Ushigusotake) and *Flammulina velutipes* (English name, Enoki;
146 Japanese name, Enokitake). Melleolide (**29**) inhibited the mycelial growth of *C. cinerea* and *F.*
147 *velutipes*, and armillarikin (**32**) inhibited the mycelial growth of *C. cinerea*, each producing a
148 radially shaped clear zone. The activity of melleolide (**29**) was stronger than positive control
149 amphotericin B. The formyl group at C-1 and the absence of a hydroxy at C-13 in the molecule
150 were important for the antifungal activities.

151

152 **Plant growth regulators in other mushrooms**

153 The edible and cultivated mushroom *Stropharia rugosoannulata* (Saketsubatake in Japanese,
154 and wine-cap stropharia in English) belongs to family Strophariaceae and is widespread in northern
155 temperate zones throughout the world. We reported the isolation of three steroids (**33** to **35**) from
156 the fruiting bodies of *S. rugosoannulata* (Fig. 4). Examination of the effects of compounds **33** to
157 **35** on lettuce growth showed that compounds **34** and **35** showed statistically significant inhibition
158 of hypocotyl growth of lettuce at 1, 10, 100, 1000 nmol/paper and promoted root growth at 1, 10,
159 100 nmol/paper with statistically significant differences. Compound **33** exhibited no activity.
160 Comparison of the structures of compounds **33** to **35** indicated that the double bond between C-8
161 and C-9 or C-8 and C-14 in the sterol skeleton is the key structural component for regulating lettuce
162 growth [65].

163 Since ancient times, *Tricholoma flavovirens* (English name, Yellow knight; Japanese name,
164 Kishimeji) belonging to the family Tricholomataceae has been known throughout the world as an
165 edible mushroom. Two novel indole derivatives (**36**, **38**) and three known compounds (**37**, **39**, **40**)
166 were isolated from the fruiting bodies (Fig. 4). Compound **36** showed the promotion effect on the
167 growth of root of lettuce at 10 nmol/paper with significant differences, and compound **37** showed
168 a similar tendency to promote growth. Compounds **38** and **39** promoted root growth of lettuce and
169 inhibited hypocotyl growth at 1 μ mol/paper. Compound **40** inhibited hypocotyl and root growth
170 in a dose-dependent manner. In a comparison of **38** and **39**, **39** showed stronger promotion activity
171 than **38**, suggesting that the methoxy group at C-7 weakened the activity [66, 67].

172 *Hericium erinaceus* is an edible and medicinal mushroom belonging to family Hericiaceae. It
173 is called Yamabushitake in Japanese, Houtougu (monkey head) in Chinese, and Lion's mane in
174 English after its shape. In the past 30 years, we have isolated phenols (hericenones A and B), a
175 series of benzyl alcohol derivatives (hericenones C to H, 3-hydroxyhericenone F), and other
176 hericenone analogues (hericenones I and J) from fruiting bodies [68–72]. Chlorinated orcinol
177 derivatives and a series of diterpenoid derivatives (erinacines A to K) have been isolated from
178 mycelia of the fungus [73–79]. Hericenones C to H and erinacines A to I significantly induced the
179 synthesis of nerve growth factor (NGF) *in vitro* and/or *in vivo*. Erinacine K showed anti-MRSA
180 activity. 3-Hydroxyhericenone F showed protective activity against endoplasmic reticulum (ER)
181 stress-dependent cell death [80, 81]. Several ER stress-suppressive compounds were also isolated
182 from scrap cultivation beds of this mushroom [82]. Erinapyrones A and B have been isolated from
183 the culture broth of the fungus [83], and they were shown to have cytotoxicity toward HeLa cells.

184 In our continuing search for bioactive compounds from culture broth, we identified nineteen
185 compounds (**41–59**) that are plant growth regulators (Fig. 4). Novel compounds **41–45** were named
186 erinaceolactone A (**41**), B (**42**), erinachromane A (**43**), B (**44**), and erinaphenol A (**45**). While
187 compounds **48**, **49**, and **58** had been synthesized, this is the first report of them as natural products
188 [84, 85]. In the bioassay examining plant growth regulatory activity, all of the compounds
189 suppressed the growth of lettuce.

190 The edible mushroom *Leccinum extremiorientale* (Japanese name, Akayamadori) belongs to
191 genus *Leccinum* in family Boletaceae, and it can be found from summer to autumn. The mushroom
192 has a red brown areolate cap and has a distribution mainly in the northern temperate zone. In our
193 previous research on bioactive compounds from the mushroom, two sterols showed the ability to
194 suppress formation of osteoclasts, and leccinine A showed protective activity against ER stress-
195 dependent cell death [86, 87]. In order to find plant growth regulatory compounds from the
196 mushroom, we obtained two compounds (**60**, **61**) (Fig. 4). Compound **60** dose-dependently
197 promoted root growth at levels as low as 100 nmol/paper and inhibited hypocotyl growth at 1
198 $\mu\text{mol/paper}$. Compound **61** inhibited root and hypocotyl growth of lettuce [88].

199 *Russula vinosa* is an edible wild mushroom with high medicinal value. Extracts of *R. vinosa*
200 have an inhibitive effect on bacteria, yeasts and molds. Our group reported that five compounds
201 (**62 to 66**) that were isolated from the fruiting bodies regulated the growth of plants (Fig. 4).
202 Compound **65** weakly inhibited the root and hypocotyl growth of lettuce at 1 $\mu\text{mol/paper}$, while
203 compound **64** showed an inhibition at as low as 100 nmol/paper. As for the root growth of lettuce,
204 compound **63** showed promotion at 10 and 100 nmol/paper but showed inhibition at 1 nmol/paper
205 and 1 $\mu\text{mol/paper}$. As for hypocotyl growth of lettuce, compound **62** showed inhibition at 10 and
206 100 nmol/paper and promotion at 1 nmol/paper, and compound **63** showed promotion at 100
207 nmol/paper, while compound **66** showed promotion at lower doses (1 and 10 nmol/paper) [89].

208 *Pholiota lubrica* (Japanese name, Chanametsumutake) belongs to genus *Pholiota* of family
209 Strophatiaceae and has a widespread distribution, especially in temperate regions, and it frequently
210 grows on wood or at the base of trees. This mushroom exhibited an allelopathic activity against
211 lettuce. Recently, a new cinnamamide (**67**) and four compounds (**68 to 71**) were isolated from the
212 fruiting bodies (Fig. 4). Compound **71** was first isolated from natural sources. All the compounds
213 were subjected to plant regulatory assays against lettuce. Toward the hypocotyl, compounds **67**,
214 **70**, and **71** showed significant inhibition of growth at 0.1 and 1 $\mu\text{mol/paper}$, while the other

215 compounds had no activity. For the root, we observed growth inhibitory activity of **67** at 1
216 $\mu\text{mol}/\text{paper}$ and **70** at 0.1 and 1 $\mu\text{mol}/\text{paper}$. Compounds **68** and **69** exhibited promotion activity
217 at 0.1 and 1 $\mu\text{mol}/\text{paper}$, respectively, and (22*E*,24*S*)-5 α ,8 α -epodioxy-24-methyl-cholesta-
218 6,9,(11)22-trien-3 β -ol] that was also isolated from this mushroom showed no activity. This finding
219 indicates that the carbonyl group at C-7 of **68** and **69** plays an important role in plant growth
220 promotion activity. Cinnamamide and its derivative, betaine cinnamamide, have been reported to
221 promote and stimulate the length of the root and shoot of wheat [90]. In order to investigate the
222 structure activity relationship of **67**, commercially available compounds, cinnamamide and
223 cinnamic acid, were used in the lettuce growth regulatory assay. These results showed that
224 compound **67** and cinnamic acid inhibited growth of the hypocotyl at 0.01, 0.1, and 1 $\mu\text{mol}/\text{paper}$.
225 Meanwhile, cinnamamide inhibited growth at all concentrations. As for the root, compound **67**
226 inhibited growth at 1 $\mu\text{mol}/\text{paper}$, while cinnamamide and cinnamic acid showed inhibition
227 activity at 0.1 and 1 $\mu\text{mol}/\text{paper}$. These results suggest that the cinnamoyl moiety in tested
228 compounds was essential for plant growth inhibition activity [91].

229 *Cortinarius caperatus* (English name, Gypsy mushroom; Japanese name, Shogenji) is an
230 edible mushroom and grows widely in the temperate zone of the northern hemisphere. This species
231 has been reported to produce an antiviral compound, RC-183, toward herpes simplex virus. We
232 isolated four compounds (**72** to **75**) from the fruiting bodies (Fig. 4). For growth regulatory
233 activities toward rice seedlings, compounds **72** and **75** promoted growth of the root at 1 mM.
234 Compound **73** promoted root growth at 100 μM , but inhibited root and shoot growth at 1 mM.
235 Compound **75** showed the strongest promoting activity against the root among compounds tested.
236 For the shoot, compound **74** inhibited growth of the shoot at 1 mM. In the lettuce growth
237 experiment, compounds **74** and **75** inhibited growth of the root at 1 $\mu\text{mol}/\text{paper}$. For the hypocotyl,
238 compounds **73** and **74** showed inhibition at 1 and 1000 nmol/paper, respectively. Compounds **74**
239 and **75** promoted the plant at 10 and 100 nmol/paper, respectively [92].

240

241 **Conclusion**

242 Mushrooms remain a largely unexplored biological resource. Plant growth regulators from
243 mushrooms play important roles in the development of fungus-plant interactions, and/or the life
244 cycle of mushrooms themselves. Our study findings provide useful information not only for

245 understanding those roles but also regarding utilization of these compounds in agriculture and
246 other fields.

247

248 **Acknowledgements**

249 This research was supported in part by a Grant-in-Aid for Scientific Research on Innovative
250 Areas “Frontier Research on Chemical Communications” from MEXT (No. 17H06402).

251

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468

469 **Titles and legends to figures**

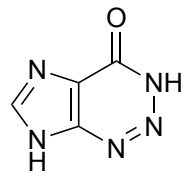
470 **Fig. 1** Fairy chemicals (**1** to **10**) and diketopiperazines (**11** to **13**) isolated from *Lepista sordida*.

471 **Fig. 2** Agrocybynes A to E (**14** to **18**) and two compounds (**19**, **20**) isolated from *Agrocybe praecox*.

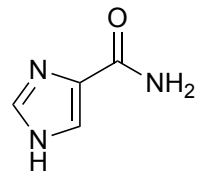
472 **Fig. 3** Plant growth regulators isolated from *Armillaria* sp.

473 **Fig. 4** Plant growth regulators from various mushrooms.

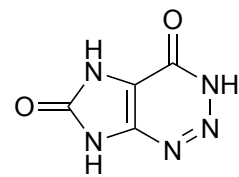
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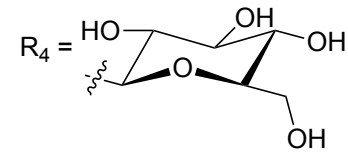
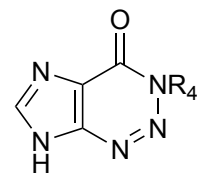
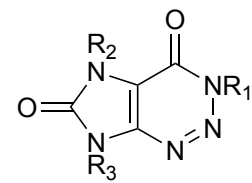
AHX (1)



ICA (2)



AOH (3)

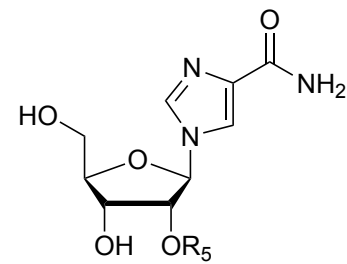


4: $R_1 = R_4, R_2 = H, R_3 = H$

7

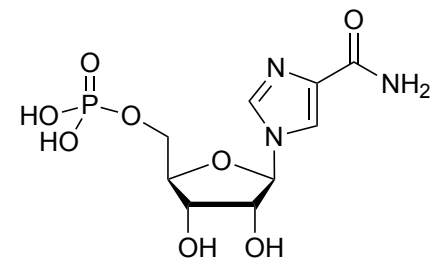
5: $R_1 = H, R_2 = H, R_3 = R_4$

6: $R_1 = H, R_2 = R_4, R_3 = H$

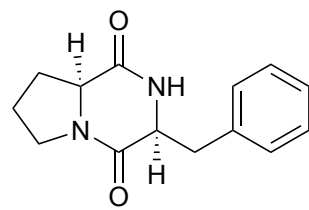


8: $R_5 = H$

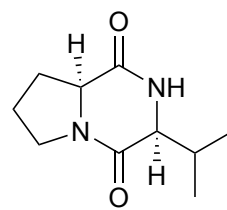
9: $R_5 = R_4$



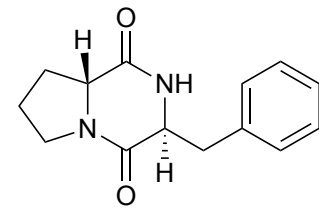
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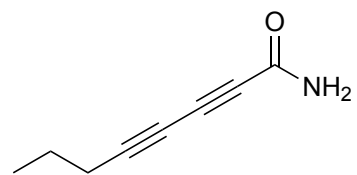
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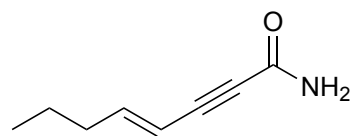
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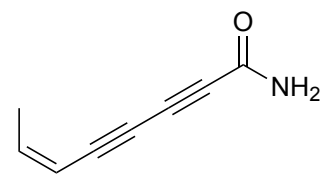
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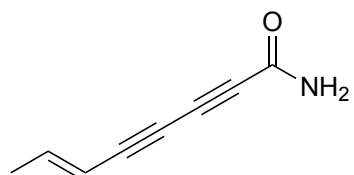
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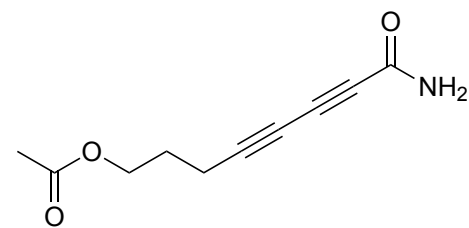
agrocybyne B (15)



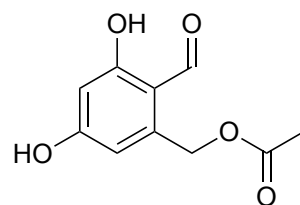
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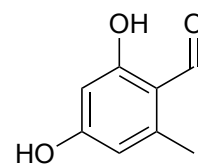
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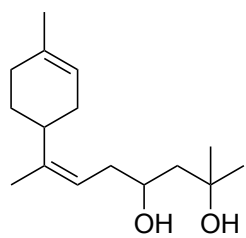
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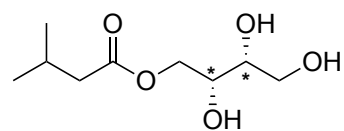
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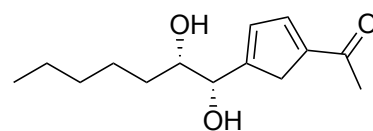
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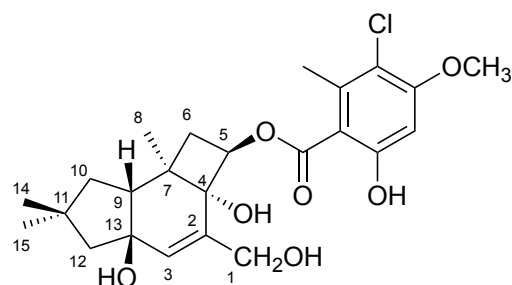
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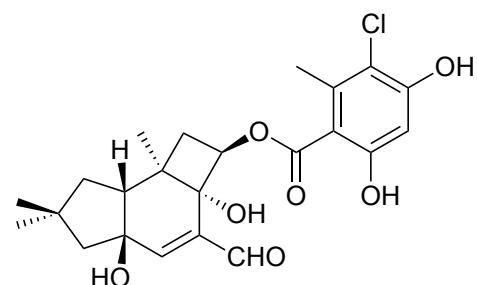
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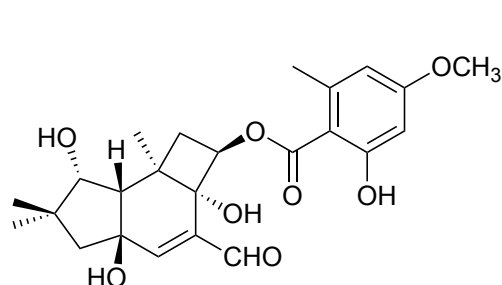
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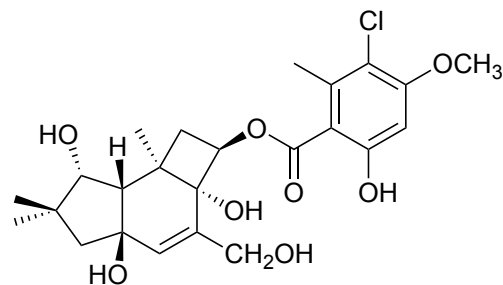
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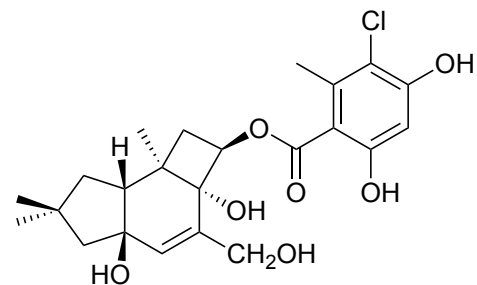
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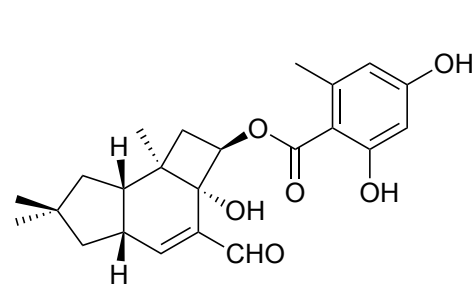
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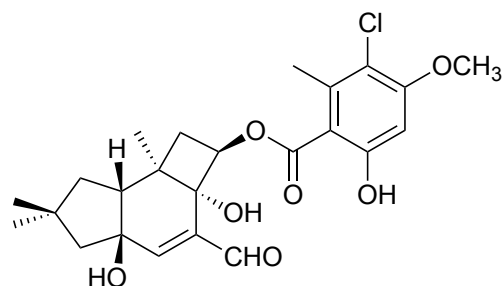
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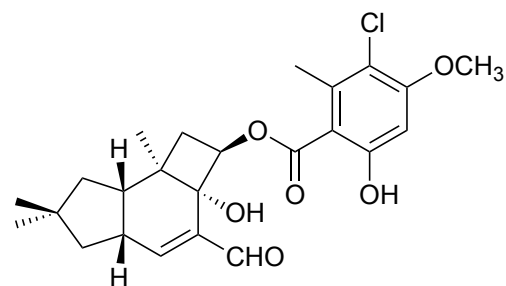
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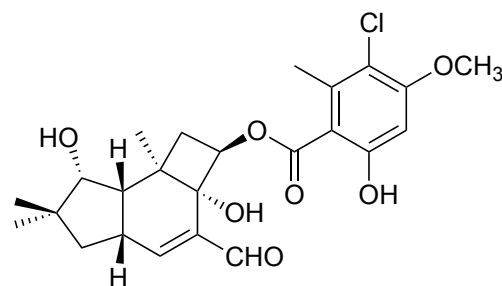
melleolide (29)



armillarinin (30)

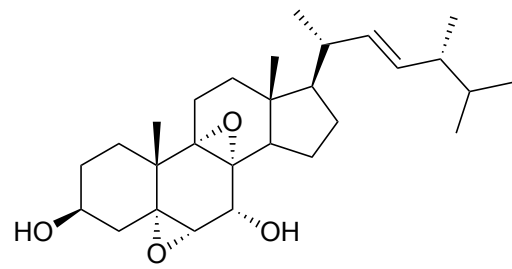


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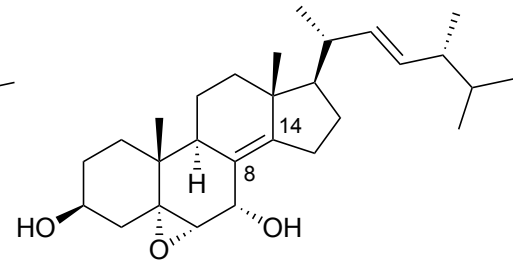


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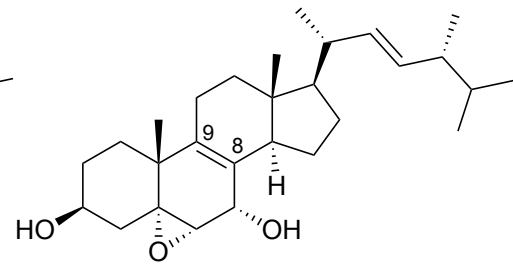
Stropharia rugosoannulata (33–35)



33

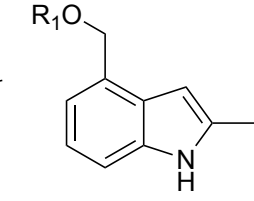


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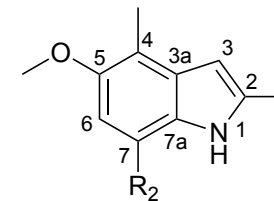
35

Tricholoma flavovirens (36–40)



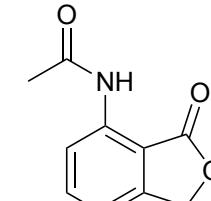
36: R₁ = ethyl

37: R₁ = methyl



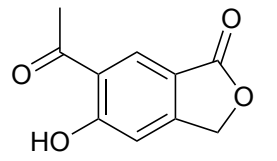
38: R₂ = OCH₃

39: R₂ = H

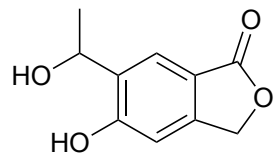


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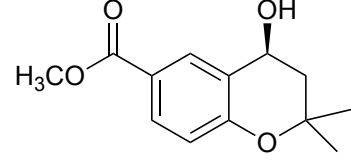
Hericium erinaceus (41–59)



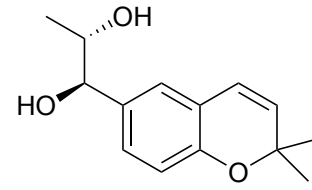
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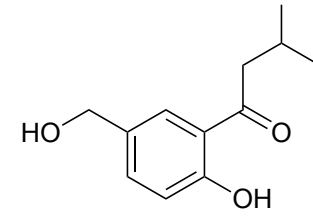
erinacelactone B (42)



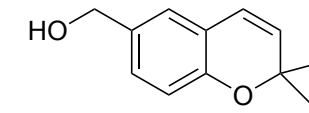
erinachromane A (43)



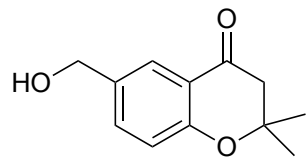
erinachromane B (44)



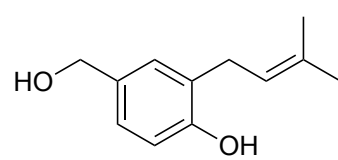
erinaphenol A (45)



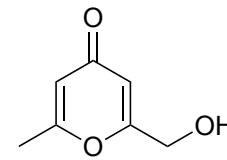
46



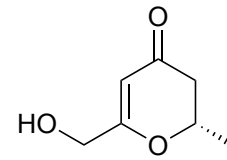
47



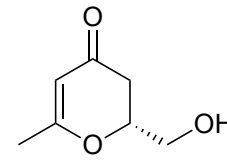
48



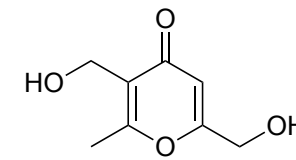
49



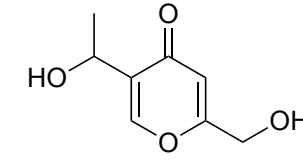
50



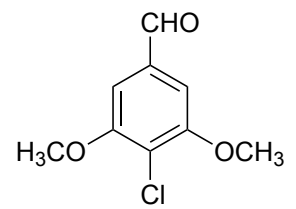
51



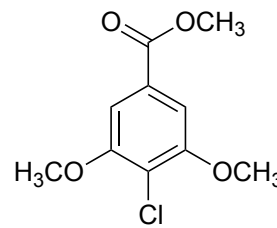
52



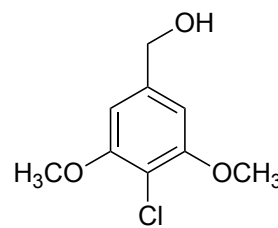
53



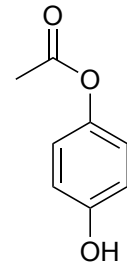
54



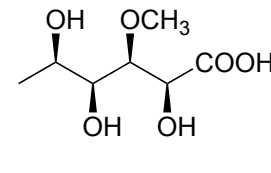
55



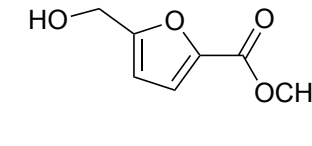
56



57

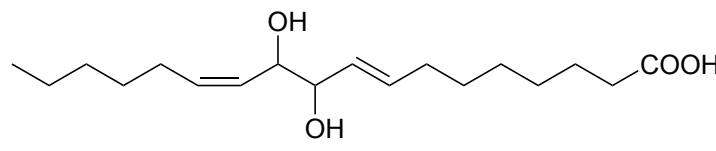


58

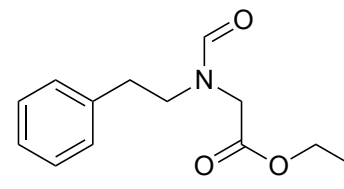


59

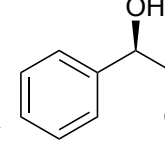
Leccinum extremorientale (60, 61)



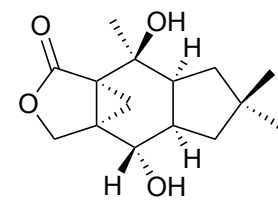
60



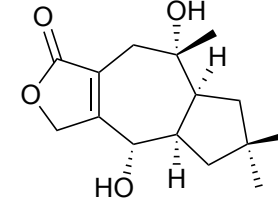
61



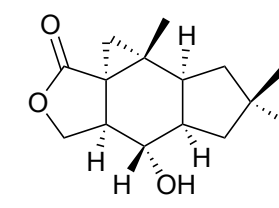
62



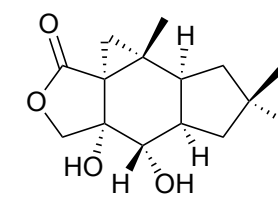
63



64



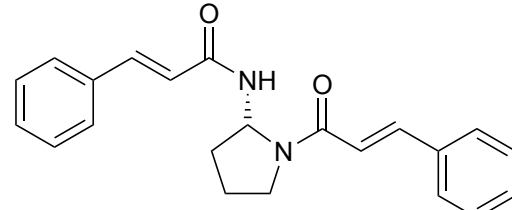
65



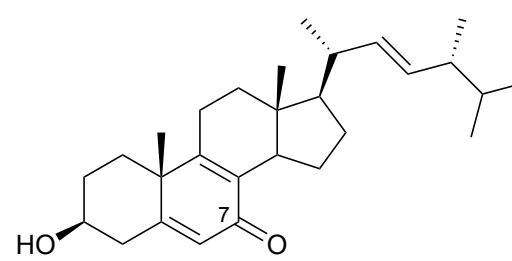
66

Russula vinosa (62–66)

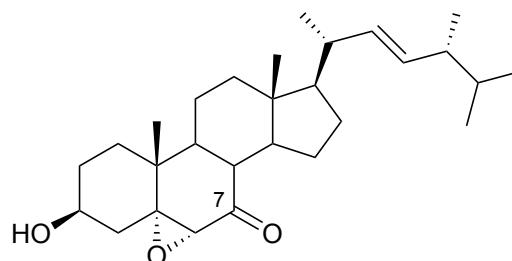
Pholiota lubrica (67–71)



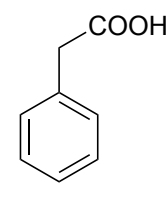
67



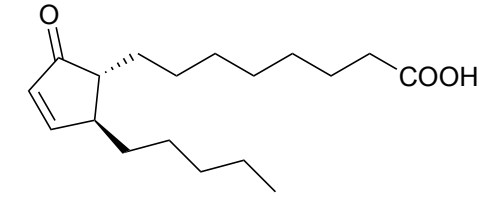
68



69

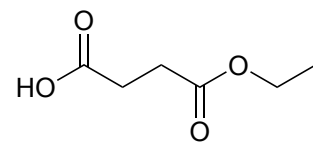


70

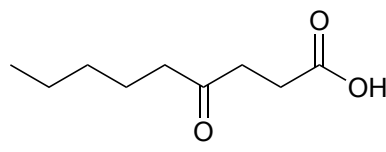


71

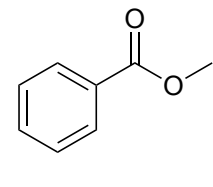
Cortinarius caperatus (72–75)



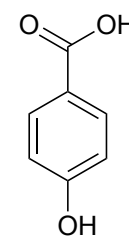
72



73



74



75