The Novel Compounds with Biological Activity Derived from Soil Fungi in the Past Decade

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Abstract: The secondary metabolites isolated from soil fungi have received more and more attention, especially new compounds that exhibited good biological activities. In this review, a total of 546 new compounds are included in the relevant literature since 2011. The new compounds are isolated from soil fungi. We divided these compounds into seven categories, including alkaloids, terpenoids, steroids, ketones, phenylpropanoids, quinones, esters, lactones, etc. In addition, the biological activities and structure–activity relationships of these compounds have also been fully discussed. The activities of these compounds are roughly divided into eight categories, including anticancer activity, antimicrobial activity, anti-inflammatory activity, antioxidant activity, antiviral activity, antimalarial activity, immunosuppressive activity and other activities. Since natural products are an important source of new drugs, this review may have a positive guiding effect on drug screening.

Keywords: soil fungi, new compounds, chemical structure, biological activity

Introduction

During the period of 1981 to 2019, almost 60% of the clinically approved drugs were derived directly or indirectly from natural products.¹ Nature can breed many species, including prokaryotes and eukaryotes. Among them, fungi play an important role in the ecosystems of plants, animals and humans.² Soil is an excellent natural habitat for microorganisms and has a large number of microorganisms.³ Soil represents a very heterogeneous environment for its microbiota. Among the soil inhabitants, bacteria and fungi are important organisms as they are involved in key biogeochemical cycling processes.⁴ Terrestrial microorganisms have long been regarded as profile producers of specialised metabolites with unique structures or new modes of action, and particularly in recent years, the discovery of new active natural products from soil-derived microorganisms has increased rapidly, contributing significantly to drug development.⁵ Since Alexander Fleming discovered penicillin in 1928, fungi have become a considerable resource for novel compounds and new drugs.⁶ The secondary metabolites of fungi are a rich source of small molecule compound libraries, and some metabolites have significant biological activities,⁷ such as the antibacterial agent penicillins, immunosuppressive drug cyclosporin A, antifungal drug echinocandin B, and cholesterol-lowering agent lovastatin.⁸ Fungi are an ideal source for obtaining novel skeletons through large-scale culture: compared with plants, fungi can proliferate rapidly from small amounts of spores to a mass of branching hyphae, which are more environmentally friendly than collecting plant materials; compared with bacteria, fungi can be cultured in a solid medium for a longer time.⁹ Therefore, soil-derived fungi are receiving continuous attention as the source of biologically active secondary metabolites. Since 2011, a large number of new compounds have been obtained from soil-derived fungi, but few people have summarized and analyzed these compounds. This review summarizes the compounds derived from soil fungi from 2011 to 2022, and classifies their structures and activities. Importantly, we made statistical analysis of these new compounds, readers can clearly understand which genus of soil fungi has great potential to produce new compounds. In addition, through the analysis of activity data, readers can clearly understand which kind of structural compounds account for the majority of compounds with certain activities, which kind of structural compounds account for the majority of compounds with certain activity. By summarizing the structure and activity of the new compound, a total of 546 compounds were isolated...
from the metabolites of soil fungi during the decade of 2011–2022, mainly including alkaloids, terpenes, steroids, ketones, phenylpropanoids, quinones, esters and lactones, of which ketones (31.9%), terpenoids and steroids (22.2%) are the main structural types. Among the 546 compounds, 279 compounds (approximately 51%) have good biological activities, including anticancer, antimicrobial, anti-inflammatory, antioxidant, antiviral, antimalaria, and immunosuppressive activities. Among them, anticancer and antimicrobial activities accounted for the highest proportion (Figure 1).

In the author’s personal view, this review can provide a positive guidance for the screening of new drugs. This is also the significance of writing this review. In addition, we also analyzed the habitat sources of these soil fungi, which provides some directions for researchers who want to obtain new compounds from soil fungi from special habitats.

**Structure Types of New Compounds Derived from Soil Fungi**

### Alkaloids

**Indole alkaloids**

A quinazolinone-containing indole derivative, named pseudofischerine 1 (Figure 2A), was isolated from the fungus *Neosartorya pseudofischeri* S.W. Peterson.\(^{10}\) Two new compounds, named peneciraistins E 2 and F 3 (Figure 2A), were isolated from saline soil-derived fungus *Penicillium raistrickii*. Compounds 2 and 3 are the first naturally occurring 3-indoleformic acid derivatives.\(^{11}\) A new indole alkaloid named exopisiod 4 (Figure 2A) was obtained from the fermentation products of *Exophiala pisciphila* PHF-9.\(^{12}\) Waikialoid A 5 (Figure 2A) was isolated from *Aspergillus* sp.\(^{13}\) Effusin A 6 and dihydrocryptoechinulin D 7 (Figure 2A), two new spiropolyketide-diketopiperazines were isolated from the fungus *Aspergillus effuses* H1-1. Effusin A 6 possessed an unprecedented 3′,3a′,5′,6′-tetrahydrospiro[piperazine-2,2′-pyran][2,3,4-de]chromene] skeleton.\(^{14}\) One new prenylated indole diketopiperazine alkaloid, named dihydroneochinulin B 8 (Figure 2A), was isolated from the mangrove rhizosphere soil-derived fungus, *Aspergillus effuses* effuses H1-1.\(^{15}\) A new azsonalenin analogue 9c (Figure 2A) was isolated from the culture of the soil fungus *Neosartorya fischeri* (KUFC 6344).\(^{16}\) Six new indole-diterpenoids 10–15 (Figure 2A and B) were isolated from the fermentation broth of an aciduric fungal strain *Penicillium camemberti* OUCMDZ-1492 grown at pH 5.0.\(^{17}\) Asperdiazapinones A-F 16–21 (Figure 2B) were isolated from the mycelial extract of the soil fungus *Aspergillus* sp. PSU-RSPG185.\(^{18}\) Mangrovamides A-C 22–24 (Figure 2B), featured a bicyclo[2.2.2] diazoctane core and possessed a novel γ-methyl proline and isoprene derived dimethyl γ-pyrone functionalities hitherto unknown among the family of paraherquamides, were isolated from the fungus *Penicillium* sp. SYFz-1.\(^{19}\) Rubrumazines A-C 25–27 (Figure 2B) were isolated and identified from a culture extract of *Eurotium rubrum* MA-150, a fungus obtained from mangrove-derived rhizospheric soil collected from the Andaman Sea.

![Figure 1](https://doi.org/10.2147/DDDT.S377921)

**Figure 1** The percentage of various compounds.
coastline, Thailand.\textsuperscript{20} Three new indolyl diketopiperazine derivatives, penillines A \textsuperscript{28} and B \textsuperscript{30} (Figure 2B), isopenilline A \textsuperscript{29} (Figure 2B), were isolated from the Antarctic soil-derived fungus \textit{Penicillium} sp. SCSIO 05705.\textsuperscript{21} Cultivation and fractionation of secondary metabolites from \textit{Aspergillus kumbius} revealed a unique chemotype comprising three new bis-indolyl benzenoids, kumbics A-C \textsuperscript{31–33} (Figure 2B and C).\textsuperscript{22} Two new bisindolylbenzenoid alkaloids asterriquins E \textsuperscript{34} and F \textsuperscript{35} (Figure 2C) were isolated from the fermentation products of the fungus \textit{Aspergillus} sp. CBS-P-2.\textsuperscript{23} Cyclopiamines C \textsuperscript{36} and D \textsuperscript{37} (Figure 2C) were obtained from \textit{Penicillium} sp. CML 3020, a fungus sourced from an
Atlantic Forest soil sample. Tolypoclads A-J 38–47 (Figure 2C and D) have been isolated from a culture of a mine-soil-derived fungus, *Tolypocladium* sp. XL115. Two novel cytochalasan alkaloids, chaetomadrasins A 48 and B 49 (Figure 2D), were isolated from the solid-state fermented culture of desert soil-derived *Chaetomium madrasense* 375. Paraherquamide J 50 (Figure 2D) was isolated from the fermentation product of the fungus *Penicillium janthinellum* HK1-6. Two new compounds tryptoquivalines W 51 and X 52 (Figure 2D) were isolated from a Hawaiian soil fungal strain *Aspergillus terreus* FS107. Three new cytochalasins Z24, Z25, Z26 (53–55, resp.) (Figure 2D) were isolated from the fungus *Eutypella* sp. D-1 which was isolated from the soil of high latitude of the Arctic. Purification of an extract from the broth of the soil fungus *Aspergillus* sp. PSU-RSPG185 resulted in the isolation of one new cytochalasin,
aspergilluchalasin 56 (Figure 2D). Two new alkaloids, iizukines C 57 and D 58 (Figure 2D), were isolated from the culture of Aspergillus iizukae. Chemical screening of culture medium from the soil fungus Stachybotrys sp. resulted in the isolation of the three new phenylspirodrimanes MBJ-0030 59 (Figure 2D), MBJ-0031 60 and MBJ-0032 61 (Figure 2D). Pycnidioforones A-D 62–65 (Figure 2E) were isolated from cultures of the wetland-soil-derived fungus Pycnidiofora dispersa. Clonorosins A 66 and B 67 (Figure 2E), two novel indole alkaloids featuring unprecedented 6/5/6/6/5 and 6/5/5 cores, were isolated from the soil-derived fungus Clonostachys rosea YRS-06.
Other Alkaloids

Gymnastatins T-Y 68–73 (Figure 2E) and dankastatin D 74 (Figure 2E), were isolated from the soil fungus *Gymnascella dankaliensis* through fermentation on solid rice medium following addition of NaBr.35 Two new threonine-containing metabolites, N-[4-hydroxy-3-prenyl-benzoyl]-L-threonine 75 (Figure 2E) and N-[2,2-dimethyl-2H-chromene-6-carbonyl]-L-threonine 76 (Figure 2E), were isolated from the fermentation broth of the soil fungus *Curvularia inaequalis* strain HS-FG-257.36 A new isoquinolinone alkaloid, (5S)-3,4,5,7-tetramethyl-5,8-dihydroxy-6(5H)-isoquinolinone 77 (Figure 2E) was isolated from *Penicillium* sp. H9318.37 Compound 78 (Figure 2E), named 3,8-Diacetyl-4-(3-methoxy-4,5-methylenedioxy)benzyl-7-phenyl-6-oxa-3,8-diazabicyclo[3.2.1]octane, was isolated from the fungus *Neosartorya*...
**pseudofischeri** S.W. Peterson. In search for antibiotics from soil and endophytic fungi, the secondary metabolites of *Fusarium avenaceum* SF-1502. An alkaloid, fusaravenin 79 (Figure 2E), representing a new naphthoisoxazole formic acid connected with a morpholino carbon frame, the first example of a natural naphthoisoxazole type zwitter-ionic alkaloid, was characterized.\(^{38}\) (–) Benzomalvins E 80 (Figure 2F) was isolated from solid cultures of an interrhizospheric fungus *Penicillium* sp. SYPF 8411.\(^{39}\) A new tryptoquivaline analog, tryptoquivaline V 81 (Figure 2F) and a new brasiliamide analog, brasiliamide G 82 (Figure 2F), were isolated from the fungus *Neosartorya pseudofischeri*.\(^{40}\) A new compound, talarodone A 83 (Figure 2F) in co-culture of *Talaromyces pinophilus* and *Paraphaeosphaeria* sp. isolated from soil collected in Miyazaki Prefecture, Japan.\(^{41}\) One new pyrrolidine derivative, asperidine A 84 (Figure 2F), and two new piperidine derivatives, asperidines B 85 and C 86 (Figure 2F), were isolated from the soil-derived fungus *Aspergillus sclerotiorum* PSU-RSPG178. Compound 86 possessed an unprecedented 7-oxa-1-azabicyclo[3.2.1]octane
skeleton with four chiral centers. A new alkaloid, named iizukine E (Figure 2F) was isolated from the culture of *Aspergillus iizukae*. In order to investigate bioactive metabolites from aciduric fungi, *Aspergillus* sp. OUCMDZ-1914 was isolated from the mangrove soil in Wenchang Hainan, China. The strain was fermented under low pH and the products were extracted and the extract was purified by column chromatography over silica gel, Sephadex LH-20 and semi-preparative HPLC. The structures were identified by means of NMR, MS, UV, IR and X-ray single crystal diffraction. As a result, a new compound, methyl (2Z,3E,5E,7E,9E)-4,10-dimethyl-11-(2,5-dioxopyrrolidin-3-yl)-2-(2-hydroxyethylidene)-11-oxoundeca-3,5,7,9-tetraenoate (Figure 2F) was obtained. A new γ-lactam, virgaricin B (Figure 2F), was isolated from a fermentation broth of the fungus *Virgaria boninensis* FKI-4958. From this active
Paecilomyces lilacinus extract, a novel pyridone alkaloid, named Paecilomide 90 (Figure 2F), was isolated and its structure was elucidated by modern nuclear magnetic resonance techniques and mass spectrometric analyses. The soil-derived fungus Clonostachys rosea. Fermentation of the fungus on white beans instead of rice afforded a new γ-lactam 91 (Figure 2F), named Clonostalactam. A new nitrogen-containing compound, trichothioneic acid 92 (Figure 2F), was discovered from the metabolites of fungal strain Trichoderma virens FKI-7573.

Terpenoids and Steroids
Terpenoids
Sesquiterpene
Two new drimane sesquiterpenoids, fudecadiones A 93 and B 94 (Figure 3A), were isolated from the soil fungus Penicillium sp. BCC 17468. Two new trichothecenes, named 8α-hydroxyroridin H 95 and myrotheacin A 96 (Figure 3A), were isolated from the fermentation broth of a halotolerant fungus Myrothecium sp. GS-17, which was separated from the soil sample of a salina. Among them, compound 96 represents a class of rare trichothecenes with the linkage from C-13 to C-10, missing the epoxide group normally observed at C-12, C-13. Penicilinales A 97 and B 98 (Figure 3A) were characterized from Penicillium bilaiae MA-267, a fungus obtained from the rhizospheric soil of the mangrove plant Lumnitzera racemosa. Two eremophilane sesquiterpenes, penicilleremophilanes A 99 and B 100 (Figure 3A) were isolated from the soil fungus Penicillium coticola PSURSPG138. A new sesquiterpenoid derivative, named aspergiketone 101 (Figure 3A), was isolated from the coastal saline soil fungus Aspergillus fumigatus.

Ochraceopones A-E 102–106 (Figure 3A) were isolated from an Antarctic soil-derived fungus, Aspergillus ochraceopetaliformis SCSIO 05702. Ochraceopones A-D 107–110 (Figure 3A) were characterized from the green Chinese onion-derived fungus Penicillium copticola SCSIO 05702. Ochraceopones A-D 111–115 (Figure 3A) were discovered from the brown Chinese cowpea-derived fungus Eutypella sp. 1–15. A new acarone sesquiterpene, 3β-hydroxy-β-acoreno1 112 (Figure 3A), has been discovered from the brown Chinese onion-derived fungus Eupenicillium AF-04. and a sesquiterpenoid 113 (Figure 3A), cyclonerotriol B, was isolated from the extracts of the soil fungus F. avenaceum SF-1502. Three new sesquiterpenes Trichodermapenes A-C 113–115 (Figure 3A) were isolated from the soil-derived fungus Trichoderma reesei PSU-SPSF015. Chemical investigation of the Dicytosporium digitatum fungus resulted in the identification of three undescribed compounds 116–118 (Figure 3A), which were named Dictyosporin A 116, Dictyosporin B 117, Dictyosporin C 118 respectively. Two new sesquiterpenes, trichocitrinovirenes A 119 and B 120 (Figure 3A), were isolated from the soil-derived fungus Trichoderma citrinovireide PSU-SPSF346. Five new sesquiterpenoids (121–125) (Figure 3B), one new ophiobolin sesterterpenoid (126) (Figure 3B), and one new 3.5-dimethylorsellinic acid (DMOA)-based meroterpenoid (127) (Figure 3B), were isolated and characterized from fungus Aspergillus calidoustus, which was separated from the wetland soil collected at Dianchi Lake, Yunnan Province.

Diterpene
A new meroditerpene sartorypyrone A 128 (Figure 3B) was isolated from the culture of the soil fungus Neosartorya fischeri (KUFC 6344). Interestingly, sartorypyrone A 128, which possesses a monocyclic diterpene core, Libertellenones G 129 and H 130 (Figure 3B) were isolated from the fungus Eutypella sp. D-1 isolated from the soil of high latitude of Arctic. Compounds 131 and 132 (Figure 3B) were isolated from the fermentation broth and the mycelia of the soil fungus Penicillium sp. CM-7. Libertellenones O-S 133–137 (Figure 3B and C), eutypellenones A 138 and B 139, libertellenones M 140 and N 141 (Figure 3C), were isolated from the culture of Eutypella sp. D-1 obtained from high-latitude soil of the Arctic. Structurally, compounds 133–137 possess a cyclopropyl-fused pimarane diterpene moiety, whereas compounds 138 and 139 share an unusual cyclobutyl-fused pimarane diterpene skeleton. Five new diterpenoid glycosides, dongtingnoids A-E 142–146 (Figure 3C), two new diterpenoid aglycones, dongtingnoids F 147 and G 148 (Figure 3C), were isolated from the fungus Penicillium sp. DT10, which was derived from wetland soil from Dongting Lake. Tolypocladiins K 149 and L 150 (Figure 3C), were isolated from the solid fermentation culture of a mine soil-derived fungus Tolypocladium sp. XL115.
Other Terpenoids

One new monoterpene named Trichodermanene 151 (Figure 3C) was isolated from the soil-derived fungus *Trichoderma reesei* PSU-SPSF013. Three new meroterpenoid derivatives, 4,25-dehydrominiolutelide B 152 (Figure 3C), 4,25-dehydro-22-deoxyminiolutelide B 153 and isominiolutelide A 154 (Figure 3C), were isolated from the shaken culture of the fungus *Penicillium* sp. MA-37. Purpurogenolides A-E 155–159 (Figure 3C and D), were isolated from the solid substrate fermentation cultures of the fungus *Penicillium purpurogenum* MHZ 111. A search for cytotoxic agents from cultures of the *Penicillium* sp., isolated from the rhizosphere soil of *Penicillium* sp., led to the isolation of four new hybrid polyketide-terpenoid metabolites 160–163 (Figure 3D). Terretonin M 164 (Figure 3D), a new highly oxygenated tetracyclic meroterpenoid, was isolated from the thermophilic fungus *Aspergillus terreus* TM8. Nine novel polyketide...
terpenoid hybrids 165–173 (Figure 3D), characterized by a 1-alkylated-3,5-dihydroxyphenyl derivative coupled with a modified farnesyl pyrophosphate (FPP) unit, were isolated from a soil-derived fungus Bipolaris zeicola. Compound 173 represents the first example of meroterpenoid having an unusual thiazol-2(3H)-one moiety. Four dimeric acremines, bisacremines A-D 175–178 (Figure 3D), with a novel carbon skeleton and a new monomer, acremine T 174 (Figure 3D), were obtained from cultures of the soil-derived fungus Acremonium persicinum SC0105. Three dimeric acremines, bisacremines E-G 179–181 (Figure 3D and E), with an unusual carbon skeleton were isolated from cultures of the soil-derived fungus Acremonium persicinum SC0105. By employing a large-scale culture approach, five undescribed compounds, namely asperanstinoids A–E 182–186 (Figure 3E), were obtained from fungus Aspergillus calidoustus, which was isolated from the wetland soil collected at Dianchi Lake, Yunnan Province. Ten new meroterpenoids,
bipolaquinones A–J 187–196 (Figure 3E), were isolated and identified from the fermented rice cultures of a soil-derived fungus, Bipolaris zeicola. 72

Six new meroterpenoids, bipolarinoids A—F 197–202 (Figure 3E and F), were isolated from a soil-derived fungus Bipolaris zeicola. 73

Three nortriterpenoids aspergorakhins B–D 203–205 (Figure 3F) were obtained from Aspergillus gorakhpurensis F07ZB1707, which was fermented by a salt-containing medium. 6 Encindolenes D–H 206–210 (Figure 3F), were isolated from the fungus Penicillium sp. HFF16 from the rhizosphere soil of Cynanchum bungei Decne. 74
Steroids

Compound 211 (Figure 3F) was isolated from a soil fungus *Curvularia borreriae* (Pleosporaceae) strain HS-FG-237.75 One new steroid 212 (Figure 3F) was discovered in the extract of a soil-derived fungus *Aspergillus flavus* JDW-1.76 Aspergorakhin A 213 (Figure 3F) was obtained from the extract of soil-derived fungus *Aspergillus gorakhpurensis* F07ZB1707.6

Figure 3 Continued.
Ketones

Polyketides

A new polyketide compound 214 (Figure 4A) was characterized from the ethyl acetate extract of a soil-derived fungal strain, *Exophiala pisciphila* PHF-9.77 Pyrenocine J 215 and pyrenoacetic acid D 216 (Figure 4A) were obtained from the fermentation broth of *Curvularia affinis* strain HS-FG-196.78 Phytochemical investigation of the soil microfungus *Eupenicillium parvum* led to the isolation of two new compounds: a chromone derivative euparvione 217 and a new mycophenolic derivative euparvilactone 218 (Figure 4A).79 A new polyketide penicillither 219 (Figure 4A), was isolated from the soil fungus *Penicillium* sp. PSU-RSPG9.80 Tanzawaic acids I-L 220–223 (Figure 4A), were isolated from the culture filtrates of the fungal strain *Penicillium* sp. IBWF104-06 isolated from a soil sample.81 Four new pyrenoacetic acid derivatives pyrenoacetic acids E-H 227–230 (Figure 4A), three new secalonic acid analogues Blennolides H-J 224–226 (Figure 4A) were purified from an *Alternaria* sp. isolate obtained from a Hawaiian soil sample.82 Three new
polyketides, namely, asperochrins A-C 231–233 (Figure 4A), were isolated from *Aspergillus ochraceus* MA-15, a fungus obtained from the rhizospheric soil of marine mangrove plant *Bruguiera gymnorrhiza*. A new diphenyl derivative, named iizukine A 234 (Figure 4A) was isolated from coastal saline soil-derived fungus *Aspergillus iizukae*. Three new pyran rings containing polyketides, penicipyrans A-B 235–236 (Figure 4A), and penicipyran E 237 (Figure 4A) were isolated from the saline soil-derived *Penicillium raistrickii*. Cultivation of the mangrove rhizosphere soil-derived fungus *Penicillium janthinellum* HK1-6 with NaBr led to the isolation of two new tricyclic polyketides, penijanthinones A 238 (Figure 4A) and B 239 (Figure 4B). Two novel oxaphenalenone dimers, talaroketals A 240 and B 241 (Figure 4B), were isolated from the soil fungus *Talaromyces stipitatus*. Compound 240 features a rare benzannulated
5.6-spiroketal ring system within the dimeric bis(oxaphenalenone) skeleton, while the parent compound 241 harbors a fused bicyclic furano-pyran moiety. Aspergorakhins E–J, L (242–247, 248) (Figure 4B) were obtained from the extract of soil-derived fungus *Aspergillus gorakhpurensis* F07ZB1707. Six new polyketide-derived oxaphenalenone dimers, talaromycesone C 249 and macrosporuses A–E 250–254 (Figure 4B), were isolated from the mycelium of the fungus *Talaromyces macrosporus* KFU-1NK8. Four new oxaphenalenone dimers (bacillisporins I 255 and J 256 (Figure 4B), duclauxamides B 257 and C 258 (Figure 4C)) were isolated from the soil fungus *Talaromyces bacillisporus* BCC17645.
Duclauxamides B and C were the rare N-containing oxaphenalenone dimers isolated from this fungus. New polyketide-derived oligophenalenone dimers, 9a-epi-bacillisporin E 259 and bacillisporins F-H 260–263 (Figure 4C), were isolated from the fungus Talaromyces stipitatus. A new chromanone derivative Aspergone 264 (Figure 4C) was isolated from Aspergillus sp. SCSIO41002. A novel compound 7-methoxy-2,2-dimethyl-4-octa-4′,6′-dienyl-2H-naphthalene-1-one 265 (Figure 4C) was isolated from Penicillium sp. Aspereusins C-E 266–268 (Figure 4C) were obtained from the fermentation product of Aspergillus terreus YIM PH30711.

Flavones
One new xanthone, penicillixanthone 269 (Figure 4C), was isolated from the soil fungus Penicillium sp. PSU-RSPG9. Castochrin 270 (Figure 4C), a new dimer of sulochrin linked by thioether bonds and a new secalonic acid analogues (∓)-Blennolide G 271 (Figure 4C) were purified from an Alternaria sp. isolate obtained from a Hawaiian soil sample. One new xanthone, penicillone C 272 (Figure 4C), is isolated from the soil fungus Penicillium citrinum PSU-RSPG95.
Compound 273 (Figure 4C) was found from the fermentation product of *Penicillium* sp., HT-28 by various spectroscopic techniques. In order to investigate new bioactive compounds, a piece of fungi *Aspergillus aculeatus* was obtained from the Jinyun mountain soil in Chongqing, China. A new compound 2-(2',4',6'-Trihydroxyphenyl)-(7-hydroxy-5-methyl) chromone 274 (Figure 4C) was obtained. A new xanthone (penicillanthone, 275) (Figure 4C) was isolated from the soil-derived fungus *Penicillium aculeatum* PSU-RSPG105. Two new sterigmatocystin derivatives, oxisterigmatocystins E 276 and F 277 (Figure 4D), were isolated from the fungus *Botryotrichum piluliferum*. Penixanthones A 278 and B 279 (Figure 4D), were isolated from the ethyl acetate extract of a culture of the fungus *Penicillium* sp. SYFz-1. Five
new 280–284 (Figure 4D) xanthones were isolated from the coastal saline soil-derived \emph{Aspergillus iizukae} by application of an OSMAC (one strain many compounds) approach.\textsuperscript{100} Three new blennolide derivatives, blennolides L–N 285–287 (Figure 4D), were isolated from the soil-derived fungus \emph{Trichoderma asperellum} PSU-PSF14.\textsuperscript{101} A new metabolite, wentixanthone A 288 (Figure 4D), was obtained from the fungus \emph{Aspergillus wentii}, isolated from soil of the hypersaline lake El Hamra in Wadi El-Natrun, Egypt.\textsuperscript{102}

**Other ketones**

Fusarpyrones A 289 and B 290 (Figure 4D), two new pyrone derivatives, were isolated from the soil fungus \emph{Fusarium solani} PSU-RSPG37.\textsuperscript{103} Two new benzopyranones, named coniochaetones E 291 and F 292 (Figure 4D), and one new
benzophenone, penicillanone 293 (Figure 4D), are isolated from the soil fungus *Penicillium citrinum* PSU-RPG95. 94 Five new secondary metabolites 294–297 (Figure 4D) and 298 (Figure 4E) of *Cephalotrichum microsporum* were isolated, which were described, respectively, as 8′-O-(3R-Hydroxy-butryl)-rasfonin 294, Cemironin A 295, Cemironin B 296, Cemironin C 297, 4-Methyl-8,10-dihydroxy-caprylic acid 298. 104 Two new meroditerpene pyrones, chevalone F 299 and 11-hydroxychevalone E 300 (Figure 4E), were isolated from the fungus *Neosartorya pseudofischeri*. 80 Peninaphones A-C 301–303 (Figure 4E), were isolated from mangrove rhizosphere soil-derived fungus *Penicillium* sp. HK1-22. 105 The fungus, *Aspergillus nidulans* BF0142, was isolated from hot spring-derived soil collected at Hell Valley in Noboribetsu, Hokkaido, Japan. A new furanone compound designated helvafuranone 304 (Figure 4E) was isolated from a culture broth of *A. nidulans*.
Enantiomers of a 2-benzofuran-1(3H)-one derivative [(−)-1 and (+)-1] described as (±)-europhenol A 305 (Figure 4E), was isolated and identified from the culture extract of Eurotium rubrum MA–150, a fungus obtained from the mangrove-derived rhizospheric soil. 107 Chromatographic separation of the broth extract of the soil-derived fungus Aspergillus sclerotiorum PSURSPG178 resulted in isolation of a furanone derivative, aspersclerotiorone E 306 (Figure 4E). 108 Three new secondary metabolites identified as harzianone 307 (Figure 4E), harzianol 308 (Figure 4E), harzianol acid 309 (Figure 4E) were isolated from a culture of Cephalotrichum microsporum. 109 Two new aromatic butenolides, gotjawaside 310 and gotjawalide 311 (Figure 4E), possessing the 4-benzyl-3-phenylbutenolide motif, were isolated from a soil ascomycete.
Ten novel furancarboxylic acids including four pairs of epimers (314, 315; 316, 317; 318, 319; 320, 321) (Figure 4E), were isolated from the fermentation of the soil-derived fungus *Penicillium* sp. sb62. Compounds 312–317 represent the first class of natural furancarboxylic acids featuring a thiophene moiety. We present a new furanone derivative from a white, woolly and fast-growing soil fungus, *Penicillium* sp. FG9RK, isolated from a soil sample collected from Agulu in Anambra state, Nigeria. The compound was identified as a new natural product, *R*-hexitronic acid 322 (Figure 4E). Three new compounds, named peneciraistins A-C 323–325 (Figure 4F), were isolated from saline soil-derived
fungus *Penicillium raistrickii*. Among them, compounds 323 and 324 are rare benzannulate 6,6-spiroketalts.\(^{11}\) Sporulosol 326 (Figure 4F), a new ketal, has been isolated from the liquid fermentation cultures of a wetland-soil-derived fungus, *Paraconiothyrium sporulosum*.\(^{113}\) Three pairs of new isopentenyl dibenzo[b,e]oxepin enantiomers, (+)-(5S)-arugosin K 327, (+)-(5R)-arugosin K 328, (+)-(5S)-arugosin L 329, (+)-(5R)-arugosin L 330, (+)-(5S)-arugosin M 331, (+)-(5R)-arugosin M 332, and a new isopentenyl dibenzo[b,e]oxepinone, arugosin N 333 (Figure 4F), were isolated from a wetland soil-derived fungus *Talaromyces flavus*.\(^{114}\) Two new indanones, asperunguisones A 334 and B 335 (Figure 4F), were isolated from the soil-derived fungus *Aspergillus unguis* PSU-RSPG204.\(^{115}\) A pair of enantiomeric cyclopentenones (336a new and 336b new natural) were isolated from *Aspergillus sclerotiorum*.\(^{116}\) Polluxochrin 337 and dioschrin 338 (Figure 4F), two new dimers of sulochrin linked by thioether bonds, and an additional new asteric acid analogue Dimethylamide asterrate 339 (Figure 4F), were purified from an *Alternaria* sp. isolate obtained from a Hawaiian soil sample.\(^{82}\) Two new cyclohexanone derivatives, nectriatones A 340 and B 341 (Figure 4F), and one new natural product, nectriatone C 342 (Figure 4F), were isolated from the culture of *Nectria* sp. B-13 obtained from high-latitude soil of the Arctic.\(^{117}\) Two new curvularin derivatives, curvulopyran 343 and *ent*-curvulone A 344 (Figure 4F), were isolated from a culture broth of the soil-derived fungus *Aspergillus polyporicola* PSU-RSPG187.\(^{118}\) 7-methoxy-2,3,6-trimethylchromone 345 was obtained from the ethyl acetate extract of a soil-derived fungal strain, *Exophiala piscipila* PHF-9.\(^{77}\) Cultivation of the mangrove rhizosphere soil-derived fungus *Penicillium janthinellum* HK1-6 with NaBr led to the isolation of two new brominated azaphilones, penicilones G 346 and H 347 (Figure 4F).\(^{86}\) As part of the ongoing search for antibiotics from fungi obtained from soil samples, the secondary metabolites of *Clonostachys rosea* YRS-06 were investigated. Through efficient bioassay-guided isolation, three new bisorpicillinoids
possessing open-ended cage structures, tetrahydrotrichodimer ether 348 (Figure 4G) and dihydrotrichodimer ether A 349 and B 350 (Figure 4G), were obtained. Compounds 348–350 are rare bisorbigclinoïds with a γ-pyrene moiety. Isochaetomium A 351 (Figure 4G), a new bis(naphthodihydropyan-4-one), was isolated from the solid-state fermented rice culture of Chaetomium microcephalum. Dong et al obtained a new compound 4,8-dihydroxy-5-(hydroxymethyl)-3-methylisochroman-1-one 356 (Figure 4F) was isolated from the fungus Aspergillus wentii. Four new azaphilones, penicilones A–D 353–356 (Figure 4G), were isolated from the mangrove rhizophore soil-derived fungus Penicillium janthinellum HK1–6. Six new azaphilone derivatives, talaraculones A–F 357–362 (Figure 4G), were obtained from the saline soil-derived fungus Talaromyces aculeatus. One new double bond isomer of asteltoxin, isoasteltoxin 363 (Figure 4G), was isolated from a soil fungus Aspergillus oryzae. Aspergillus ochraceocephaliformis SCSIO 05702. Pang et al found curvularone A 364 and 4-hydroxyradiantan 365 (Figure 4F) from Curvularia inaequalis strain HS-FG-257. A new compound 1-(2′,4′-dihydroxy-5′-methyl-3′-methylsulfanylmethylphenyl)-ethanone 366 (Figure 4G) was isolated from the ethyl acetate extract of the fermentation broth of the fungus Penicillium crustosum YN-HT-15 isolated from the red soil in Yunnan Province, China. A new compound (E)-4-hydroxy-3-[(4-hydroxy-3-methylbut-2-en-1-yl)oxy] benzoic acid 367 (Figure 4G) was obtained from Aspergillus aculeatus. Two new metabolites, talaflavuols B 368 and C 369 (Figure 4G) were isolated from the wetland soil-derived fungus Talaromyces flavus BYD07-13. Aspereusin B 370 (Figure 4G) was isolated from the culture of Aspergillus terreus YIM PH30711. Compounds Pyrenochaetayum 371 and compound Galinsogisoliyu 372 (Figure 4G and H) were successfully separated from the fermentation broth of Seltsamia galinsogisoli sp. nov. A novel compound 1-(4-hydroxy-2,6-dimethoxy-3,5-dimethylphenyl)-2-methyl-1-butanone 373 (Figure 4H) was obtained from the soil-derived fungus Aspergillus sp. isolated from the rhizospheric soil of Phoenix dactylifera (Date palm tree). Chemical investigation of the Dictyosporium digitatum fungus resulted in the identification of nine undescribed compounds 374–382 (Figure 4H): Dictyosporin D 374, Dictyophthalide A 375, Dictyofuran A 376, Dictyofuran B 377, Dictyofuran C 378, Dictyofuran D 379, Dictyosporone A 380, Xylariolide E 381, Xylariolide F 382. Cyclohexanone derivative aspergar-akhin K 383 (Figure 4H) was obtained from Aspergillus gorakhpurensis F07ZB1707. Yanchao Xu et al fermented Aspergillus fumigatus GZWMIZ-152 in a rice solid medium and isolated four new sulfur-containing benzophenones, sulfuraperines A–D 384–387 (Figure 4H).

**Phenylpropanoids**

Eight new polyphenols namely spiromastols A–F 388–393 and spiromastols J–K 394–395 (Figure 5A) were obtained from the fermentation broth of Sporormiastix sp. MCCC 3A00308. Three new tetratol analogs, myrochromanols A–C 396–398 (Figure 5A), were isolated from a soil fungus Myrothecium verrucaria HL-P-1. Peneciraistin D 399 (Figure 5A), which belong isocoumarin, was isolated from saline soil-derived fungus Penicillium raistrickii. Three new isocoumarins, A 400 and B 401 (Figure 5A), were isolated from the ethyl acetate extract of the wetland soil-derived fungus Talaromyces flavus BYD07-13. Compounds 402–404 (Figure 5A) were isolated from the fermentation broth of a deep sea-derived fungus Sporormiastix sp. MCCC 3A00308. Eight new isocoumarin glycosides 405–412 (Figure 5A) were obtained from the solid culture of the wetland soil-derived fungus Metarhizium anisopliae (No. DTH12-10). Two new isocoumarin derivatives, talaisocoumarins A 413 and B 414 (Figure 5A), and one new related metabolite, talaflavuel A 415 (Figure 5A) were isolated from the wetland soil-derived fungus Talaromyces flavus BYD07-13. Penicipyrans C 416 and D 417 (Figure 5A), were isolated from Penicillium raistrickii. In research on novel secondary metabolites from microorganisms, two new 418–419 (Figure 5B) were derived from soil fungus Hypoxylon sp. The two new compounds are assigned as (3R, 4R)-4,8-Dihydroxy-5-(hydroxymethyl)-3-methylisochroman-1-one 418 and (3R, 4S)-4,8-dihydroxy-5-(hydroxymethyl)-3-methylisochroman-1-one 419. Two new epimeric dihalogenated diaporthins, (9R*)-8-methyl-9,11-dichlorodiaporthin 420 and (9S*)-8-methyl-9,11-dichlorodiaporthin 421 (Figure 5B), have been isolated from the soil fungus Hamigera fusca NRRL 35721. Chemical characterization of ethyl acetate extract of Exophiala sp. has afforded the isolation of three compounds including a new isocoumarin named exophiafin 422 (Figure 5B).

**Quinones**

Two new benzoquinones, citriquinones A 423 and B 424 (Figure 6), were isolated from Penicillium citrinum. Penicillicquinone 425 (Figure 6) was isolated from the fermentation product of Penicillium sp. PSU-RSPG9. Tansakul et al investigated secondary metabolites produced by Penicillium herquei PSU-RSPG93 isolated from soil.
Figure 5 Phenylpropanoids 388–422. (A) Phenylpropanoids 388–417. (B) Phenylpropanoids 418–422.
collected from the Plant Genetic Conservation Project under the Royal Initiation of Her Royal Highness Princess Maha Chakri Sirindhorn at Ratchaprapa Dam in Suratthani province, Thailand. They obtained one new phenalenone derivative, peniciherqueinone 426 (Figure 6). They obtained two new phenalenones, aspergillussanones A 427 and B 428 (Figure 6) were obtained from the mycelial extract of the soil fungus *Aspergillus* sp. PSU-RSPG185. A new naphthoquinone, solaninaphthoquione 429 (Figure 6), was isolated from the soil fungus *Fusarium solani* PSU-RSPG227. Cultivation and fractionation of secondary metabolites from *Aspergillus kumbius* revealed a new bis-indolyl benzoquinone, kumbicin D 430 (Figure 6). Membrane active compound PA3-d10 431 (Figure 6) produced by *Aspergillus flavus* strain demonstrated antimicrobial activities against bacteria and yeast strains. The diastereomeric mixtures of the bianthrones wentibianthrone A (432a, b) (Figure 6) and wentibianthrone B (433a, b) (Figure 6), as well as (10R,10'S)-...
wentibianthrone C (434a) and (10R,10'R)-wentibianthrone C (434b) (Figure 6) were obtained from the fungus *Aspergillus wentii*. The study of a Hawaiian volcanic soil-associated fungal strain *Penicillium herquei* FT729 led to the isolation of one unprecedented benzoquinone-chromanone, herqueilenone A (435) (Figure 6) Herqueilenone A (435) contains a chroman-4-one core flanked by a tetrahydrofuran and a benzoquinone with an acetophenone moiety. Three unreported phenalenone derivatives 436–438 (Figure 6), named ent-12-methoxyisohercequinone (436) (Figure 6), (−)-scleroamide (437) (Figure 6), and (−)-scleroamide (438) (Figure 6) were isolated from the Hawaiian soil fungus *Penicillium herquei* FT729, collected on the Big Island, Hawaii.

### Esters and Lactones

#### Esters

A new ester of 2.4-dihydroxy-6-methylbenzoic acid (439) (Figure 7A) named 3-Hydroxy-5-methylphenyl 2.4-dihydroxy-6-methylbenzoate was isolated from the fungus *Neosartorya pseudofischeri* S.W. Peterson. Six new polyesters, talapolyesters A-F (440–445) (Figure 7A), were isolated from the wetland soil-derived fungus *Talaromyces flavus* BYD07-13. All the polyesters are composed of (R)-2,4-dihydroxy-6-(2-hydroxypropyl)benzoic acid and (R)-3-hydroxybutyric acid/S)-3,4-dihydroxybutyric acid residues. Liu et al. obtained a new compound R-3-(3′-acetyl-2′,6′-dihydroxy-5′-methylphenyl)-2-methylpropionic acid methyl ester (446) (Figure 7A) isolated from the ethyl acetate extract of the fermentation broth of the fungus *Penicillium crustosum* YN-HT-15. Compound 4-(4-hydroxyphenethoxy)-4-oxobutanoic acid (447) (Figure 7A), was isolated from the soil fungus *Fusarium solani* PSU-RSPG227. Penicillithiophenols A (448) and B (449) (Figure 7A) were isolated from *Penicillium coticola* PSURSPG138.

#### Lactones

In search for anti-influenza virus inhibitors from marine-derived fungi, a strain identified as *Aspergillus terreus* Gwq-48, was isolated from a mangrove rhizosphere soil sample collected in the coast of Fujian province. The study of its chemical components led to the isolation of one new aspulvinone, isoaspulvinone E (450) (Figure 7A). One new γ-butyro lactone, aspergillulactone (451) (Figure 7A) was isolated from the mycelial extract of the soil fungus *Aspergillus* sp. PSU-RSPG185. Two new hydroxycitric acid lactone derivatives named cinatrins D (452) and E (453) (Figure 7A), were obtained from the fungus *Virgaria boninensis* FKI-4958. One phthalide (asperlide, 454) and one dopsidone (asperdione, 455) (Figure 7B) were obtained from the fungus *Aspergillus unguis* Liu et al. obtained a new compound 4-(4-hydroxyphenethoxy)-4-oxobutanoic acid (456–460) (Figure 7B) and penicimenolide F (461) (Figure 7B) were isolated from the culture broth of a strain of *Penicillium* sp. (NO. SYP-F-7919). Chromatographic separation of the broth extract of the soil-derived fungus *Aspergillus sclerotiorum* PSURSPG178 resulted in isolation of four γ-butenolide-furanone dimers, aspersclerotiorones A-D (462–465) (Figure 7B), and two γ-butenolide derivatives, aspersclerotiorones F (466) and G (467) (Figure 7B). Zhou et al. isolated and identified a new sesquiterpene lactone named *eut*-Guaiane sesquiterpene (468) (Figure 7B) from the fungus *Eutypella* sp. derived from the soil of high latitude of Arctic. New natural products, designated pochoniolides A and B (469–470) (Figure 7B), were isolated from the cultured broth of fungal strain FKI-7537 using a physicochemical screening methodology. Three new γ-hydroxy butenolides named aspersclerolides A-C (473–474) (Figure 7B), a pair of new enantiomeric spiro-butenolides named (+)-aspersclerolide D (474) (Figure 7B), were isolated from *Aspergillus sclerotiorum*. Investigation of the soil-derived fungus *Lasiodiplodia theobromae* NSTRU-PN1.4 resulted in the isolation of two new dimeric c-lactones botryosphaerilactones D (475) and E (476) (Figure 7B). One new metabolite, theralanbutanolide A (477) (Figure 7C), was isolated from the YGP culture broth of *Thermomyces lanuginosus*. During screening for microbial regulators of bone metabolism, a new compound, 6-ethoxy-5,6-dihydopenilic acid (477) (Figure 7B), was isolated from the culture broth of the soil-derived fungus *Penicillium* sp. BF-0343. Twelve new resorcylic acid lactones (RALs) including three new 16-membered RALs (479–481) (Figure 7C), eight new 14-membered RALs (482–488) (Figure 7C), and one new 12-membered RAL (490) (Figure 7C), were identified from the fermentation of the soil-derived fungus *Ilyonectria* sp. **s.b65**. These new compounds are assigned, respectively, as Ilyoresorcy A (479), Atrop-ilyoresorcy A (480) Ilyoresorcy B (481), Ilyoresorcy C (482), Ilyoresorcy D (483), Ilyoresorcy E (484), Ilyoresorcy F (485), Ilyoresorcy G (486), Ilyoresorcy H (487), Ilyoresorcy I (488), Ilyoresorcy J (489) and Ilyoresorcy K (490).
Other Compounds

Prenylterphenyllins A-C 491–493 (Figure 8A) and prenylcandidusins A-C 495–497 (Figure 8A), and one new polyhydroxy-pterphenyl named 4ď”-dehydro-3-hydroxyterphenyllin 494 (Figure 8A), were obtained from Aspergillus taichungensis ZHN-7-07, a root soil fungus isolated from the mangrove plant Acrostichum aureum. A new benzoic acid derivative 4-hydroxy-3-(3-methoxy-3-methylbutyl)-benzoic acid 498 (Figure 8A) was isolated from Curvularia inaequalis strain HS-FG-257. Eight new 2-pentenedioic acid derivatives 499–506 (Figure 8A) were isolated from a soil-
derived fungus *Gongronella butleri* collected in Cameroon. The isolated compounds feature a 2-pentenedioic acid core structure substituted by a 2-alkyl chain that has even number of carbon atoms (C₆, C₈, and C₁₀) with or without an oxygenated substituent.¹⁵⁴ Peniciketals A–C 507–509 (Figure 8A), three new spiroketals with a benzo-fused 2,8-dioxabicyclo[3.3.1]nonane moiety, were isolated from the saline soil-derived fungus *Penicillium raistrichi*.¹⁵⁵ Masaphy et al report on the purification and characterization of a novel antifungal echinocandin – MIG0310 510 (Figure 8A) from *Fusarium brachygibbosum* strain MS-R1 and the elucidation of its molecular structure.¹⁵⁶ Two new cyclic carbonate derivatives, aspergillusols A 511 and B 512 (Figure 8A) which contain an unusual cyclic carbonate functionality, and one new eutypinic acid derivative, aspergillus acid 513 (Figure 8A) were found from *Aspergillus* sp.
The soil fungus *Gymnascella dankaliensis* was collected in the vicinity of the Giza pyramids, Egypt. When grown on solid rice medium the fungus yielded four new compounds including 11′-carboxygymnastatin N, gymnastatin S, dankamide, and aranorosin-2-methylether (Figure 8B). A new diphenyl derivative, named iizukine B (Figure 8B), was isolated from coastal saline soil-derived fungus *Aspergillus iizukae*. A new compound namely (13-(3,3-dihydroxypropyl)-1,6-dihydroxy-3,4-dihydro-1H-isochromen-8(5H)-one was isolated from an ethyl acetate extract of the borne fungi *Sclerotium rolfsii*. The new compound is also known as Sclerotium. A new lovastatin analogue versicorin (Figure 8B), was isolated from mycelial solid cultures of *Aspergillus versicolor* SC0156. Three new lovastatin analogues were isolated from the soil-derived fungus *Aspergillus sclerotiorum* PSU-RSPG178. Four previously undescribed metabolites including two lovastatin analogues, asterreusin A and one unnamed compound, additionally aspereusin A (Figure 8B) were isolated from the culture of *Aspergillus terreus* YIM PH30711. Three new lovastatin analogues (Figure 8B) were isolated from the soil-derived fungus *Aspergillus sclerotiorum* PSU-RSPG178. Four previously undescribed metabolites including two lovastatin analogues, asterreusin A and one unnamed compound, additionally aspereusin A (Figure 8B) were isolated from the culture of *Aspergillus terreus* YIM PH30711. Three new lovastatin analogues (Figure 8B) were isolated from the soil-derived fungus *Aspergillus sclerotiorum* PSU-RSPG178. Three new diphenyl ethers, aspergillusethers B-D (Figure 8B), were isolated from the soil-derived fungus *Aspergillus unguis* PSU-RSPG204. Two new aspinotriol derivatives determined as melleusin A, B were isolated from a soil-borne fungus *Aspergillus melleus*. A new diphenyl ether 3-methylpentyl-2, 4-dichloroasterrate (Figure 8C) was isolated from the metabolites of a wetland fungus *Aspergillus flavipes*. Two new unsaturated fatty acids, 6R,8R-dihydroxy-9Z,12Z-octadecadienoic acid and methyl-6R,8R-dihydroxy-9Z,12Z-octadecadienoate were isolated from the mangrove rhizosphere soil-derived fungus *Penicillium javanicum* HK1-22. A new azo compound, penoxalin (Figure 8C), a new isochromane carboxylic acid, penisochroman B (Figure 8C), two new natural products,
penisochroman A 540 (Figure 8C) and 2,6-dihydroxy-4-[(2R)-2-hydroxyheptyl] benzoic acid 542 (Figure 8C), were isolated from wetland soil fungus *Penicillium oxalicum* GY1. Fan et al report a new pentacyclic decalinoylspirotetramic acid derivative, pyrenosetin D 543 (Figure 8C), from an endophytic strain *Pyrenochaetopsis* FVE-087. One new benzofuranoid 544 (Figure 8C), was isolated and characterized from fungus *Aspergillus calidoustus*. Two new benzothiazoles (545 and 546) (Figure 8C) were isolated from the cave soil-derived fungus *Aspergillus fumigatus* GZWMJZ-152.
Biological Activity of New Compounds Derived from Soil Fungi Anticancer Activities

The cytotoxicity of compounds 491, 494 and 496 was evaluated on HL-60, A-549, and P-388 cell lines using the SRB and MTT methods with adriamycin (ADM) as positive control. Compound 491 exhibited moderate activities against all three cell lines (IC$_{50}$ 1.53–10.89 μM), whereas compounds 494 and 496 displayed moderate activities only against the P-388 cell line (IC$_{50}$ of 2.70 and 1.57 μM, respectively). Compound 93 exhibited anticancer activity against MCF-7.
Compound 214 exhibited moderate growth inhibition against A-549, Hela, PANC-28 and BEL-7402 cell lines with the IC\(_{50}\) values of 16.4, 23.4, 20.3, and 30.1 \(\mu\)g/mL, respectively. 10-hydroxycamptothecin was used as the positive control with the IC\(_{50}\) values of 0.5, 5.9, 10.6, and 4.6 \(\mu\)g/mL, respectively.\(^7\) The cytotoxic effects of compound peneciraistin C 325 were preliminarily evaluated against human lung adenocarcinoma (A549) and human breast adenocarcinoma (MCF-7) cell lines by the MTT method. Compound 325 showed comparatively significant cytotoxicities against A549 and MCF-7-60 cell lines with IC\(_{50}\) values of 3.2 and 7.6 \(\mu\)M, respectively.\(^11\) Pan et al report the anticancer mechanisms of Pe-C in a variety of lung cancer cells. The results showed that Pe-C induced caspase-independent autophagic cell death and elevated mitochondrial-derived reactive oxygen species levels, which indicated that Pe-C could be a potential drug candidate for therapy of lung cancer.\(^166\) Compound pyrenocine J 215 showed cytotoxic activity against the human hepatic cancer cell line HepG2 with an IC\(_{50}\) value of 28.5 \(\mu\)g/mL.\(^78\) Compound 4 showed cytotoxic activity against A-549, Hela, PANC-28 and BEL-7402 cell lines with IC\(_{50}\) values of 76.3, 77.2, 107.5 and 89.5 \(\mu\)mol·L\(^{-1}\), respectively.\(^12\) Compound 7 showed remarkable activities with IC\(_{50}\) values of 1.83 and 4.80 \(\mu\)M on P388 and HL-60 cells, respectively. The target of racemic 7 was also investigated and the (12R,28S,31S)-7 enantiomer showed selectivity against topoisomerase I.\(^14\) Compound 8 showed weak activity with IC\(_{50}\) values of 55.1 and 30.5 \(\mu\)M on BEL-7402 and A-549 cells, respectively.\(^15\) Compound 364

Figure 8 Other compounds 491–546. (A) Other compounds 491–513. (B) Other compounds 514–534. (C) Other compounds 535–546.
exhibited cytotoxic activity against the ACHN and HepG2 cell lines with IC\textsubscript{50} values of 4.78 and 13.11 μg mL \textsuperscript{-1}, respectively. The values of 365 were 54.18 and 52.07 μg mL \textsuperscript{-1}.\textsuperscript{123} Sartorypyrone A 128 was evaluated for its capacity to inhibit the in vitro growth of MCF-7 (breast adenocarcinoma), NCI-H460 (nonsmall cell lung cancer) and A375-C5 (melanoma) cell lines, using the protein binding dye SRB method. Interestingly, sartorypyrone A 128, which possesses a monocyclic diterpene core, was more selective, exhibiting similar inhibitory activity to sartorypyrone B against A375-C5 (GI\textsubscript{50}=21.5±1.9 μM), but less active against MCF-7 (GI\textsubscript{50}=46.3±7.6 μM) and NCI-H460 (GI\textsubscript{50}=37.3±4.0 μM) cell lines.\textsuperscript{16} Citriquinone A 423 was assayed for cell migration inhibitory activity using human cancer cell line HEp 2. After growing cells in vitro in 96 well plates a scratch was made on wells with cells at the confluence stage. Citriquinone A 423 at a concentration of 0.5 mg/mL (dissolved in growth medium containing 1% DMSO) was introduced into wells and incubated for 24 h. Development of new cells to reduce the width of the scratch from its initial stage was determined qualitatively by comparing the width of the scratch after incubation in each well in the presence of test sample and control (1% DMSO in the growth medium) using microscopic images. It was revealed that 423 had a moderate inhibitory effect on the growth/migration of the HEp2 cells when compared with the control.\textsuperscript{136} Compounds 444 and 445 were evaluated by MTT method for their cytotoxic activities against five tumor cell lines, HL-60, SMMC-7721, A-549, MCF-7, and SW480, with cisplatin and paclitaxel as the positive controls. They exhibited cytotoxicity against the tested tumor cell lines. The IC\textsubscript{50} values of compound 444 are 14.81, 18.39, 17.66, 14.59 and 26.62 μM respectively. The IC\textsubscript{50} values of compound 445 are 13.62, 15.74, 11.09, 15.96 and 15.54 μM, respectively.\textsuperscript{142} Peniciketals A-C 507–509 showed selective activities against HL-60 cells with IC\textsubscript{50} values of 3.2, 6.7, and 4.5 μM, respectively (doxorubicin as a positive control (IC\textsubscript{50}s: 0.31, 0.085, and 0.23 μM, respectively)), while were not active on other cells (IC\textsubscript{50} > 10 μM).\textsuperscript{155} Libertellenone H 130 showed cytotoxicity against seven human tumor cell lines: U251, SW-1990, SG7901, MCF-7, Huh-7, Hela and H460 cell lines at a range between 3.31 and 44.1 μM.\textsuperscript{59} Compound cytochalasin Z\textsubscript{24} 53 exhibited moderate cytotoxicity toward human breast cancer MCF-7 cell line with IC\textsubscript{50} of 9.33 μM.\textsuperscript{29} Compound aspergillassanone A 427 exhibited weak activity toward KB and Vero cells with IC\textsubscript{50} values of 48.4 and 34.2 μM, respectively.\textsuperscript{30} Compounds Polluxochrin 337, dioschirin 338 and Castochrin 270 showed weak mammalian cell cytotoxicity effects against pancreatic cancer cells (MIA PaCa-2) with IC\textsubscript{50} values of 50.8, 30.3, and 29.3 μM, respectively.\textsuperscript{82} Bisacremines A-B 175–176 exhibited weak cytotoxicity against HeLa cells with IC\textsubscript{50} values of 10.7±1.0 and 9.3±1.7 μM respectively. And 176 also showed modest activity against A549 and HepG2 cells with IC\textsubscript{50} values of 41.3±4.1 and 31.1±2.1 μM respectively.\textsuperscript{5} Compound aranorosin-2-methylether 517 showed potent cytotoxicity against the murine lymphoma cell line L5178Y with IC\textsubscript{50} values of 0.44 μM.\textsuperscript{157} Compound solaninaphthoquinone 429 showed significant cytotoxic activity against breast cancer (MCF-7) and mild cytotoxic activity against oral human carcinoma (KB) cells (IC\textsubscript{50} values of 21.3 and 22.6 μM, respectively) compared to standard compound.\textsuperscript{138} Iizukines A 234 and B 518 were tested their cytotoxicities against HL-60 (human promyelocytic leukemia), BEL-7402 (human hepatoma) and A-549 (human lung carcinoma) were tested by the MTT assay in vitro with 5-fluorouracil (5-FU) as positive control. The two compounds showed weak cytotoxic activities. IC\textsubscript{50} values of compound 234 were 26.5, 32.7 and 18.2 μM respectively, and IC\textsubscript{50} values of compound 518 were 48.7, 56.6 and 32.3 μM.\textsuperscript{84} Penicillerephospholane A 99 was obtained from Penicillium coticola PSURSPG138. It showed much weaker cytotoxic activity.\textsuperscript{51} Cytotoxicity studies of the compound 265 on cancer cell lines showed a valuable cytotoxic potential against all tested human cancer cell lines. Further, the compound induces apoptosis in lung cancer (A549) cells revealed by increase the distribution of nuclear DNA in Sub-G1 phase as observed in flow cytometry.\textsuperscript{92} For compound 519, in the present study rhodamine-123 exclusion screening test on human mdr1 gene transfected mouse gene transfected L5178 and L5178Y mouse T-cell lymphoma which showed excellent MDR reversing effect in a dose-dependent manner against mouse T-lymphoma cell line. Moreover, molecular docking studies of compound 519 also showed better results as compared with the standard.\textsuperscript{158} Kumbicin C 33 was found to inhibit the growth of mouse myeloma cells (IC\textsubscript{50} 0.74 μg mL \textsuperscript{-1}).\textsuperscript{32} Penicimenolides B-D 457–459 exhibited potent cytotoxicity against the U937 and MCF-7 tumour cell lines and showed moderate cytotoxic activity against the SH-SY5Y and SW480 tumour cell lines. There is experimental evidence that compound 457 may act as a potential MEK/ERK inhibitor, it is still need further study in the future.\textsuperscript{145} Penicipyran E 237 showed cytotoxicity effects on HL-60 and K562 cell lines with IC\textsubscript{50} values of 4.4 and 8.5 μM, respectively.\textsuperscript{85} Compounds 68–74 showed potent to moderate cytotoxicity against the L5178Y mouse lymphoma cell line with IC\textsubscript{50} values ranging from 0.99 to 14.1 μM.\textsuperscript{35} Asterrinquinol E 34 was bioassayed.
for its inhibitory effects on NO production induced by LPS in microglia cells with N\textsuperscript{6}-monomethyl-L-arginine (L-NAME) as a positive control (IC\textsubscript{50} 4.8 μM). The results showed that compound 34 showed moderate activity with IC\textsubscript{50} 49.7 μM. Cell viability was determined at the same time by the MTT method and only compound 1 exhibited cytotoxicity with an IC\textsubscript{50} 9.7 μM.\textsuperscript{23} Bacillisorpin H 263 exhibited modest cytotoxicity against HeLa cells.\textsuperscript{90} Compound Aspergiketone 101 was cytotoxic towards HL-60 and A549 cell lines with IC\textsubscript{50} values of 12.4 and 22.1 μM, respectively.\textsuperscript{52} Oxisterigmatocystins E and F (276 and 277, respectively) exhibited cytotoxicity against KB, MCF-7, and NCI-H187 cell lines (IC\textsubscript{50} = 7.7–78.6 μM). However, compounds 276–277 showed cytotoxic effects against the Vero cell line (IC\textsubscript{50} = 4.3–9.7 μM).\textsuperscript{99} Compound 107 displayed growth inhibitory effect against human Mantle cell lymphoma JEKO-1 and human hepatoma carcinoma HepG2 with IC\textsubscript{50} values of 8.4 and 28.5 μM, respectively.\textsuperscript{54} Compound penixanthone A 278 had weak cytotoxicity against the tested cancer cell lines, H1975, MCF-7, K562, HL7702 at concentration of 30 μM.\textsuperscript{99} Compound 211 exhibited poor cytotoxicity toward HCT-116 cells (20.5% inhibition at the dose of 100 μM, IC\textsubscript{50} >100 μM), while the IC\textsubscript{50} value of the positive control (doxorubicin) was 0.365±0.023 μM.\textsuperscript{75} Compound 468 exhibited in vitro a little cytotoxicity towards SGC7901 cell line with IC\textsubscript{50} value of 39.8 μM.\textsuperscript{146} Compound 160 showed potent cytotoxic capability against HL-60, THP-1 and Caco 2 cell with IC\textsubscript{50} values of 3.4 μM, 4.3 μM, 10.5 μM, and compound 161 showed significant inhibiting activities against HL-60 cell line and THP-1 cell line (IC\textsubscript{50} =7.9 μM, 11.3 μM, respectively), using 5-fluorouracil as the positive drug with IC\textsubscript{50} values of 6.4 μM, 4.4 μM, 56.6 μM for HL-60, THP-1 and Caco 2 cells, respectively.\textsuperscript{67} The cytotoxic effects of 3-methylpentyl-2, 4-dichlorosterrate 536 was evaluated using the MTT method on HL-60, HCT116, PC-3, and HT-29 cancer cell lines. The results showed that its IC\textsubscript{50} values were larger than 5-fluorouracil, smaller than 80 μM.\textsuperscript{162} Libertellenones O-S 133–137 and eutypellenones A and B (138 and 139) exhibited cytotoxicities against HeLa, MCF-7, HCT-116, PAN-C1, and SW1990 cells, with IC\textsubscript{50} values in the range of 0.8 to 29.4 μM. Compounds 138 and 139 could dose-dependently inhibit the activity of NF-κB and exhibited significantly inhibitory effects on nitric oxide production induced by lipopolysaccharide.\textsuperscript{61} (9R\textsuperscript{(*)})-8-methyl-9,11-dichlorodiaporthin 420 and (9S\textsuperscript{(*)})-8-methyl-9,11-dichlorodiaporthin 421, were evaluated the cytotoxicity against seven cancer cell lines: human-derived cell lines CCD25sk (human fibroblasts), SHSY5 (neuroblastoma), MiaPaca-2 (epithelial pancreas carcinoma), MCF-7 (breast adenocarcinoma), HepG2 (hepatocellular carcinoma), A2058 (epithelial melanoma), and A549 (lung carcinoma), exhibiting moderate activity against two of them. While both dichlorinated compounds 420–421 were active against neuroblastoma (SHSY5y cells: 420 CC\textsubscript{50} = 39.2 μM, and 421 CC\textsubscript{50} = 36.2 μM). These results correlate well with the cytotoxicity against HeLa cells recently reported for dichlorodiaporthin (CC\textsubscript{50} = 9 μg/mL = 28 μM), a compound considered as a mycotoxin.\textsuperscript{134} Sporulosol 326 showed modest cytotoxicity toward the human tumor cell line T24, with an IC\textsubscript{50} value of 18.2 μM.\textsuperscript{113} Libertellenone M 140 and libertellenone N 141 were tested for cytotoxic activities against HeLa, MCF-7, HCT-116, K562, and SW1990 cell lines. Compound 141 displayed potent cytotoxicity against K562 cells with IC\textsubscript{50} value of 7.67 μM and moderate cytotoxicity against HeLa, MCF-7, and SW1990 cell lines with IC\textsubscript{50} values of 30.06, 18.52, and 24.36 μM, respectively, and compound 140 showed weaker cytotoxic activity against these five tumor cell lines with IC\textsubscript{50} values of 34.78, 32.20, 26.67, 40.85 and 24.36 μM, respectively.\textsuperscript{62} Compound izukine C 57 exhibited cytotoxic effect towards HL-60 and A549 cell lines with IC\textsubscript{50} values of 3.8 and 7.2 μM, respectively.\textsuperscript{31} Compounds 471 and 473 showed selective cytotoxicity against HL60 (IC\textsubscript{50}: 6.5 and 12.1 μM, respectively), A549 (IC\textsubscript{50}: 8.9 and 16.7 μM, respectively), and HL-7702 (IC\textsubscript{50}: 17.6 and 22.8 μM, respectively) cell lines.\textsuperscript{116} The cytotoxicities of Compound 212 was evaluated against A-549, HeLa, HCT-116, MGC-803, and HO-8910 cell lines. Compound 212 exhibited various activities with the IC\textsubscript{50} values 5.0 to 22.4 μM, respectively.\textsuperscript{76} Tolypocladin A 38 displayed weak cytotoxicity against A549, Huh7, LN229, MGC and MHCC97H, LOVO and MDA231 cell lines with IC\textsubscript{50} values from 16.32 to 37.80 μM (positive control camptothecin: 0.32–31.8 nM) and suppressed the growth and viability of the HCC cells T1224 in the patient-derived organoids (PDOs) model.\textsuperscript{25} 8′-O-(3R-Hydroxy-butyryl)-rasfonin 294 and Cemironin A 295 displayed significant cytotoxicity on five human cancer cell lines: 786-O, A549, HeLa and MCF-7 cell lines, with the IC\textsubscript{50} values <20 μM, which are more effective than positive control 5-fluorouracil and could be considered to be potential as antitumor agents, in which they could significantly inhibit the cancer cells growth in a dose-dependent manner.\textsuperscript{104} Nectriatone A 340 showed cytotoxicities against SW1990, HCT-116, MCF-7, and K562 cells, with IC\textsubscript{50} values in the range of 26.37–42.64 μM.\textsuperscript{117} Compound 251 also showed cytotoxicity against NCI-H187 cells with an IC\textsubscript{50} value of 16.73 μM. Moreover, macrosporones A-B 250–251 and
Macrophorosunone D \text{253} exhibited cytotoxicity against Vero cells with IC\textsubscript{50} values in the range of 13.74–69.77 μM.\textsuperscript{88} Compounds 48 and 49 showed moderate cytotoxicity against HepG2 human hepatocellular carcinoma cells with an IC\textsubscript{50} of 8.7 and 19.4 μM, respectively. The IC\textsubscript{50} value of the positive control (cis-platin) was 3.14 μM.\textsuperscript{26} Compound \text{542} displayed significant cytotoxicity against human esophageal carcinoma cells OE19 with an IC\textsubscript{50} value of 5.50 μM.\textsuperscript{164} Compounds \text{255}–\text{258} had low cytotoxicity against both cancerous (MCF-7 and NCleH187) and non-cancerous (Vero) cells.\textsuperscript{89} Compounds 62–65 showed moderate cytotoxicity against five tested human tumor cell lines: HeLa, PC-3, A549, HepG-2 and HL-60.\textsuperscript{33} Pyrenosetin D \text{543} showed toxicity towards both A-375 and HaCaT cells with IC\textsubscript{50} values of 77.5 and 39.3 μM, respectively.\textsuperscript{165} Compounds 165,166, and 168 exhibited moderate cytotoxic activities with IC50 values ranging from 18.4 to 29.4 μM.\textsuperscript{69} The cytotoxicity assay revealed that asperanstonid D \text{185}, dehydroaoxistil, and austin displayed considerable cytotoxicity against the HL-60 and SU-DHL-4 tumor cell lines with IC\textsubscript{50} values ranging from 15.7 to 27.8 μM.\textsuperscript{71} Protein tyrosine phosphatases (PTPs) are signaling enzymes that regulate tyrosine phosphorylation. The disorder of PTPs could induce human diseases such as tumor, diabetes, autoimmune diseases, and infectious diseases. Compounds 213, 203, and 383 showed inhibitory effect against PTPs including PTP1B, SHP1, and TCPTP in vitro. Among them, compound 213 might exhibit selective activities against PTP1B and SHP1 over TCPTP with IC\textsubscript{50} values 0.57, 1.19, and 22.97 μM, respectively. Compounds 213 and 203 exhibited modest cytotoxicity against tumor cell lines A549, HeLa, Bel-7402, and SMMC-7721 with IC\textsubscript{50} values in the range of 6.75–83.4 μM.\textsuperscript{6} The inhibitory activity of the isolated compounds (436–438) against indoleamine 2,3-dioxygenase 1 (IDO1) was assessed. Compounds 436 inhibited IDO1, with the IC\textsubscript{50} value of 32.59 μM.\textsuperscript{141}

### Antimicrobial Activities

Compounds 95 and 96 were tested for antifungal activities. 95 and 96 were active against plant pathogenic fungi \textit{Rhizoctonia solani} and \textit{Fusarium oxysporum} using standard agar diffusion tests at 20 μg/disk.\textsuperscript{49} Compound 5 was tested for its abilities to inhibit both cell viability and biofilm formation of \textit{Candida albicans}. It demonstrated dose-dependent activity in the biofilm inhibition assay with an IC\textsubscript{50} value of 1.4 ± 0.2 μM.\textsuperscript{13} Citriquinone A \text{423} was evaluated for antibacterial activity against \textit{Bacillus} sp. At a dose of 250 μg/disc using the Kirby-Bauer Disc Diffusion method. Amoxicillin 25 μg and a disc soaked with MeOH and dried completely served as positive and negative control, respectively. It was found that 423 had moderate antibacterial activity compared with amoxicillin.\textsuperscript{136} Compounds 97 and 98 exhibited selective activity against \textit{Colletotrichum gloeosporioides} with MIC values of 1.0 and 0.125 μg/mL, respectively, the latter of which is better than that of the positive control, zeocin (MIC 0.25 μg/mL). This result indicated that compounds 97 and 98 are responsible for the activity against \textit{C. gloeosporioides} during the preliminary assay of the crude extract, and acetylation of 4-OH likely enhanced the activity.\textsuperscript{50} Libertellenone G \text{129} exhibited antibacterial activity against \textit{Escherichia coli}, \textit{Bacillus subtilis}, and \textit{Staphylococcus aureus}.\textsuperscript{39} Novel echinocandin compound MIG0310 \text{510} exhibiting antifungal activity, MIG0310 showed activity against two ATCC strains and 10 clinical isolates of \textit{Candida albicans}. It also showed activity against a clinical isolate of \textit{C. tropicalis}, showing a potential inhibition of this particular \textit{Candida} species as well. The antifungal agent had MFC values (killing activity) similar to the MIC for \textit{C. albicans}, reminiscent of other echinocandins used as drugs, which showed also kill at growth-inhibiting concentrations for most of \textit{Candida} species isolates (Moore et al 2001).\textsuperscript{156} Isochaetomium A\textsubscript{2} \text{351} possessed significant antimicrobial activity against \textit{Escherichia coli} 1.044, \textit{Staphylococcus aureus} 1.252, and \textit{Bacillus subtilis} 1.079.\textsuperscript{120} Minimum inhibitory concentration (MIC) of the active compound 273 ranged from 0.5 to 15 μg/mL. Viable cell count studies of the active compound 273 showed \textit{Staphylococcus aureus}, \textit{Escherichia coli}, \textit{Staphylococcus epidermis}, and \textit{Salmonella typhimurium} 1 to be the most sensitive.\textsuperscript{95} Compounds Polluxochrin 337, dioschirin 338 and Castochrin 270 exhibited anti-MRSA activity, with MIC values of 4.1, 4.9, and 3.2 μg (2.9, 3.2, and 2.0 μg/mL), respectively, whereas the MIC for chloramphenicol was 5 μg (1.6 μg/mL).\textsuperscript{82} Compounds 388–390 exhibited potent antibacterial activities against all tested strains of bacteria, including \textit{Xanthomonas vesicatoria} ATCC 11633, \textit{Pseudomonas lachrymans} ATCC11921, \textit{Agrobacterium tumefaciens} ATCC11158, \textit{Ralstonia solanacearum} ATCC11696, \textit{Bacillus thuringiensis} ATCC 10792, \textit{Staphylococcus aureus} ATCC 25923 and \textit{Bacillus subtilis} CMCC 63501, with minimal inhibitory concentration (MIC) values ranging from 0.25 to 4 μg/mL, while compounds 394–395 and 404 showed moderate inhibition with MIC values in the range of 8–64 μg/mL.\textsuperscript{129} The antibacterial activity of asperochrin A \text{231} was evaluated. Compound 231 showed inhibitory activity against aquatic pathogenic bacterial \textit{Aeromonas hydrophila}, \textit{Vibrio anguillarum}, and \textit{Vibrio harveyi}. However, compound 231 displayed
selective antibacterial activity against *A. hydrophilia, V. anguillarum,* and *V. harveyi,* with IC\textsubscript{50} values ranging from 8.0 to 16.0 μg/mL.\textsuperscript{83} Compounds 452 and 453 were shown to be weakly active against the bacteria *Bacillus subtilis* KB 211 (ATCC 6633) with inhibition zones of 7.3 and 7.2 mm, respectively, as well as against *E. coli* KB 213 (NIHJ), with inhibition zones of 10.9 and 14.7 mm, respectively, at 100 μg per 6 mm disc. Compound 89 displayed only weak antibacterial activity against *E. coli* KB 213 (NIHJ) with an inhibition zone of 7.8 mm at 30 μg per 6 mm disc.\textsuperscript{44} Penicilleremophilane A 99 was approximately half as active against *Plasmodium falciparum* with the IC\textsubscript{50} value of 3.45 μM.\textsuperscript{51} MIC of the compound 265 ranged from 0.5 to 15 μg/mL, which was found to be comparable with the standard antibiotics.\textsuperscript{92} Compound 349 (MIC 25 μg/mL) exhibited stronger antibacterial activity against *E. coli* than erythromycin, streptomycin, and ampicillin. Compound 350 (MIC 50 μg/mL) exhibited more prominent activity than streptomycin against *Bacillus subtilis.* Compound 350 (MIC 50 μg/mL) also displayed similar activity against *Escherichia coli* compared to erythromycin and ampicillin, and greater than streptomycin.\textsuperscript{119} Kumbicin C 33 was found to inhibit the growth of Gram-positive bacterium *Bacillus subtilis* (MIC 1.6 μg mL\textsuperscript{−1}).\textsuperscript{22} Compound 405 showed antibacterial activity comparable with (Z)-4-bromo- 5-(bromomethylene)-2(5H)-furanone (BF), which may block the QS system of *Pseudomonas aeruginosa* with the mechanism of reducing biofilm formation and virulence factor secretion.\textsuperscript{132} Talaroketals A 240 and B 241 display modest antimicrobial activity against *Staphylococcus aureus* with an IC\textsubscript{50} value around 50 μg mL\textsuperscript{−1} but no activity against the other bacterial strains:*Staphylococcus haemolyticus,* *Escherichia coli* and *E. faecalis.*\textsuperscript{87} The antimicrobial activity of bacillispinor H 263 was evaluated against a panel of human pathogenic bacteria: *Escherichia coli* (ATCC 8739), *Staphylococcus aureus* (ATCC 6538), *Staphylococcus hemolyticus* (MNHN26), and *Enterococcus faecalis* (CIP 103014). Also of note is the effect of compound 263 against *Staphylococcus aureus* with a MIC value of 5.0 μM.\textsuperscript{90} Compound 533 exhibited moderate antifungal activity against *Candida albicans* (NCPF3153), fluocytosine-resistant *Cryptococcus neoformans* (ATCC90113) and *Penicillium marneffei* with the MIC values of 16, 8 and 16 μg/mL, respectively.\textsuperscript{115} Compound 107 exhibited inhibitory efficacy against *Bacillus subtilis* CMCC63501 and *Bacillus pumilus* CMCC63202 with IC\textsubscript{50} value of 18.1 and 23.8 μM, respectively.\textsuperscript{54} The antibacterial activities of Penicilones B-D 354–356 were evaluated with Gram-positive *S. aureus* (ATCC 43300), *S. aureus* (ATCC 33591), *S. aureus* (ATCC 29213), *S. aureus* (ATCC 25923), *Enterococcus faecalis* (ATCC 51299), *E. faecium* (ATCC 35667), and Gram-negative *Escherichia coli* (ATCC 25922). The results indicated that 354–356 showed significant antibacterial activities against the tested Gram-positive bacteria including both antibiotic-resistant and -susceptible strains with MIC values ranging from 3.13 to 12.5 μg/mL, while none of the tested compounds exhibited activity against *E. coli.*\textsuperscript{121} The antibacterial activities of talaraculone B 358 against three Gram-positive bacteria and three Gram-negative bacteria were tested. It showed selective activities against the pathogenic bacteria *Vibrio anguillarum,* with the same MIC values of 0.26 μg/mL, stronger than the positive control ciprofloxacin (MIC = 0.52 μg/mL).\textsuperscript{122} When the compound was 50 μg on the antibacterial paper (Ø 6 mm), compound 468 showed strong antibacterial activities against *Escherichia coli, Bacillus subtilis* and *Staphylococcus aureus* such as the positive control ampicillin.\textsuperscript{146} Compound 160 showed antibacterial activity toward *Bacillus cereus* (IC\textsubscript{90} =49 μg/mL, IC\textsubscript{90} =111 μg/mL) and *Bacillus subtilis* (IC\textsubscript{50}=10 μg/mL, IC\textsubscript{90}=85 μg/mL) [191]. Libertellenone M 140 exhibited antibacterial activity against *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 27217), and *Vibrio vulnificus* (ATCC 27562) with MIC values of 32, 32, and 16 μg/mL, respectively.\textsuperscript{62} Compound 285 displayed antifungal activity against *Cryptococcus neoformans* ATCC90112 and ATCC90113 fluocytosine-resistant with the MIC values of 128 and 64 μg/mL, respectively.\textsuperscript{101} 11-Hydroxychevalone E 300 showed weak antibacterial activity against *Escherichia coli* and *Salmonella enterica* serovar *Typhimurium,* both with MIC 128 μg/mL.\textsuperscript{40} Membrane active compound PA3-d10 431 produced by *Aspergillus flavus* strain demonstrated antimicrobial activities against bacteria and yeast strains.\textsuperscript{139} Compounds 346 and 347 showed moderate to strong inhibitory activity against the tested Gram-positive bacteria. It is worth noting that 347 and 238 displayed potent antibacterial activities against methicillin-resistant *Staphylococcus aureus* ATCC 35971 with the same MIC value of 3.13 μg/mL, which was close to the positive control vancomycin (MIC 1.56 μg/mL).\textsuperscript{86} Compounds 372 and 371 both displayed antimicrobial activities against *Staphylococcus aureus* with MIC values of 25 and 75 μg/mL, respectively. Moreover, morphological observation showed the coccoid cells of *S. aureus* to be swollen to a volume of 1.4 and 1.7-fold after treatment with compounds 371 and 372, respectively. Microbial filamentous temperature-sensitive protein Z (FtsZ) is a novel target for drug discovery, which plays a key role in cell division. The inhibitors of FtsZ prevent the cellular fusion of bacteria, which lead to apoptosis of bacteria. Molecular docking was carried out to investigate interactions of filamentous temperature-sensitive protein Z (FtsZ) with compounds 371 and 372. The results indicated that compounds 372 might form lower potential energies
and more stable binding sites with the target protein FtsZ compared to compound 371 which validated the observed antimicrobial activities.\textsuperscript{126} MIC values of 200 μg/mL were obtained for compounds 472–473 towards \textit{Staphylococcus aureus} and \textit{Escherichia coli} using the micro-broth dilution method.\textsuperscript{116} Penicillaphones A-C (301–303) showed antibacterial activity against \textit{Staphylococcus aureus}. Compound 303 exhibited significant activity against the rice sheath blight pathogen \textit{Rhizoctonia solani}.\textsuperscript{105} Compounds 308 and 309 displayed moderate inhibitory effects on \textit{Staphylococcus aureus} and \textit{Bacillus cereus} with an inhibition rate of more than 50%. Additionally, compounds 307–309 showed weak antibacterial effects on MR \textit{Staphylococcus aureus}.\textsuperscript{109} Compounds 38 and 45 displayed significant antimicrobial activities. Compound 38 showed obvious inhibitory activities against seven pathogenic fungi (\textit{Alternaria fragariae}, \textit{Corynespora cassiicola}, \textit{Alternaria alternata}, \textit{Botrytis cinerei} Pers., \textit{Cercospora personata}, \textit{Verticillium dahliae} Kleb, \textit{Sclerotinia sclerotiorum}) with MIC values of 6.25–25 μg/mL (ketoconazole: 0.78–1.56 μg/mL), and compounds 38–47 except for 45 were active against \textit{A. fragariae} with MIC values of 6.25–50 μg/mL (ketoconazole: 0.78 μg/mL). Compounds 38–47 were also evaluated for their antibacterial activity toward Gram-positive and Gram-negative human pathogenic bacterial strains. The results indicated that compound 45 was active against all tested bacteria and compound 38 was active against \textit{Bacillus cereus} and methicillin-resistant \textit{Staphylococcus aureus}. Moreover, compound 39 exhibited weak activity against methicillin-resistant \textit{S. aureus}.\textsuperscript{25} Compound 373 exhibited potent antimicrobial activities against \textit{Staphylococcus aureus} with MIC values of 2.3 μg mL\textsuperscript{−1} and significant growth inhibitions of 82.3 ± 3.3 against \textit{Candida albicans} and of 79.2 ± 2.6 against \textit{Candida parapsilosis}. Compound 373 further showed strong activity against the pathogenic bacteria \textit{Escherichia fergusonii} with MIC of 3.1 μg mL\textsuperscript{−1}.\textsuperscript{127} Compounds 115 and 151 displayed interesting antifungal activity against \textit{Cryptococcus neoformans} ATCC90113 with the respective MIC values of 8 and 4 μg/mL. Moreover, only 115 was active against \textit{C. neoformans} ATCC90112 with the MIC value of 32 μg/mL.\textsuperscript{55} Compounds 295–297 also displayed moderate inhibitory effects on MR \textit{Staphylococcus aureus}, \textit{Staphylococcus aureus} and \textit{Bacillus subtilis}, which could be the major anti-bacterial constituents of \textit{Cephalotrichum microsporum}.\textsuperscript{104} Tolypocladin K 149 displayed moderate antifungal activity against \textit{Sclerotinia sclerotiorum}, \textit{Helminthosporium maydis}, \textit{Botrytis cinereal} Pers. and \textit{Colletotrichum acutatum} Simmonds with an MIC value of 50 μg/mL.\textsuperscript{64} Duclauxamide B 257 showed anti-\textit{Mycobacterium tuberculosis} activity with MIC value of 12.5 μg/mL and also had anti-\textit{Bacillus cereus} and anti-\textit{Staphylococcus aureus} with equal MIC values of 12.5 μg/mL.\textsuperscript{89} Compounds 312–321 showed antimicrobial inhibitory activities against \textit{Escherichia coli}, \textit{Staphylococcus aureus}, and \textit{Candida albicans} with MIC values ranging from 0.9 to 7.0 μg/mL, from 1.7 to 3.5 μg/mL, and from 3.3 to 7.0 μg/mL, respectively.\textsuperscript{111} Compound 66 was active against \textit{Fusarium oxysporum} with an MIC value of 50 μg/mL.\textsuperscript{34}

### Anti-Inflammatory Activities

In the in vitro anti-inflammation assay, bisacremine G 181 exhibited dose-dependent inhibitory effects on the production of TNF-α, IL-6, and nitric oxide (NO) in LPS-stimulated RAW 264.7 macrophages. At 50 μM, it inhibited TNF-α, IL-6, and NO production by 80.1%, 89.4%, and 55.7%, respectively. The inhibition was comparable to that of dexamethasone (inhibition rates at 50 μM: 78.0%, 92.6%, and 62.6%, respectively).\textsuperscript{70} Compounds 156–158 showed inhibitory activity against NO production in BV-2 microglial cells using the Griess assay with IC\textsubscript{50} values of 30.0 ± 1.5, 15.5 ± 0.5 and 8.8 ± 0.1μM, respectively. Indomethacin was used as a positive control (IC\textsubscript{50} = 34.5 ± 1.2 μM).\textsuperscript{66} Compounds 457–459 exhibited a significant inhibitory effect on the production of nitric oxide (NO) in murine macrophages (RAW 264.7) activated by lipopolysaccharide (LPS).\textsuperscript{145} Asterriquinol E 34 and asterriquinol F 35 have inhibitory effects on NO production induced by LPS in microglia cells with L\textsuperscript{L}-monomethyl-L\textsuperscript{L}-arginine (L\textsuperscript{L}-NMMA) as a positive control (IC\textsubscript{50} 4.8 μM) with IC\textsubscript{50} values of 11.3 μM and 49.7 μM respectively.\textsuperscript{23} Compared with dimethyl fumarate (DMF), a potent inflammation inhibitor, compound 211 exhibited weak anti-inflammatory activity in an ANA-1 murine macrophages model.\textsuperscript{75} There is experimental evidence that 138 and 139 could dose-dependently inhibit the activity of NF-κB and exhibited significantly inhibitory effects on nitric oxide (NO) production induced by lipopolysaccharide (LPS) in the murine RAW 264.7 macrophage cells.\textsuperscript{61} Mycroromanols A 396 and C 398 inhibited lipopolysaccharide (LPS)-induced NO production in BV2 cells with IC\textsubscript{50} values of 26.04 and 25.80 μM, respectively.\textsuperscript{130}
Antioxidant Activities
Compounds 323, 324 and 399 showed radical scavenging activity against DPPH with IC$_{50}$ values of 38.9, 42.7, and 87.5 μM, respectively.\textsuperscript{11} (E)-4-hydroxy-3-[(4-hydroxy-3-methylbut-2-en-1-yl)oxy] benzoic acid 367 showed radical scavenging activity against DPPH with IC$_{50}$ value of 0.51 mg/mL.\textsuperscript{96} Compound 305 exhibited potent DPPH radical scavenging activities with IC$_{50}$ value of 1.23μg/mL.\textsuperscript{107} Pochoniolides A 469 and B 470 showed hydroxyl radical-scavenging and singlet oxygen-quenching activities. Quercetin, pochoniolides A 469 and B 470 all showed scavenging activity against ·OH as well as a quenching effect on O$_2$. The detected values of ·OH and O$_2$ were suppressed by 6.7% and 4.3% in quercetin, 7.9% and 3.1% in pochoniolide A, and 1.2% and 0.5% in pochoniolide B, with being assumed that 100% generation represented a negative control.\textsuperscript{147} Trichotheic acid 92 exhibited hydroxyl radical-scavenging and singlet oxygen-quenching activities.\textsuperscript{47} Compounds 545–546 displayed radical-scavenging activity against 2,2-diphenyl-1-picyrylhydrazyl free radicals with the IC$_{50}$ values of 3.45 ± 0.02, 23.73 ± 0.08 μM, respectively. Compounds (±)-385, 387 exhibited potent antioxidant capacity with oxygen radical absorbance capacity values of 1.73 ± 0.13, 1.65 ± 0.03 μmol TE/μmol, respectively. Compounds (±)-385 and (±)-386 also exhibited protective effects on oxidative injury of PC12 cells induced by H$_2$O$_2$.\textsuperscript{128}

Antiviral Activities
Isoaspluvinone E 450 showed significant anti-influenza A H1N1 virus activities, with IC$_{50}$ value of 32.3 μg/mL.\textsuperscript{143} When compared with ribavirin (IC$_{50}$ 113.1 μM), compounds 10–12 and 14–15 exhibited significant protection against H1N1 virus-induced cytopathogenicity in MDCK cells with IC$_{50}$ values of 28.3, 38.9, 32.2, 73.3, 34.1 μM, respectively.\textsuperscript{17} Ochraceopeone A 102 and isoasteltoxin 363 exhibited antiviral activities against the H1N1 and H3N2 influenza viruses with IC$_{50}$ values of >20.0/12.2 ± 4.10 and 0.23 ± 0.05/0.66 ± 0.09 μM, respectively. It was noteworthy that the selectivity indexes (SI) of anti-H1N1 activity of 363 was 2.35.\textsuperscript{53} Compounds 280 and 281 exhibited anti-H1N1 activity with IC$_{50}$ values of 133.4, 44.6, respectively (ribavirin was used as the positive control, IC$_{50}$ 101.4 μM). They also showed a strong anti-HSV-1 activity with IC$_{50}$ values of 55.5 and 21.4 μM, respectively, compared with the positive control (acyclovir, IC$_{50}$ 150.2 μM). Compound 281 also possessed a strong anti-HSV-2 effect with IC$_{50}$ value of 76.7 μM (acyclovir as the positive control, IC$_{50}$ 128.6 μM), respectively.\textsuperscript{100}

Antimalarial Activities
Compound 17 was tested for antimalarial activity against the parasite Plasmodium falciparum (K1, multidrug resistant strain), and it showed weak antimalarial activity with an IC$_{50}$ value of 16.7 μM.\textsuperscript{18} Solaninaphthoquione 429 displayed weak antimalarial activity (IC$_{50}$ of 26.1 μM).\textsuperscript{138} Penicillermophile A 99 was approximately half as active against Plasmodium falciparum with the IC$_{50}$ value of 3.45 μM.\textsuperscript{51} Oxisterigmatocystin E 276 showed antimalarial activity against Plasmodium falciparum with IC$_{50}$ value of 7.9 μM.\textsuperscript{98} Macrosporone B 251 exhibited antimalarial activity against Plasmodium falciparum with IC$_{50}$ values of 10.28 μM.\textsuperscript{88}

Immunosuppressive Activities
Isochaetomium A2 351, compound 351 showed obvious inhibitory effects on mouse spleen cell proliferation with successive IC$_{50}$ values of 0.52 μM.\textsuperscript{120} Compounds 481 and 482 exhibited significant inhibition of ConA-induced T-cell proliferation, with IC$_{50}$ values of 4.1 and 1.9 μM, and LPS-induced B-cell proliferation with IC$_{50}$ values of 9.8 and 1.1 μM, respectively. Compounds 484, 485, and 488 exhibited selective immunosuppressive effects toward the LPS-induced B-cell proliferation with IC$_{50}$ values ranging from 5.5 to 21.9 μM.\textsuperscript{151} The bioactivity assays revealed that compounds 165, 166, 169, 170, and 173 exhibited a significant immunosuppressive effect against concanavalin A (ConA)-induced T lymphocyte proliferation with IC$_{50}$ values ranging from 5.6 to 8.8 μM.\textsuperscript{69} The immunosuppressive activity assay revealed that compounds 188, 189, and 193–196 showed significant inhibitory activity against concanavalin A (ConA)-induced T lymphocyte proliferation with IC$_{50}$ values ranging from 4.1 to 9.4 μM.\textsuperscript{72} In the immunosuppressive activity assay, compounds 201–202 showed potent inhibitory activity against concanavalin A (ConA)-induced T
lymphocyte proliferation with IC\textsubscript{50} values of 78.3, 81.1 nmol/L, respectively, which provided promising leads for designing and developing new immunsuppressive agents to treat auto-immunological diseases.\textsuperscript{73}

**Other Activities**

Paecilomide \textsuperscript{90} was evaluated for acetylcholinesterase inhibition, presenting 57.5±5.50\% of acetylcholinesterase inhibition.\textsuperscript{45} Compound \textsuperscript{217} was evaluated using in vitro binding assays of opioid receptors (subtypes δ, κ, and μ) and cannabinoid receptors (CB1 and CB2). Compound \textsuperscript{217} selectively inhibited 42\% of the specific binding of [3H]-DAMGO to CHO-K1 cell membranes expressing human μ-opioid receptors at 10 μM.\textsuperscript{79} For antiacetylcholinesterase activity, Mangrovamide C \textsuperscript{24} showed moderate acetylcholinesterase inhibitory effect with an IC\textsubscript{50} value of 58.0 μM.\textsuperscript{19} Compounds \textsuperscript{222} and \textsuperscript{223} were found to inhibit the conidial germination in the rice blast fungus \textit{Magnaporthe oryzae} at concentrations of 25 μg/mL, 50 μg/mL, respectively.\textsuperscript{81} Talacoumarins A \textsuperscript{400} and B \textsuperscript{401} had moderate anti-Aβ\textsubscript{42} aggregation activity, with relative inhibitory rates of (49.33 ± 3.16)\% and (44.99 ± 3.64)\% [the positive control EGCG had a relative inhibitory rate of (67.23 ± 2.51)\%] at the concentration of 100 μM, and this is the first report on the Aβ\textsubscript{42} inhibitory aggregation activity of coumarins.\textsuperscript{131} In the brine shrimp lethality assay, rubrumazine B \textsuperscript{26} exhibited potent activity, with LD\textsubscript{50} value of 2.43 μM, Compounds \textsuperscript{25, 27} displayed modest activities, with LD\textsubscript{50} values of 29.8 and 16.5 μM.\textsuperscript{20} Compound \textsuperscript{523} exhibited the most potent activity against HMG-CoA reductase, with an IC\textsubscript{50} value of 387 μM. In addition, the present study indicated the direct interaction of compound \textsuperscript{523} with HMG-CoA reductase.\textsuperscript{160} Talaraculones A and B (357 and 358) exhibited stronger inhibitory activity against α-glucosidase than the positive control acarbose (IC\textsubscript{50} = 101.5 μM), with IC\textsubscript{50} values of 78.6 and 22.9 μM, respectively.\textsuperscript{122} Asperuein A \textsuperscript{526} was active against acetylcholinesterase (AchE) with a ratio of 62\% at the concentration of 50 μM.\textsuperscript{93} (–) Benzomalvins E \textsuperscript{80} enhanced the cytotoxic capability of 5-fluorouracil against A549 on a different level.\textsuperscript{39} Compounds \textsuperscript{142, 145, and 146} showed comparable seed-germination-promoting activities to that previously reported for the growth regulator cotylenin E.\textsuperscript{63} Exophiarin \textsuperscript{422} has been evaluated by glucose uptake assay (GUA) using L6 skeletal muscle cells (myotubes), which takes up glucose for its metabolic activities through the glucose transporter protein, GLUT4. And exophiarin \textsuperscript{422} with TPI-2 and TPI-5 have displayed moderate improvement in glucose uptake activity when tested in rat skeletal muscle cell line L6.\textsuperscript{135} Compound \textsuperscript{478} dose-dependently inhibited bone morphogenetic protein–induced alkaline phosphatase activity in myoblasts with half-maximal inhibitory concentration values of 19.8 μM.\textsuperscript{150} Compounds \textsuperscript{206–210} could inhibit the hepatic glucose production with EC\textsubscript{50} values of 17.6, 30.1, 21.3, 9.6, and 9.9 μM, respectively, and decrease the cAMP contents in glucagon-induced HepG2 cells.\textsuperscript{74}

**Concluding Remarks and Discussion**

Based on the above literature, as mentioned above, we analyzed the classification of these new compounds and the proportion of different types of these new compounds. From the analysis data, 279 of the 546 new compounds are active. In these activity categories, anticancer and antimicrobial active compounds accounted for a large proportion, 36.2\% and 30.8\%, respectively (Figure 9). From the strain sources of these new compounds, \textit{Aspergillus}, \textit{Penicillium} and \textit{Talaromyces} accounted for the majority, accounting for about 56\%. We also classified and analyzed the compounds from different strains, as illustrated in Figure 10. In addition, we also analyzed the habitats of these source strains. Compared with special habitats, such as alpine, polar regions, oceans, etc., most of the strains are from non-extreme living environments (66.9\%) and rhizosphere soil (21.8\%) (Figure 11). We also made an interesting analysis to analyze the proportion of different compounds in the same activity, for example, among the 86 compounds with antimicrobial activity, there are 44 ketone compounds, accounting for about 51\%. Among the compounds with immunosuppressive activity, terpenes and steroids accounted for about 68\% (Figure 12).

In this review, we summarized 546 new compounds derived from soil fungi, classified them according to their structures, and classified their activities, including anticancer, antimicrobial, anti-inflammatory, antioxidant, antiviral, antimalaria, and immunsuppressive activities. From the 546 new compounds from soil fungi and their activities summarized in this review since 2011, it is noteworthy that among these active compounds, anticancer and antimicrobial activities account for almost 51\%. In order to facilitate readers’ understanding, we have made a table In this table, readers can more clearly and simply understand the microbial sources, biological activities, habitats of microbial sources, and
relevant references of these new compounds. All information about the new compounds are briefly summarized in Table 1. It may provide a lot of help for future drug research and development. Microorganisms have provided abundant sources of natural products, which have been developed as commercial products for human medicine, animal health, and plant crop protection. 

Fungi are an ideal source for obtaining novel skeletons through large-scale culture: compared with plants, fungi can proliferate rapidly from small amounts of spores to a mass of branching hyphaes, which are more environmentally friendly than collecting plant materials; compared with bacteria, fungi can be cultured in a solid medium...
for a longer time. Specifically, a large-scale culture can produce unexpected rearrangements and combinatorial chemistry, which serve as “dark tunnels” to novel scaffolds. Artifacts are formed during isolation/purification of natural products. Factors such as pH, temperature, light, oxygen, humidity, and metal ions can lead to structural changes. Specific examples have been discussed in detail in a recent review on the formation of natural-product artifacts. Artifacts are often intentionally or unintentionally overlooked, but in large-scale culture it is an issue that cannot be ignored. Extensive separation of large-scale extracts exposes natural products to longer exposure to solvents, heat, air, light, and pH variations during extraction, partitioning, chromatography and drying. The change of these external factors will inevitably affect the metabolism of microorganisms and the change of compound structure. Therefore, one problem arising from the use of large-scale cultivation of fungi is how to obtain stable access to those minor metabolites with novel skeletons. This may need to be solved in combination with chemical synthesis. Another problem is the habitat source of the strains. In this review, we analyzed the habitats of the strains involved. Although most of the strains come from non-extreme habitats, we still expect to obtain fungal strains from some extreme habitats. The extremobiosphere encompasses a broad range of biomes that include hyperarid deserts, deep-sea sediments and permafrost soils, as well as acid and high-temperature environments. Such extreme habitats are characterized by combinations of environmental
### Table 1 Brief Summary of New Compounds

| NO | Compounds         | Fungal Strain          | Place                              | Biological activity                                                                 | Ref. |
|----|-------------------|------------------------|------------------------------------|--------------------------------------------------------------------------------------|------|
|    | **Alkaloids**     |                        |                                    |                                                                                      |      |
| 1  | Pseudofischerine  | Neosartorya pseudofischeri | Anngthong Province, Thailand       | --                                                                                   | [10] |
| 2–3| Peneciraistins E-F| Penicillium raistrickii | Shandong Province, China           | -                                                                                   | [11] |
| 4* | Exopisiod         | Exophiala piscipha strain PHF 9 | Yunnan Province, China             | Induction of apoptosis                                                              | [12] |
| 5* | Walskiazoid A     | Aspergillus sp.        | Honolulu, Hawaii                   | Suppresses Hyphal Morphogenesis and Inhibits Biofilm Development in Pathogenic Candida albicans | [13] |
| 6  | Effusin A         | Aspergillus effusae    | Fujian Province, China             | Antitumor activity                                                                  | [14] |
| 7* | Dihydrocryptochoxinulin D |                      |                                    |                                                                                      |      |
| 8* | Dihydroneochinulin B | Aspergillus effusae   | Fujian Province, China             | Cytotoxic activity                                                                  | [15] |
| 9  | Unnamed           | Neosartorya fischeri  | KUFC 6344                          | -                                                                                   | [16] |
| 10*| 3-deoxo-4b-deoxypaxilline | Penicillium camemberti       | Hainan Province, China             | Antiviral activity against the H1N1 virus                                            | [17] |
| 11*| 4a-demethylpapaline-4a-carboxylic acid |                        |                                    |                                                                                      |      |
| 12*| 4a-demethylpapaline-3,4,4a-triol |                        |                                    |                                                                                      |      |
| 13 | 2'-hydroxyxapilline |                        |                                    |                                                                                      |      |
| 14*| 9,10-disopentenylxapilline |                      |                                    |                                                                                      |      |
| 15*| (6,7R,10E,14E)-16-(1H-Indol-3-yl)-2,6,10,14-tetramethylhexadeca-2,10,14-tetraene-6,7-diol |                        |                                    |                                                                                      |      |
| 16, 17*, 18-21| Asperdiazapiones A-F | Aspergillus sp. PSU- RSPG185 | Suratthani Province, Thailand       | Antimalarial activity                                                                | [18] |
| 22-23, 24*| Mangrovamides A-C | Penicillium sp. SYFz- | Hainan Province, China              | Moderate acetylcholinesterase inhibitory activity                                   | [19] |
| 25*, 26*, 27*| Rubrumazines A-C | Eurotium rubrum MA-150 | Andaman Sea coastline, Thailand     | Brine shrimp lethality                                                              | [20] |
| 28 | Penilline A       | Penicillium sp. SCSIO 05705 | Chinese Antarctic station          | -                                                                                   | [21] |
| 29 | Isopenilline A    |                        |                                    |                                                                                      |      |
| 30 | Penilline B       |                        |                                    |                                                                                      |      |
| 31–32, 33*| Kumbicins A-C  | Aspergillus kumbias FRR6049 | Southern Queensland, Australia     | Antitumour activity; Antimicrobial activity                                        | [22] |
| 34*, 35*| Astarriquinols E-F | Aspergillus sp.CBS- P-2 | Jilin Province, China              | Inhibitory activities against LPS-induced NO production in microglia BV-2 cells (34*, 35*); Cytotoxicity (34*) | [23] |
| 36–37| Cyclopiamines C-D | Penicillium sp. CML 3020 | Atlantic Forest, Brazil            | -                                                                                   | [24] |

(Continued)
Table 1 (Continued).

| NO | Compounds                      | Fungal Strain          | Place                  | Biological activity                                                                 | Ref. |
|----|--------------------------------|------------------------|------------------------|-------------------------------------------------------------------------------------|------|
| 38*, 39*, 40*, 41*, 42*, 43*, 44*, 45*, 46*, 47* | Tolypocladins A-J      | Tolypocladium sp. XLI15 | Hunan Province, China                   | Cytotoxic activity (38*); Antibacterial activity (38*, 39*, 45*); Antifungal activity (38*, 40*, 41*, 42*, 43*, 44*, 46*, 47*) | [25] |
| 48*, 49* | Chaetomadrasins A-B  | Chaetomium madrasense 375 | Sinkiang Province, China | Cytotoxicity                                                                      | [26] |
| 50 | Paraherquamide J               | Penicillium janthinellum HKI-6 | Hainan Province, China | -                                                                                  | [27] |
| 51–52 | Trypomadrasins W-X  | Aspergillus terreus FS107 | Top of Mauna Kea, Hawaii | -                                                                                  | [28] |
| 53*, 54–55 | Cytochalasins Z24-26 | Eustypella sp. D-1       | London Island of Kongsfjorden, Arctic | Cytotoxicity                                                                     | [29] |
| 56 | Aspergillichalasin             | Aspergillus sp. PSU-RSPG185 | Surat Thani Province, Thailand | -                                                                                  | [30] |
| 57*, 58 | Iizukines C-D                | Aspergillus iizukae      | Shandong Province, China | Cytotoxicity                                                                      | [31] |
| 59 | MBj-0030                      | Stachybotrys sp. Ω23793  | Shizuoka prefecture, Japan | -                                                                                  | [32] |
| 60 | MBj-0031                      |                         |                         |                                                                                   |      |
| 61 | MBj-0032                      |                         |                         |                                                                                   |      |
| 62*, 63*, 64*, 65* | Pycnidiphorones A-D | Pycnidiphora dispersa    | Hebei Province, China | Cytotoxicity                                                                      | [33] |
| 66* | Clonorosin A                  | Clonostachys rosea      | Bank of the Yellow River in Lanzhou, Gansu, China | Active (66*) against Fusarium oxysporum                                              | [34] |
| 67 | Clonorosin B                  |                         | Bank of the Yellow River in Lanzhou, Gansu, China |                                                                                   |      |
| 68*, 69*, 70*, 71*, 72*, 73* | Gymnastatins T-Y         | Gymnascella dankaliensis | Giza pyramids, Egypt | Cytotoxicity                                                                      | [35] |
| 74* | Dankastatin D                 |                         |                         |                                                                                   |      |
| 75 | N-[4-hydroxy-3-prenyl-benzoyl]-L-threonine | Curvularia inaequalis strain HS-FG-257 | Heilongjiang Province, China | -                                                                                  | [36] |
| 76 | N-[2,2-dimethyl-2H-chromene-6-carbonyl]-L-threonine | Penicillium sp. H9318 | Malaysia | -                                                                                  | [37] |
| 77 | (S5)-3,4,5,7-tetraamethyl-5,8-dihydroxy-6(5H)-isoquinolione | Neosartorya pseudofischeri | Anhong Province, Thailand | -                                                                                  | [10] |
| 78 | 3,8-Diacetyl-4-(3-methoxy-4,5-methyleneoxy)benzyl-7-phenyl-6-oxa-3,8-diazabicyclo[3.2.1]octane | Neosartorya pseudofischeri | Anhong Province, Thailand | -                                                                                  |      |
| 79 | Fusaravenin                   | Fusarium oxysporum SF-1502 | Gansu Province, China | -                                                                                  | [38] |
| NO | Compounds | Fungal Strain | Place | Biological activity | Ref. |
|----|------------|---------------|-------|---------------------|------|
| 80* | (-) Benzomalvins E | *Penicillum* sp. SYPF 0411 | Xinjiang Uygur Autonomous Region, China | Indoleamine 2,3-dioxygenase (IDO) inhibitor | [39] |
| 81 | Tryptoquivaline V | *Neosartorya pseudofischeri* | Chiang Mai forest, Thailand | - | [40] |
| 82 | Brasiliamide G | | | | |
| 83 | Talarodone A | Co-culture of *Talaromyces pinophilus* and *Paraphaeosphaeria* sp. | Miyazaki Prefecture, Japan | - | [41] |
| 84–86 | Asperidines A-C | *Aspergillus* sclerotiorum PSU-RSPG178 | Surat Thani Province, Thailand | - | [42] |
| 87 | Iizukine E | *Aspergillus iizukae* | Shandong Province, China | - | [31] |
| 88 | Methyl (2Z,3E,5E,7E,9E)-4,10-dimethyl-11-(2,5-dioxopyrrolidin-3-yl)-2-(2-hydroxyethylidene)-11-oxoundeca-3,5,7,9-tetraenoate | *Aspergillus* sp. OUCMDZ-1914 | Hainan Province, China | - | [43] |
| 89* | Virgarcin B | *Virginia boninensis* FKI-4958 | The Bonin Islands, Tokyo, Japan | Antibacterial activity | [44] |
| 90* | Paecilomide | *Poeckonomyces lilacinus* | UPMG, MG, Brazil | Acetylcholinesterase inhibitory activity | [45] |
| 91 | Clonostalactam | *Clonostachys rosea* | Banyumas, Indonesia | - | [46] |
| 92* | Trichothioneic acid | *Trichoderma virens* FKI-7573 | Obihiro, Hokkaido, Japan | | |
| | Terpenoids and steroids | | | | |
| 93*, 94 | Fudecadiones A-B | *Penicillum* sp. BCC 17468 | Khao Yai National Park, Nakhon Ratchasima, Thailand | Anticancer activity | [48] |
| 95* | Bu-Hydroxyroridin H | *Myrothecium* sp. GS-17 | Gansu Province, China | Antifungal Activity | [49] |
| 96* | Myrotheacin A | | | | |
| 97*, 98* | Penicibitaenes A-B | *Penicillum biliae* MA-267 | Hainan Province, China | Antifungal activity | [50] |
| 99*, 100 | Penicilleremophilanes A-B | *Penicillum copécalus* PSU-RSPG138 | Surat Thani Province, Thailand | Cytotoxic activity; Antimycobacterial activity; Antimalarial activity | [51] |
| 101* | Aspergiketone | *Aspergillus fumigatus* | Shandong Province, China | Cytotoxicity | [52] |
| 102*, 103–106 | Ochraceopones A-E | *Aspergillus ochraceopetaliformis* SCSIO 05702 | Chinese Antarctic station | Antiviral activity | [53] |

(Continued)
| NO  | Compounds                                                                 | Fungal Strain                  | Place                          | Biological activity                                      | Ref.   |
|-----|---------------------------------------------------------------------------|--------------------------------|--------------------------------|---------------------------------------------------------|--------|
| 107*| 13-Hydroxy-3,8,7(11)-eudesmatrien-12,8-olide                             | Eutypella sp. 1–15             | Fujian Province, China         | Antibacterial activity; Anticancer activity             | [54]   |
| 108 | 13-Hydroxy-3,5,8,7(11)-eudesmatetraen-12,8-olide                        |                                |                                |                                                         |        |
| 109 | 2-One-13-hydroxy-3,5,8,7(11)-eudesmatetraen-12,8-olide                  |                                |                                |                                                         |        |
| 110 | 8,13-Dihydroxy-3,7(11)-eudesmadien-12,8-olide                          |                                |                                |                                                         |        |
| 111 | 3/-hydroxy-3/-acoreniol                                                   | Fusarium proliferatum AF-04   | Green Chinese onion            | -                                                       | [38]   |
| 112 | Cyclonerotriol B                                                          | Fusarium oxysporum SF-1502     |                                | -                                                       |        |
| 113–114, 115*| Trichodermapenes A-C                                                      | Trichoderma reesei PSU-SPSF013 | Narathiwat Province, Thailand  | Antifungal activity                                     | [55]   |
| 116–118| Dictyosporins A-C                                                         | Dictyosporium digitatum        | Herod, Illinois, USA           | -                                                       | [56]   |
| 119 | Trichoctinovirene A                                                       | Trichoderma citrinoviride PSU-SPSF346 | Sirindhorn Peat Swamp Forest, Narathiwat Province, Thailand | - | [57] |
| 120 | Trichoctinovirene B                                                       |                                |                                |                                                         |        |
| 121 | unnamed                                                                   | Aspergillus calidoustus        | Dianchi Lake, Yunnan Province.China | - | [58] |
| 122 | unnamed                                                                   |                                |                                |                                                         |        |
| 123 | unnamed                                                                   |                                |                                |                                                         |        |
| 124 | unnamed                                                                   |                                |                                |                                                         |        |
| 125 | unnamed                                                                   |                                |                                |                                                         |        |
| 126 | unnamed                                                                   |                                |                                |                                                         |        |
| 127 | unnamed                                                                   |                                |                                |                                                         |        |
| 128*| Sarotrypyrone A                                                           | Neosartorya fischeri KUFC 6344 | Thailand                       | Anticancer activity                                     | [16]   |
| 129*, 130*| Libertellenones G-H                                                       | Eutypella sp. D-I              | London Island of Kongsfjorden, Arctic | Antibacterial activity (129*); Anticancer activity (130*) | [59]   |
| 131 | 4b-deoxy-1'-D-acetylpenicilline                                           | Penicillium sp. CM-7           | Yunnan Province, China         | -                                                       | [60]   |
| 132 | 4b-deoxy-1'-O-acetylpaxilline                                             |                                |                                |                                                         |        |
| 133*, 134*, 135*, 136*, 137*| Libertellenones O-S                                                       | Eutypella sp. D-I              | London Island of Kongsfjorden, Arctic | Cytotoxicity (133*,139*); Inhibit the activity of NF-κB inhibitory effects on nitric oxide production induced by lipopolysaccharide (138*, 139*) | [61]   |
| 138*, 139*| Eutypellenones A-B                                                        |                                |                                |                                                         |        |
| 140*, 141*| Libertellenones M-N                                                       | Eutypella sp. D-I              | London Island of Kongsfjorden, Arctic | Cytotoxicity (140*, 141*); Antibacterial activity (140*) | [62]   |
| 142*, 143, 144, 145*, 146*, 147, 148 | Dongtingnoids A-G                                                         | Penicillium sp. DT10           | Hunan Province, China | Seed-germination-promoting activity                      | [63]   |

(Continued)
Table 1 (Continued).

| NO            | Compounds                                | Fungal Strain            | Place                        | Biological activity                        | Ref. |
|---------------|------------------------------------------|--------------------------|------------------------------|--------------------------------------------|------|
| 149*, 150     | Tolypocladins K-L                        | Tolypocladium sp. XL115  | Hunan Province, China        | Antifungal activity (149*)                  | [64] |
| 151*          | Trichodermanene                          | Trichoderma reesei PSU-SPSF013 | Narathiwat Province, Thailand | Antifungal activity                        | [55] |
| 152           | 4,25-dehydrodiminolutelide B             | Penicillium sp. MA-37    | Hainan Province, China       |                                            | [65] |
| 153           | 4,25-dehydro-22-deoxyminolutelide B      |                         |                              |                                            |      |
| 154           | Isominolutelide A                        |                          |                              |                                            |      |
| 155, 156*,    | Purpurogenolides A-E                     | Penicillium purpureum MHz111 | Heilongjiang Province, China  | Inhibition of nitric oxide production      | [66] |
| 157*, 158*,   |                                        |                          |                              |                                            |      |
| 159           |                                        |                          |                              |                                            |      |
| 160*, 161*,   | Unnamed                                  | Penicillium sp.          | Liaoning Province, China     | Cytotoxic activity (160*, 161*); Antibacterial activity (160*) | [67] |
| 162–163       |                                        |                          |                              |                                            |      |
| 164           | Terretonin M                             | Aspergillus terreus TMB  | A hot (~50 °C) desert place, South Egypt |                                            | [68] |
| 165*          | Δ12,19-dehydroxyarthripenoid A           | Bipolaris zeicola        | Hubei Province, China        | Significant inhibitory effect against concanavalin A (ConA)-induced T lymphocyte proliferation (165*, 166*, 169*, 170*, 173*); Cytotoxic activity (163*, 166*, 168*) | [69] |
| 166*          | 12,19-didehydroxy-arthripenoid A         |                          |                              |                                            |      |
| 167           | Tetrahydrofuran-3-epi-cochlioquinone A   |                          |                              |                                            |      |
| 168*          | Isotetrahydrofuran-3-epi-cochlioquinone A|                          |                              |                                            |      |
| 169*          | 19-dehydroxy-arthripenoid A              |                          |                              |                                            |      |
| 170*          | Δ1,19-dehydroxy-arthripenoid A           |                          |                              |                                            |      |
| 171           | 4-acetoxy-isocochlioquinone D             |                          |                              |                                            |      |
| 172           | 4-acetoxy-31α-methoxy-isocochlioquinone D|                          |                              |                                            |      |
| 173*          | 19-dehydroxyl-31-keto-3-epi-arthripenoid A|                          |                              |                                            |      |
| 174           | Acremine T                               | Acremonium persinicum SCO10S | Guangdong Province, China | Cytotoxicity                               | [5]  |
| 175*, 176*, 177–178 | Bisacremines A-D          |                          |                              |                                            |      |
| 179–180,181*  | Bisacremines E-G                         | Acremonium persinicum SCO10S | Guangdong Province, China | Anti-inflammatory activity                  | [70] |
| 182           | Asperanstinoid A                         | Aspergillus calidoustus  | Dianchi Lake, Yunnan Province, China | Cytotoxicity (185*) against the HL- 60 and SU-DHL-4 tumor cell lines. | [71] |
| 183           | Asperanstinoid B                         |                          |                              |                                            |      |
| 184           | Asperanstinoid C                         |                          |                              |                                            |      |
| 185*          | Asperanstinoid D                         |                          |                              |                                            |      |
| 186           | Asperanstinoid E                         |                          |                              |                                            |      |

(Continued)
| NO  | Compounds               | Fungal Strain       | Place                                                                 | Biological activity                                                                 | Ref. |
|-----|-------------------------|---------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------|------|
| 187 | Bipolaquinone A         | Bipolaris zeicola   | Mo Mountain of East Lake, Wuhan City of Hubei Province, China         | Inhibitory activity (188*, 189*, 193*, 194*, 195*, 196*) against concanavalin A (ConA)-induced T lymphocyte proliferation | [72] |
| 188*| Bipolaquinone B         |                     |                                                                      |                                                                                     |      |
| 189*| Bipolaquinone C         |                     |                                                                      |                                                                                     |      |
| 190 | Bipolaquinone D         |                     |                                                                      |                                                                                     |      |
| 191 | Bipolaquinone E         |                     |                                                                      |                                                                                     |      |
| 192 | Bipolaquinone F         |                     |                                                                      |                                                                                     |      |
| 193*| Bipolaquinone G         |                     |                                                                      |                                                                                     |      |
| 194*| Bipolaquinone H         |                     |                                                                      |                                                                                     |      |
| 195*| Bipolaquinone I         |                     |                                                                      |                                                                                     |      |
| 196*| Bipolaquinone J         |                     |                                                                      |                                                                                     |      |
| 197 | Bipolarinoid A          | Bipolaris zeicola   | Mo Mountain of East Lake, Wuhan City of Hubei Province, China        | Inhibitory activity (201*, 202*) against concanavalin A (ConA)-induced T lymphocyte proliferation | [73] |
| 198 | Bipolarinoid B          |                     |                                                                      |                                                                                     |      |
| 199 | Bipolarinoid C          |                     |                                                                      |                                                                                     |      |
| 200 | Bipolarinoid D          |                     |                                                                      |                                                                                     |      |
| 201*| Bipolarinoid E          |                     |                                                                      |                                                                                     |      |
| 202*| Bipolarinoid F          |                     |                                                                      |                                                                                     |      |
| 203*| Aspergorakhin B         | Aspergillus gorakhpurensis F07ZB1707 | Mountainous region of shennongjia Forestry District, Hubei Province of China | Inhibitory effect (203*) against Protein tyrosine phosphatases including PTP1B, SHP1, and TCPTP in vitro. | [6]  |
| 204 | Aspergorakhin C         |                     |                                                                      |                                                                                     |      |
| 205 | Aspergorakhin D         |                     |                                                                      |                                                                                     |      |
| 206*| Encindolene D           | Penicillium sp. HFF16 | Rhizosphere soil of Cynanchum bungei Deone., in Mount Tai, China    | Inhibit the hepatic glucose production(206*, 207*, 208*, 209*, 210*)                | [74] |
| 207*| Encindolene E           |                     |                                                                      |                                                                                     |      |
| 208*| Encindolene F           |                     |                                                                      |                                                                                     |      |
| 209*| Encindolene G           |                     |                                                                      |                                                                                     |      |
| 210*| Encindolene H           |                     |                                                                      |                                                                                     |      |
| 211*| 4α-methyl-9α-methoxyandrosta-8,15-diene-3,17-dione | Curvularia borreri strain HS-FG-237 | - | Cytotoxicity; anti-inflammatory activity | [75] |
| 212*| unnamed                | Aspergillus flavus JDW-1 | - | Cytotoxicity | [76] |
| 213*| Aspergorakhin A         | Aspergillus gorakhpurensis F07ZB1707 | Mountainous region of Shennongjia Forestry District, Hubei Province of China | Inhibitory effect against Protein tyrosine phosphatases including PTP1B, SHP1, and TCPTP in vitro. | [6]  |

**Ketones**

| NO  | Compounds                   | Fungal Strain       | Place                               | Biological activity                                                                 | Ref. |
|-----|-----------------------------|---------------------|-------------------------------------|------------------------------------------------------------------------------------|------|
| 214*| 1-(3,5-dihydroxyphenyl)-4-hydroxypentan-2-one | Exsiphia pascipha PHF-9 | Yunnan Province, China,              | Cytotoxicity                                                                        | [77] |
| 215*| Pyrenocine J                | Curvularia affinis strain HS-FG-196 | Jilin Province, China               | Cytotoxicity                                                                        | [78] |
| 216 | Pyrenochaetic acid D        |                     |                                     |                                                                                    |      |
| NO   | Compounds             | Fungal Strain                | Place                        | Biological activity                                      | Ref. |
|------|-----------------------|------------------------------|------------------------------|----------------------------------------------------------|------|
| 217* | Euparvione            | Eupenicillium parvum         | Cuba                         | Binding human µ- opioid receptors                        | [79] |
| 218  | Euparvilactone        |                              |                              |                                                          |      |
| 219  | Penicillither          | Penicillium sp. PSU-RSPG99   | Surat Thani Province, Thailand|                                                          |      |
| 220-221, 222*, 223* | Tanzawaic acids I-L   | Penicillium sp. IBWF104-06   | Kaiserslautern, Germany                             | Inhibited the conidial germination in Magnaporthe oryzae | [81] |
| 224-226 | Blennolides H-J     | Alternaria sp.               | Vicinity of Wailua Falls, Hawaii |                                                          |      |
| 227-230 | Pyrenochoaetic acids E-H |                              |                              |                                                          |      |
| 231*, 232,233 | Asperochrins A-C   | Aspergillus ochraceus MA-15  | Hainan Province, China                  | Antibacterial activity                                   | [83] |
| 234* | Iizukine A            | Aspergillus iizukae          | Shandong Province, China                  | Cytotoxicity against cancer cell                        | [84] |
| 235-236 | Penicipyran A-B      | Penicillium rostrincki       | Shandong Province, China                  | Cytotoxicity                                             | [85] |
| 237* | Penicipyran E         |                              |                              |                                                          |      |
| 238*, 239 | Penijanthinones A-B  | Penicillium janthinellum HK1-6| Hainan Province, China                  | Displayed potent antibacterial activity                  | [86] |
| 240*, 241* | Talaroketals A-B    | Talaromyces stipitis ATCC 10500 |                              | Antimicrobial activity                                   | [87] |
| 242  | Aspergorakhin E       | Aspergillus gorakhppurensis F07ZB/1707 | Mountainous region of Shennongia Forestry District, Hubei Province of China |                                                          | [6]  |
| 243  | Aspergorakhin F       |                              |                              |                                                          |      |
| 244  | Aspergorakhin G       |                              |                              |                                                          |      |
| 245  | Aspergorakhin H       |                              |                              |                                                          |      |
| 246  | Aspergorakhin I       |                              |                              |                                                          |      |
| 247  | Aspergorakhin J       |                              |                              |                                                          |      |
| 248  | Aspergorakhin L       |                              |                              |                                                          |      |
| 249  | Talaromycesone C      | Talaromyces macrosporus KU-KNK8 | Khon Kaen Province, Thailand     | Antimalarial activity (251*); Cytotoxicity (250*, 251*, 253*) | [88] |
| 250*, 251*, 252, 253*, 254 | Macroporusones A-E |                              |                              |                                                          |      |
| 255*, 256* | Bacillisporsin I-J   | Talaromyces bacillisporsin BCC17645 | Khao Yai National Park, Nakhon Ratchasima Province, Thailand | Cytotoxicity (255*-258*); Antibacterial activity (257*) | [89] |
| 257*, 258* | Duclauxamides B-C    |                              |                              |                                                          |      |
| 259  | 9a-epi-Bacillisporsin E | Talaromyces stipitis          |                              | Antimicrobial activity; Cytotoxicity                     | [90] |
| 260  | Bacillisporsin F      |                              |                              |                                                          |      |
| 261  | 1-epi-bacillisporsin F |                              |                              |                                                          |      |
| 262, 263* | Bacillisporsins G-H  |                              |                              |                                                          |      |
| 264  | Aspergone              | Aspergillus sp. SCSIO41002   | Hainan Province, China                  |                                                          | [91] |

(Continued)
| NO  | Compounds                                                                 | Fungal Strain                      | Place                                    | Biological activity                        | Ref. |
|-----|---------------------------------------------------------------------------|------------------------------------|------------------------------------------|--------------------------------------------|------|
| 265* | 7-methoxy-2,2-dimethyl-4-octa-4',6'-dienyl-2H-naphthalene-1-one          | Penicillium sp                     | Punjab, India                            | Antimicrobial activity; Cytotoxicity       | [92] |
| 266–268 | Aspereusins C-E                                      | Aspergillus terreus YIM PH30711  | New Delhi, India                         | -                                          | [93] |
| 269  | Penicilloxanthone                                                        | Penicillium sp. PSU-RSPG99         | Surat Thani Province, Thailand           |                                            | [80] |
| 270* | Catochrin                                                                | Alternario sp.                     | Vicinity of Waiula Falls, Hawaii         | Antibacterial activity; Cytotoxic activity | [82] |
| 271  | Blennolide G                                                             |                                     |                                          |                                            |      |
| 272  | Penicilloxanthone                                                        | Penicillium citrinum PSU-RSPG95    | Surat Thani Province, Thailand           | -                                          | [94] |
| 273a | 6-[1,2-dimethyl-6-(2-methyl-allyloxy)-hexyl]-3-(2-methoxy-phenyl)-chromen-4-one | Penicillium sp. HT-28 | Punjab, India                            | Antibacterial activity                     | [95] |
| 274  | 2-(2',4',6'-Trihydroxyphenyl)-(7-hydroxy-5-methyl)chromone                | Aspergillus aculeatus              | Chongqing, China                         | -                                          | [96] |
| 275  | Penicillanthone                                                          | Penicillium aculeatum PSU-RSPG105  | Surat Thani Province, Thailand           | -                                          | [97] |
| 276*, 277* | Oxisterigmatocystins E-F                                          | Botryatrium piliferum              | Sangkhla Buri, Kanchanaburi Province, Thailand | Antimalarial activity (276*); Cytotoxicity(276*, 277*) | [98] |
| 278*, 279 | Penixanthones A-B                                                  | Penicillium sp. SYFz-1             | Hainan Province, China                   | Cytotoxicity                               | [99] |
| 280* | Methyl-(2-chloro-6-dihydroxy-3-methylxanthone)-8-carboxylate           | Aspergillus iizukae                | Shandong Province, China                 | Antiviral activity                         | [100]|
| 281* | Methyl-(4-chloro-6-dihydroxy-3-methylxanthone)-8-carboxylate            |                                    |                                          |                                            |      |
| 282  | Methyl-(4-chloro-6-hydroxy-1-methoxy-3-methylxanthone)-8-carboxylate    |                                    |                                          |                                            |      |
| 283  | Methyl-(6-hydroxy-1-methoxy-3-methylxanthone)-8-carboxylate             |                                    |                                          |                                            |      |
| 284  | 4-chloro-1,6-dihydroxy-3-methylxanthone-8-carboxylic acid              |                                    |                                          |                                            |      |
| 285*–286–287 | Blennolides L-N                | Trichoderma asperellum PSU-PSF14   | Narathiwat Province, Thailand            | Antifungal activity                        | [101]|
| 288  | Wentixanthone A                                                          | Aspergillus wenti                  | Hypersaline lake El Hamra in Wadi El-  | -                                          | [102]|
| 289–290 | Fusarpynes A-B                                              | Fusarium solani PSU-RSPG37         | Surathani Province, Thailand             | -                                          | [103]|
| 291–292 | Coniochetonones E-F                                                  | Penicillium citrinum PSU-RSPG95    | Surat Thani Province, Thailand           | -                                          | [94] |
| 293  | Penicillanone                                                            |                                     |                                          |                                            |      |

(Continued)
Table 1 (Continued).

| NO  | Compounds                                      | Fungal Strain               | Place                          | Biological activity                                                                 | Ref.  |
|-----|-----------------------------------------------|-----------------------------|--------------------------------|-------------------------------------------------------------------------------------|-------|
| 294 | 8′-O-(3R-Hydroxy-butryl)-rasfonin             | Cephalotrichum microsporum  | Yunnan Province, China         | Antibacterial (295*-297*) activity; Anti-tumor activity (294*, 295*)                 | [104] |
| 295-297 | Cemironins A-C                                 |                             |                                |                                                                                      |       |
| 298 | 4-Methyl-B,10-dihydroxy-caprylic acid         |                             |                                |                                                                                      |       |
| 299 | Chevalone F                                   | Neosartorya pseudofischeri  |                                | Antibacterial activity                                                               | [40]  |
| 300 | 11-hydroxychevalone E                         |                             |                                |                                                                                      |       |
| 301*, 302*, 303* | Peninaphones A-C                             | Penicillium sp. HK1-22      | Hainan Province, China           | Antibacterial activity (301*, 302*); Antimicrobial activity (303*)                   | [105] |
| 304 | Helvafuranone                                  | Aspergillus nidulans BF0142 | Hokkaido, Japan                 | -                                                                                    | [106] |
| 305* | (α)-europhenol A                              | Eurotium rubrum MA-150      | Andaman Sea coastline, Thailand  | DPPH radical scavenging activities                                                   | [107] |
| 306 | Aspersclerotiorone E                          | Aspergillus sclerotiorum PSU-KSPG178 | Surat Thani Province, Thailand | -                                                                                    | [108] |
| 307* | Harzianone                                    | Cephalotrichum microsporum  | Yunnan Province, China          | Antibacterial activity                                                               | [109] |
| 308* | Harzialol                                     |                             |                                |                                                                                      |       |
| 309* | Harzialol acid                                |                             |                                |                                                                                      |       |
| 310 | Gotjawaside                                   | Auxarthron sp. KCB15F070    | Volcanic island Jeju, Korea     | -                                                                                    | [110] |
| 311 | Gotjawalide                                   |                             |                                |                                                                                      |       |
| 312*, 313* | Thiocarboxylics A-B                         | Penicillium sp. zb62        | Hunan Province, China           | Antibacterial activity                                                               | [111] |
| 314*, 315* | Thiocarboxylics C1-2                    |                             |                                |                                                                                      |       |
| 316*, 317* | Thiocarboxylics D1-2                   |                             |                                |                                                                                      |       |
| 318*, 319* | Gregatin F1-2                            |                             |                                |                                                                                      |       |
| 320*, 321* | Gregatin G1-2                          |                             |                                |                                                                                      |       |
| 322 | R-Hexitronic acid                            | Penicillium sp. FG9RK       | Agulu in Anambra state, Nigeria | -                                                                                    | [112] |
| 323*, 324*, 325* | Penecirastins A-C                        | Penicillium rasnitzky       | Shandong Province, China         | Radical scavenging activity against DPPH (323*, 324*); Induces caspase-independent autophagic cell death through mitochondrial-derived reactive oxygen species production in lung cancer cells (325*) | [11,166] |
| 326* | Sporulosol                                    | Pantoconiumtium sporulosum  | Jiangxi Province, China         | Cytotoxicity                                                                         | [113] |
| 327 | (+)-(S)-arugosin K                           | Tolotomyces flavus          | Sinkiang Province, China        | -                                                                                    | [114] |
| 328 | (-)-(S)-arugosin K                           |                             |                                |                                                                                      |       |
| 329 | (+)-(S)-arugosin L                           |                             |                                |                                                                                      |       |
| 330 | (-)-(S)-arugosin L                           |                             |                                |                                                                                      |       |
| 331 | (+)-(S)-arugosin M                           |                             |                                |                                                                                      |       |
| 332 | (-)-(S)-arugosin M                           |                             |                                |                                                                                      |       |
| 333 | Arugosin N                                   |                             |                                |                                                                                      |       |
Table 1 (Continued).

| NO     | Compounds                          | Fungal Strain       | Place                                      | Biological activity                                      | Ref.   |
|--------|------------------------------------|---------------------|--------------------------------------------|----------------------------------------------------------|--------|
| 334–335| Asperunnguisones A-B               | Aspergillus unguis  | PSU-RSPG204 (Thailand)                     |                                                          | [115]  |
| 336    | (±)-4-hydroxy-3-methoxy-5-methyl-2-cyclopentenone | Aspergillus Seratrum | Shandong Province, China                   |                                                          | [116]  |
| 337*   | Polluxochrin                      | Alternaria sp.      | Vicinity of Wailua Falls, Hawaii          | Antibacterial activity; Cytotoxic activity                | [82]   |
| 338*   | Dioschin                          |                     |                                            |                                                          |        |
| 339    | Dimethylamide asterrate           |                     |                                            |                                                          |        |
| 340*, 341–342 | Nectriatones A-C               | Nectria sp. B-13    | Arctic island of Spitzbergen, Svalbard    | Cytotoxicity                                             | [117]  |
| 343    | Curvulopyran                      | Aspergillus polyporicola PSU-RSPG187 | Surat Thani Province, Thailand          |                                                          | [118]  |
| 344    | ent-curvulone A                   |                     |                                            |                                                          |        |
| 345    | 7-methoxy-2,3,6-trimethylchromone | Exaphilo pisciphila  | Yunnan Province, China                    |                                                          | [77]   |
| 346*, 347* | Penicilones G-H                 | Penicillium janthellum HK1-6 | Hainan Province, China                   | Show moderate inhibitory activity against Gram-positive bacteria (346*); Antibacterial activity (347*) | [86]   |
| 348    | Tetrahydrotrichodimer ether        | Clonostachys rosea  | Gansu Province, China                     | Antibacterial activity                                   | [119]  |
| 349*, 350* | Dihydrotrichodimer ethers A-B   |                     |                                            |                                                          |        |
| 351*   | Isochaetomium A$_2$               | Chaetomium microcephalum | Sichuan Province, China              | Antibacterial activity; Inhibitory effects on mouse spleen cell proliferation | [120]  |
| 352    | Wensthenone A                     | Aspergillus wentii  | Hypersaline lake El Hamra in Wadi El-Natrun, Egypt |                                                          | [102]  |
| 353, 354*, 355*, 356* | Penicilones A-D                | Penicillium janthellum HK1-6 | Hainan Province, China                   | Antibacterial activity                                   | [121]  |
| 357*, 358*, 359–362 | Talaraculones A-F             | Tolaramyces aculeatus | Shandong Province, China                 | Inhibitory activity against α-glucosidase (357*, 358*); Antibacterial activity (358*) | [122]  |
| 363*   | Isoasteltoxin                     | Aspergillus ochraceopetaliformis SCSIO 05702 | Chinese Antarctic station               | Antiviral activity                                        | [53]   |
| 364*   | Curvularone A                     | Curvulario inequalis strain HS-FG-257 | Heilongjiang Province, China           | Antitumor activity                                        | [123]  |
| 365*   | 4-hydroxyradianthin               |                     |                                            |                                                          |        |
| 366    | 1-(2',4'-dihydroxy-5'-methyl-3'-methylsulfanyl(methylphenyl)-ethanone | Penicillium crustosum YN-HT-15 | Yunnan Province, China                  |                                                          | [124]  |
| 367*   | (E)-4-Hydroxy-3-[(4-hydroxy-3-methylbut-2-en-1-yl)oxy] benzoic acid | Aspergillus aculeatus | Chongqing, China                        | Antagonism to DPPH                                        | [96]   |
| 368–369 | Talatflavols B-C                  | Tolaramyces flavus  BYD07-13 | Guangzhou Province, China               |                                                          | [125]  |
| 370    | Aspereusin B                      | Aspergillus terreus  YIM PH30711 | New Delhi, India                        |                                                          | [93]   |
| 371*   | Seltsamiayu                       | Seltsania galinsgooli sp. nov. | Liaoning Province, China                | Antibacterial activity                                   | [126]  |
| 372*   | Galinsogoolyu                     |                     |                                            |                                                          |        |

(Continued)
Table 1 (Continued).

| NO   | Compounds                                                                 | Fungal Strain                      | Place                                           | Biological activity                                                                 | Ref. |
|------|----------------------------------------------------------------------------|------------------------------------|------------------------------------------------|-------------------------------------------------------------------------------------|------|
| 373* | 1-(4-hydroxy-2,6-dimethoxy-3,5-dimethylphenyl)-2-methyl-1-butanone          | Aspergillus sp.                   | Riyadh, Saudi Arabia                           | Antimicrobial activity                                                               | [127] |
| 374  | Dictyosporin D                                                             | Dictyosporium digitatum            | Herod, Illinois, USA                           | -                                                                                   | [56]  |
| 375  | Dictyocyclhalide A                                                         |                                    |                                                 |                                                                                     |      |
| 376–379 | Dictyofurans A-D                                                          |                                    |                                                 |                                                                                     |      |
| 380  | Dictyosporon A                                                             |                                    |                                                 |                                                                                     |      |
| 381–382 | Xylariolides E-F                                                        |                                    |                                                 |                                                                                     |      |
| 383* | Aspergorakhin K                                                            | Aspergillus gorakhpurensis         | Mountainous region of Shennongjia Forestry District, Hubei Province of China | Inhibitory effect against Protein tyrosine phosphatases including PTP1B, SHP1, and TCPTP in vitro. | [6]  |
| 384  | Sulfurasperine A                                                           | Aspergillus fumigatus F07ZB1707    |                                                 |                                                                                     |      |
| 385* | Sulfurasperine B ((±)-2)                                                  |                                    | Caves in Guizhou province of China            | Antioxidant capacity (385*, 387*); protective effects (385*, 386*) on oxidative injury of PC12 cells induced by H2O2 | [128] |
| 386* | Sulfurasperine C ((±)-3)                                                  |                                    |                                                 |                                                                                     |      |
| 387* | Sulfurasperine D                                                           |                                    |                                                 |                                                                                     |      |

Phenylpropanoids

| 388*, 389*, 390*, 391–393 | Spiromastols A-F                                          | Spiromastix sp. MCCC 3A00308 | South Atlantic Ocean | Antibacterial activity | [129] |
| 394*, 395*               | Spiromastols J-K                                        |                                    |                                                 |                                                                                     |      |
| 396*, 397*, 398*         | Myrochromans A-C                                        | Myrothecium verrucaria HL-P-1     | Heilongjiang Province, China                     | Inhibited lipopolysaccharide (LPS)-induced NO production in BV2 cells             | [130] |
| 399*                     | Penecraistin D                                           | Penicillum raistrickii            | Shandong Province, China                         | Radical scavenging activity against DPPH                                         | [11]  |
| 400* , 401*              | Talacoumarins A-B                                       | Talaromyces flavus BYD07-13      | Hebei Province, China                            | Anti-β<sub>42</sub> aggregation activity                                        | [131] |
| 402–403, 404*            | Spiromastols G-I                                        | Spiromastix sp. MCCC 3A00308     | South Atlantic Ocean                            | Antibacterial activity                                                            | [129] |
| 405*                     | (35)-6-O-((4'-O-methyl-6'-acetetyl-β-D-glucopyranoside)-7-O-methyl-8'-hydroxyl-3-[(3E)-pent-3-enyl]-3,4-dihydroisocoumarin | Metarhizium anisopliae DTH12-10 | -                                               | Antibacterial activity                                                            | [132] |
| 406                       | (35)-7-O-((4'-O-methyl-6'-glucopyranoside)-6,8-dihydroxyl-3-[(3E)-pent-3-enyl]-3,4-dihydroisocoumarin |                                    |                                                 |                                                                                     |      |
| 407                       | (35)-6-O-((4'-O-methyl-6'-glucopyranoside)-7-O-methyl-8'-hydroxyl-3-[(3E)-pent-3-enyl]-3,4-dihydroisocoumarin |                                    |                                                 |                                                                                     |      |
| 408                       | (35)-6-O-((4'-O-methyl-6'-glucopyranoside)-8-hydroxyl-3-[(3E)-pent-3-enyl]-3,4-dihydroisocoumarin |                                    |                                                 |                                                                                     |      |

(Continued)
| NO | Compounds                                                                 | Fungal Strain          | Place                                      | Biological activity                                      | Ref.  |
|----|---------------------------------------------------------------------------|------------------------|--------------------------------------------|----------------------------------------------------------|-------|
| 409| (3S)-6-O-(4'-O-methyl-D-glucopyranoside)-5,8-dihydroxy-3-[(3E)-pent-3-enyl]-3,4-dihydroisocoumarin |                        |                                            |                                                          |       |
| 410| 6-O-(4'-O-methyl-D-glucopyranoside)-7-O-methyl-8-hydroxy-3-[(3E)-pent-3-enyl]-isocoumarin          |                        |                                            |                                                          |       |
| 411| (3R)-6-O-(4'-O-methyl-D-glucopyranoside)-8-hydroxy-3-[(1E,3E)-penta-1,3-dienyl]-dihydroisocoumarin |                        |                                            |                                                          |       |
| 412| (3R)-6-O-(4'-O-methyl-D-glucopyranoside)-7-O-methyl-8-hydroxy-3-[(1E,3E)-penta-1,3-dienyl]-dihydroisocoumarin |                        |                                            |                                                          |       |
| 413–414| Talaisocoumarins A-B                                                  | Talaromyces flavus BYD07-13 | Guangzhou Province, China                  |                                                          | [125] |
| 415| Talaflavuol A                                                           |                        |                                            |                                                          |       |
| 416–417| Penicipyrans C-D                                                     | Penicillium raistrickii | Shandong Province, China                   |                                                          | [85]  |
| 418| (3R,4R)-4,8-Dihydroxy-5-(hydroxymethyl)-3-methylisochroman-1-one       | Hypoxylon sp.          | Heilongjiang Province, China              |                                                          |       |
| 419| (3R,4S)-4,8-Dihydroxy-5-(hydroxymethyl)-3-methylisochroman-1-one       |                        |                                            |                                                          |       |
| 420*| (9R*)-8-methyl-9,11-dichlorodiaporthin                                  | Hamigera fusca NRRL 35721 | Maoueni, Grande Comore Island            | Cytotoxic activity against cancer cell lines              | [134] |
| 421*| (9S*)-8-methyl-9,11-dichlorodiaporthin                                  |                        |                                            |                                                          |       |
| 422*| Exophiarin                                                              | Exophiala sp.          | Kaziranga National Park, Assam            | Improvement in glucose uptake activity when tested in rat skeletal muscle cell line L6 | [135] |

Quinones

| NO | Compounds                        | Fungal Strain          | Place                                      | Biological activity                                      | Ref.  |
|----|----------------------------------|------------------------|--------------------------------------------|----------------------------------------------------------|-------|
| 423*, 424| Citriquinones A-B              | Penicillium citrinum | University of Srijayawardenepura, Sri Lanka | Antibacterial activity; Cell migration inhibitory activity | [136] |
| 425| Penicilliquinone                | Penicillium sp. PSU-RSPG99  | Surat Thani Province, Thailand             |                                                          | [80]  |
| 426| Penicherqueinone                | Penicillium herquei PSU-RSPG93  | Surat Thani Province, Thailand             |                                                          | [137] |
| 427*, 428| Aspergillusansones A-B         | Aspergillus sp. PSU-RSPG185  | Surat Thani Province, Thailand             | Cytotoxicity                                              | [30]  |
| 429*| Solaninaphthoquione            | Fusarium solani PSU-RSPG227  | Surat Thani Province, Thailand             | Cytotoxic; Antimalarial activity                          | [138] |
| 430| Kumbicin D                      | Aspergillus kumbius FRR6049  | Queensland, Australia                      |                                                          | [22]  |
| 431*| PA3-d10                         | Aspergillus flavus       | Iran                                       | Antimicrobial activity                                    | [139] |
Table 1 (Continued).

| NO | Compounds                  | Fungal Strain            | Place                                      | Biological activity                           | Ref. |
|----|----------------------------|--------------------------|--------------------------------------------|------------------------------------------------|------|
| 432–433 | Wentibianthrones A-B   | Aspergillus wentii       | Hypersaline lake El Hamra in Wadi El Nazrun, Egypt | -                                              | [102]|
| 434 | Wentibianthrones C (cis/trans) | Penicillium hortense FT729 | Active volcano, Hawaii                     | -                                              | [140]|
| 435 | Herqueilenone A          | Penicillium hortense FT729 | Big Island, Hawaii                        | Inhibitory activity (436*) against indoleamine 2,3-dioxygenase 1 (IDO1) | [141]|
| 436* | (-)-scleroamide          | Penicillium hortense FT729 | Big Island, Hawaii                        | Inhibitory activity (436*) against indoleamine 2,3-dioxygenase 1 (IDO1) | [141]|
| 437 | (+)-scleroamide          | Penicillium hortense FT729 | Big Island, Hawaii                        | Inhibitory activity (436*) against indoleamine 2,3-dioxygenase 1 (IDO1) | [141]|
| 438 | Esters and lactones      | Neosartorya pseudofischeri | Anghong Province, Thailand                | -                                              | [10] |
| 439 | R-3-(3'-acetyl-2',6'-dihydroxy-5'-methylphenyl)-2-methyl-propanoic acid methyl ester | Penicillium crustulatum YN-HT-15 | Yunnan Province, China | -                                              | [124]|
| 440–443, 444*, 445* | Telapolyesters A-F     | Tolomoryses flavus BY067-13 | Hebei Province, China                     | Cytotoxic activity                             | [142]|
| 446 | 4-(4-Hydroxyphenethoxy)-4-oxobutanoic acid | Fusarium solani PSU-RSPG227 | Surat Thani Province, Thailand            | -                                              | [138]|
| 447 | Penicillithiophenols A-B | Penicillium coticola PSU-RSPG138 | Surat Thani Province, Thailand            | -                                              | [51]  |
| 448–449 | Isoasapulinone E     | Aspergillus terreus Gwoq-48 | Fujian Province, China                  | Anti-influenza A viral (H1N1)                 | [143]|
| 450* | Aspergillusulstone      | Aspergillus sp. PSU-RSPG185 | Surat Thani Province, Thailand           | -                                              | [30]  |
| 451 | Cinartrins D-E          | Virgaria boninensis FKI-4958 | Bonin Islands, Tokyo, Japan               | Antibacterial activity                         | [44]  |
| 452*, 453* | Aspersclerotiorones A-D | Aspergillus unguis PSU-RSPG199 | Surat Thani Province, Thailand           | -                                              | [144]|
| 454 | Aspersclerotiorones F-G | Aspergillus unguis PSU-RSPG199 | Surat Thani Province, Thailand           | -                                              | [144]|
| 456, 457*, 458*, 459*, 460, 461 | Penicimenoles A-F   | Penicillium sp. SYP-F-7919 | Yunnan Province, China                  | Cytotoxicity; Inhibitory effect on NO production | [145]|
| 462–465 | Aspersclerotiorones A-D | Aspergillus sclerotiorum PSU-RSPG178 | Surat Thani Province, Thailand           | -                                              | [108]|
| 466–467 | Aspersclerotiorones F-G | Aspergillus sclerotiorum PSU-RSPG178 | Surat Thani Province, Thailand           | -                                              | [108]|
| 468* | eut-Guaines sesquiterpene | Eutypella sp. D-1 | London Island of Kongfjorden, Arctic     | Antibacterial activity; Cytotoxicity          | [146]|
| 469*, 470* | Aspersclerotiorones A-B | Pochonia chamydiaspora var. spinulospora FKI-7537 | Nichima, Tokyo, Japan                  | Antioxidant activity                            | [147]|
| 471*, 472*, 473* | Aspersclerotiorones A-C | Aspergillus Sclerotiorum | Shangdong Province, China                | Cytotoxic activity (471*, 473*); Antibacterial activity (472*, 473*) | [116]|
| 474 | (z)-Aspersclerolide D   | Aspergillus Sclerotiorum | Shangdong Province, China                | Cytotoxic activity (471*, 473*); Antibacterial activity (472*, 473*) | [116]|

(Continued)
Table 1 (Continued).

| NO  | Compounds                                                                 | Fungal Strain                               | Place                                      | Biological activity                                                                                     | Ref.   |
|-----|---------------------------------------------------------------------------|---------------------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------------------------|--------|
| 475–476 | Botryosphaerilactones D-E                                                  | Lasiodiplodia theobromae NSTRU-PN1.4       | Nakhon Si Thammarat Province, Thailand     | -                                                                                                       | [148]  |
| 477  | Therlanubutanolide A                                                       | Thermomyces lanuginosus                     | Yunnan Province, China                     | -                                                                                                       | [149]  |
| 478* | 6-ethoxy-5,6-dihydropenillic acid                                         | Penicillium sp. BF-0343                     | Fuji Cemetery, Shizuoka, Japan             | Inhibited BMP-induced ALP activity                                                                   | [150]  |
| 479  | Ilyoresorcy A                                                              | Ilyonectria sp. sb65                        | Hunan Province, China                      | Inhibition of ConA-induced T-cell proliferation (481*, 482*); Immunosuppressive effects toward the LPS-induced B-cell proliferation (484*, 485*, 488*) | [151]  |
| 480* | Acrop-ilyoresorcy A                                                        | Ilyoresorcs B-K                             |                                           |                                                                                                        |        |
| 481*, 482, 483*, 484*, 485, 486, 487*, 488–490 | Other compounds                          |                                             |                                           |                                                                                                        |        |
| 491*, 492–493 | Prenylphenyllins A-C                                                      | Aspergillus taichungensis ZHN-7-07          |                                           | -                                                                                                       | [152]  |
| 494* | 4'-dehydro-3-hydroxytrypophenyllin                                        |                                             |                                           |                                                                                                        |        |
| 495, 496*, 497 | Preynycandidusins A-C                                                      |                                             |                                           |                                                                                                        |        |
| 498  | 4-hydroxy-4-(3-methoxy-3-methylbutyl)-benzoic acid                        | Curvularia inaequalis strain HS-FG-257      | Heilongjiang Province, China               | -                                                                                                       | [153]  |
| 499  | (Z)-2-(5-hydroxyhexyl)pent-2-enedioic acid                               | Gongronella butleri                         | Forest at Koukoue, Cameroon               | -                                                                                                       | [154]  |
| 500  | (Z)-2-hexylpent-2-enedioic acid                                           |                                             |                                           |                                                                                                        |        |
| 501  | (Z)-2-(5-oxohexy)pent-2-enedioic acid                                     |                                             |                                           |                                                                                                        |        |
| 502  | (Z)-oct-2-ene-1,3,8-tricarboxylic acid                                    |                                             |                                           |                                                                                                        |        |
| 503  | (Z)-2-(5-hydroxyoctyl)pent-2-enedioic acid                               |                                             |                                           |                                                                                                        |        |
| 504  | (Z)-2-(3-methoxy-3-oxopropylidene) decanoic acid                          |                                             |                                           |                                                                                                        |        |
| 505  | (Z)-2-(7-oxooctyl)pent-2-enedioic acid                                   |                                             |                                           |                                                                                                        |        |
| 506  | (Z)-2-(8-hydroxyoctyl)pent-2-enedioic acid                               |                                             |                                           |                                                                                                        |        |
| 507*, 508*, 509* | Peniciketals A-C               | Penicillium raistrichii                     | Shangdong Province, China                 | Cytotoxic activity                                                                                     | [155]  |
| 510* | MIG0310                                                                   | Fusarium brachygibbus strain MS-R1          | Mediterranean forest, Israel               | Antimicrobial activity                                                                                  | [156]  |
| 511–512 | Aspergilusols A-B                           | Aspergillus sp. PSU-RSPG185                 | Surat Thani Province, Thailand             |                                                                                                        | [30]   |
| 513  | Aspergillic acid                                                           |                                             |                                           |                                                                                                        |        |

(Continued)
| NO | Compounds                                | Fungal Strain                                      | Place                        | Biological activity                                      | Ref.   |
|----|------------------------------------------|---------------------------------------------------|------------------------------|----------------------------------------------------------|--------|
| 514| 11'-carboxygymnastatin N                 | Gymnascella dankaliensis                          | Giza pyramids, Egypt         | Cytotoxicity                                              | [157]  |
| 515| Gymnastatin S                            |                                                   |                              |                                                          |        |
| 516| Dankamide                                |                                                   |                              |                                                          |        |
| 517*| Aranorosin-2-methylether                |                                                   |                              |                                                          |        |
| 518*| izukine B                                | Aspergillus izukian                              | Shandong Province, China     | Cytotoxicity against cancer cell                         | [84]   |
| 519*| Scerotiumol                              | Sclerotium rolfsai                               | District Malakand, Khyber Pakhtunkhwa Pakistan | Effective multidrug resistant (MDR) mediated by P-glycoprotein (P-gp) modulator | [158]  |
| 520| Versicorin                               | Aspergillus versicolor SC0156                    | Guangdong Province, China    |                                                          | [159]  |
| 521–522, 523*| Unnamed                               | Aspergillus sclerotinum PSU-RSPG178           | Surat Thani Province, Thailand | Activity against HMG-CoA reductase                         | [160]  |
| 524| Asterreusin A                            | Aspergillus terreus YIM PH30711                   | New Delhi, India             | Inhibitive activities against acetylcholinesterase (AChE) | [93]   |
| 525| Unnamed                                  |                                                   |                              |                                                          |        |
| 526*| Aspereusin A                             |                                                   |                              |                                                          |        |
| 527| Epiaspereusin A                          |                                                   |                              |                                                          |        |
| 528–530| Penicillidic acids A-C                  | Penicillium oculatum PSU-RSPG105               | Surat Thani Province, Thailand |                                                          | [97]   |
| 531–532, 533*| Aspergilusethers B-D                 | Aspergillus unguis PSU-RSPG204                   | Surat Thani Province, Thailand | Antifungal activity                                      | [115]  |
| 534–535| Melleusins A-B                          | Melleus YIM PH001                                | New Delhi, India             |                                                          | [161]  |
| 536*| 3-methylpentyl-2,4-dichloroasterrinate | Aspergillus flavipes PJ03-11                    | Lisoning Province, China     | Cytotoxic activity                                        | [162]  |
| 537| 6R,8R-dihydroxy-9Z,12Z-octadecadienoic acid | Penicillium javanicum HK1-22                 | Hainan Province, China       |                                                          | [163]  |
| 538| Methyl-6R,8R-dihydroxy-9Z,12Z-octadecadienoate | Penicillium oculatum PSU-RSPG105           | Surat Thani Province, Thailand |                                                          |        |
| 539| Penoxalin                                | Penicillium oculatum                             | Shanghai, China              | Cytotoxic activity                                        | [164]  |
| 540–541| Penisochromans A-B                     | Penicillium oculatum                             | Shanghai, China              | Cytotoxic activity                                        | [164]  |
| 542*| 2,6-dihydroxy-4-[[2R]-2-hydroxyheptyl] benzoic acid | Penicillium oculatum                             | Shanghai, China              | Cytotoxic activity                                        | [164]  |
| 543*| Pyrenosetin D                           | Pyrenochetops sp. PVE-087                        | Falckenstein Beach, Kiel Fjord, Baltic Sea, Germany | Cytotoxic activity                                        | [165]  |
| 544| Unnamed                                  | Aspergillus calidustus                           | Dianchi Lake, Yunnan Province, China |                                                          | [58]   |
| 545*| 4-Methoxy-7-methylbenzo[d]thiazole-5,6-diol | Aspergillus flavipes GZVMHz-152                | Caves in Guizhou province of China | Radical-scavenging activity (545*, 546*) against 2,2'-diphenyl-1-picrylhydrazyl free radicals | [128]  |
| 546*| 2'-Hydroxymethyl-4-methoxy-7-methylbenzo[d]thiazole-5,6-diol | Aspergillus flavipes GZVMHz-152                | Caves in Guizhou province of China | Radical-scavenging activity (545*, 546*) against 2,2'-diphenyl-1-picrylhydrazyl free radicals | [128]  |

Note: *Bioactive compounds.
variables, such as anoxia, aridity, extreme temperatures, low concentrations of organic matter, high salinity and intense irradiation. The search for new bioactive compounds from the extremobiosphere rests on the premise that harsh abiotic conditions select for novel microorganisms that express new chemistry.\textsuperscript{169} In order to adapt to extreme habitats, the strains are bound to adjust their metabolism, and new secondary metabolites will increase in this process, we may get some compounds with good biological activity.

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**Disclosure**

The authors report no conflicts of interest in this work.

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