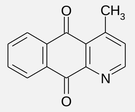
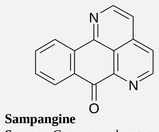
Total syntheses of natural products

worked out by the Bracher group

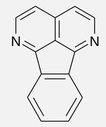
Polycyclic aromatic alkaloids:



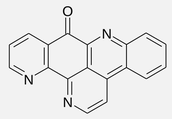
Cleistopholine
Source: *Cleistopholis patens* (Annonaceae)
Synthesis: Liebigs Ann. Chem. **1989**



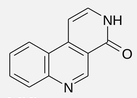
Sampangine
Source: *Cananga odorata* (Annonaceae)
Synthesis: Liebigs Ann. Chem. **1989**; Eur. J. Chem. **2015**



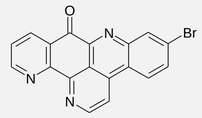
Eupolauridine
Source: *Cleistopholis patens and others* (Annonaceae)
Synthesis: Arch. Pharm. (Weinheim) **1989**



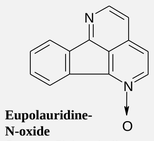
Ascididemin
Source: *Didemnum sp.* (Didemnidae; ascidian)
Synthesis: Heterocycles **1989**



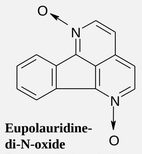
Perlolidine
Source: *Lolium perenne* (Poaceae)
Synthesis: Arch. Pharm. (Weinheim) **1989**



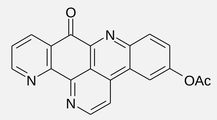
Bromoleptoclinidinone
Source: *Leptoclinides sp.* (ascidian)
Synthesis: Liebigs Ann. Chem. **1990**



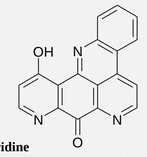
Eupolauridine-N-oxide
Source: *Cleistopholis patens* (Annonaceae)
Synthesis: Pharmazie **1993**



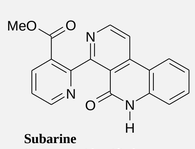
Eupolauridine-di-N-oxide
Source: *Cleistopholis patens* (Annonaceae)
Synthesis: Pharmazie **1993**



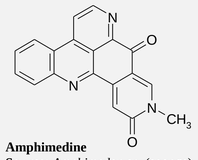
Neocalliactine acetate
Source: *Calliactis parasitica* (sea anemone)
Synthesis: Liebigs Ann. Chem. **1992**



Meridine
Source: *Amphicarpa meridiana* (ascidian)
Synthesis: Tetrahedron **1997**

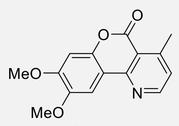


Subarine
Source: unidentified Singaporean ascidian
Synthesis: Sci. Pharm. **2009**

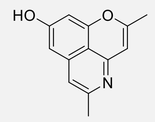


Amphimedine
Source: *Amphimedon sp.* (sponge)
Synthesis: Liebigs Ann. **1996**

Demethyldeoxyamphimedine
Source: *Cystodytes dellechiajei* (ascidian)
Synthesis: J. Org. Chem. **2014**

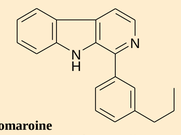


Polynemoraline C
Source: *Polyalthia nemoralis and others* (Annonaceae)
Synthesis: Eur. J. Org. Chem. **2023**



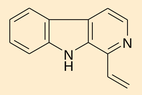
Cassiarin A
Source: *Cassia siamea* (Leguminosae)
Synthesis: to be published

β-Carboline and canthinone alkaloids:

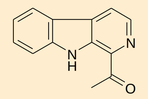


Komaroine
Source: *Nitraria komarovii* (Zygophyllaceae)
Synthesis: Liebigs Ann. Chem. **1992**

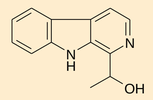
Perlolyrine
Source: *Lolium perenne and others*
Synthesis: Liebigs Ann. Chem. **1992**



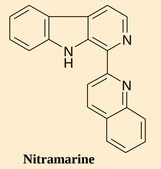
Pavettine
Source: *Pavetta lanceolata*, (Rubiaceae) and others
Synthesis: Liebigs Ann. Chem. **1992**



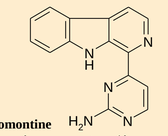
1-Acetyl-β-carboline
Source: *Ailanthus malabarica* (Simaroubaceae) and others
Syntheses: Liebigs Ann. Chem. **1993**; Synth. Commun. **1995**



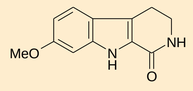
1-Hydroxyethyl-β-carboline
Source: *Costaticella hastate* (Bryozoa)
Syntheses: Liebigs Ann. Chem. **1993**; Tetrahedron **1994**



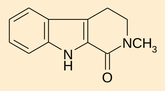
Nitramarine
Source: *Nitraria komarovii* (Zygophyllaceae)
Syntheses: Liebigs Ann. Chem. **1993**; Tetrahedron **1994**



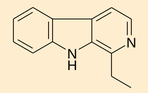
Annomontine
Source: *Annona montana* (Annonaceae)
Synthesis: Liebigs Ann. Chem. **1993**; J. Heterocyclic Chem. **2009**



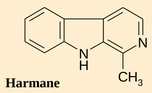
Harmalacidine
Source: *Banisteriopsis caapi* (Malpighiaceae) *and others*
Synthesis: Pharmazie **1993**



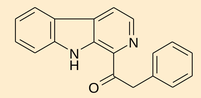
Strychnocarpine
Source: *Strychnos elaeocarpa and others*
Synthesis: Pharmazie **1993**



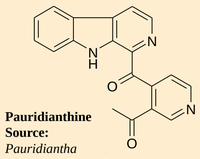
1-Ethyl-β-carboline
Source: *Hannoa klaineana and others*
Synthesis: Liebigs Ann. Chem. **1993**



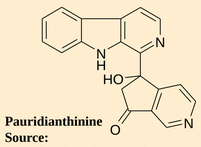
Harmane
Source: *Peganum harmala* (Nitrariaceae) and others
Syntheses: Liebigs Ann. Chem. **1993**; J. Heterocyclic Chem. **2004**; Tetrahedron **2016**



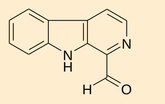
Eudistomin T
Source: *Eudistoma olivaceum* (ascidian)
Synthesis: Arch. Pharm. (Weinheim) **1994**



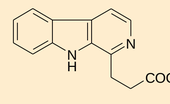
Pauridianthine
Source: *Pauridiantha callicarpoides* (Rubiaceae)
Synthesis: Tetrahedron **1994**



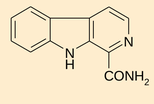
Pauridianthinine
Source: *Pauridiantha callicarpoides* (Rubiaceae)
Synthesis: Tetrahedron **1994**



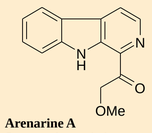
1-Formyl-β-carboline
Source: *Picrasma quassioides* (Simaroubaceae)
Synthesis: Tetrahedron **1994**



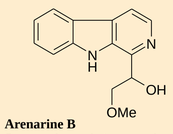
Infractine
Source: *Cortinarius infractus* (fungus) and others
Synthesis: Pharmazie **1995**



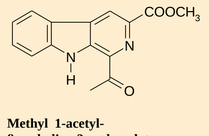
1-Carbamoyl-β-carboline
Source: *Nauclea diderrichii and others*
Synthesis: Synth. Commun. **2003**



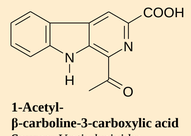
Arenarine A
Source: *Arenaria kansuensis* (Caryophyllaceae)
Synthesis: J. Heterocyclic Chem. **2004**



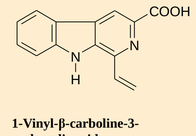
Arenarine B
Source: *Arenaria kansuensis* (Caryophyllaceae)
Synthesis: J. Heterocyclic Chem.**2004**



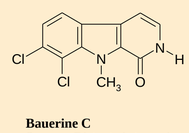
Methyl 1-acetyl-β-carboline-3-carboxylate
Source: *Vestia lycioides* (Solanaceae)
Synthesis: Nat. Prod. Res. **2004**



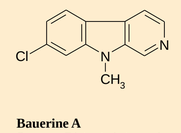
1-Acetyl-β-carboline-3-carboxylic acid
Source: *Vestia lycioides* (Solanaceae)
Synthesis: Nat. Prod. Res. **2004**



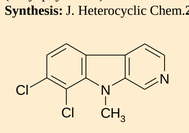
1-Vinyl-β-carboline-3-carboxylic acid
Source: *Nocardiopsis sp.* (bacterium)
Synthesis: Nat. Prod. Res. **2004**



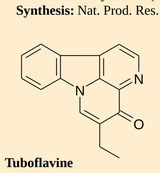
Bauerine C
Source: *Dichothrix baueriana* (blue-green alga)
Synthesis: Synth. Commun. **2007**



Bauerine A
Source: *Dichothrix baueriana* (blue-green alga)
Synthesis: Synth. Commun. **2007**



Bauerine B
Source: *Dichothrix baueriana* (blue-green alga)
Synthesis: Synth. Commun. **2007**



Tuboflavine
Source: *Pleiocarpa mutica and others*
Synthesis: J. Heterocyclic Chem. **2009**

Norisotuboflavine
Source: *Pleiocarpa mutica* (Apocynaceae)
Synthesis: J. Heterocyclic Chem. **2009**; Tetrahedron **2015**

Isotuboflavine
Source: *Pleiocarpa mutica* (Apocynaceae)
Synthesis: Tetrahedron **2015**

Isoharmine
Source: *Peganum harmala* (Nitriariaceae)
Synthesis: Tetrahedron **2016**

1-Ethyl-7-methoxy-9H-pyrido[3,4-b]indole
Source: *Peganum harmala* (Apocynaceae)
Synthesis: *Molecules* **2020**

Benzylisoquinoline alkaloids:

Papaverinol
Source: *Papaver somniferum* (Papaveraceae) and others
Synthesis: Org. Biomol. Chem. **2015**

Papaveraldine
Source: *Papaver somniferum* (Papaveraceae) and others
Synthesis: Org. Biomol. Chem. **2015**

Papaverine
Source: *Papaver somniferum* (Papaveraceae) and others
Synthesis: Org. Biomol. Chem. **2015**

Palaudine
Source: *Papaver somniferum* (Papaveraceae)
Synthesis: Org. Biomol. Chem. **2015**

Thalimicrinone
Source: *Thalictrum minus var. microphyllum* (Ranunculaceae)
Synthesis: Org. Biomol. Chem. **2015**

Setigerine
Source: *Papaver setrigerum DC* (Papaveraceae)
Synthesis: BOrg. Biomol. Chem. **2015**

Setigeridine
Source: *Papaver setrigerum DC* (Papaveraceae)
Synthesis: Org. Biomol. Chem. **2015**

Annocherin A
Source: *Annona cherimola* (Annonaceae)
Synthesis: Org. Biomol. Chem. **2015**

Annocherin B
Source: *Annona cherimola* (Annonaceae)
Synthesis: Org. Biomol. Chem. **2015**

Muraricine (racemic)
Source: *Berberis vulgaris* (Berberidaceae)
Synthesis: Arch. Pharm. **2020**

rac-**Tetrandrine** *(R,R/S,S)*
rac-**Isotetrandrine** *(S,R/R,S)*

rac-**Tetrandrine** and *rac*-**Isotetrandrine**
Source: *Stephania tetrandra* (Menispermaceae)
Synthesis: Org. Biomol. Chem. **2020**

rac-**Armepavine**
Source: *Nelumbo nucifera* (Nelummbonaceae) and others
Synthesis: Cell Chem. Biol. **2021**

rac-armepavine (**2a**)
rac-norarmepavine (**2b**)
rac-laudanine (**2c**)
rac-pseudocodamine (**2d**)
rac-reticuline (**2e**)
rac-orientaline (**2f**)

rac-cinnamolaurine (**3a**)
rac-norcinnamolaurine (**3b**)
rac-*N*-demethylphyllocryptine (**3c**)

rac-thalifendlerine (**4**)

Nr.	R	R^1	R^2	R^3	R^4	R^5
2a	CH_3	CH_3	H	H	H	CH_3
2b	CH_3	CH_3	H	H	H	H
2c	CH_3	CH_3	OH	CH_3	H	CH_3
2d	CH_3	CH_3	H	H	OCH_3	CH_3
2e	CH_3	H	OH	CH_3	H	CH_3
2f	CH_3	H	H	H	OCH_3	CH_3
3a	-		H	H	H	CH_3
3b	-		H	H	H	H
3c	-		OH	CH_3	H	CH_3

Substitution patterns of the 1-benzyl-1,2,3,4-tetrahydroisoquinoline alkaloids.

1-benzyl-1,2,3,4-tetrahydroisoquinoline alkaloids

Source: rac-**Armepavine**: *Nelumbo nucifera* (Nelummbonaceae), *Rhamnus frangula* (Rhamnaceae) and others
rac-**Norarmepavine**: *Nelumbo nucifer*
rac-**Laudanine**: *Papaver somniferum*, pseudocodamine
rac-**Pseudocodamine:** metabolite of isoorientaline in *Corydalis platycarpa makino* cell species
rac-**Reticuline:** *Papaver somniferum*
rac-**Orientaline:** *Cryptocarya amygdalina*
rac-**Cinnamolaurine:** *Cinnamomum sp. T.G.H. 13077*
rac-**Norcinnamolaurine:** *Cinnamomum sp. T.G.H. 13077*
rac-*N*-**Demethylphyllocryptine:** *Cryptocarya phyllosternon*
rac-**Thalifendlerine:** *Thalictrum fendleri*
Synthesis: Beilst. J. Org. Chem. **2021**

Oxoaporphine and oxoisoaporphine alkaloids:

Lysicamine
Source: *Lysichiton camtschatcense Schott var. japonicum Makino* (Araceae)
Synthesis: Org. Biomol. Chem. **2015**

Oxoglaucine
Source: *Liriodendron tulipifera* (Magnoliaceae)
Synthesis: Org. Biomol. Chem. **2015**

6-*O*-Demethylmenisporphine
Source: *Menispermuim dauricum* DC (Menispermaceae)
Synthesis: Beilstein J. Org. Chem. **2017**

Dauriporphinoline
Source: *Menispermuim dauricum* DC (Menispermaceae)
Synthesis: Beilstein J. Org. Chem. **2017**

Menisporphine
Source: *Menispermuim dauricum* DC (Menispermaceae)
Synthesis: Beilstein J. Org. Chem. **2017**

Dauriporphine
Source: *Menispermuim dauricum* DC (Menispermaceae)
Synthesis: Beilstein J. Org. Chem. **2017**

Bianfugecine
Source: *Menispermuim dauricum* DC (Menispermaceae)
Synthesis: Beilstein J. Org. Chem. **2017**

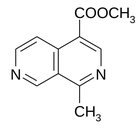
Carbazole alkaloids:

Hyellazole
Source: *Hyella caespitosa* (blue-green alga)
Synthesis: Tetrahedron Lett. **2020**

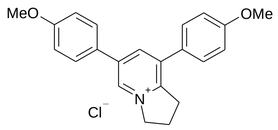
Total syntheses of natural products

worked out by the Bracher group

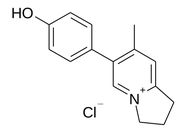
Other alkaloids:



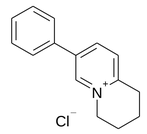
Neozeylanicine
Source: *Neonauclea zeylanica* (Rubiaceae)
Synthesis: Liebigs Ann. **1995**



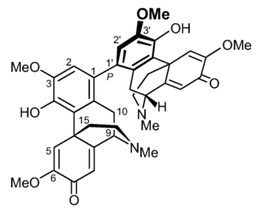
Ficuseptine
Source: *Ficus septica* (Moraceae)
Synthesis: Eur. J. Org. Chem. **2002**



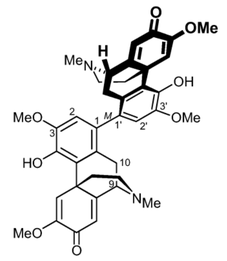
Ipalbidinium
Source: *Ipomoea alba* (Convolvulaceae)
Synthesis: Monatsh. Chem. **2003**



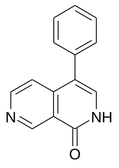
Clathryimine B
Source: *Clathrya basilana* (marine sponge)
Synthesis: Monatsh. Chem. **2003**



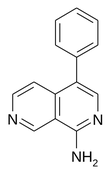
Saludimerine A
Source: *Croton flavens* (Euphorbiaceae)
Synthesis: J. Org. Chem. **2004**



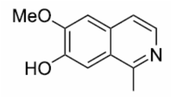
Saludimerine B
Source: *Croton flavens* (Euphorbiaceae)
Synthesis: J. Org. Chem. **2004**



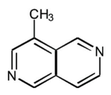
Lophocladine A
Source: *Lophocladia sp.* (red alga)
Synthesis: Arch. Pharm. Chem. Life Sci. **2006**



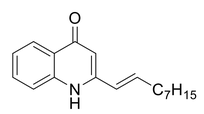
Lophocladine B
Source: *Lophocladia sp.* (red alga)
Synthesis: Arch. Pharm. Chem. Life Sci. **2006**



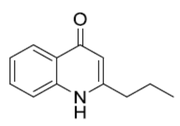
7-Hydroxy-6-methoxy-1-methylisoquinoline
Source: *Hernandia nymphaeifolia (Hernandiaceae)*
Synthesis: Beilst. J. Org. Chem. **2018**



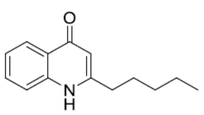
4-Methyl-2,6-naphthyridine
Source: *Antirrhinum majus* (Plantaginaceae)
Synthesis: Lett. Org. Chem. **2019**



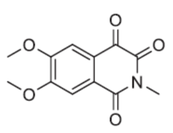
Pyo-III
Source: *Pseudomonas aeruginosa*
Synthesis: Tetrahedron Lett. **2018**



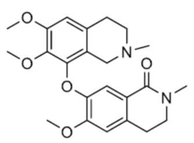
2-Propylquinolin-4-one
Source: *Boronia ternate* (Rutaceae)
Synthesis: Tetrahedron Lett. **2019**



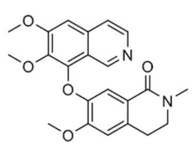
2-Pentylquinolin-4-one
Source: marine Pseudomonad 201-3, *Boronia ternata* (Rutaceae)
Synthesis: Tetrahedron Lett. **2019**



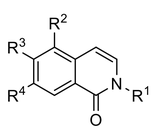
1,3,4-Trioxoisoquinoline
Source: *Menispermum dauricum* (Menispermaceae)
Synthesis: Tetrahedron **2020**

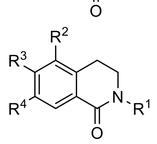


Berbidine
Source: *Berberis* sp. (Berberidaceae)
Synthesis: Tetrahedron **2020**



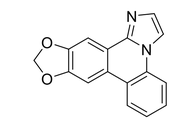
Berbanine
Source: *Berberis* sp. (Berberidaceae)
Synthesis: Tetrahedron **2020**



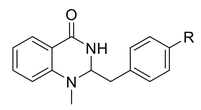


unnamed alkaloid	R^1 = Me, R^2 = H, R^3 ,R^4 = OMe
***N*-Demethyldoryphornine**	R^1 = H, R^2 = H, R^3 = OMe, R^4 = OH
Doryphornine	R^1 = Me, R^2 = H, R^3 = OMe, R^4 = OH
Thalactamine	R^1 = Me, R^2, R^3, R^4 = OMe
unnamed alkaloid	R^1 = H, R^2 = H, R^3-R^4 = OCH_2O
Corydaldine	R^1 = H, R^2 = H, R^3, R^4 = OMe
***N*-Methylcorydaldine**	R^1 = Me, R^2 = H, R^3, R^4 = OMe
Northalifoline	R^1 = H, R^2 = H, R^3 = OMe, R^4 = OH
Thalifoline	R^1 = Me, R^2 = H, R^3 = OMe, R^4 = OH
***N*-Methylthalidaldine**	R^1 = Me, R^2, R^3, R^4 = OMe
Noroxyhydrastine	R^1 = H, R^2 = H, R^3-R^4 = OCH_2O

1-Oxoisoquinoline alkaloids
Source: plants from different families (Berberidaceae, Ranunculaceae, Menispermaceae, Papaveraceae), *Menispermum dauricum* (Menispermaceae) and others
Synthesis: Tetrahedron **2020**



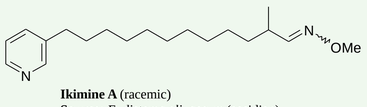
Zephycandidine A
Source: *Zephyranthes candida* (Amaryllidaceae)
Synthesis: to be published



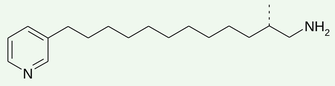
Glycozolone A R = H
Glycozolone B R = OMe

Glycozolone A/B
Source: *Glycosmis cochinchinensis* (Lour.) Pierre (Rutaceae)
Synthesis: Nat. Prod. Res. **2022**

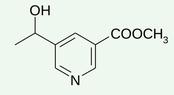
Alkylpyridine alkaloids:



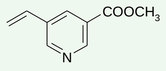
Ikimine A (racemic)
Source: *Eudistoma olivaceum* (ascidian)
Synthesis: Nat. Prod. Lett. **1994**



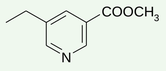
Niphatesine C
Source: *Niphates sp.* (marine sponge)
Syntheses: J. Chem. Soc. Perkin Trans. 1 **1995**, Arch. Pharm. Pharm. Med. Chem. **2004**



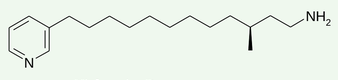
Unnamed Rubiacea alkaloid
Source: *Nauclea diderrichii* (Rubiaceae), *Isertia haenkeana* (Rubiaceae)
Synthesis: Monatsh. Chem. **1995**



Unnamed Rubiacea alkaloid
Source: *Nauclea diderrichii* (Rubiaceae)
Synthesis: Monatsh. Chem. **1995**



Unnamed alkaloid (artefact?)
Source: *Ligustrum vulgare* (Oleaceae)
Synthesis: F. Bracher, T. Papke, Monatsh. Chem. **1995**

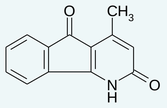


Niphatesine D
Source: *Niphates sp.* (sponge)
Synthesis: Monatsh. Chem. **1996**

Structure revisions by total synthesis:

Dielsine
Source: *Guatteria dielsiana* (Annonaceae)
Synthesis: Arch. Pharm. (Weinheim) **1992**

Postulated structure:

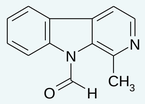


Correct structure:

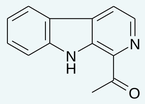
unknown

Lycii alkaloid I
Source: *Lycium chinense* (Solanaceae)
Synthesis: Liebigs Ann. Chem. **1993**

Postulated structure:

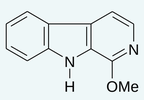


Correct structure:
identical to 1-acetyl-β-carboline



Taraxacine A
Source: *Taraxacum formosanum* (Asteraceae)
Synthesis: Z. Naturforsch. B, **2009**

Postulated structure:

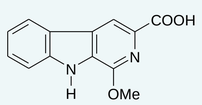


Correct structure:

unknown

Taraxacine B
Source: *Taraxacum formosanum* (Asteraceae)
Synthesis: Z. Naturforsch. B, **2009**

Postulated structure:

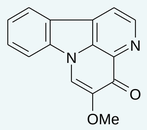


Correct structure:

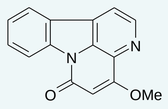
unknown

Drymaritine
Source: *Drymaria diandra* (Caryophyllaceae)
Synthesis: J. Nat. Prod. **2009**

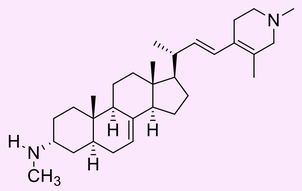
Postulated structure:



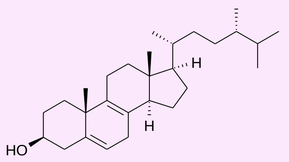
Correct structure:
identical to cordatanine



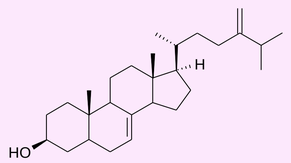
Steroids:



Plakinamine B
Source: *Plakina sp.* (sponge)
Synthesis: Tetrahedron **2014**

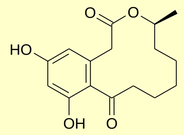


Ergosta-5,8-dien-3β-ol
Source: *Chlorella ellipsoids* (alga) and others
Synthesis: Sci. Pharm. **2008**

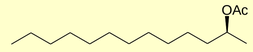


Episterol
Source: *Pisaster ochraceus* (starfish) and others
Synthesis: Tetrahedron **2015**

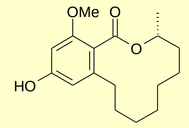
Polyketides:



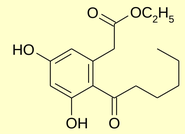
Curvularin
Source: *Curvularia* and others
Syntheses: Nat. Prod. Lett. **1995**; Liebigs Ann./Recueil **1997**



Tridecanol acetate
Source: *Drosophila mulleri* (fruit fly)
Synthesis: Org. Prep. Proc. Int. **1995**



Lasiodiplodin
Source: *Lasiodiplodia theobromae* (fungus) and others
Synthesis: J. Chem. Soc., Perkin Trans. 1 **1996**



Seccocurvularin
Source: *Spirastrella vagabunda* (sponge)
Synthesis: Nat. Prod. Lett. **1998**

Curvulin
Source: *Curvularia siddiqui* (fungus)
Synthesis: Nat. Prod. Lett. **1998**

Curvulin*Curvularia siddiqui* (fungus)
Synthesis: F. Bracher**ic acid**
Source: Nat. Prod. Lett. **1998**

Lunularic acid
Source: *Lunularia cruciate* and others
Synthesis: Nat. Prod. Lett. **2000**

Lunularin
Source: *Marchantia polymorpha* (Hepaticaceae)
Synthesis: Nat. Prod. Lett. **2000**; Z. Naturforsch. B **2015**

***O*-Methyllunularin**
Source: *Marchantia polymorpha* (Hepaticaceae)
Synthesis: Z. Naturforsch. B **2015**

Zearalanone (racemic)
Source: *Fusarium reticulatum* (fungus)
Synthesis: Monatsh. Chem. **2001**

Zearalane
Source: *Gibberella zeae* (fungus)
Synthesis: Eur. Org. Chem. **2001**

6-Nor-Fluvirucinin B1 (nor-derivative of natural product)
Source: *Actinomadura vulgaris* (actinomycete)
Synthesis: Synlett **2002**

Citreofuran
Source: *Penicillium citreo-viride* (fungus)
Synthesis: Nat. Prod. Res. **2003**

4-Ipomeanol
Source: *Ipomoea batatas* (Convolvulaceae)
Synthesis: Turk. J. Chem. **2005**

Azafluorenones:

Onychine	R^1 = R^2 = R^3 = R^4 = H
6-Methoxyonychine	R^1 = R^3 = R^4 = H, R^2 = OMe
7-Methoxyonychine	R^1 = R^2 = R^4 = H, R^3 = OMe
Ursuline	R^1 = OMe, R^2 = OH, R^3 = R^4 = H
Isoursuline	R^1 = OH, R^2 = OMe, R^3 = R^4 = H
Oncodine	R^1 = R^4 = H, R^2 = OH, R^3 = OMe
Polyfothine	R^1 = R^4 = H, R^2 = R^3 = OMe
Darienine	R^1 = R^2 = OMe, R^3 = OH, R^4 = H
7-Hydroxy-5,8-dimethoxyonychine	R^1 = R^4 = OMe, R^2 = H, R^3 = OH
6,8-Dihydroxy-7-methoxyonychine	R^1 = H, R^2 = R^4 = OH, R^3 = OMe
Muniranine	R^1 = R^3 = R^4 = OMe, R^2 = OH
5,6,7,8-Tetramethoxyonychine	R^1 = R^2 = R^3 = R^4 = OMe

Onychine and onychine derivatives
Source: *Cleistopholis patens, Guatteria dielsiena, Polyalthia longifolia* and others (Annonaceae)
Synthesis: Arch. Pharm. (Weinheim) **1989**; Synlett **1991**; Arch. Pharm. (Weinheim) **1994**; Eur. J. Org. Chem. **2023**

Fluorenones:

Nobilone
Source: *Dendrobium nobile* (Orchidaceae)
Synthesis: Beilstein J. Org. Chem. **2021**