

Spermatocarpia (gymnosperm fruits)

Note: The term aril refers to any cupular structure surrounding a seed, or its scale, or its bract. The aril may be formed by a single seed scale or by united seed scales, or by a bract, or by a bract fused with a scale, or by a collar. The seed or its intimately associated bract or scale structure is either partly visible from an opening at the apex of the cup when fully enveloped, or by a partially exposed seed. Aril that completely covers the seed will key as aril not evident.

1. Cones (or seeds and their accessory structures) on inflorescence-like shoots, terminal or axillary to angiosperm-like or fern-like leafy shoots, the inflorescences capitate, spicate, or dichasial (*Cycadales*, *Ginkgo*, *Gnetum*, *Welwitschia*) 2
 Cones (or seeds and their accessory structures) near ends of secondary scaly shoots (*Ephedraceae*), or bracteate-scale shoot complexes that are often axillary to a needle-leaf or a scale-leaf on primary shoots (conifers) 6
2. Seed cones, or megaporophyll clusters (megastrobilus), solitary on a plant, terminal on a primary shoot..... 3
 Seed cones, or seeds and their accessory structures, more than one on a plant, usually on secondary shoots..... 4
3. Seeds usually many on open modified leaves (frond-like megasporophylls), aggregated into head-like clusters at shoot apices along with vegetative (normal) fronds (*Cycadaceae*: *Cycas*) **Carpophylletum**
 Seeds developing within cones; these composed of scale-like megasporophylls tightly packed in a spiral arrangement around a shoot axis, scales two-seeded, irregularly separating at maturity (*Stangeriaceae*, *Zamiaceae*)..... **Simple cone**
4. Seed 1, developing in a ellipsoidal slightly angular dry cone with decussate closely overlapping scales, surrounded by two fused bracts—a tubillus in flower that develops into a wing in fruit—in addition to the two outer dry seed envelopes (*Welwitschiaceae*: *Welwitschia*) **Tubilluspermalata cone**
 Seed(s) 1 or more, not in a cone but nearly terminal on peduncular shoots, or along spike-like inflorescence shoots, with a fleshy envelope 5
5. Seeds many, opposite or whorled on spike-like inflorescences, arising axillary to blade-like leaves on leafy shoots; seed covered by three envelopes, an inner integument + 2 outer envelopes, the outermost fleshy (*Gnetaceae*: *Gnetum*)..... **Trithecal sarcospermidium**
 Seed(s) 1 or paired, terminal on a short stalk above a collar below which is a long bare peduncle arising from a short spur shoot with or without long stalked fan-shaped leaves; seed covered by a single envelope (integument), 3-layered, the outer fleshy, middle stone-like, inner papery (*Ginkgoaceae*: *Ginkgo*) **Tristratal sarcospermidium**
6. Seed shoots generally with several to 5 pairs or more of decussate (or trimerous) scales arising from branch nodes, lower scales sterile, uppermost further differentiated as bracts,

- 2 or 3 around each seed; seeds 1–2 (-3), appearing terminal but each axillary to a bract of a reduced secondary shoot; true leaves scale-like, not photosynthetic; seed envelopes 2, outer coriaceous, inner (integument) membranous (Ephedraceae)..... **Ephedroid carpidium-7**
 Seeds in typical cones or attached to fleshy structures axillary to leafy stems..... 8
7. Fruit fleshy, the bracts winged or not winged (*Ephedra altissima*, *E. americana*, *E. antisiphilitica* + 35 spp.)..... **Ephedroid sarcocarpidium**
 Fruit dry, bracts winged (*E. alata*, *E. funerea*, *E. multiflora* + 3 spp.)**Ephedroid pterocarpidium**
 Fruit dry, bracts not winged (*E. aspera*, *E. californica*, *E. viridis* + 4 spp.).....**Ephedroid apterocarpidium**
8. Cones partly or entirely fleshy at maturity, or with brightly coloured fertile scales, or seeds with an aril-like structure (aril)..... **Fleshy cone group**
 Cones mostly dry, uniformly brownish, generally composed of densely packed ovuliferous scales fused with sterile bracts; cone scales and/or fertile bracts sometimes fleshy when young but separating as they dry in maturation; seeds and/or scales often winged (Pinales)..... **Dry cone group**

Dry cone group

1. Ovuliferous scale fused with subtending bract, sometimes appearing as one except in early stage of development; cone scales often peltate, ending as angular plates when viewed externally (Araucariaceae, Cupressaceae, Sciadopityaceae)..... 2
 Ovuliferous scales in the axils of bracts, which may become reduced at maturity; cone scales usually thin and rounded at ends (Pinaceae)**12**
2. Cones breaking apart at maturity, the scales and seeds stacked like dishes, which separate from one another; seeds one per scale (Araucariaceae)..... **Schizocones-3**
 Cones remaining intact, or breaking up into irregularly shaped chunky sections; seeds 1 or more per scale (Cupressaceae, Sciadopityaceae) 4
3. Seeds winged (*Agathis*)..... **Pterospermal schizocone**
 Seed not winged, scale-bracts winged or thinner along margins (*Araucaria*, *Wollemia*)**Pteroscale schizocone**
4. Cones breaking apart into various irregularly shaped sections (*Taxodium*)**Platygalbulus schizocone**
 Cones remaining intact, or scales spreading apart from the base much like some angiosperm capsules 5
5. Cone scales separating at base similar to some angiosperm capsular fruits **Valvular cones-6**
 Cones scales separating or spreading at base and above 9
6. Cone scales with a prominent straight to curved central spine (*Libocedrus*, *Pilgerodendron*, *Platycladus*) **Spiny valvular-cone**
 Cones scales with a central umbo or mostly flat, or shortly spine tipped from apex 7

7. Seeds not winged (*Microbiota*)..... **Apterospermal valvular-cone**
 Seeds winged 8
8. Seed wings unequal (*Actinostrobus, Austrocedrus, Callitris, Calocedrus, Papuacedrus*) **Anisopterospermal valvular-cone**
 Seed wings equal (*Diselma, Neocallitropsis, Tetraclinus, Thuja, Widdringtonia nodiflora*)..... **Isopterospermal valvular-cone**
9. Cones generally spherical; scales not overlapping, \pm spreading radial, the exterior surface with angular flat to recessed plates, \pm diamond or hexagonal in outline **Galbuloid cones-10**
 Cones generally oblong; cone scales overlapping like shingles, spreading apart along a longitudinal axis, longitudinally relatively flat, thin, and rounded to apex (*Taiwania, Sciadopitys*; also Pinaceae excluding *Pinus*)..... **Imbricate Cone**
10. Cone scales peltate, with a terminally exterior expanded flat surface except for a central umbo that may be present (*Chamaecyparis, Cunninghamia, Cupressus, Fitzroya, Fokienia, Metasequoia, Sequoia, Sequoiadendron*) **Platygalbulus**
 Outer \pm flattened surface of cone scales conical or knobby, or centrally to subterminally spiny.....11
11. Cones scales with central to subterminal spines or horns (*Arthrotaxis, Cryptomeria, Glyptostrobus*) **Spiny galbulus**
 Cone scales largely conical or knob shaped (*Thujopsis*) **Knobby galbulus**
12. Cones breaking apart from a central axis (*Abies, Cedrus*)..... **Columnifragal schizocone**
 Cones remaining intact, except for the scales spreading apart from one another to disperse seeds13
13. Scales mostly erect, flattened, and rounded to apex (Pinaceae excluding *Pinus*; also Cupressaceae (*Taiwania, Sciadopitys*) **Imbricate cone**
 Scales mostly spreading, thickened towards apex, the external expanded surface often with a prickle (*Pinus*) **Platyglottal cone**

Fleshy Cone Group

1. Seed(s) completely enclosed within the entire fleshy berry-like cone, composed of one to three alternating pairs or trios of scales that fuse together in fruit (essentially a fleshy galbulus; *Juniperus, Cupressaceae*)..... **Arcesthidium**
 Seed(s) partially or entirely covered by part of the cone structure, a single fleshy scale, or an aril-like appendage, or by separate or united bracts, or by a scale united with a bract 2
2. Fruit cone similar to the cashew (*Anacardium occidentale*); seed embedded in a fleshy scale (epimatium) upon a swollen fleshy receptacle (podocarpium), which develops from fusion and swelling of bracts

- with the cone axis (Podocarpaceae: *Acropyle*, *Dacrycarpus*, *Dacrydium*, *Falcatifolium*, *Lepidothamnus*, *Nageia wallichiana*, *Podocarpus*).....**Podospermatium**
2. Fruit cone berry-like, drupe-like, or with aril-like structures..... 3
3. Seed partially covered with aril-like structure (aril)..... 4
 Aril not evident, seeds entirely covered by scales or bracts10
4. Aril of many bracts ± united to form a fleshy cup; cones either developing on a phylloclade, or on a specialized shoot (Phyllocladaceae: *Phyllocladus*)**Arillosyncarpidium**
 Aril formed from a single scale or bract or both 5
5. Aril formed by a seed-scale (epimatium) 6
 Aril formed by a bract or collar, not by a scale alone, sometimes by a scale fused with the bract 7
6. Aril strongly cupular, fleshy or thin but not swollen; seed and attached bract surrounded by aril scale (epimatium) dispersing separately from cone (Podocarpaceae: *Lagarostrobos*, *Manoao*)**Pseudoarillocarpidium**
 Bract and fertile scale (epimatium) both swollen and fleshy, scale (epimatium) cupular; entire seed cone—of many fleshy scales—appearing to collectively disperse (Podocarpaceae: *Microcachrys*)**Syncarpidium**
7. Aril developing from a collar—at the proximal end of the carpidium—that partly surrounds the seed scale (epimatium) and its enclosed seed in the axil of leaf-like bract (Podocarpaceae: *Halocarpus*) **Arillocarpidium**
 Aril not clearly enveloping a scale (that encloses a seed)..... 8
8. Aril a fleshy seed scale fused with its bract—in a cone similar to a knobby galbulus, the scales united at base and swollen at maturity (Podocarpaceae: *Saxegothaea*) **Arillospermia syncarpidium**
 Aril formed from an bract; seeds usually 1, occasionally 2 , appearing terminal on a secondary short scaly shoot 9
9. Aril cupular, loose around seed (Taxaceae) **Arillocarpium**
 Aril tightly adhering to seed, open at tip, splitting longitudinally at maturity (Austrotaxaceae: *Austrotaxus*; see also Cephalotaxaceae, *Torreya*)..... **Fissuricidal arillocarpium**
10. Seed embedded in an epimatium; fruit cone similar to a berry or drupe (Podocarpaceae: *Afrocarpus*, *Nageia nagi*, *Parisitaxus*, *Prumnopitys*, *Retrophyllum*, *Sundacarpus*)**Epispermatium**
 Seed partly or completely covered by a bract11
11. Bract attached to seed mostly at base, not fleshy (Podocarpaceae: *Microstrobos*)..... **Podocarpoid carpidium**
 Bract completely covering seed and intimately fused with the seed coat, also regarded as an aril12

12. Bract (aril) splitting at maturity (Cephalotaxaceae: *Torreya*; also Austrotaxaceae: *Austrotaxus*)..... **Fissuricidal arillocarpium**
 Aril remaining intact (Cephalotaxaceae: *Amentotaxus*, *Cephalotaxus*) **Compound arillocarpium**

Glossary

Anisopterospermal valvular-cone: A valvular fruit cone in which seeds are not winged as in Cupressaceae: *Actinostrobus*, *Austrocedrus*, *Callitris*, *Calocedrus*, and *Papuacedrus*

Apterospermal valvular-cone: A valvular fruit cone in which neither the seed nor the bract are winged as in *Microbiota* (Cupressaceae)

Arceuthidium: A fruit cone similar to a galbulus but is fleshy and closed at maturity (*Juniperus*)

aril: In gymnosperms a seed enclosed by a cupular-like structure, usually fleshy, derived from a single bract or many fused bracts, or developing from scale or from a collar, any of which may also fuse with the outer seed coat

Arillocarpidium A fruit cone in which an aril develops from a collar at the proximal end of the carpidium that partially encloses the seed scale (epimatium) and its seed as in *Halocarpus* (Podocarpaceae)

Arillocarpium: A fruit cone with a seed and surrounding aril that develop subterminally on a secondary shoot as in Taxaceae (*Pseudotaxus*, *Taxus*)

Arillospermia syncarpidium: A fruit cone similar to a knobby galbulus, consisting of scales united at their base from where they expand and separate at maturity, dispersing seeds that are covered by an aril derived from a fleshy seed scale fused with its bract as in *Saxegothaea* (Podocarpaceae).

Arillosyncarpidium: A fruit cone consisting of \pm united bracts that form a fleshy cup as in *Phyllocladus* (Phyllocladaceae)

bract: . In gymnosperms, a basal foliar appendage of the cone axis or dwarf shoot, or part of a fused ovuliferous bract-scale complex in a compound cone.

capitate: Megasporophylls aggregated into a head subtended by bracts

carpidium: A fruit cone in which a seed is attached to the bract as opposed to a scale, the scale often reduced or absent.

carpophyll: A megasporophyll with mature ovules

Carpophylletum: A mature megastrobilus with seeds on open modified leaves (frond-like megasporophylls) that are aggregated into head-like cluster at the apex of a primary shoot along with vegetative (normal) fronds (Cycadaceae: *Cycas*)

Columnifragal schizocone: A schizocone that breaks apart from a persistent cone axis

Compound arillocarpium: A fruit consisting largely of a gymnosperm seed characterised by having a fleshy outer seed coat surrounded by and united with a fleshy aril for most of its length as in Cephalotaxaceae: *Amentotaxus* and *Cephalotaxus*

cone: a megasporangiate or microsporangiate complex structure of various forms but in context of a fruit typically a cylindrical or conical structure of spirally arranged megasporophylls with or without scales and/or bracts around a central axis.

dichasial: a fertile leafless shoot that divides into branches of equal length

Dry cone group: In gymnosperms fruit cones that are mostly uniform in colour in which scales or bracts separate to release seed(s).

envelope: pertaining to structures surrounding the nucellus of a seed

Ephedroid apterocarpidium: A dry ephedroid carpidium in which bracts are not winged

Ephedroid carpidium: A gymnosperm fruit characterised by a seed shoot of decussate or trimerous scales arising from branch nodes, the uppermost bracteate with 2 or 3 bracts around each of 1–2 (-3) seeds, the seed with two envelopes, the outer coriaceous, the inner (integument) membranous (Ephedraceae).

Ephedroid pterocarpidium: An ephedroid carpidium with winged bracts

Ephedroid sarcocarpidium: An ephedroid carpidium with fleshy bracts

Epispermatium: A berrylike fruit of the gymnosperms, specifically the Podocarpaceae formed by a swollen fertile scale (epimatium) in which the seed is embedded

Fissuricidal arillocarpium: A gymnosperm fruit consisting of a seed covered by an aril that splits along one side upon maturity.

Fleshy cone group: A conifer fruit cone consisting of one or more fleshy scales or bracts fused with the seed(s)

Galbuloid cones: various types galbulus cones

Galbulus: A conifer fruit cone in which the scales extend from a central area of the cone axis and have a peltate external surface

Knobby galbulus: A dry galbuloid cone having scales with central to subterminal spines or horns as in *Arthrotaxis*, *Cryptomeria*, and *Glyptostrobus*.

Imbricate cone: A conifer fruit cone generally oblong with scales overlapping like shingles, the scales \pm spreading from a longitudinal axis during maturation, the scales longitudinally relatively flat, thin and rounded at ends as in Cupressaceae *Taiwania* and *Sciadopitys*, and also Pinaceae excluding *Pinus*

peltate: a seed cone scale centrally stalked from a shield-like outer face

Isopterispermal valvular-cone: A valvular cone in which the seeds have equally developed wings as in the Cupressaceae *Diselma*, *Neocallitropsis*, *Tetraclinus*, *Thuja* and *Widdringtonia nodiflora*

phylloclade: a flat stem resembling a leaf

Platygalbulus: A \pm spherical fruit cone with scales spreading radial from a central part of the cone axis and terminally expanded into flat surface as seen from external view except for a central umbo that is frequently present as in Cupressaceae *Chamaecyparis*, *Cunninghamia*, *Cupressus*, *Fitzroya*, *Fokienia*, *Metasequoia*, *Sequoia*, and *Sequoiadendron*

Platyglottal cone: A cylindrical to ellipsoidal fruit cone, often tapering to apex, with small bracts at the base of conspicuously winged two-seeded scales that spread widely and spirally along a central axis and are thickened and expanded near the ends on the exposed shield-like surface, which often bears a prickle or umbo as in *Pinus*

Platygalbulus schizocone: A galbuloid cone that breaks apart upon maturity into irregularly shaped sections as in *Taxodium*

Podocarpium: A fleshy part of the conifer fruit derived from a highly modified cone of some Podocarpaceae, formed by fusion of the cone scales with the cone axis that swells at maturity and upon which develops the fleshy epimatium and its embedded seed matures, also commonly referred to as a receptacle

Podocarpoid carpidium: A conifer cone consisting largely of spirally arranged bracts in which the seed is mostly attached to the base of a closely adhering bract as in Podocarpaceae, *Microstrobus*

Podospermatium: A conifer fruit consisting of a fleshy scale (epimatium), in which the seed is embedded, developing on top of a fleshy podocarpium; the whole fruit resembling the angiosperm glans of *Anacardium occidentale*, the swollen fleshy base not derived from a peduncle but from a podocarpium formed by fusion and swelling of bracts with the cone axis as in Podocarpaceae: *Acmopyle*, *Dacrycarpus*, *Dacrydium*, *Falcatifolium*, *Lepidothamnus*, *Nageia wallichiana*, and *Podocarpus*

Pseudoarillocarpidium: A fruit cone in which the aril formed is by a scale (epimatium) that is not swollen, and in which the seed is attached to a bract, each seed-bract-scale structure disperses separately from cone as in Podocarpaceae: *Lagarostrobos* and *Manoao*

pteroscale: a winged scale

Pteroscale schizocone: A schizocone that completely breaks up at maturity dispersing seeds and their winged or thin-margined bracts as in Araucariaceae: *Araucaria* and *Wollemia*

pterosperm: a winged seed

Pterospermal schizocone: A cone that breaks apart at maturity releasing winged seeds

scale: a foliar appendage of an ovuliferous dwarf-shoot) born in the axil of a bract, further differentiated as sterile scales and fertile scales (ovule-bearing foliar appendages)

Schizocone(s): A cone that breaks apart at maturity, generally recognised as a fruit in conifers

Simple cone: A cone with scale-like megasporophylls tightly spiralled around a shoot axis, each scale two seeded, the scales irregularly separating at maturity (Stangeriaceae, Zamiaceae)

Spiny galbulus: A galbuloid fruit cone with scales bearing central to subterminal spines or horns as in Cupressaceae: *Arthrotaxis*, *Cryptomeria* and *Glyptostrobos*

spicate: sessile ovulate structures along a leafless shoot

Spiny valvular-cone: A valvular cone with scales having a prominent straight to curved central spine as in Cupressaceae: *Libocedrus*, *Pilgerodendron* and *Platycladus*

Syncarpidium: A fruit cone consisting of fleshy bracts and scales, each scale a swollen aril around a seed attached to a swollen bract, appearing to disperse as a single unit, or by the individual scale-bract-seed structure, as in Podocarpaceae: *Microcachrys*

Tristratal sarcospermidium: A gymnosperm fruit consisting of one or 2-paired seeds that develop terminally on a short stalk above a collar upon which each seed is covered by a single 3-layered envelope (integument), the outer fleshy, middle stone-like, and inner papery (Ginkgoaceae: *Ginkgo*)

Trithecal sarcospermidium: A gymnosperm fruit consisting largely of a seed covered by three envelopes, an inner integument and two outer envelopes, the outermost fleshy (Gnetaceae: *Gnetum*)

Tubilluspermalata cone: A cone with decussate closely overlapping scales in which a single seed develops, the seed with three envelopes, the innermost derived from a tubillus—two fused bracts that develop into a wing around the seed (Welwitschiaceae: *Welwitschia*)

Valvular cone(s): A conifer fruit cone with scales united at base that spread apart during maturation to release the seed(s) as reminiscent of an angiosperm capsular fruit, exemplified by cones of Cupressaceae.