

# **Tentative Physiognomic-Ecological Classification of Plant Formations of the Earth**

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This physiognomic classification has been elaborated as a basis for mapping world vegetation on a scale of 1:1 million or smaller. It will permit the worldwide comparison of ecological habitats indicated by equal plant life form combinations.<sup>1</sup> Plant formations and other divisions in this context are conceived as combinations of "plant life forms", i.e., as physiognomic units. For naming, ecological terms have been included for brevity; wherever possible, definitions are based on physiognomic criteria. In the following classification, units of unequal rank are distinguished by different symbols:

<b>1, II etc.</b>	= <b>FORMATION CLASS</b>
<b>A, B, etc.</b>	= <b>Formation subclass</b>
<b>1, 2, etc.</b>	= <b>Formation group</b>
<b>a, b, etc.</b>	= Formation
<b>(1), (2), etc.</b>	= Sub-formation
<b>(a), (b), etc.</b>	= Further subdivisions

### **I**      **CLOSED FORESTS**, formed by trees at least 5 m tall with their crowns interlocking.<sup>2</sup>

**A. Mainly evergreen forests**, i.e., the canopy is never without foliage, however, individual trees may shed their leaves.

**1. Tropical ombrophilous forests.** (Conventionally called tropical rain forests.) Consisting mainly of evergreen trees mostly with little or no bud protection, neither cold nor drought resistant, Truly evergreen, i.e. individual trees may stand leafless for a few weeks only and not at the same time as all the others, Leaves of many species with "drip tips."

a. Tropical ombrophilous lowland forest. Composed of numerous species of fast growing trees, some of them exceeding **50** m in height, generally with smooth bark, some with buttresses. Very sparse under growth and this composed mainly of tree reproduction Palms and other tuft trees usually rare, lianas nearly absent except pseudo-lianas (i.e., - plants originating on tree branches, subsequently rooting in the ground). Crustose lichens and green algae are the only constantly present epiphytic life forms; vascular epiphytes are less abundant than in b - d.<sup>3</sup>

b. Tropical ombrophilous submontane forest. Tree growth largely the same as in a. In the undergrowth herbaceous life forms more frequent. The most important difference from a is the more frequent appearance of vascular epiphytes.

#### **(IA1)**

c. Tropical ombrophilous montane forest. (Corresponds most closely to textbook descriptions of the virgin tropical rain forest.) Abundant vascular and other epiphytes Tree sizes markedly reduced (<50 m); crowns extending deeper down the stem than in a or b. Bark

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<sup>1</sup> Some formations are covering only small areas which cannot be represented on small scale maps. They have been mentioned here to facilitate a more general use of this physiognomic-ecological classification. A key to the plant life forms is given in Appendix A.

<sup>2</sup> In reproductive stage or as immature secondary growth temporarily less than 5 m tall, but individuals of scapose life form (i.e., real trees, not shrubs). In subpolar conditions, the limit may be only 3 m, in tropical ones 8 or 10 m.

<sup>3</sup> In lowlands vascular epiphytes are abundant only where fog frequently occurs, e.g., near the coast.

often more or less rough, Undergrowth abundant, often represented by rosulate nano-microphanerophytes (e.g., tree ferns or small palms; the ground layer rich in hygromorphous herbs and cryptogams.

- (1). Broad-leaved most common form
  - (2). Needle-leaved or microphyllous
  - (3). Bamboo, rich in tree-grasses replacing largely the tuft micro- or nanophanerophytes
- d. Tropical ombrophilous "subalpine" forest. (Not including cloud forest or woodland. Considered unique by some investigators, but probably not important. Definition required.)
- e. Tropical ombrophilous cloud forest. Tree crowns, branches and trunks as well as lianas burdened with epiphytes, mainly chamaephytic bryophytes. Also the ground covered with hygromorphic chamaephyte (e.g., Selaginella and herbaceous ferns). Trees often gnarled, with rough bark and rarely exceeding 20 m in height.
- (1) Broad-leaved, most common form
  - (2) Needle-leaved or microphyllous
- f. Tropical ombrophilous alluvial forest. Similar to b, but richer in palms and in undergrowth life forms, particularly tall forbs\* (e.g., Musaceae); buttresses frequent.
- (1) Riparian (on the lowest forested river banks, frequently flooded), most dominated by fast-growing trees: herbaceous undergrowth nearly absent, epiphytes extremely rare, poor in species
  - (2) Occasionally flooded (on relatively dry terraces accompanying active rivers) most common form of f; more epiphytes than in (1) and many lianas
  - (3) Seasonally water-logged (along the lower river courses, where the water accumulates on large flats for several months; trees frequently stilt roots; canopy density not uniform; as a rule poor in undergrowth except for more open places
- g. Tropical ombrophilous swamp forest. (Not along rivers, but edaphically wet habitats, which may be supplied either with fresh or brackish water). Similar to f, but as a rule poorer in tree species. Many trees with buttresses or pneumatophores; mostly higher than 20 m.
- (1) Broad-leaved, dominated by dicots
  - (2) Dominated by palms, but broad-leaved trees in the undergrowth
- h. Tropical evergreen peat forest (with organic surface deposit. Poor in tree species, with lower canopy than g (as a rule not higher than 20 m), Trees have slow growth rates and thin diameters are commonly equipped with pneumatophores or stilt roots.
- (1). Broad-leaved, dominated by dicotylous plants
  - (2). Dominated by palms, which may be equipped with asparagus-shaped pneumatophores
2. **Tropical and subtropical evergreen seasonal forests.** consisting mainly of evergreen trees with some bud protection. Foliage reduction during the dry season is noticeable, often as partial shedding. Transitional between 1 and 3. Subdivisions a-c largely similar to those under 1.
- a. Tropical (or subtropical) evergreen seasonal lowland forest,
  - b. Tropical (or subtropical) evergreen seasonal submontane forest.
    - (1). *broad-leaved*, most common form
    - (2). *needle-leaved*
  - c. Tropical (or subtropical) evergreen seasonal montane forest. In contrast to 1 c no tree ferns, instead, evergreen shrubs are more frequent.
  - d. Tropical (or subtropical) evergreen dry "subalpine" forest (Physiognomically resembling the winter-rain evergreen sclerophyllous dry forest (8a), usually occurring above the cloud

forest (1e) Mostly evergreen sclerophyllous trees, smaller than **20** m, with little or no undergrowth (if not opened by human activity). Poor in lianas and epiphytes, except lichens.

- 3. Tropical and subtropical semi-deciduous forests.** Most of the upper canopy trees drought-deciduous many of the understory trees and shrubs evergreen and more or less sclerophyllous. Nearly all trees with bud protection; leaves with drip tips.” Trees show rough bark, except some bottle trees, which may be present.
- a. Tropical (or subtropical) semi-deciduous lowland forest. The taller trees are often bottle trees (*e.g.*, *Ceiba*). Practically no epiphytes present. Undergrowth composed of tree reproduction and true woody shrubs. Succulents may be present (*e.g.*, in form of thin-stemmed caespitose cacti). Both therophytic and hemicryptophytic lianas occur occasionally. A sparse herb layer may be present, mainly consisting of graminoid hemicryptophytes and forbs.

Tropical (or subtropical semi-deciduous montane or cloud forest. Similar to a, but canopy lower and covered with xerophytic epiphytes (*e.g.*, *Tillandsia usneoides*). Within group **3**, a submontane formation cannot be clearly distinguished.

- 4. Subtropical ombrophilous forests.** (Present only locally and in small fragmentary stands, because the subtropical climate is typically a climate with a dry season. Where the subtropical ombrophilous forest occurs *e.g.*, Queensland/Australia and Taiwan, it usually grades rather inconspicuously into the tropical ombrophilous forest, Its trees are less vigorous and allow some shrubs to grow in the understory. The subtropical ombrophilous forest should however not be confused with the tropical ombrophilous montane forest, which occurs in a climate with a similar mean annual temperature, but with less pronounced temperature differences between summer and winter.) Consequently, seasonal rhythms are more evident in all subtropical forests, even in the ombrophilous ones. The subtropical ombrophilous forest is physiognomically more closely related to the tropical than to the temperate one, Therefore the subdivisions conform more or less to point 1 a-h.
- 5. Mangrove forests.** (Occur only in the tidal range of the tropical and subtropical zones.) Composed almost entirely of evergreen sclerophyllous broad-leaved trees and shrubs with either stilt roots or pneumatophores. Epiphytes in general rare, except lichens on the branches and adnate algae on the lower parts of the trees. (Subdivisions possible; transitions to 1 g exist).
- 6. Temperate and subpolar evergreen ombrophilous forests.** (Occurring only in the extremely oceanic, nearly frostfree climate on the southern hemisphere, mainly in Chile). Consisting mostly of truly evergreen hemisclerophyllous trees and shrubs, Rich in thallopiphytes and in ground-rooted herbaceous ferns,
- a. Temperate evergreen ombrophilous broad-leaved forest. Some vascular epiphytes and lianas present; height generally exceeds 10m.
- (1). Without conifers
- (2). With conifers admixed
- b. Temperate evergreen ombrophilous alluvial forest. Richer in herbaceous undergrowth than a. (Not yet sufficiently investigated).

- c. Temperate evergreen ombrophillous swamp forest. (Perhaps existing, but not yet known.)
- d. Subpolar evergreen ombrophillous forest. In contrast to a, vascular epiphytes lacking canopy height much reduced in general less than 10 m).

**7. Temperate evergreen seasonal broad-leaved forests.** (With pronounced summer rainfall<sup>4</sup>) Consisting mainly of hemi-sclerophyllous evergreen trees and shrubs, Rich in herbaceous chamaephytic and hemicryptophytic undergrowth. Very few or no vascular epiphytes and lianas. Grades into subtropical or temperate ombrophilous forest. Probably includes subpolar types. (Subdivisions similar to 2a-d possible.)

**8. Winter-rain evergreen broad-leaved sclerophyllous forests.** Often understood as Mediterranean, but present also in southwest Australia, Chile, etc. Climate with pronounced summer drought.) Consisting mainly of sclerophyllous evergreen trees and shrubs, most of which show rough bark. Herbaceous undergrowth almost lacking. No vascular and only few cryptogamic epiphytes, but evergreen woody lianas present.

- a. Winter-rain evergreen sclerophyllous lowland forest (including submontane) Corresponds largely to the description under 8.
- b. (Alluvial and swamp forests of this type perhaps existing, but not sufficiently known.)

**9. Temperature and subpolar evergreen coniferous forests.** Consisting mainly of needle-leaved or scale-leaved evergreen trees, but broad-leaved trees may be admixed. Vascular epiphytes and lianas practically lacking.

- a. Evergreen giant conifer forest. Dominated by trees higher than 50 - 60 m (e.g., Sequoia and Pseudotsuga forest in the Pacific West of North America.
- b. Evergreen (nongiant) conifer forest with rounded crowns. Dominated by trees 5 - 50 m high, with more or less broad, irregularly rounded crowns (e. g Pinus spp.).
  - (1). With evergreen sclerophyllous understory (Mediterranean)
  - (2). Without evergreen sclerophyllous understory
- c. Evergreen (nongiant) conifer forest with conical crowns. Dominated by trees 5 - 60 m high (only exceptionally higher), with more or less conical crowns (like most Piceo and Abies).
- d. Evergreen (nongiant) conifer forest with cylindrical crowns (boreal). Similar to c, but crowns with very short branches and therefore very narrow, cylindro-conical.

**B. Mainly deciduous forests.** Majority of trees shed their foliage simultaneously in connection with the unfavorable season.

**1. Drought-deciduous forests.** (Tropical and subtropical). Unfavorable season mainly characterized by drought, in most cases winter-drought. Foliage is shed regularly every year. Most trees with relatively thick, fissured bark.

a. Drought-deciduous lowland (and submontane) forest. Practically no evergreen plants in any stratum, except some succulents. Woody and herbaceous lianas present occasionally, also deciduous bottle-trees. Ground vegetation mainly herbaceous (hemicryptophytes, particularly grasses, geophytes and some therophytes), but sparse.

- (1) Broad-leaved deciduous forests.
- (2) Microphyllous (including feathery-leaved legume-trees)

b. Drought-deciduous montane (and cloud) forest. Some evergreen species in the understory.

<sup>4</sup> Corresponds to the "lauraceous" forests of RUBEL, etc., which are often believed to be "winter-rain evergreen," but in reality cannot withstand much summer drought. Most frequent in East Asia.

Drought-resistant epiphytes present or abundant, often of the bearded form (e.g., *Usnea* or *Tillandsia usneoides*); canopy as in a. This formation is not frequent, but well developed, e.g., in northern Peru. (Further types of drought-deciduous forest may need recognition.)

- 2. Cold-deciduous forests with evergreen trees (or shrubs) admixed.** Unfavorable season mainly characterized by winter frost. Deciduous trees dominant, but evergreen species present as part of the main canopy or as understory. Climbers and vascular epiphytes scarce or absent.
  - a. Cold-deciduous forest with evergreen broad-leaved trees and climbers (e.g., *Hedera helix* in Western Europe). Rich in cryptogamic epiphytes, including mosses. Even vascular epiphytes may be present at the base of tree stems.
  - b. Cold-deciduous forest with broad-leaved sclerophyllous under story (e.g., sub-Mediterranean forest).
  - c. Cold-deciduous forest with evergreen needle-leaved trees (Further subdivisions possible).
- 3. Cold-deciduous forests without evergreen trees.** Deciduous trees absolutely dominant evergreen chamaephytes and some evergreen nanophanerophytes may be present. Climbers insignificant, vascular epiphytes absent (except occasionally at the lower base of the trees) thallo-epiphytes always present, particularly lichens
  - a. Temperate lowland and submontane cold-deciduous forest. Trees up to 50 m tall. Primarily algae and crustose lichens as epiphytes.
  - b. Montane or boreal cold-deciduous forest (including lowland or submontane in topographic positions with high atmospheric humidity) Foliose and fruticose lichens, and bryophytes as epiphytes. Trees up to 50 m tall, but in montane or boreal forest normally not taller than 30 m.
    - (1) Mainly broad-leaved
    - (2) Mainly deciduous coniferous (e.g., *Larix*)
    - (3) Mixed broad-leaved and deciduous coniferous
  - c. Subalpine or subpolar cold deciduous forest. In contrast to a and b canopy height significantly reduced (not taller than 20 m). Tree trunks frequently gnarled Epiphytes similar to U, but in general more abundant. Often grading into woodland (see If).
    - (1) With primarily hemicryptophytic undergrowth
    - (2) With primarily chamaephytic undergrowth, may merge with forests admixed with conifers (see 2c)
  - d. Cold-deciduous alluvial forest. (Flooded by rivers, therefore moister and richer in nutrients than a.) Trees and shrubs with high growth rates and vigorous herbaceous undergrowth. Occasionally flooded; physiognomically similar to a, with tall trees and abundant macrophyllous shrubby undergrowth. Regularly flooded; trees not as tall and dense as in a, but herbaceous abundant and tall (in Eurasia *Salix* or *Alnus* species frequently dominating)
  - e. Cold-deciduous swamp or pest forest. (Flooded until late spring or early summer, surface soil organic.) Relatively poor in tree species. Ground cover mostly continuous. (Subdivisions like b.)

**C. Extremely xeromorphic forests.** Dense stands of xeromorphic phanerophytes, such as

bottle trees, tuft trees with succulent leaves and stem succulents. Undergrowth with shrubs of similar xeromorphic adaptations, succulent chamaephytes and herbaceous hemicryptophytes, geophytes and therophytes. Often grading into woodlands (see **II**).

- 1. Sclerophyllous-dominated extremely xeromorphic forests.** Life form combination as above, except for predominance of sclerophyllous trees, many of which have bulbous stem bases largely imbedded in the soil (xylopods). (Subdivisions possible, but not yet sufficiently investigated)
  
- 2. Thorn-forests.** Species with thorny appendages predominate.
  - a. Mixed deciduous-evergreen thorn forest. Many merge with **1**.
  - b. Purely deciduous thorn forest. Most common form.
  
- 3. Mainly succulent forests.** Tree-formed (scapose) and shrub-formed (caespitose) succulents very frequent, but the other xero-phanerophytes present as well.

- II. WOODLANDS. (Open stands of trees).** Formed by trees at least 5 m tall, with most of their crowns not touching each other, but covering at least **30%** of the surface; grass cover sometimes present. This formation class does not include savannas or parklands.
- A. Mainly evergreen woodlands, i.e., evergreen as defined in IA.**
- 1. Evergreen broad-leaved woodlands.** Mainly sclerophyllous trees and shrubs, no epiphytes. (Subdivisions with regard to undergrowth variations possible.)
  - 2. Evergreen needle-leaved woodlands.** Mainly needle- or scale-leaved. Crowns of many trees extending to the base of the stem or at least very branchy.
    - a. Evergreen coniferous woodlands with rounded crowns (e.g., *Pinus*). Without evergreen sclerophyllous understory (Mediterranean) (Further subdivisions according to undergrowth variations and frequency of epiphytes are possible).
    - b. Evergreen coniferous woodland, with conical crowns prevailing (mostly subalpine).
    - c. Evergreen coniferous woodland with very narrow cylindro-conical crowns (e.g., *Picea* in the boreal region).
- B. Mainly deciduous woodlands (see I B).**
- 1. Drought-deciduous woodlands.** (Subdivisions more or less like forests).
  - 2. Cold-deciduous woodlands with evergreen trees (see 1B2).**
  - 3. Cold-deciduous woodlands. (See IB3: most frequent in the subarctic region, elsewhere only on swamps or bogs). Without evergreen trees.**
    - a. Broad-leaved deciduous woodland.
    - b. Needle-leaved deciduous woodland.
    - c. Mixed deciduous woodland (broad-leaved and needle-leaved).
- C. Extremely xeromorphic woodlands.** Similar to IC, the only difference being the more sparse stocking of individual trees. (Subdivisions as under IC).

- III SCRUB.** (Shrublands or thickets.) Mainly composed of caespitose woody phanerophytes 0,5-5 m tall.\* Each of the following subdivisions may be either of the following:
- shrubland = most of the individual shrubs not touching each other, often with a grass stratum
  - thicket = individual shrubs interlocked
- A. Mainly evergreen scrub.** (Evergreen in the sense of IA.)
- 1. Evergreen broad-leaved shrublands.** (Or thickets.)
    - a. Low bamboo thicket (or, less frequently, shrubland). Lignified creeping graminoid nano- or microphanerophytes.
    - b. Evergreen tuft tree shrubland (or thicket). Composed of small trees and wood shrubs (e.g., Mediterranean dwarf palm shrubland or Hawaiian tree fern thicket).
    - c. Evergreen broad-leaved hemi-sclerophyllous thicket (or shrubland). Caespitose, creeping or lodged nano- or microphanerophytes with relatively large and soft leaves (e.g., subalpine *Rhododendron* thickets, or *Hibiscus tiliaceus* matted thickets of Hawaii).
      - (1). Evergreen broad-leaved sclerophyllous shrubland (or thicket). Dominated by broad-leaved sclerophyllous shrubs and immature trees (i.e., chaparral or macchia). May often merge with parkland, grassland or heath.
      - (2) Evergreen suffruticose thicket (or shrubland). Stand of semilignified nanophanerophytes that in dry years may shed part of their shoot systems (e.g., *Cistus* heath.)\* (Additional units may be distinguished.)
  - 2. Evergreen needle-leaved and microphyllous shrublands** (or thickets).
    - a. Evergreen needle-leaved thicket {or shrubland). Composed mostly of creeping or lodged needle-leaved phanerophytes (e.g., *Pinus montana*, "krummholz").
    - b. Evergreen microphyllous shrubland (or thicket. Often ericoid shrubs (mostly in tropical subalpine belts). (Further subdivisions possible.)
- B. Mainly deciduous scrub.** (Deciduous in the sense of IB.)
- 1.-3.** Subdivisions similar to **IIB1-3.**
  - 4. Cold-deciduous shrublands.** (Or thickets).
    - a. Temperate deciduous thicket (or shrubland). More or less dense scrub without or with only little herbaceous undergrowth. Poor in cryptogams.
    - b. Subalpine or subpolar deciduous thicket {or shrubland). Up-right or 'lodged caespitose nanophanerophytes with great vegetative regeneration capacity. As a rule completely covered by snow for at least half a year.
      - (1) With primarily hemicryptophytic undergrowth, mainly forbs (e.g., subalpine *Alnus viridis* thicket)
      - (2) With primarily chamaephytic undergrowth, mainly dwarf shrubs and fruticose lichens (e.g., *Betula tortuosa* shrubland at the polar tree line)
    - c. Deciduous alluvial shrubland (or thicket). Fast growing shrubs, occurring as pioneers on river banks or islands that are often vigorously flooded, therefore mostly with very sparse undergrowth.
      - (1) With lanceolate leaves (e.g., *Salix*, mostly in lowland or submontane regions)
      - (2) Microphyllous (e.g., *Tamarix*). Deciduous peat shrubland (or thicket). Upright caespitose nano-phanerophytes with *Sphagnum* and (or) other peat mosses. (Subdivisions possible.)

**C. Extremely xeromorphic (subdesert) shrublands.** Very open stands of shrubs with various xerophytic adaptations, such as extremely scleromorphic or strongly reduced leaves, green branches without leaves, or succulent stems, etc., some of them with thorns.

**1. Mainly evergreen subdesert shrublands.** In extremely dry years some leaves and shoot portions may be shed.

a. (Truly) evergreen subdesert shrubland.

(1) Broad-leaved, dominated by sclerophyllous nanophanerophytes, including some phyllocladous shrubs (e.g., mulga scrub in Australia)

(2) Microphyllous, or leafless, but with green stems (e.g., *Retama retarn*)

(3) Succulent, dominated by variously branched stem and leaf succulents

b. Semi-deciduous subdesert shrubland. Either facultatively deciduous shrubs or a combination of evergreen and deciduous shrubs.

(1) Facultatively deciduous (e.g., *Atriplex-Kochia-saltbush* in Australia)

(2) Mixed evergreen and deciduous, transitional to **2**

**2. Deciduous subdesert shrublands.** Mainly deciduous shrubs, often with a few evergreens.

a. Deciduous subdesert shrubland without succulents.

b. Deciduous subdesert shrubland with succulents.

**IV. DWARF-SCRUB AND RELATED COMMUNITIES**, rarely exceeding 50 cm in height (sometimes called heaths or heath-like formations. According to the density of the dwarf-shrub cover are distinguished:

dwarf-shrub thicket = branches interlocked

dwarf-shrubland = individual dwarf-shrubs more or less isolated or in clumps  
cryptogamic formations surface densely covered with mosses or lichens

with dwarf-shrubs = (thallochamaephytes); dwarf-shrubs occurring in small clumps or individually; in the case of bogs locally dominating graminoid communities may be included

**A. Mainly evergreen dwarf-scrub. Most dwarf-shrubs evergreen**

**1. Evergreen dwarf-shrub thickets.** Densely closed dwarf-shrub cover, dominating the landscape ("dwarf-shrub heath" in the proper sense).

a. Evergreen caespitose dwarf-shrub thicket. Most of the branches standing in upright position, often occupied by foliose lichens. On the ground pulvinate mosses, fruticose lichens or herbaceous life shoot systems (e.g., *Cistus* heath.)\*

b. Evergreen creeping or matted dwarf-shrub thicket. Most 'branches creeping along the ground. Various combined with thallochamaephytes in which the branches may be imbedded (e.g., *Loiseleuria* heath). Subdivision possible.

**2. Evergreen dwarf-shrublands.** Open or more loose cover of dwarf-shrubs.

a. Evergreen cushion shrubland. More or less isolated clumps of dwarf-shrubs forming dense cushions, often equipped with thorns (e.g., *Astragalus* and \* *Acantholimon* 'porcupine-heath of the East Mediterranean mountains).

b. Evergreen mosaic dwarf-shrubland. Colonies or clumps of dwarf-shrubs interrupted by other life forms, bare soil or rocks (e.g., *Erica tetralix* swamp heath. Transitions into **D** and **E** possible.

**3. Mixed evergreen dwarf-scrub and herbaceous formations.** More or less open stands of evergreen suffrutescent or herbaceous chamaephytes. various hemicryptophytes, geophytes, etc.

a. Truly evergreen dwarf-scrub and herb mixed formation (*Nardus-Colluna*-heath).

b. Partially evergreen dwarf-scrub and herb mixed formation. Many individual's shed parts of their shoot systems during the dry season (e.g., *Phrygana* in Greece).

**B. Mainly deciduous dwarf-scrub.** Similar to **A**, but mostly consisting of deciduous species,

**1. Facultatively drought deciduous dwarf-thickets.** (Or dwarf-shrublands.). Foliage is shed only in extreme years.

**2. (Obligatory) drought-deciduous dwarf-thickets.** (Or dwarf-shrublands.)

Densely closed dwarf-scrub stands which lose all or at least part of their leaves in the dry season,

a. Drought-deciduous caespitose dwarf-thicket Corresponding to **A1a**.

b. Drought-deciduous creeping or matted dwarf -thicket. Corresponding to **A1b**.

c. Drought-deciduous cushion dwarf-shrubland. Corresponding to **A2a**.

d. Drought-deciduous mosaic (or mixed) dwarf-shrubland. Deciduous and evergreen dwarf-

shrubs, caespitose hemicryptophytes, succulent chamaephytes and other life forms intermixed in various patterns.

- 3. Mixed cold-deciduous and evergreen dwarf-thickets. (Or dwarf-shrub lands.)** Subdivisions similar to **2**.
  - 4. Cold-deciduous dwarf-thickets.** (Or dwarf -shrublands.) Physiognomically similar to **2**, but shedding the leaves at the beginning of a cold season. Usually richer in cryptogamic chamaephytes. Subdivisions similar to **2**. Transitions into D and E possible. In **A** and **B**, further subdivisions are possible. e g., subdivisions based on the distribution pattern and height of woody phanerophytes in the dwarf-scrub matrix, similar to **VA**.
- C. Extremely xeromorphic dwarf-shrublands.** More or less open formations consisting of dwarf-shrubs, geophytes, therophytes and other life forms adapted to survive or to avoid a long dry season. Mostly subdesertic. (Subdivisions similar to **IIIC**.)
- D. Moss, lichen and dwarf-shrub tundras.** Slowly growing, low formations, consisting mainly of dwarf-shrubs and cryptogams, beyond the subpolar tree line. (Except in boreal regions, dwarf-scrub formations above the mountain tree line should not be called tundras, because they are as a rule richer in dwarf-shrubs and grasses, and grow taller due to the greater radiation in lower latitudes.) Often showing plant patterns caused by freezing movements of the soil (cryoturbation).
- 1. Mainly bryophyte tundras.** Dominated by mats or small cushions of chamaephytic mosses. Groups of dwarf—shrubs are as a rule scattered irregularly and are not very dense. General aspect more or less dark green, olive green or brownish.
    - a. Caespitose dwarf-scrub-moss tundra.
    - b. Creeping or matted dwarf-scrub-moss tundra.
  - 2. Mainly lichen tundras.** Mats of fruticose lichens dominating, giving the formation a more or less pronounced grey aspect. Dwarf-shrubs mostly evergreen, creeping or pulvinate.
    - a. Dwarf-scrublichen tundra. (Other tundra types more or less rich in chamaephytes may be distinguished.)
- E. Mossy bog formations with dwarf-shrubs.** Oligotrophic peat accumulations formed mainly by Sphagnum or other mosses, which as a rule cover the surface as well. Dwarf-shrubs are concentrated on the relatively drier parts or are loosely scattered. To a certain extent they resemble dwarf-scrub formations on mineral soil Graminoid hemicryptophytes, geophytes with rhizomes and other herbaceous life forms may dominate locally. Slowly growing trees and shrubs can grow as isolated individuals, in groups or in woodlands, which are marginal to the bog or may be replaced by open formations in a cyclic succession. The following subdivisions correspond to the classification of bog types adopted in Europe.
- 1. Raised bogs.** By growth of Sphagnum species raised above the general ground-water table and having a ground-water table of their own. Therefore no more supplied by mineral water (i.e., water having been in touch with the inorganic soil), but only by rain water (truly ombro-trophic bogs).
    - a. Typical raised bog (suboceanic, lowland and submontane). Mosses dominating throughout, except on locally raised dry hummocks, which are dominated by dwarf-shrubs. **Trees rare**

and, if present, concentrated on the marginal slopes of the convex peat accumulation. Mostly surrounded by a very wet, but less oligotrophic sedge swamp (Swedish "lagg," see **VD**).

- b. Montane (or 'subalpine') raised bog. Growing slower than the typical' raised bog (or formed in an earlier period with a warmer climate and actually "dead' or being destroyed by erosion). Often covered with sedges or evergreen dwarf-shrubs. Micro- or nanophanerophytes (e.g., *Pinus montana*) locally dominating.
- c. Subcontinental "wood" and bog. Temporarily covered by open wood of low productivity, which in a sequence of wetter years may be replaced by *Sphagnum* formations similar to a. (Various subdivisions of a b and c possible.)

**2. Nonraised bogs.** Not or not very markedly raised above the mineral water table of the surrounding landscape, Therefore in general wetter and not as oligotrophic as **1**. Poorer in mosses than la, to which various forms of transitions are possible.

- a. Blanket bog (oceanic lowland, submontane or montane). The micro-surface of the bog is less undulating and less rich in actively growing mosses than in la. Evergreen dwarf-shrubs are scattered as well as caespitose hemicryptophytes (sedges or grasses) and some rhizomatous geophytes.
- b. String bog (Finnish aapa' bog) Flat oligotrophic bog with strings in the boreal lowlands, The Finnish name indicates an open bog without or with only a few trees of very poor vigor, which grow on narrow and low elongated hummocks, the so-called strings. These peat strings are formed by pressure of the ice covering the more or less flooded bog from early fall to late spring. Only these strings are covered by, dwarf-shrubs and are rich in *Sphagnum*. The main part of the bog is similar to a wet sedge swamp. Subdivisions of a and b possible.

- V. TERRESTRIAL HERBACEOUS COMMUNITIES.** Grasses, graminoid and other herbaceous plants are predominant in the cover, but woody plants may be sparingly present (i.e., covering not more than 30%).
- A. Savannas and related grasslands** (tropical or subtropical grasslands and parklands). Trees or shrubs almost regularly present often fire-scarred (fires frequent in the dry season).
- 1. Tall-grass savannas.** Dominated by broad-leaved and tall grasses (corresponding to relatively humid conditions within the tropics and subtropics). Hernicryptophytic caespitose grasses most frequent, yellowing during the dry season. In general without cryptogams. Subdivisions are based on the distribution pattern and height of woody phanerophytes in the grassy matrix.<sup>5</sup>
    - a. Woodland with patches of tall-grass savanna (woodland savanna). Tree groups and isolated trees which are interspersed by small patches of grassland. (Subdivisions according to woodland formation, see **II.**).
    - b. Tall-grass savanna with isolated trees (tree savanna). Isolated trees dispersed more or less regularly over the grassy matrix.
      - (1) With evergreen broad-leaved trees
      - (2) With palms
      - (3) With deciduous trees
      - (4) With extremely xeromorphic trees or succulents
    - c. Tall-grass savanna with shrubs (scrub savanna) Stands of shrubs alternating in various with grassland. (Subdivisions similar to
    - b. Tall-grass savanna (grass savanna). Practically without woody phanerophytes, in general due to anthropogenic influence. Normally called tropical grassland,” but the grass cover is physiognomically identical to above-mentioned units.
    - e. Flood savanna. Periodically inundated in various mosaic patterns, with either palms or groups of other trees on raised positions.
      - (1) With trees
      - (2) With scrub
      - (3) Without woody plants
  - 2. Short-grass savannas.** Dominated by narrow-leaved and more or less short grasses (indicating relatively drier conditions). In addition to perennial grasses annuals more frequent than in 1, in some places even predominant. (Subdivisions based on patterns formed by woody plants.)
    - a. Short-grass savanna with isolated trees.
      - (1) With evergreen trees
      - (2) With deciduous trees
      - (3) With xeromorphic trees except succulents
      - (4) With tree-succulents
    - b. Short-grass savanna with shrubs. (Subdivisions as in a.)
    - c. Short-grass savanna (grass savanna). Without trees or shrubs (e.g., tropical montane grassland, like ‘puna’ grassland of the Andes).
- B. Steppes and related grasslands** (e.g., North American “prairies,” etc.; temperate, with late summer drought and winter frost season). Trees or shrubs absent as a rule, except on

<sup>5</sup> Studies have shown that these patterns are largely related to human influence, except in the case of the flood savanna. Savannas may form various mosaics with either forest, woodland or scrub, often fire-scarred.

wetter sites,<sup>6</sup> e.g., along rivers, in ravines and in the forest border ecotone. Seasonal change of physiognomic-floristic aspects very pronounced. In spring therophytes and geophytes are most conspicuous, later hemicryptophytes dominate the aspect.

- 1. Tall-grass steppes.** (Or prairies.) Caespitose grasses taller than 1. m dominate (indicating a more humid climate).
    - a. Tall-grass steppe with trees.
    - b. Tall-grass steppe with shrubs.
    - a. Tall-grass steppe without woody plants.
  - 2. Mid-grass steppes.** (Or prairies.) Intermediate between **1** and **3**. Medium-sized grasses locally frequent. (Subdivisions as in **1**.)
  - 3. Short-grass steppes.** (Or prairies.) Mostly composed of mat-forming, more or less low grasses. (Subdivisions a - c as in **1**.)
    - d. Short-grass steppe with suffrutescent plants.
  - 4. Forb-rich steppes. Broad-leaved forbs,** mostly hemicryptophytes, are frequent (in a climate transitional to forest climate, e.g., in Russia.) These “meadow steppes” resemble the meadows under C. (Subdivisions as in **1**.)
- C. Meadows, pastures or related grasslands.** (Temperate or subpolar grasslands in a forest climate with no marked dry season.) Mesophytic hemicryptophytes dominating as a rule. Below the snow cover many plants remain green at least partially during the whole winter.
- 1. Meadows and pastures below tree line.** Anthropozoogenic formations in the forest climate belt (except avalanche grassland). As a result of different management distinguished as:
    - meadow = grassland mainly used for hay production, growing rhythm and aspects largely determined by mowing once or several times per year
    - pasture = grassland mainly used for grazing; no marked seasonal aspects; by selective grazing, the animals produce small scale mosaics of tall and low groups of plantsThe following subdivisions are based on distribution patterns of woody phanerophytes:
    - a. Woodland pasture. Woodland opened up through grazing practice, consisting of isolated irregularly grouped trees.
    - b. Tree meadow (or pasture). Grassland with isolated trees. c, Scrub pasture (or meadow). Shrub groups in grassland.
    - d. Grassy pasture without trees or shrubs. Frequently grazed. Height of grasses, legumes and other forbs varies with region and management.
      - (1) Extensively grazed (German Triftweide, not fertilized); hard, thorny or other plants on which animals do not feed (“grazing weeds”) are most frequent
      - (2) Intensively grazed (German “Standweide” or “Untriebsweide,” fertilized); kept in closely cropped condition, forms a dense grass carpet; soft food plants dominating throughout; “grazing weeds” usually rare
    - e. Grassy meadow without trees or shrubs. Mowed and only exceptionally grazed. More or less tall caespitose grasses and tall, mostly scapose herbs dominating.
      - (1) Litter meadow (German “Streuweise,” mowed for obtaining straw for bedding animals in the stables; generally not fertilized and mowed only in the faU, after the shoots have dried); as a result the slowly developing bunch grasses become dominating

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<sup>6</sup> Only in anthropogenic steppes, trees or shrubs and steppe-grassland may occur on the same physical habitat.

(2) Hay meadow (German ‘Futterwiese,’ generally fertilized; mowed for making hay to feed animals); rapidly developing in the early growing season, therefore rich in malacophyllous grasses and forbs, mowed several times a year; this management produces a very marked change in aspect

(a) Poor in spring geophytes (lowland or submontane)

(b) Rich in spring geophytes (montane or subalpine); snow cover disappears late in spring and prevents grasses from growing up earlier than geophytes (e.g., Crocus or Narcissus)

- f. Sedge—rush meadow. More or less sclerophyllous graminoid herbs dominate, indicating periodically water-logged soil (transition to D).
- g. Avalanche grassland. (The only non-anthropogenic meadow. Occurring as narrow strips of grassland between forests on steep slopes of high mountains, where avalanches, descending annually in spring, prevent forest establishment.) Composition of herb cover similar to d(1), but very variable. Major variations:
  - (1) With shrubs or damaged trees
  - (2) Without shrubs

**2. Pastures and meadows above mountain tree line.** (Or beyond northern tree line.) Only exceptionally with shrubs or gnarled trees. Covered with snow more than **6** months of the year.

- a. Closed alpine (or subpolar) mat. Without snow cover at least **4 - 5** months.
  - (1) *Rich* in graminoids
  - (2) Rich in forbs
  - (3) With dwarf-shrubs
- b. Alpine (or subnivean) mat-patches (upper alpine or subnivean). More or less open formation, covers the soil unevenly. (Subdivisions similar to a.)
- c. Snow bed formation. (Covered by snow more than 8—9 months yearly; water-logged by melting snow.) Open formation, rich in small forbs or forb-like dwarf shrubs (e.g., *Salix herbacea*). (Subdivisions possible.)

**D. Sedge swamps and flushes.** Open formations on constantly or more or less water-logged ground, without or with only a few woody plants.

**1. Sedge peat swamps and similar swamps.** Dominated by sedges (i.e., graminoid hemicryptophytes or geophytes), seasonally flooded.

- a. Tall-sedge swamp. (Frequently flooded, and commonly for long periods: as a rule natural.) Foliage taller than 30-40 cm, sedges dominating throughout; very few other life forms.
  - (1) With creeping sedges, forming large homogeneous stands (e.g., *Carex gracilis*)
  - (2) With caespitose sedges, forming tufts or hummocks (e.g., *Carex elata*)
- b. Low-sedge swamp. (Flooded only little or only for short periods; mostly anthropogenic.) Small sedges (*Carex*, *Juncus*, *Scirpus*, etc., foliage not higher than 30 cm) of low productivity dominating, intermixed with many other herbaceous life forms.
- c. Hard hummock swamp. Formed by very hard-leaved, mostly small sedges, therefore more compact and easier to walk on than a (2). Rare (e.g., in the tropical Andes).

**2. Flushes** (German "Quellfluren"). Evergreen herbaceous or cryptogamic vegetation growing on habitats where seepage water crops up at the surface. (Constantly wet, but rarely flooded.)\*

- a. Forb flush. Mostly dominated by small forbs.

- (1) Calcareous; older parts of plants covered by a white or brownish crust of precipitated carbonate
  - (2) Non-calcareous
  - b. Moss flush. Dominated by mosses. Covering only very small areas, often forming mosaics with graminoid formations. (Subdivisions like a.)
- E. Herbaceous and half-woody salt swamps.** Halophilous or salt-tolerant plants building more or less dense permanent formations. Most species are suffrutescent (half-woody). Shrubs or trees absent or only exceptionally present.
- 1. Halophytic half-woody shrub formations.** Dominated by more or less succulent half-woody shrubs up to 1 m high, at least partially evergreen.
    - a. Marine half-woody salt marsh. (Growing near the sea coast on marine deposits. Flooded from time to time, but in any case for only a short period.) Rich in microscopic algae growing on the soil surface.
      - (1) Succulent; dominated by succulents (e.g., *Salicornia*)
      - (2) Nonsucculent; poor in truly succulent plants, frequently rich in more or less nitrophilous, quickly growing half-shrubs (e.g., *Obione* or *Artemisia* spp.); often forming narrow strips or bands along the rills on the seashore, where organic matter has been deposited
    - b. Inland half-woody salt marsh. Similar to a (but growing in continental depressions, flooded in wet seasons and drying out during the less rainy ones). In general more xeromorphic than a. Poor in algae
      - (1) Succulent
      - (2) Nonsucculent
  - 2. Salt meadows.** Mainly herbaceous. More or less closed formations of hemicryptophytes, herbaceous chamaephytes and other nonwoody life forms, but poor in annuals.
    - a. Marine salt meadow. (Within the tidal range of temperate sea shores. but not flooded daily). More or less densely closed stands of quickly growing grasses and (or) succulent forbs.
      - (1) Rich in succulents
      - (2) Poor in succulents
    - b. Inland salt meadow. Similar to a (but growing in continental conditions). In general less vigorous and less dense.
      - (1) Closed; physiognomically similar to a (2), but more xeromorphic
      - (2) Open; most plants growing isolated or in tufts; soil with a more or less thick salt cover, at least in the dry season; transitional to **VI B**
- F. Forb vegetation<sup>7</sup> and similar communities.** More or less broad-leaved herbs dominating, normally mesophyllous and deciduous. Woody life forms only exceptionally present. In general covering small areas which cannot be represented on small scale maps.
- 1. Mainly perennial forb communities.** Dominated by nongraminoid hemi-cryptophytes and geophytes. Annuals sometimes present, but of little importance.
    - a. Forest border herb formation, Between adjoining phanerogamic and herbaceous vegetation occurring as a narrow transitional band, consisting of hemicryptophytes, geophytes and therophytes. Growing more vigorously than the adjacent pasture or meadow,
    - b. Tall-forb formation (German "Hochstauden" formation). Dense stands of broad-leaved,

<sup>7</sup> Forb (American) means "nongraminoid herb" (German "Kraut").

mostly dicotyledonous herbs taller than 50 cm, mesophyllous, well provided with nitrogen and other nutrients.

- c. Fern thicket (or heath). *Pteridium aquilinum* or *Dicranopteris* sp. dominating and forming nearly pure stands on pastured heathlands within forest regions. (The only forb formation covering large areas).
- d. Perennial forb formation on organic deposits at the flood lines. Consisting of broad-leaved herbs, growing abundantly on more or less decomposed organic deposits, which are often renewed by floods.
- e. Perennial ruderal and clearing herb formation. More or less broad-leaved herbs (growing on debris, ruins and other places strongly influenced by man).
- f. Mainly perennial weed formation on cultivated land. Mostly hemicryptophytic or geophytic weeds, growing more or less abundantly in the shade of cultivated perennial plant stands. Annual weeds are present, but not predominant (see 2d). The significance of weed formations greatly diminished by use of herbicides.\*

**2. Mainly ephemeral forb communities.** Therophytes more frequent than perennial herbs. Vegetation cover often not as dense as in A.

- a. Tropical or subtropical ephemeral cloud desert forb formation. (Best developed on the coastal hills of Peru and northern Chile. where, from fall to spring, moving clouds moisten the vegetation and the soil by condensed water.) Dominated by annual broad-leaved herbs. which germinate at the beginning of the cloudy season and grow abundantly until the end of it, giving the landscape a fresh and green look. In the dry season the aspect is desert-like. Phanerophytes may be present as relicts of natural cloud-woodland. Geophytes and cryptogamic hemicryptophytes or chamaephytes are constantly present and may become dominant locally.
- b. Ephemeral halophytic formation. (Growing normally in more extreme conditions than salt meadows, see VE2.) More or less open formation of annual halophytes. Some permanent herbs and grasses may be present.
- c. Ephemeral ruderal and clearing forb formation Like 1e, but dominated by annuals.
- d. Mainly ephemeral weed formation on cultivated. Similar to 1f, but rich in annuals or species that germinate in fall and die after fructification during the next vegetation period.

**3. Episodical forb communities.** Very unstable ephemeral plant groupings on small scale maps, crops rather than weed formations are to be shown, appearing not regularly every year, but only when the growing conditions are favorable.

- a. Episodical desert forb formation ("flowering desert"). Mostly broad-leaved, rapidly developing herbs with hardy seeds that germinate after episodical rain fall. Often concentrated in depressions (some of them hardly discernible) where the surface water accumulates. Sometimes this formation may fill the gaps between permanent subdesert plant, e.g., xeromorphic shrubs or succulents belonging to formations III C or IV C.
- b. Episodical formation on pond muds and similar sites. (Developing, when the pond water has been drained—every year or after some or several' years.) Dominated by forbs, whose seeds neither decay nor germinate while the bottom of the pond is inundated, but germinate and grow rapidly after the mud has emerged again.
- c. Episodical forb formation on organic deposits at the flood lines. Similar to 1d, but less permanent and mainly composed of annuals, whose seeds have been carried along together with organic deposits. Perennials may be present.
- d. Episodical river bed formation. Ephemeral herbs, grasses or sedges developing in the dry

parts of river beds during low water periods of more than 2 months. Depending upon seeds supplied by the river; therefore very unstable not only in density but also in species composition and pattern.

**VI. DESERTS AND OTHER SCARCELY VEGETATED AREAS.** (Subdeserts are included in the formation classes HI to V.) Bare mineral' soil determines the aspect more or less constantly. Plants are scattered or may be absent.

**A. Scarcely vegetated rocks and screes.**

**1. Scarcely vegetated rocks.**

a. Chasmophytic vegetation. Permanent plants rooting in fissures of rocks or walls. (subdivisions according to life forms in different latitudes and altitudes.)

b. Adnate Bromeliaceae on rocks (only in the neotropics).

C. Cryptogamic mat on rocks.

(1) Foliose lichens and mosses dominant

(2) Crustose lichens dominant

(3) Blue algae dominant ("ink-strips," German "Tintenstriche"); dark strips on rocks caused by Cyanophyceae that grow actively when the water is trickling down

**2. Scarcely vegetated screes.** (More or less unstable, steep slopes of stones beneath weathering rocks.) Mostly permanent herbs or half-woody plants adapted to survive the movement of stones at the scree surfaces sometimes even stopping them. Subdivisions mainly according to the length of the **vegetation** period:

a. Lowland and submontane scree formation.

b. Montane scree formation,

c. High mountain scree formation.

**B. Scarcely vegetated sand accumulations.** (Wood, scrub, grassland and other more or less closed formations on fixed dunes are treated in the formation classes listed above) Moving quicksand with isolated plants that are contributing to its fixation: or bare shifting sand dunes. Vegetation covering not more than one third of the surface.

**1. Scarcely vegetated sand dunes.**

a. Tall-grass dune. (Coastal white dune," Mostly rich in carbonates and nutrients.) Built up and partially covered by geophytic grasses or grass-like plants which are able to adapt their root and shoot system to new accumulations of sand that bury them in stormy periods.

(1) Tropical and subtropical

(2) Temperate, showing a marked annual growing rhythm

b. Short-grass dune. (Mostly continental, more or less acid and poor in nutrients). Low hemicryptophytic or geophytic grasses and sedges fixing the quicksand

c. Forb dune (possibly existing).

**2. Bare sand dunes.** Only exceptionally with some isolated plants.

a. Shifting dunes in desert climate (natural).

b. Shifting dunes in forest climate (anthropozoogenic).

**C. True deserts.** Vegetation largely absent,

(Subdivisions possible only according to geological and morphological criteria. Desert valleys may be classified into one of the preceding formations.)

- VII. AQUATIC PLANT FORMATIONS**, Composed of rooted and (or) floating plants that endure or need water covering the soil constantly or at most times of the year.
- A. Floating meadows.** Densely interwoven forbs and (or) mosses covering permanent fresh water accumulations, Most of the phanerogams being heliophytes, not true water plants.
- 1. Mainly herbaceous floating meadows.** Dominated by sedges or herbs with rhizomes. Chamaephytes and even phanerophytes may be present.
    - a. Tropical and subtropical herbaceous floating meadow.
    - b. Temperate and subpolar herbaceous floating meadow, with pronounced seasonal aspects.
  - 2. Mainly mossy floating meadows.** Mosses dominating throughout, but phanerogams may be present.
    - a. Mossy floating meadow (temperate or subpolar). (Further formations possibly exist)
- B. Reed-swamps.** Tall heliophytes rooting in the soil at the bottom of shallow lakes, slowly flowing rivers or similar waters.
- 1. Reed-swamp formations of fresh water lakes.** Mostly broad-leaved plants which cannot endure high salt concentration. All shoots upright, only exceptionally floating in the water.
    - a. Tropical and subtropical fresh water reed-swamp. Seasonal aspects not pronounced.
    - b. Temperate and subpolar fresh water reed-swamp. In winter time most plants yellow or dormant.
  - 2. Reed-swamp formations of salt water lakes.** More or less scleromorphous plants resisting high salt concentrations, Normally not as tall as **1**.
    - a. Tropical and subtropical salt water reed-swamp.
    - b. Temperate salt water reed-swamp.
  - 3. Reed-swamp formations of flowing water.** Shoots more flexible than in **1** and **2**, sometimes with floating leaves.
    - a. Tropical and subtropical reed-swamp on river banks.
    - b. Temperate reed-swamp on river banks.
- C. Rooted floating-leaf communities.** (Subdivisions more or less similar to B.)
- D. Rooted underwater communities.** Comprised of aquatic plants that are structurally supported by water (i e., non-self-supporting in contrast to aquatic heliophytes). (Subdivisions possible.)
- E. Free-floating (nonrooted) fresh water communities.**
- 1. Broad-leaved, free-floating communities.**
    - a. Tropical and subtropical broad-leaved, free-floating formation (e. g , Pistia, Pontederia and Eichhornia).
    - b. Temperate broad-leaved, free-floating formation. Disappearing in the cold season (e.g., Stratiotes).
  - 2. Lemna-type free-floating communities.**  
(Subdivisions similar to **1**.)
  - 3. Free-floating macroscopic algal communities.** (Subdivisions possible.)