KINDS OF STIPULES—There are several kinds of stipules, *viz* :—*(i)* free-lateral, *(ii)* adnate, *(iii)* intrapetiolar, *(iv)* interpetiolar, *(v)* ochreate, *(vi)* foliaceous, *(vii)* tendrillar, *(viii)* spinous and *(ix)* bud scales.

(i) Free-lateral stipules—These are tiny slender free outgrowths on both sides of the petiole at the base. This type is found in most members of the family Malvaceae, e.g. *Hibiscus rosa-sinensis* (China rose), *Abelmoschus esculentus.*

(ii) Adnate stipules—Here the two stipules are attached with the petiole on both sides upto certain distance so that petiole-base appears to be winged, e.g. *Rosa* sp. (Rosaceae).

(iii) Intrapetiolar stipules—When stipules, occurring on both sides of opposite leaves, unite together by their inner margins and are placed in between the leaves and stem i.e. at the axils of a leaf e.g. *Gardenia jasminoides* (Rubiaceae). This type is characteristic of the family Rubiaceae.

(iv) Interpetiolar stipules—These are present in most of the plants of the family Rubiaceae e.g. *Ixora* (Rangan), *Anthocephalus indicus* (Kadam), etc. These stipules are small, semi-lanceolate bodies occurring on both sides of opposite leaves, here two pairs of stipules of the two opposite leaves unite together by their outer margins—as a result the four stipules are transformed into two fused stipules and appear on two sides of the stem between the petioles of the two opposite leaves.

(v) Ochreate stipules—Ochreate stipules are sheath-like and more or less tubular in structure, enclosing greater portion of the internode. In this type several stipules unite together to form the enveloping sheath. These stipules are the characteristic feature of the family Polygonaceae, e.g. *Polygonum barbatum* (Pani marich), *Rumex vesicarius* (Chuka palang), etc.

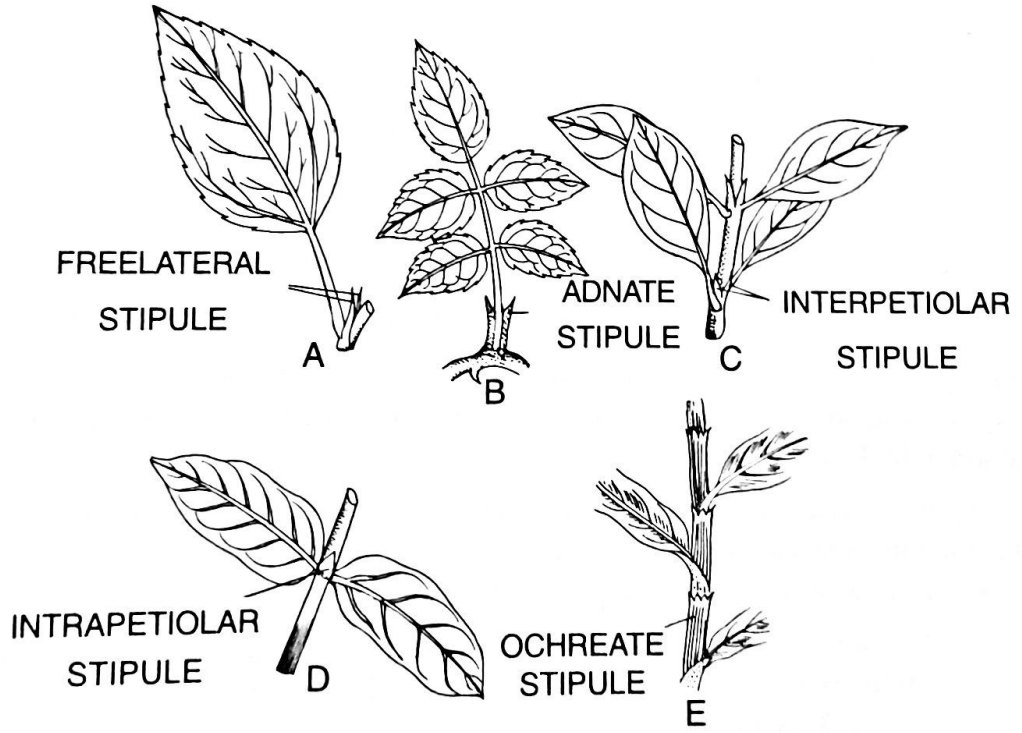

Fig. 3.5 Types of stipules (S), A - Free - Lateral; B - Adnate; C - Interpetiolar; D - Intrapetiolar; E - Ochreate.

MODIFIED STIPULES—

(vi) Foliaceous stipule—Foliaceous stipules are very conspicuous and large leaf-like on the both sides at the leaf base. In *Pisum sativum* (Papilionaceae), the foliaceous stipules look like large leaflets. In *Lathyrus aphaca* (Jangli matar, Papilionaceae), the entire leaf is modified into tendril, the large foliaceous semi-triangular stipules do the function of leaves (Fig. 3.6 A).

(vii) Tendrillar stipule—In this type the stipules become modified into coily and slender tendrils which help the plants in climbing up. Tendrillar stipules are found in *Smilax zeylanica* (Liliaceae) (Fig. 3.6 B).

(viii) Spinous stipules are those which are modified to form spinous structures, e.g. in *Capparis spinosa* (Capparidaceae), *Zizyphus mauritiana* (Rhamnaceae), *Acacia* sp. (Mimosaceae), etc. the stipules are modified into sharp pointed structures. These spines serve as defensive function (Fig. 3.6 C,D).

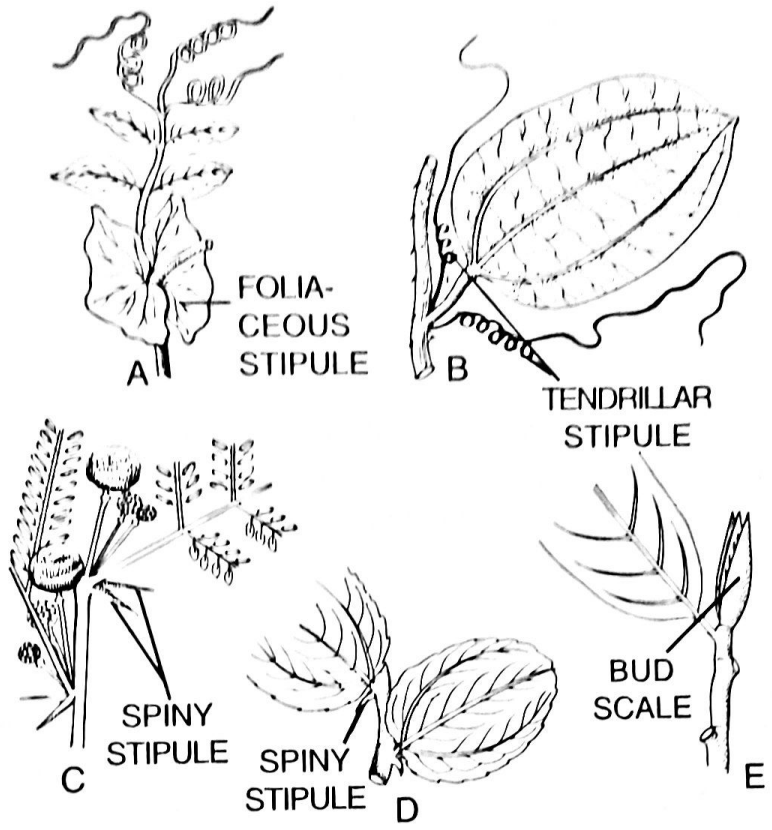

Fig 3.6 Modified stipules (S). A - Foliaceous in *Pisum* sp. B - Tendrillar in *Smilax* sp. C - Spiny in *Acacia* sp. D - Spiny in *Zizyphus* sp. E - Convolute (bud scale) in *Artocarpus* sp.

(ix) Convolute stipules or *Bud-scales*—When stipules are modified into membranous scale-like structures and protect buds by covering all round, e.g., *Artocarpus heterophyllus, Ficus benghalensis* (Moraceae) etc. Function is protection of buds (Fig. 3.6 E).

Functions of stipules : The functions of stipules are various ; these are, (a) protection of leaf bud, (b) retention of moisture in some cases, (c) function of leaves e.g. as by foliaceous stipule, (d) as defensive organs by spinous stipules, (e) as organs of support by tendrillar stipules.

Stipel—These are two small stipule-like appendages, present at the base of a leaflet in some compound leaves. Stipels are seen in many genera belonging to the family Leguminosae e.g. *Dolichos lablab, Vicea faba, Desmodium* sp., etc. (Fig. 3.28 A).

● **3.12 Phyllotaxy :** ***Phyllotaxy is the mode of arrangement of leaves on the stem and the branch in a defined orderly manner.*** The main principle of this arrangement of leaves on the stem and the branch is to avoid shading one another so that each and every leaf may get maximum amount of sunlight to perform their normal function, Eames and MacDaniels (1947) have also stated that "leaf arrangement on the stem or phyllotaxy, and variations in size and shape are doubtless in part correlated with the exposure of the photosynthetic surface to light." This arrangement of leaves in a definite manner may also bear an intimate structural relation to the vascular skeleton system of the axis.

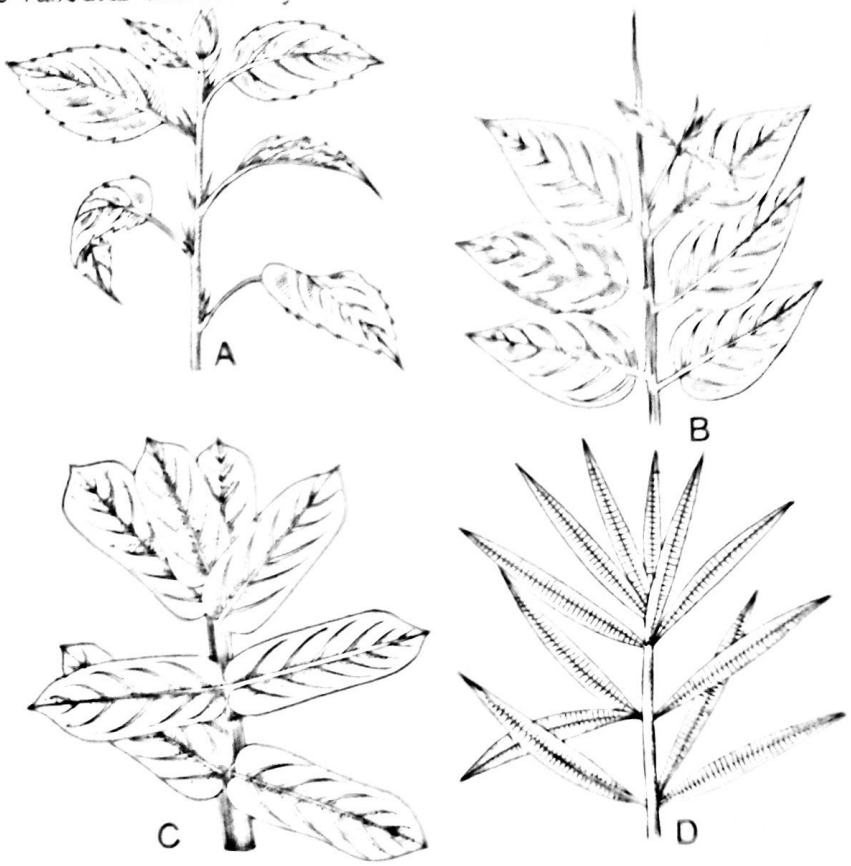

Fig. 3.15 Different types of phyllotaxy
A - Alternate, B - Opposite superposed, C - Opposite decussate, D - Whorled.

Phyllotaxy is of three principal types viz : *(i) spiral or alternate or acyclic, (ii) opposite and (iii) whorled or verticillate.* Opposite and whorled or verticillate types are commonly called cyclic type of phyllotaxy.

1. SPIRAL OR ALTERNATE PHYLLOTAXY (i.e. *acyclic type*)—In this type, leaves are arranged at each node in a spiral manner all round the stem. If an imaginary spiral line is drawn winding round the stem, it will pass through consecutive nodes. Hence it is termed as spiral phyllotaxy. This imaginary spiral line is known as *genetic spiral.* When imaginary vertical lines are drawn from upwards and downwards, it is found that all the leaves of the plant lie in a fixed number on these vertical lines ; these vertical straight lines passing through leaves are known as *orthostichies* (singular, orthostichy). The distance formed upon the spiral on the stem between two successive leaves is called *divergence.* The angle subtended by the divergence at the centre is known as *angular divergence.* The angular divergence can be found out by the following formula:

$$\text{the angular divergence} = \frac{\text{number of circle or circles}}{\text{number of leaves or orthostichies}} \text{ of a circle i.e. } 360^\circ.$$

Spiral phyllotaxy is of several kinds, such as (a) distichous or $\frac{1}{2}$ phyllotaxy, (b) tristichous or $\frac{1}{3}$ phyllotaxy, (c) pentastichous or $\frac{2}{5}$ phyllotaxy, (d) octastichous or $\frac{3}{8}$ phyllotaxy etc.

(a) *Distichous* or *Two-ranked* or $\frac{1}{2}$ *phyllotaxy*—It is a simple type found in all grasses (Gramineae e.g.

Cynodon dactylon, Oryza sativa, Triticum aestivum, etc.) and *Vanda roxburghii* (Orchidaceae). In this type, the third leaf base falls vertically above the first, the fourth above the second, the fifth above the third and so on. So, there are only two orthostichies on which all the leaves are placed. Upto the base of the third leaf there is one complete turn round the stem (*i.e.* one circle) on the genetic spiral which includes two leaves ; hence the leaves are equidistant. Therefore any two consecutive leaves are placed $^1/_3$ the distance of a circle, this is constant ; so the angle subtended by two consecutive or successive leaves in the centre of the

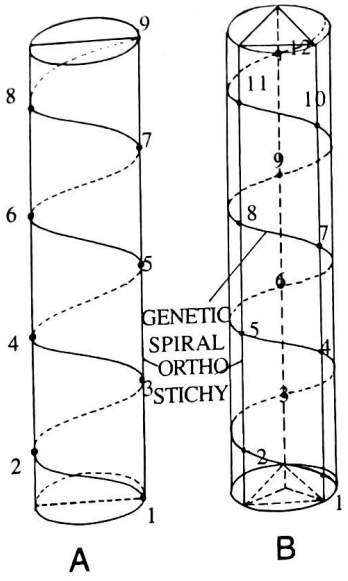

Fig. 3.16 Different types of alternate (A. Distichous, B. Tristichous) phyllotaxy showing genetic spiral and orthostichy.

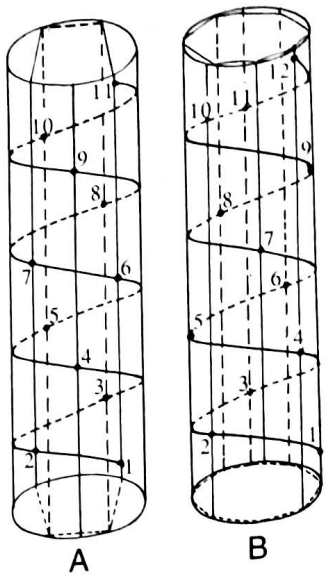

Fig. 3.17 A. Pentastichous or five-ranked phyllotaxy; B. Octastichous or eight-ranked phyllotaxy.

stem is $\frac{1 \text{ (circle)}}{2 \text{ (orthostichies)}}$ of 360^0, hence the angular divergence is 180^0 (Fig. 3.16A).

(b) *Tristichous* or *Three-ranked* or $^1/_3$ *rd phyllotaxy*—This type is found in all the members of the family Cyperaceae (*Cyperus rotundus,* etc.). The first, fourth, seventh leaf bases are on one orthostichy; the second,

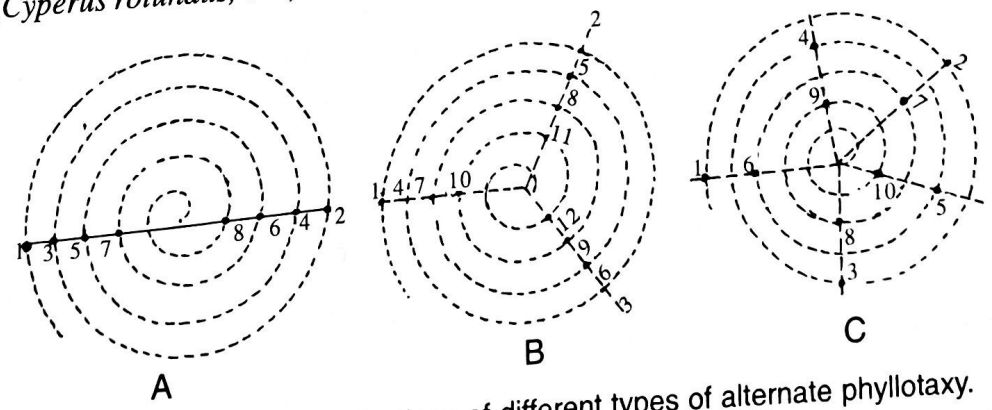

Fig. 3.18 Transverse projections of different types of alternate phyllotaxy.

fifth, eighth leaf bases on the second orthostichy; third, sixth and nineth on the third orthostichy. The three consecutive leaves at different nodes are equidistant i.e. upto the base of the fourth leaf there is one complete turn or circle which includes three leaves. Three orthostichies are found in this case. As the divergence between any two consecutive leaves being $^1/_3$ rd of a circle, the angular divergence is C-H $^1/_3$ of 360^0 = 120^0 (Fig. 3.16B).

(c) *Pentastichous* or *Five-ranked* or $^2/_5$ *th phyllotaxy*—This type of phyllotaxy is found in *Hibiscus rosa-*

sinensis (Malvaceae), *Ficus benghalensis* (Moraceae), etc. In this case the sixth leaf base stands vertically above the first, the seventh leaf base above the second, the eighth leaf base above the third and so on ; upto the base of the sixth leaf there are two complete turns including five leaves. Hence any two consecutive leaves are placed at $^2/_5$ th distance of a circle. Here five orthostichies are found, therefore the angular divergence is $^2/_5$ of $360^0 = 144^0$ (Fig. 3.17, A).

(d) Octastichous or *eight-ranked* or $^3/_8$ *th phyllotaxy*—This type of phyllotaxy is noticed in plants like *Hibiscus mutabilis* (Malvaceae), *Carica papaya* (Caricaceae), *Thevetia peruviana* (Apocynaceae), etc. Here the nineth leaf base falls vertically above the first, the tenth above the second, the eleventh above the third and so on ; there are eight orthostichies on which all the leaves are inserted. The consecutive leaves are placed at $^3/_8$ th distance of a circle, as upto the base of the nineth leaf there are three complete turns or circles which include eight leaves, therefore the angular divergence is $^3/_8$ of $360^0 = 135^0$ (Fig. 3.17, B).

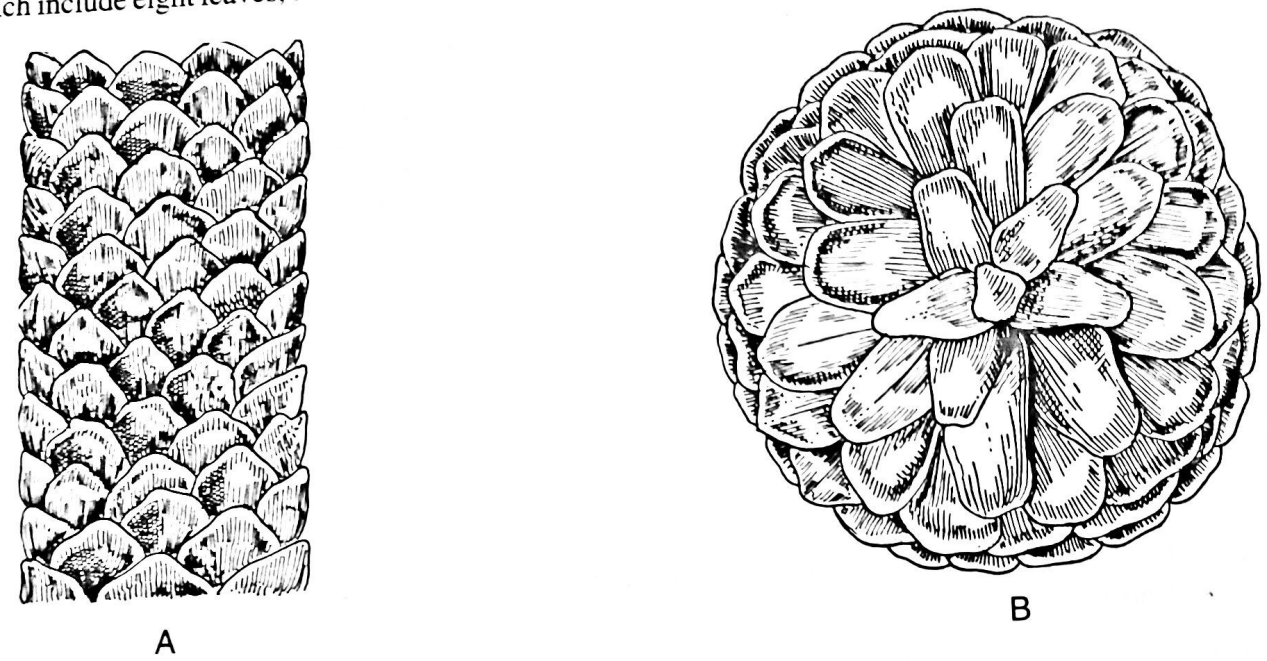

Fig. 3.19. A. - Parastichous type of phyllotaxy (shown by leaf bases only on stem) in *Phoenix* sp.
B - A pine cone showing parastichous arrangement of sporophylls.

Parastichous is a type of phyllotaxy when orthostichies are not possible to count owing to a big fraction of the divergence. In this type, many leaves are crowdedly situated on nodes and the internodes are very short, e.g. *Phoenix* sp. (Palmae). Fig. 3.19A.

2. OPPOSITE PHYLLOTAXY—In this type of phyllotaxy two leaves are inserted at each node opposite to each other ; it is of two kinds—

(i) *Opposite decussate*—When one pair of leaves of one node stands at a right angle to the next upper and lower pair of leaves, it is called opposite decussate e.g. *Ixora arborea* (Rubiaceae), *Calotropis procera* (Asclepiadaceae), *Ocimum sanctum* (Labiatae), etc.

(ii) *Opposite superposed*—When the opposite consecutive pairs of leaves are arranged in one plain i.e. serially arranged on top of one another not forming a cross, it is called opposite superposed, e.g. *Psidium guajava* (Myrtaceae), *Quisqualis indica, Hiptage benghalensis* (Malpighiaceae), etc.

3. WHORLED PHYLIOTAXY—In this type of arrangement three or more leaves are arranged at each node in a circle or whorl round the stem. Leaves are arranged at each node verticillately. The leaves are so nicely arranged that the respective leaves of the whorls of upper and next lower fall between the inter spaces, so that no over crowding of leaves takes place, e.g. *Allamanda sp., Alstonia scholaris, Nerium indicum* (Apocynaceae), etc.