Based on the leaf structure the distinction between the five taxa of east-Himalayan junipers can be presented in the form of a key as follows:

A. Leaves scaly

AA. Leaf apex broadly obtuse, cuticle smooth in cross-section, stomata small (40 x 30 u), resin-gland globular and wide with a very small resin canal both together measuring 1.2 mm.

*J. pseudosabina*

AB. Leaf apex sub-acute, cuticle slightly undulating, stomata bigger (52 x 32 u), resin gland somewhat ovoid and narrow with a comparatively longer resin canal both together measuring 1.7 mm.

*J. wallichiana*

B. Leaves sciricular

BA. Leaves small up to 2.5 mm long, stomata small (average length 45 u).

*J. squamata var. wilsonii*

BB. Leaves longer, up to 4 mm long,

BBA. Stomata smaller (average length 40 u), epidermal cells papillate.

*J. squamata var. fargesii*

BBB. Stomata bigger, (average length 50 u), epidermal cells non-papillate.

*I. recurva*

The xylotomic distinction between these two species is very difficult if not altogether impossible. Most of the wood structure is similar. But still there are a few features of distinction. On the transverse surface of wood in *L. wallichiana* there are only 2,500 tracheids per sq. mm, whereas in *L. pseudosasbina* these are 6,500 on an average. This is mainly due to the difference in the diameters of the tracheids. They are wider in *L. wallichiana* than those in *L. pseudosasbina*. The second most important difference is that of the amount of vertical parenchyma. It is less abundant (27-30 cells) in *L. wallichiana* but much more abundant (80-100 cells) in *L. pseudosasbina* per mm circumference of the growth ring. Also the vertical parenchyma cells are with a little resinous contents in *L. wallichiana* whereas in the other species these are completely filled up with it. The intercellular spaces in the springwood are quite frequent and larger in *L. wallichiana* than in the other species. On the tangential surface of wood the major difference between these two species is that of the number of rays per unit area and the height of rays. The number of rays per unit area in *L. wallichiana* (100 per mm²) is less than that in *L. pseudosasbina* (150 per mm²). The number of ray cells per mm² is 360 in *L. wallichiana* but 260 cells in *L. pseudosasbina*, indicating thereby that the rays are higher in *L. wallichiana* (1-9 cells and upto 200 plus microns) than in *L. pseudosasbina*. 
The tangential walls of the ray cells in surface view possess transverse bars in both the species but these bars are thinner in L. wallichiana than in the other species. On the radial surface there is only one major difference and that is in the thickness of the cell walls of the ray parenchyma. The horizontal walls in L. pseudosabina are highly thickened but they are less thick in L. wallichiana. The beads of the tangential walls are big in L. pseudosabina but are very small in size in L. wallichiana.

XYLOTOMIC DISTINCTION BETWEEN var. fargesii AND var. wilsonii OF Juniperus squamata

The xylotomic distinction between these two varieties of Juniperus squamata can be based on the following features. The general dimensions of the wood elements in var. fargesii are bigger than those in var. wilsonii. The percentage of summerwood is less in var. fargesii (10-15%) than in var. wilsonii (15-25%). There is a big difference in the number of tracheids per sq. mm., it is ± 2,000 in var. fargesii and ± 5,400 in var. wilsonii. The number of vertical parenchyma cells is far less in var. fargesii (25-35 per mm. of the ring) than in var. wilsonii (80-100 per mm of the ring). The vertical parenchyma cells are completely filled up with dark contents in var. wilsonii while they are not so in var. fargesii. The intercellular spaces are very common in var. fargesii, whereas they occur occasionally in var.
On the tangential surface there is a great difference in the number of rays and ray cells per unit area. In var. *fargesii*, the rays are far less in number (85 per sq. mm) than in var. *wilsonii* (170 per sq. mm); similar is the case with the number of ray cells per sq. mm (210 in var. *fargesii* and 360 in var. *wilsonii*). In general the rays are higher in var. *fargesii* (up to 11 plus cells and 230 plus microns) and low in var. *wilsonii* (up to 8 plus cells and 150 plus microns). The ray cells are more in height in var. *fargesii* (21 u - 29 u) than in var. *wilsonii* (14 u - 18 u). Another most interesting point to note in var. *fargesii* is the presence of eupressoid pits on the tangential walls of vertical parenchyma, whereas in var. *wilsonii* they are absent. On the radial surface some distinction may be made from the cross fields; in var. *fargesii* the number of pits per ray crossing is mostly 2-3 or 4 but in var. *wilsonii* there are most frequently only 2 pits per ray-crossing. In var. *fargesii* these are located mostly near to the corners of the cross-field whereas in var. *wilsonii* they are mostly superposed.

**INTERSPECIFIC XYLOTOMIC DISTINCTION IN THE EAST-HIMALAYAN JUNIPERS (Tables: IV to VI)**

The first attempt on the structure of the wood of Himalayan Junipers was made by Rushton (1915). He discussed the wood anatomy of only four species viz. *L. recurva* Hem.; *L. wallichiana* Hook. f. and Thoms. (syn. *L. pseudosabina*, Fisch. et Mey.); *L. macrooda* Boiss. (syn. *L. excelsa* Brandis, not Bieb.).
and _J. communis_ Linn. Out of these only two species are concerned with the present investigation (_J. recurva_, _J. wallichiana_). But his descriptions are outdated now and cannot be relied upon since there had been a great confusion in the taxonomy of Junipers in the Himalayas. What he referred as _J. recurva_ from the inner Himalayas of Punjab (Inner Himalayas) was probably _J. squamata_ since _J. recurva_ Buch. Ham. (sensu stricto) has been observed to be confined to the eastern Himalayas only. Same is the case with _J. wallichiana_ Hook. f. In the present investigation it has been established that _J. wallichiana_ Hook. f. is not synonymous with _J. pseudosabina_ Fisch. et Mey., so it is not sure whether the specimen of _J. wallichiana_ used by Rushton was typical _J. wallichiana_ Hook. f. or it was _J. pseudosabina_ Fisch. et Mey., since both of these occur in Sikkim, the source of his specimen.

In the present investigation the wood structure of five taxa of Junipers belonging to four species occurring in the eastern Himalayas was investigated viz. _J. pseudosabina_ Fisch. et Mey., _J. wallichiana_ Hook. f., _J. squamata_ var. _wilsonii_ Rehder, _J. squamata_ var. _fargesii_ Rehder and Wilson, and _J. recurva_ Buch.-Ham. Though the wood structure in these five taxa is quite similar but still on the basis of some minute features (variable to some extent) a distinction may be made between them. To make it more convenient they may be segregated into two major groups: Group I includes woods with very abundant vertical parenchyma and more than 5,000 tracheids per sq. mm viz. _J. pseudosabina_ and _J. squamata_.


var. wilsonii. As a matter of coincidence both these taxa are shrubs. The wood in both of these contain 80-100 vertical parenchyma cells per mm tangential length of the growth ring. It is very very difficult to distinguish the wood of these two taxa. On the tangential surface the ray height is little more in *L. squamata* var. wilsonii (1-8 cells up to 150 u) than in *L. pseudosabina* (1-6 cells; up to 100 u). On the radial surface the horizontal walls of ray parenchyma are slightly more thick in *L. pseudosabina* than in the second taxa.

Group II includes woods with less abundant vertical parenchyma and less than 4,000 vertical tracheids per sq. mm of the transverse surface viz. *L. wallichiana*, *L. squamata* var. fargesii and *L. recurva*. These three taxa are all trees. Vertical parenchyma cells in this group are not filled up with dark contents. Out of these three, *L. recurva*, may be distinguished on the basis that in it the transition from springwood to summerwood is almost abrupt and the intercellular spaces are less frequent and the number of ray cells per sq. mm of the tangential surface is the minimum amongst the three (140 cells). Now between *L. wallichiana* and *L. squamata* var. fargesii there is no point of distinction on the transverse surface of the wood. The most important point to note on the tangential surface is that in *L. squamata* var. fargesii the tangential walls of the vertical parenchyma cells are frequently provided with numerous uniseriate cupressoid pits similar to those present in the cross-fields on the radial surface, whereas in *L. wallichiana* the tangential walls of vertical parenchyma
cells lack any such pits. The second point to differentiate between these two woods on the tangential surface is that in *L. wallichiana*, the tangential walls of the ray parenchyma cells possess thin transverse bars running across the radial walls, whereas in *L. squamata* var. *fargesii* transverse bars radiate out all around a central plate of wall material. On the radial surface of wood there is a difference in the number of pits in the ray-crossings in the two species. In *L. squamata* var. *fargesii*, in general, the pits are of more frequent occurrence, 2, 3 and 4 pits per cross-field are all equally predominant and when the number is 2 they are mostly horizontally or diagonally placed. In *L. wallichiana* the most frequent number of pits occurring per cross-field is 2, and they are mostly superposed in position.

Thus taking into consideration these features of differences in the wood structure, simple key may be prepared as follows:

I. Vertical parenchyma cells abundant (50-100 per mm circumference of the growth ring) and full of dark contents. Tracheids more than 5,000 per sq. mm.
   a) Ray height upto 150 u *L. squamata* var. *wilsonii*
   b) Ray height upto 100 u *L. pseudoschima*

II. Vertical parenchyma cells less abundant (20-50 per mm. circumference of the growth ring) and devoid of dark contents. Tracheids less than 4,000 per sq. mm.
   a) Transition from springwood to summerwood almost abrupt, intercellular spaces less common *L. recurva*
b) Transition from springwood to summerwood gradual, intercellular spaces very common

1) Tangential walls of vertical parenchyma frequently provided with cupressoid pits, most frequently 2, 3 and 4 pits per cross-field
   *L. squamata* var. *fargesii*

2) Tangential walls of vertical parenchyma always without pits; most frequently 2 superposed pits per cross-field
   *L. wallichiana*

**INTER-SPECIFIC IDENTIFICATION OF THE WOOD OF JUNIPERUS**

Though it is rather less difficult to identify limited number of species on the basis of the wood structure (as under the present investigations), but considering all the species of *Juniperus* (about 60 species, Dallimore and Jackson 1966), it becomes very problematic. This is so because the wood is rather simple in structure and there is not much variation in the qualitative characters, and consequently one has to depend upon the quantitative characters such as the number of tracheids per sq. mm, number of rays and ray-cells per sq. mm, amount of vertical parenchyma etc., and these characters have to be studied statistically. The problem is further complicated by the fact that some of these factors are influenced by the age, and environment as stated by Greguss (1955). Greguss has investigated about 40 *Juniperus* species and has separated them mostly on the quantitative features only. Phillips (1941) separated *L. prostrata* from the American Junipers on the basis of the rays with thin horizontal walls. Penhallow (1907) studied about 11 species of Junipers and he used the shape of ray cells (in tangential aspect) as a diagnostic feature along with their resinous nature.
All these features could not be used to distinguish the east-Himalayan Juniper woods because of their much similarity in these structures. Kaiser (1953) made an intensive study of the wood structure of 39 species of Juniperus. He laid much stress upon the range in numbers and most frequent numbers of pits in cross-fields, horizontal walls of ray cells and the intercellular spaces. He supports the separation of the genus into at least two groups; in the first group the most frequent number of the cross-field pits is higher (more than 2) and there is a greater tendency for the occurrence of taxodioid type of cross-field pitting, whereas in the second group the most frequent number of cross-field pits is lower (2) and the taxodioid pits are either of rare occurrence or are lacking. This segregation by Kaiser seems to be somewhat natural since it tallies more or less with Endlicher's classification of the genus Juniperus into three sections: Ceryocedrus, Oxycedrus and Sabina which is otherwise confirmed on the basis of the female cone evolution. Section Ceryocedrus and Oxycedrus are included in the first group of Kaiser and the section Sabina corresponds to the second group. Out of the five east-Himalayan taxa of Junipers we find that three (J. recurva, J. squamata var. farnealii and var. wilsonii) belong to the first group of Kaiser, there being a more frequent occurrence of more than 2 cross-field pits in the outer ray cells of the springwood. The other two taxa J. pseudosabina and J. wallichiana certainly belong to the second group because of the most frequent occurrence of 2 cross-field pits in the outer ray.
cells of the springwood. This is confirmed even otherwise on the basis of morphological characters (discussed later under the female cone structure) indicating that *L. recurva*, *L. squamata* var. *fargesi* and var. *wilsonii* belong to the section *Oxycedrus* of Endlicher, and the other two taxa *J. pseudosabina* and *J. wallichiana* belong to the section *Sabina*. However, the author did not come across the taxodioid type of pitting in any one of the three taxa of section *Oxycedrus* which should otherwise be having these according to Kaesler's grouping. This probably might be so because of the most evolved status of these taxa in the section *Oxycedrus*. Thus the wood structure in *Juniperus* indicates that there have been at least two independent lines of evolution, one leading to the section *Caryocedrus* and *Oxycedrus*, the other leading to the section *Sabina*. The close similarity of the wood structure in *J. drupacea* (section *Caryocedrus*) and the relatively primitive species of the section *Oxycedrus* indicates a close relationship between the two.

**TAXONOMIC DISTINCTION OF THE EAST-HIMALAYAN JUNIPERUS TAXA ON THE BASIS OF THE FEMALE CONE STRUCTURE (Table: VII)**

The present anatomical investigations of the female cone of the five taxa of East-Himalayan Junipers which are otherwise morphologically less distinct and often pose a disputable taxonomic status can help to a great extent the taxonomic distinction between them. This is particularly so in the case of *J. pseudosabina* and *J. wallichiana*. Brandis (1874),
Salley (1933), Clinton-Baker (1913) and Dallimore and Jackson (1965) are of the view that *J. pseudosabina* Fisch. et Mey. does not occur in India and the Himalayan species identified as *J. pseudosabina* Hook. f. is *J. wallichiana* Hook. f. According to Dallimore and Jackson (1966) *J. wallichiana* Hook. f. is a tree high in the Himalayas from Indus to Bhutan, becoming shrubby (*J. pseudosabina* Hook. f.) in the western parts of its range. But our present investigations reveal that they are not the forms of the same species but are rather two different species, more distinct in their cone anatomy than in their cone morphology. Morphologically the female cones of *J. pseudosabina* Fisch. et Mey. are smaller, borne on recurved pedicels, whereas those of *J. wallichiana* Hook. f. are bigger and borne on erect pedicels. Anatomically there are some very contrasting qualitative differences such as the presence of tanniniferous cells and the absence of sclereids in the spongy tissue zone of *J. pseudosabina*. In *J. wallichiana* the situation is just the opposite, i.e. the tannin cells are absent and the sclereids are present. Another point of difference is this that the vascular traces of the lower verticil in *J. wallichiana* are much longer and upright than those in the other species. The xylem of the vascular traces in *J. wallichiana* is very strongly lignified than that in *J. pseudosabina*. Still another point of difference is in the nature of the bract trace, which is invariably undivided in *J. pseudosabina*, but very often forked at least in one of the bract traces, in *J. wallichiana*. The differences of seed in these two species is that of size and
the thickness of the testa. Seed size is approximately 3 to 4
times bigger in *J. wallichiana* than in *J. pseudosabina* and the
seed coat (testa) is also more thicker in the former.

The other three *Juniperus* taxa in the eastern Himalayas
with a ternate arrangement in their cones belong to *J. recurva*
of Hooker. Hooker (1866) states that 'at lower elevations it
is a tree with a straight trunk and pendulous branchlets,
becoming stunted at higher elevations and in alpine or exposed
situations passes into var. *squamata* which is a decumbent or
prostrate bush. But the present investigations on the female
cone structure of these have shown that what Hooker has
described as *J. recurva* is a complex of at least three distinct
taxa in the eastern Himalayas; (i) *J. recurva* Buch-Ham. (sensu
stricto) is a tree with big ovoid female cones; (ii) *J. squamata*
var. *fargesii* Rehder and Wilson, also a tree similar to
*J. recurva* but with small ellipsoid cones; (iii) *J. squamata*
var. *wilsonii* is a shrub (corresponding to the *J. recurva* var.
squamata of Hooker) with medium sized ovoid cones.

The present anatomical investigations, particularly
the vasculature of the female cones of these taxa, hardly
leave any doubt for the distinction of these three taxa.
The most important character amongst these is the fate of the
bract trace (B₂) of the upper verticil. In the shrubby species
*J. squamata* var. *wilsonii* this bract trace is invariably
unbranched. In *J. squamata* var. *fargesii* this bract trace may
sometimes be just once dichotomised. But in *J. recurva* (sensu
stricto) it is always divided into 2-3 unequal branches. Another
major point of distinction is that of the anterior branch $S_2$ (AB) of the scale supplies in the upper verticil just opposite to the bract trace. This anterior branch is totally absent in the case of *J. squamata* var. *wilsonii*. But in the other two taxa it is present but their nature is a bit different in the two taxa. In *J. recurva* the anterior branch is undivided, but in *J. squamata* var. *fargesii* this anterior branch is forked once or twice towards its distal part.

In addition to these differences in the vasculature of the cone, there are encountered some other anatomical differences too. The epidermal cells in *J. squamata* var. *wilsonii* include enormous oil globules, while these are absent in the other two taxa. The amount of sclereids in the spongy tissue zone also differs. The sclereids are very numerous in *J. squamata* var. *fargesii* and less in the other two taxa. These are strongly lignified in *J. squamata* var. *fargesii* and in *J. recurva* but not so in *J. squamata* var. *wilsonii*. The seed-coat-surface resin glands are very deep and prominent in *J. squamata* var. *fargesii* and leave deep pits on the seed surface. In *J. recurva* and *J. squamata* var. *wilsonii* the seed-coat-surface resin glands are very shallow and narrow, leaving inconspicuous pits on the seed surface.

The testa of the seed in *J. squamata* var. *wilsonii* is divided into three parts in the distal half of the seed (tri-partite) by thin sheets of non-lignified cells. In the other two taxa the testa is only bi-partite. The testa cells are smaller in
L. squamata var. fargesii and in L. squamata var. wilsonii but very strongly lignified in the former almost occluding the lumen. Whereas in L. recurva, the testa cells are bigger and with moderately thick-walls. The seed morphology is also of great help in distinguishing these taxa from one another. The seed size is biggest in L. recurva (0.9 cm x 0.7 cm), medium in L. squamata var. wilsonii (0.75 cm x 0.55 cm), and smallest (0.65 cm x 0.45 cm) in L. squamata var. fargesii. The seed apex is acute and tri-radiate in L. squamata var. fargesii, tri-radiate and with an apical groove in var. wilsonii, and sub-acute multi-radiate in L. recurva.

Thus we find that the morpho-anatomical differences amongst the five taxa are sufficient to allot them distinct taxonomic status. A suitable key of their female cone characters can be made as follows:

A. Bract-scales opposite

B. Cones small (0.8 x 0.6 cm), sub-globose, borne on recurved pedicels, sclereids absent, tannin cells present, bract trace invariably indelible, seed small (0.35 x 0.35 cm) and biradiate

    L. pseudosakigata

BB. Cones big (1.0 x 0.8 cm), oval, borne on erect pedicels, sclereids present, tannin cells absent, bract trace sometimes forked, seed very big (0.9 x 0.5 cm), and biradiate

    L. wallischiana

AA. Bract-scales mostly ternate

C. Cones big in size (0.9 x 0.7 cm), bract trace divided into more than two branches, seed radial.
B. Anterior scale trace present, sclereids few but strongly lignified, seed big in size, with polyradiate apex, testa bimpartite, seed-coat surface pits shallow. \( L. \) recurva

CC. Cones small in size, bract trace either indivisible or just once forked, seed-tri-radiate \( L. \) squamata

DD. Cones smaller (0.65 x 0.45 cm), on erect pedicels, anterior scale trace present and often divided; bract trace sometimes forked; sclereids numerous and very thick walled, seed-coat-surface pits very deep \( L. \) squamata var. ferroa

DDD. Cones bigger (0.75 x 0.55 cm), on recurved pedicels, anterior scale trace absent, bract trace invariably indivisible, oil globules in epidermal cells, sclereids few, less thicker, seed-coat-surface pits very shallow and inconspicuous \( L. \) squamata var. wilsonii

**TAXONOMIC CONSIDERATIONS OF** \( L. \) squamata var. wilsonii and var. ferroa

\( L. \) squamata var. ferroa differs from var. wilsonii not only in habit, but also in the characters of the wood and the female cone. Whereas, the former is a tree, the latter is a shrub. Vertical parenchyma cells in the wood of var. wilsonii are much more abundant (80-100 cells per mm circumference of the growth ring) in var. wilsonii than in var. ferroa (20-50 cells per mm circumference of the growth ring). Moreover, in the wood of var. ferroa the tangential walls of vertical parenchyma are frequently provided with cupressoid pits
which are absent in var. *wilsonii*. In the female cone, in
var. *wilsonii* the oil cells are abundant and the sclereids
are few, but in var. *fargesii* the condition is just the reverse.
The bract trace in var. *wilsonii* is invariably indivisible,
but in var. *fargesii* it is sometimes forked. The female cone
size is comparatively smaller in var. *fargesii* than in var.
*wilsonii*. So there is ample justification in treating
*L. squamata* var. *fargesii* as a distinct species and name it
as *L. fargesii* Komarov.

**SYSTEMATIC RELATIONS WITH THE OTHER SPECIES OF THE GENUS JUNIPIRUS**

The genus *Juniperus*, comprising nearly 60 species in the
world, is the only representative of the tribe Juniperae in the
family Cupressaceae. The fleshy nature of the female cone, is
the only characteristic that separates it from the other tribes
of the family Cupressaceae. Endlicher (1847) divided the genus
*Juniperus* into three sections: Caryocedrus, Oxycedrus and Sabina.
Max Lemoiné- Sebastian (1967) has justified this division on
the basis of the vegetative characters and the evolutionary
trends in the female cone of *Juniperus* species. Geussen (1968)
has divided the genus *Juniperus* into ten sections on the basis
of the leaf and pollen characters.

In the section Sabina, the adult leaves are small and
squamiform; the female cone is composed of 1-3 verticils of
opposite pieces, each axilling 1-2 ovules; at the top of the
cone a verticil of sterile pieces forms the columella; this
columella may be missing and the ovules occupy terminal position.
In the section Oxycedrus and Caryocedrus the adult leaves are long, scalar and ternately arranged; the pieces of the female cone are likewise ternate, and generally there are three ovules in terminal position; there is no columella. In the section Oxycedrus the ovules alternate with the last pieces (distal most) of the cone; and in the section Caryocedrus the ovules are opposite to the last pieces of the cone.

Thus two of the five east-Himalayan Juniperus taxa i.e. *L. pseudosabina* Fisch. et Mey. and *L. wallichiana* Hook. f., belong to the section Sabina of the tribe Juniperaceae. The remaining three taxa with ternate arrangement of pieces, belong to either the section Caryocedrus or section Oxycedrus. But the distinction between these two sections is very very difficult, since it is based on just one character, the position of the ovule i.e. median or lateral, a character which is hard to determine particularly in case of the most evolved species with a single terminal ovule. Such is the case with the present taxa, *L. recurva*, *L. squamata* var. *farsseli* and *L. squamata* var. *wilsonii*, all of which possess a single terminal ovule in the female cones. Lemoine-Sebastian (1967) has stated from the evolutionary studies that the section Caryocedrus is the least evolved of all the three sections and is represented by only one species *L. oxyacanthos*. This would by implication mean that the three taxa under consideration belong to the section Oxycedrus, and the presence of the single terminal ovule indicates their most advanced state.
NATURE OF THE FEMALE CONE IN JUNIPERUS

Morphological observations fail to reveal the true nature of the female cone in Juniperus species which is a fused mass of a variable number of scales enclosing a variable number of ovules. One has to study the developmental anatomy and the vascularisation of the cone in order to understand its composition in terms of the structures of the female cone of other conifers.

The development of the female cone has been studied in detail by Hame Lemoine-Sebastian (1967). She has described it for a type possessing a columella and a fertile verticil. In the beginning, a bud of closely overlapping leafy pieces is formed. Each of these leafy pieces possess a dorsal procambial bundle and a single gland (corresponding to the nature of the conifer bracts). The ovules are borne against the principle axis in the axil of the leafy pieces (the number of ovules developed depends upon the species). Later on the ovules appear to slip much tightly on to their axilling piece. The vascular strand in the latter branches itself in some species (branched bract trace). In the species with a single ovule in the cone, the former develops in the terminal position never slipping suddenly, but is progressively engulfed by the tissues of the fertile and the sterile pieces.

In the young cone a cushion proliferates on the adaxial side of the bract like an axillary bud, but which does not individualise itself. A procambial bundle makes its way
towards the ovule where it does not penetrate.

While the cone is growing, two lateral vascular trunks appear in the cushion on the adaxial side of the fertile piece and penetrate into its axis, independent of the dorsal vascular strand or the bract trace. Later on, the bract trace does not modify much, but the lateral vascular trunks develop in the fast growing cushion which pushes away the pieces of the cone and overtop the ovules and exceed the bracts. The lateral vascular trunks turn inverse. At start of this moment, the pieces of the cone are the bract-scale complexes and differ from the sterile bracts at the base of the cone. Often the scale and the bract unite their vascular trunks into a common trunk at the base of the piece.

This anatomical study leads us to the following conclusions: the cone of the Juniperus is always an inflorescence composed of a large number of bract-scale complexes, all fused at maturity imperceptibly into a common fleshy mass. The scales develop quite late, even later than the ovule belonging to it, and remain fused to the tissues of the bract. The columella and some of the pieces at the base of the cone remain simple i.e. do not develop any scale in their axil.

The basic structure of the Juniperus cone thus reflects the structure of the cone of the Pinaceae, but much modified; the bracts of the cone axilling a fertile formation homologue of the scale, which carries the ovules first and develops itself subsequently above them. Each piece of the cone, fertile or sterile, is a complex containing a vascular trace of the
bract and the vascular traces of the scale.

EVOLUTION OF THE FEMALE CONE IN JUNIPERUS

The force of evolution has been exerting its pressure mainly in the following cone characters: number of verticils in the cone, arrangement of the bract-scale-complexes, number of the ovules, nature of the bract trace, and the nature of the scale traces. The morpho-anatomical investigations of the female cone in a large number of Eurasistic, as well as American species of Juniperus by Lemoina-Sebastian (1967) suggests that there has been a great reduction in each of the above mentioned characters of the female cone, during the course of progressive evolution.

1) Arrangement of the bracts scales in the cone

Both the ternate as well as the opposite arrangement is quite predominant in the present day species of Juniperus. Ternate arrangement characterises the section Caryocedrus and Oxycedrus (except sometimes for the highly evolved species J. squamata). The opposite arrangement is predominant in the section Sabina (exceptions in J. pachyplexa and J. oshenisee). This opposite arrangement is considered to be derived from the ternate arrangement very early in the history of the genus. J. pachyplexa seems to be the most primitive species of the section Sabina in this regard, because of its having both the arrangements equally predominant.

11) Reduction in the number of ovules per scale

Three ovules per scale has been considered to be the
most primitive condition. This condition has been reported to be occurring sometimes in *J. cheenies*, *J. excelsa* and *J. thurlfera* of the section Sabina and also in *J. communis* of the section *Oxycedrus*. This number of three ovules per scale is reduced to firstly 2 per scale and then 1 per scale in the section Sabina, but directly to 1 per scale in the sections *Oxycedrus* and *Caryocedrus*. But the position of the ovule retained is very important. In the section *Caryocedrus* (*J. oxycedra*) the single ovule retained per scale is the median one. But in the other two sections, the ovules retained are the lateral ovules of the corresponding scale. As a matter of fact this is the only major character that separates the section Caryocedrus from the section *Oxycedrus*. This progressive reduction in the number of the ovules ultimately results in a state of single terminal ovule per cone in the sections *Oxycedrus* (*J. squamata*) and Sabina (*J. wallichiana*, *J. pseudo-sabina*). This places all of our east-Himalayan taxa in the most evolved state of the two sections, there being only 1-terminal ovule in all the cases. *J. squamata* and *J. recurva* represent the evolutionary terminus of the section *Oxycedrus*, whereas *J. pseudo-sabina* and *J. wallichiana* represent the evolutionary terminus of the section Sabina. Thus the single terminal ovule retained in our east-Himalayan taxa represents phylogenetically one of the lateral ovules belonging to one of the scales in the uppermost verticil of the cone.

iii) **reduction in the number of verticils composing the cone**

A large amount of variation exists in the number of
verticils composing a female cone. The maximum number of verticils reported in the literature is 4 (including those constituting the columella), found sometimes in *L. chamaedora* and the minimum number can be up to 1 observed quite often in *L. squamata, L. recurva* and *L. monosperma.* A species with a larger number of verticils in its female cone is considered to be at a primitive state of evolution. During the course of evolution there has been a progressive reduction in the number of verticils in the female cone. This reduction occurred from the both ends of the cone i.e. apically as well as proximally. But the latter is supposed to be more predominant than the former. Apically there has been a disappearance of the columella (the distalmost sterile verticil). This disappearance of the columella had occurred very early in the sections Caryocedrus and Oxycedrus, so much so that in these two sections none of the existing species possesses the columella. But the columella is retained till very late in the evolution of the section Sabina, so much so that most of the existing species possess it (*L. chamaedora, L. chinesis, L. uschuthloca, L. thuifera, L. gracillia, L. sabina, L. virginiana* etc.).

It should be noted that the columella is absent in the east-Himalayan taxa belonging to the section Sabina (*L. pseudoasabina* and *L. wellichiana*). This is because of their being at the most advanced state of evolution. In the section Caryocedrus, except for the disappearance of the columella there has been no further reduction. Further reduction in the section Oxycedrus has occurred by the sterilisation and gradual
of the proximal verticils of the cone. This has gone to such an extent that ultimately only one ternate verticil is retained in the species like *L. communal*, *L. enneadryus*, *L. squamata* etc. In *L. squamata* this reduction reached a step further in that sometimes there are only two opposite scales in the only verticil instead of the usual three. In the section Sabina the reduction in the number of verticils has occurred mainly by the sterilisation and gradual exclusion of the proximal verticils only. This is revealed by the fact that most of the species belonging to this section still retain the ancestrally inherited columella. The process of exclusion of a verticil is very gradual and very interesting. It does not happen so abruptly. First of all there has been a progressive reduction in the number of ovules per scale to such an extent that ultimately there was no ovule left in the axil of the scales belonging to the lower verticils. Then there has been an increasing reduction in the scale development, which is indicated by a reduced development of the vascular supply of the scales in the lower verticils of the present day species. This last factor has been very clearly observed in *L. squamata* var. *wilsonii* and *L. recurva*. In these two species we have observed many of the female cones apparently with two verticils, but in the lower verticil the scale supplies develop in 1 or 2 units only out of the three. Furthermore these scale supplies consist of just a few branches only. Sometimes the scale supplies may be altogether absent in the lower verticil, which means the absence of development of the scales in the lower verticil.
Thus the lower verticil is left with only the bracts without any scales in their axils. (These steps are revealed only by the vasculature studies but otherwise externally there is hardly any indication). The next step is the exclusion of the bracts. The latter occurs by the gradual reduction in the amount of the spongy tissue so that ultimately it is comparable to that present in the leaves. Thus ultimately the members of the lower verticils of the female cone were gradually converted into small sterile leafy structures such as those present on the cone pedicels of the advanced species.

The exclusion of the proximal verticils of the female cone is not involved in the section Caryocedrus, which, therefore, represents its comparatively less advanced state.

iv) Vasculature of the bract

The median dorsal branch at the base of each bract-scale-complex unit represents the vascular supply to the bract. The extent of branching is quite variable in the different species. A branched bract supply represents the primitive state and an unbranched one represent the highly evolved state. This conclusion has been derived from the study of some other cone characters which are of primitive nature and associated with a highly branched bract nerve. In the section Sabina the bract nerve is always more or less branched except for the most highly evolved species such as L. pseudosabina. In the section Oxycedrus except L. rigida (Lemoine-Sebastian, 1967) and L. recurva (author), the bract bundle remains undivided right up to the end of the bract or very rarely dichotomises
itself, the two branches remaining very near to each other (observed sometimes in \textit{J. squamate} var. \textit{fargesi} by the author). Regarding the nature of the bract nerve in the east-Himalayan Junipers, \textit{J. wallichiana} and \textit{J. pseudosabina} represent the most highly evolved state in the section \textit{Sabina}. But comparatively speaking \textit{J. wallichiana} seems to be less advanced than its counterpart \textit{J. pseudosabina}, because in the former we sometimes observe a dichotomy of the bract nerve whereas in the latter species the bract nerve is invariably undivided.

Of the other three taxa belonging to the section \textit{Oxycedrus}, \textit{J. recurva} (sensu stricto) is the least evolved species because it possesses prominently branched bract nerve; whereas \textit{J. squamate} var. \textit{fargesi} possesses mostly unbranched bract nerve but sometimes a single dichotomy is observed, and in \textit{J. squamate} var. \textit{wilsonii} the bract nerve is invariably undivided. This latter, therefore, represents the most highly evolved taxon of the east-Himalayan representatives of the section \textit{Oxycedrus}.

v) \textit{Vascuclature of the scale}

The vascuclature of the scale to start with at the base of each bract-scale complex is represented by either two laterals and one anterior trunk or only two lateral trunks, present just opposite to the bract trace and with centrifugal xylem. According to Lemoine-\-Sebastian (1967) the vascuclatisation of the scale first of all branched in a fanshaped manner to form an arc involving an anterior branch, lost this branch and does not conserve more than two lateral trunks. In the cones of the
most reduced type it forms two independent brushes. Thus the presence of an anterior branch indicates the primitive state of vasculature of the scale. The disappearance of this anterior branch seems to have been very late in the course of evolution, since we find it even in \textit{J. recurva} and \textit{J. squamata} var. \textit{fargesii}, the species which are otherwise considered to be highly evolved (1-2 verticils and 1-terminal ovule). In \textit{J. recurva} the anterior branch is undivided, whereas in \textit{J. squamata} var. \textit{fargesii} it dichotomises once or twice towards its terminus. The significance of this branching at such a late stage of evolution is not understood. But in any case since this branching is exhibited only towards the apical part it seems to be a phenomenon, secondarily evolved, perhaps to compensate the lesser amount of branches of the lateral trunks in the apical part of the cone. In \textit{J. squamata} var. \textit{wilsonii} the anterior branch has totally disappeared. It is also absent in our \textit{J. pseudosabina} and \textit{J. wallichiana} (Section Sabina). In these three species the scale vasculature forms two independent brushes.

The extent of branching of the two lateral trunks is a question of the size of the cone and cannot be given any evolutionary significance.

Thus from the above discussion we arrive at the conclusion that the evolution in the female cone of the tribe Juniperese of family Cupressaceae has been taking place by the progressive reduction in the number of ovules, the number of verticils, the branching of the bract trace and the loss of the anterior branch.
of the scale vasculature. But we find that each of these characters are undergoing evolutionary reduction independent of one another, each having its own speed of evolutionary march. This is very clearly exemplified by *Juniperus recurva* which possesses a branched bract trace, an anterior scale trace (primitive characters) but having only a single terminal ovule in its cone (considered as the most highly advanced character).

The three sections of the tribe Juniperaceae can be easily derived from a hypothetical ancestral type possessing 4-ternate verticils of bract-scale complexes; each scale axilling 3 ovules, the terminal verticil in the form of a columella, bract vascularisation highly branched and the scale vascularisation possessing an anterior branch (Table VIII).

However it may be mentioned that the examples given in the following evolutionary chart do not mean any direct descendence from one another but rather represent the intermittent steps of evolution and may have many more intermediate stages. Secondly some of the present day species particularly in the section Sabina, such as *J. phoenicea* and *J. excelsa* and *J. chinensis* possess a large amount of variation in the cone characters in the same general evolutionary pattern supposed to have occurred in the derivation of the most advanced members from the primitive ones.

In the following chart (Table VIII) only the Eurasian species have been taken into consideration which seem to be more closely related to one another than to the American species.