absent (exception *Gnetum*), companion cells also absent in phloem. (d) As the flowers are unisexual, hence chances of self fertilization is reduced, lots of pollen grains are wasted due to wind pollination and (e) Further the ovules and seeds are naked as no formation of fruit takes place due to the absence of ovary.

A. Characteristic features of Gymnosperms

(*a*) Plants are sporophytes; majority are tall woody perennial and evergreen trees; rarely shrubs. Sporophytes are much larger in size and independent (when mature); true roots, stems and leaves are present. Plants are always heterosporous i.e. there is difference in the two types of spores in that, one type produces a male gametophyte and the other a female gametophyte.

(*b*) Vascular bundles in stems are conjoint, collateral and open—arranged in a ring. Xylem is composed of tracheids with bordered pits and xylem parenchyma, *true vessels i.e. tracheae are absent* (except *Gnetum*); phloem is composed of phloem parenchyma and sieve tubes only, companion cells are absent. Active cambium produces considerable secondary xylem and phloem during secondary growth. In case of gymnosperms, the secondary wood are of two types — (i) *monoxylic* (found in Cycadophyta, in nature parenchymatous, porous, soft, with wide medullary rays) or (ii) *pycnoxylic* (found in Coniferophyta, compact, hard, with narrow medullary rays).

(*c*) Leaves are usually *dimorphic* i.e., leaves are of two types viz., (i) brown small *scale leaves* and (ii) green *foliage large leaves* which are evergreen and provided with thick cuticle. The former cases are called microphyllous and the later megaphyllous.

(*d*) Flowers are *unisexual, simple,* reduced and naked i.e., without perianth (except *Gnetum*). Male and female flowers are represented by *microsporophylls* i.e. stamens and *megasporophylls* i.e. carpels respectively. Microsporophylls are aggregated together forming male *cones* i.e. *strobili.* In most cases megasporophylls are also aggregated together forming female strobili. Megasporophylls are simply leaf-like structures, they do not undergo any modification (due to folding up) forming a specialised carpel like those of angiosperms in which the carpel is differentiated into a swollen basal ovary, a hollow style and a terminal stigma. Megasporangia i.e. ovules are *directly* borne on the megasporophylls, so that ovules remain uncovered (naked).

(*e*) At the time of pollination, pollen grains (microspores) are directly carried by *wind* to the micropyle of the ovule.

(*f*) The gametophytes are much smaller i.e. reduced, but more conspicuous than those

of angiosperms. The male gametophyte i.e. microgametophyte is a multicellular structure bearing two prothallial cells, a tube nucleus, a stalk cell (except *Gnetum*) and two male gametes.

The female gametophyte *i.e.* megagametophyte is a multicellular structure bearing one or more archegonia (except *Gnetum*).

(*g*) Male gametes are either ciliated and motile (=sperms) as seen in some gymnosperms (*Cycas, Ginkgo*, etc.) or non-ciliated and non-motile as found in other gymnosperms e.g. *Pinus, Gnetum*, etc.

(*h*) Endosperm formation takes place within female gametophyte *before fertilization*; as such, the endosperm tissue is *haploid*. But in *Gnetum* endosperm tissue formation takes place partly before and partly after fertilization.

(*i*) Embryo development is not initiated by the formation of any transverse or vertical wall (except *Gnetum*). Embryo is developed at the end of a *long suspensor* which is generally *straight* and embedded in endosperm; the embryo is generally differentiated later into upper (haustorial), middle (suspensorial) and basal (embryonal cells) regions. Sometimes several embryos i.e. more than one embryo arise in each ovule, such a phenomenon is called *polyembryony*.

(*j*) Number of cotyledons varies from one to *many*.

(*k*) True seeds are always present. The seeds are borne uncovered or *naked*, i.e. seeds are not encased within fruits, as fruits are *not* developed due to failure of carpels (megasporophylls) in the formation of a closed chamber, i.e. ovary which ultimately matures into fruits.

B. Comparative account of Gymnosperms and Pteridophytes

Gymnosperms	*Pteridophytes*
1. In gymnosperms true roots present.	1. Adventitious root present in pteridophytes.
2. Stems are aerial in case of gymnosperms.	2. Mostly underground rhizomatous stem in case of pteridophytes.
3. All gymnosperms are heterosporous producing microspores and megaspores.	3. Pteridophytes are generally homosporous but some are heterosporous.
4. Seeds are produced in gymnosperms (naked seeded plants).	4. No seeds are produced in case of pteridophytes.
5. In case of gymnosperms secondary growth takes place.	5. In case of most pteridophytes secondary growth does not take place.
6. Pollen tube produced due to the germination of pollen grains in case of all living gymnosperm.	6. In most pteridophyte no formation of pollen tube due to the germination of spores.
7. The retention of female gametophyte permanently within the megasporangium.	7. The permanent retention of female gametophyte within megaspore.
8. In gymnosperms the megasporangium is protected by means of an integument.	8. In pteridophyte the megasporangium is not protected by means of integument.
9. Neck canal and neck canal cells are absent in the archegonia of gymnosperms. In case of *Gnetum* archegonia is absent.	9. Neck canal and neck canal cells are present in the archegonia of pteridophytes.

megasporangium, like the gymnospermic plants.

(*g*) In having ciliated sperms (*Cycas* and *Ginkgo*).

(*h*) In general morphology of the members of Cycadofilicales.

D. Comparative account of Gymnosperms and Angiosperms

Gymnosperms	*Angiosperms*
1. Plants are woody perennial trees or shrubs.	1. Plants are annual, bi-annual or perennial herbs, shrubs or trees—either woody or herbaceous.
2. Xylem generally consists of tracheids and xylem parenchyma and phloem of sieve tubes and phloem parenchyma only.	2. Xylem generally contains three elements viz. (a) tracheids, (b) tracheae and (c) xylem parenchyma; similarly phloem consists of three elements viz. sieve tubes, companion cells and phloem parenchyma.
3. Usually, leaves are of two types (dimorphic) e.g. green foliage leaves and brown scale leaves.	3. Leaves are of usually one type only, such as green foliage leaves.
4. Flowers are always unisexual, simple and without perianth (except *Gnetum*). Pollen sacs (microsporangia) or anthers and ovules or megasporangia (ovule) occur on distinct sporophylls i.e., microsporophylls (=stamens) and megasporophylls (=carpels) respectively.	4. Flowers are either unisexual or bisexual, with or without perianth.
5. Carpels (megasporophylls) are not differentiated into stigma, style and ovary.	5. Carpels are modified to form stigma, style and ovary.
6. The ovules are freely exposed on carpels; hence seeds remain naked—not enclosed in a fruit chamber i.e. mature ovary-chamber.	6. Carpels form an ovarian chamber in which ovules are enclosed, consequently seeds remain enclosed within the fruit.
7. At the time of pollination, pollen grains (microspores) are directly carried by wind to the micropyle of the ovule.	7. Pollen grains are carried by various agents and are deposited on the stigma—nor directly to the micropyle, as ovules are enclosed within the ovary-chamber (s).

Gymnosperms	*Angiosperms*
8. The mature male gametophyte has 2 or 1 small prothallial cell, a tube nucleus, 2 male nuclei or sperms (*Cycas, Ginkgo*) and one stalk cell (except *Gnetum*).	8. The mature male gametophyte is still more reduced as prothallial cell or cells, stalk cell etc. are absent—the gametophyte contains only two male nuclei and a tube nucleus.
9. The female gametophyte is mainly monosporic or tetrasporic (*Gnetum* only)—and is multicellular bearing at the micropylar side distinct archegonia (*Gnetum* exception).	9. The female gametophyte is either monosporic, bisporic, or tetrasporic; it has no cellular tissue (i.e. not multicellular) and archegonia; but normally it contains the egg apparatus (consisting of 2 synergids and one egg), secondary nucleus and three antipodals.
10. Endosperm tissue i.e. prothallial tissue formation generally takes place before fertilization, the cells of endosperm are haploid (n).	10. Endosperm tissue formation takes place after fertilization as a result of the union of one of the male cells of the pollen tube with secondary nucleus. The cells of the endosperm are triploid (3*n*).
11. Development of embryo is generally associated with the free nuclear division of the oospore nucleus, and the basal part of the pro-embryo gives rise to the embryo proper.	11. Development of embryo is associated by laying down a wall into two cells *viz.*, (a) apical and (b) basal cell—apical cell gives rise to embryo proper.
12. Embryo consists of 1 to many cotyledons. In gymnosperms, generally several embryos develop in each ovule, although but one embryo survives; thus gymnosperms are *polyembryonic.*	12. Embryo consists of 1 or 2 cotyledons. In angiosperms usually one embryo develops in each ovule; hence angiosperms usually are not *polyembryonic.*

E. Classification— C. J. Chamberlain (1935), based on morphological and anatomical

(carpels), in presence of pollen tube for carrying male gametes to the egg, retention of megaspore inside the megasporangium and its development into female gametophyte etc.

H. Economic importance of Gymnosperms— The tuber and seeds of *Cycas circinalis* produce arrowroot, a type of sago. Sometimes the seeds and young shoots are also taken as food. The stem produces gum. The juice of the tender leaves is supposed to be helpful for reducing vomiting. *Cycas revoluta* also recognised as an important plant in the decoration of the garden. It is also said to be a tonic, helps expectoration. The resin of *Cycas rumphii* is used for the treatment of ulcers.

The woods of Pinaceae is of great commercial importance. *Pinus* produces a good quality of timber, which is used as building material, fuel, in making furniture, poles, shingles, packing cases, match boxes, pencils etc. Several species of Pinus, of which. *Pinus roxburghii,* commonly called 'chir', is the principal source of methyl alcohol, turpentine and resin. The resin is also internally used in connection with stomach troubles and as a remedy for gonorrhoea. It is externally applied as a plaster to inflammed swelling of the glands and for the collection of pus in the cavity. It is also used as timber. The seeds of *Pinus gerardiana,* commonly called chilgoza, are eaten after roasting. It is very nourishing. An oil is also obtained from the seeds, which is applied for dressing wounds and ulcers. Some *Pinus* species produces pulp for paper industry. The woods of *Pinus wallichiana* is superior in quality to that of *Pinus roxburghii* and yields resin. An essential oil produced by the leaves and wood of *Pinus insularis* is used as fuel. The seeds of *Pinus edulis* are consumed by human beings. The fossilised resin of *Pinus succinifera* (now extinct) is known as amber, which is of great commercial value and even used in jewellery.

Ephedra produces a medicine called ephedrine, which is used against asthma and bronchial troubles.

The seeds of *Gnetum gnemon* and *G. latifolium* are edible. The seeds are taken as food after roasting or boiling and rejecting the yellowish red outer coat of the fruit. The seed-kernel is crushed, moulded to form cakes or biscuits. After drying in the sun it is fried in the boiling oil. The young leaves and inflorescences are eaten as vegetable. The bark of the plant produces a fibre, which is strong, durable in sea water and has a good tensile strength both in dry and wet condition. It is used for fishing nets and lines. Ropes prepared from it are strong, flexible and light. The wood is used for anchoring posts for rafts and junks (a chinese vessel). Split branches may be used for basket. The seeds of *Gnetum ula* are also edible and produces a cooking oil, used for edible purposes. *Gnetum montanum* is supposed to be able to kill fish i.e. they possess pesticidal properties.
