MEGASPOROGENESIS

STRUCTURE OF OVULE- MAIN TERMS

- **Placenta- Place of attachment of ovule on the ovary wall.**

- **Funicle (Funicuclus)- The small slender stack of the ovule, which attaches the ovule to the placenta in the ovary wall.**

- **Nucellus- Central mass of tissue in the mature ovule.**

- **Megaspore- Female spore or macrospore developed inside the ovule in the nucellus**

IMPORTANT TERMS …….

- **Integuments- The protective covering around the nucellus leaving a small opening.**

- **Caruncle- outgrowth of the outer integument in the micropylar region. Eg. Castor.**

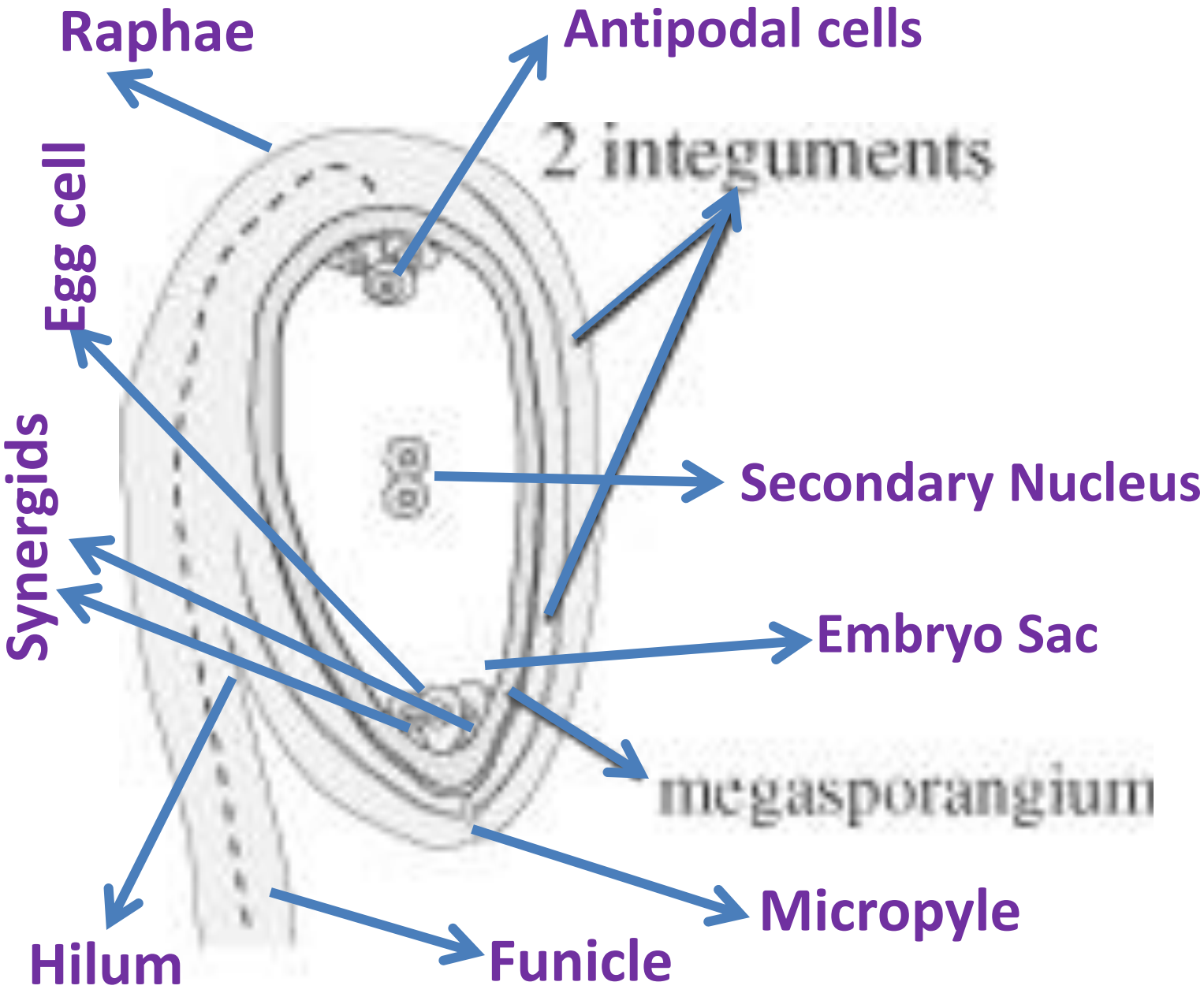
- **Aril – Collar-like out growth from the base of the ovule which forms third integument. Eg. Nutmeg.**

- **Micropyle-Small opening left by the integuments at the apical end.**

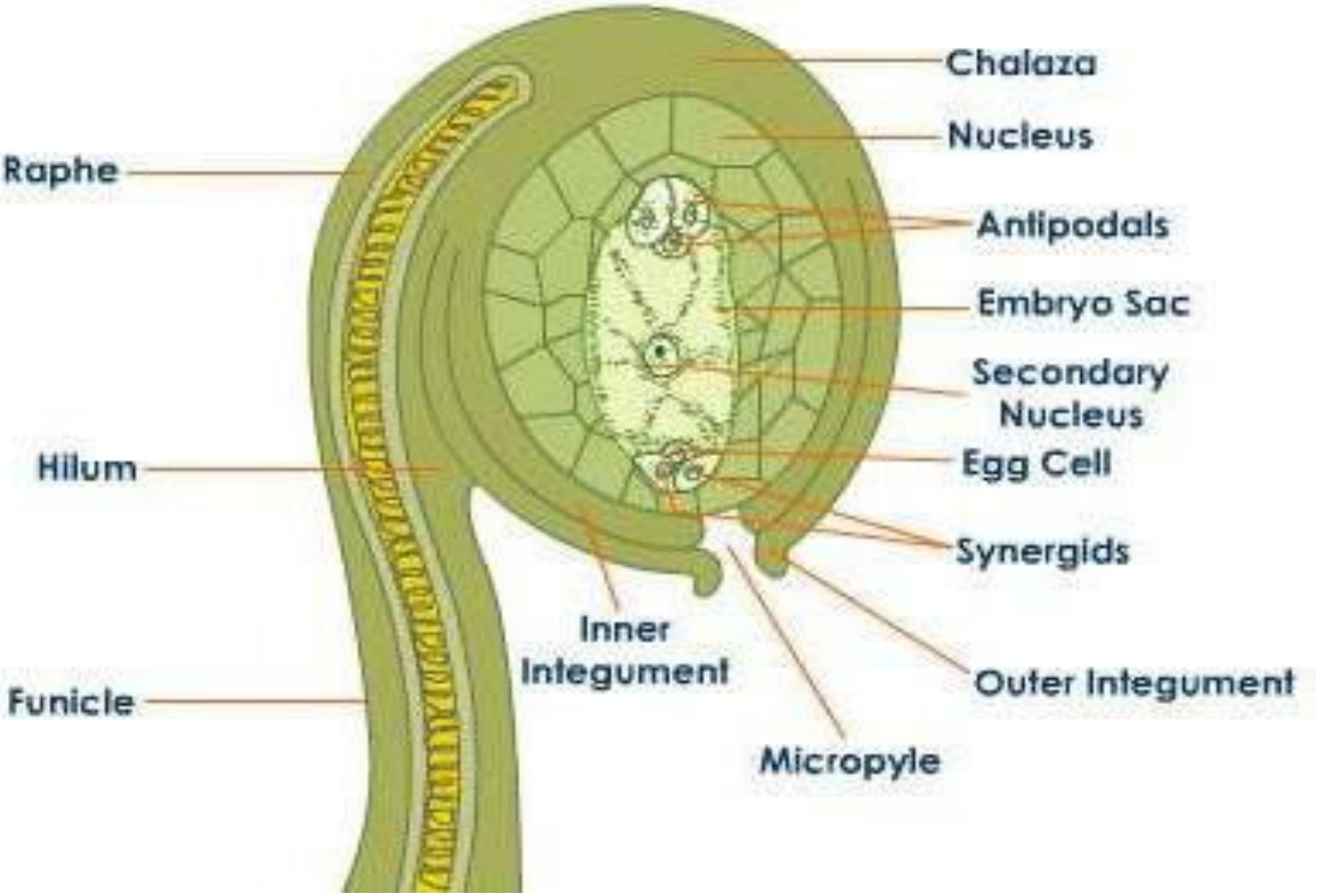
IMPORTANT TERMS …….

- **Hilum- Point of attachment of the Funicle to the body proper of the ovule.**
- **Raphae- The continuation of the funicle beyond hilum along the surface of the ovule as a ridge.**
- **Chalaza- Basal part of the ovule, where nucellus, integuments and funicle meet and merge.**
- **Embryo sac – Large oval cell embedded at the micropylar end of the nucellus, which is the female gametophyte.**

MATURE OVULE -STRUCTURE



MATURE OVULE -STRUCTURE



MATURE OVULE -STRUCTURE

- Ovule or egg is an oval or spherical body attached to the inner wall of the ovary on the placenta by funicle
- A mature ovule consists of nucellus, which is covered by one or two integuments except at the micropylar region
- Micropyle is the passage for the entry of pollen tube to discharge the male gametes for fertilization
- Chalaza is observed opposite to the micropyle on the ovule

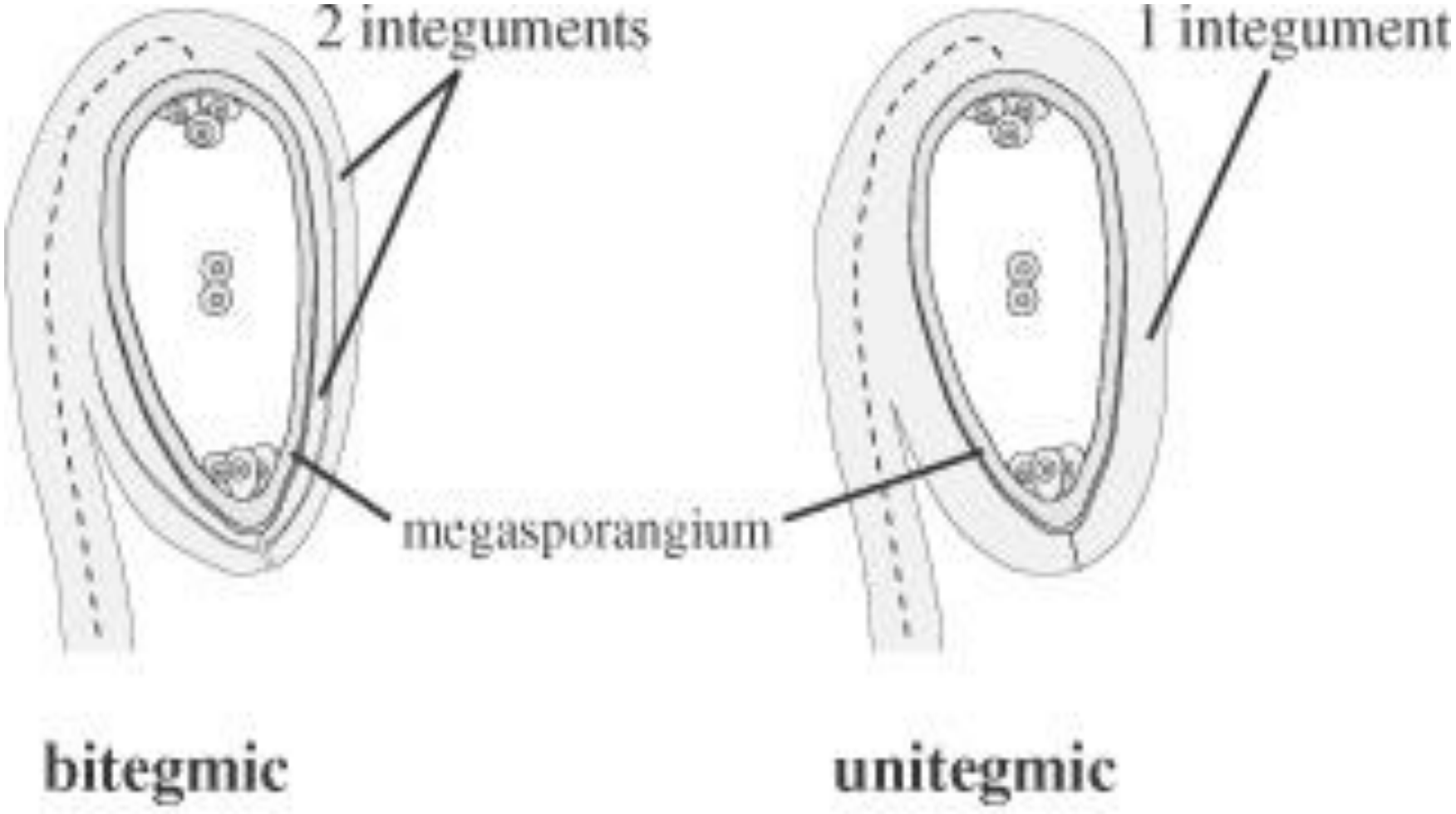
MATURE OVULE –STRUCTURE….

- The embryo sac is seen embedded in the nucellar tissue at the micropylar end
- It contains eight haploid nuclei arranged 3 at the micropylar end, 3 at the chalazal end and 2 at the centre of the embryo sac
- Chalazal nuclei organized into antipodal cells and the micropylar into egg apparatus
- The central nuclei are the polar nuclei
- Egg apparatus contains egg cell or female gametophyte at the centre and to synergids on either side

OVULE –TYPES

- **Based on the number of integuments:**
  - **Ategmic** **eg. Olax, Liriosma**
  - **Unitegmic** **Eg. All gamopetalae members**
  - **Bitegmic** **eg. Polypetalae & Monocots**

OVULE- INTEGUMENT TYPES



OVULE –TYPES

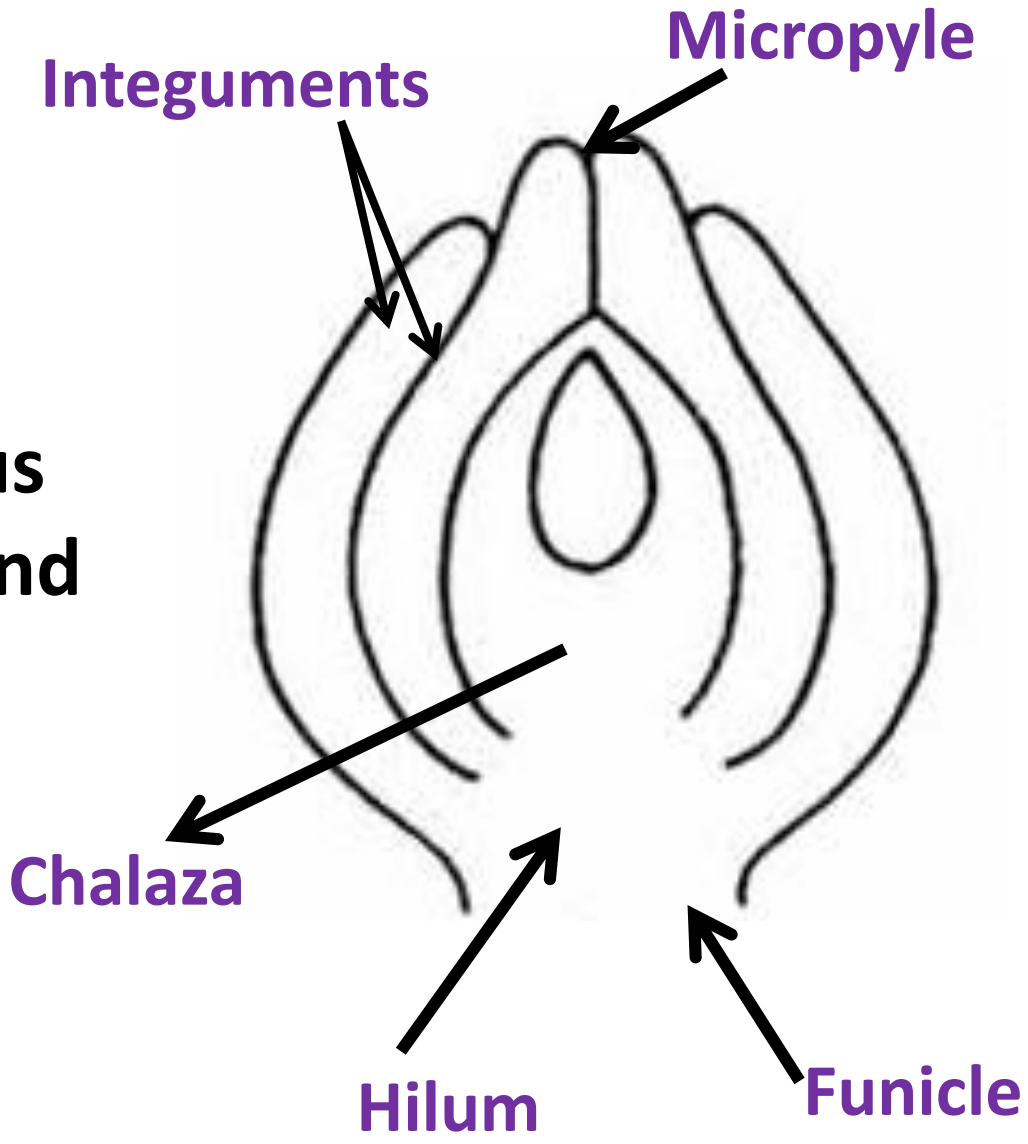
- **Based on the position of micropyle in relation to the funicle**
  - **Orthotropous/ Atropous- straight upright ovule**
  - **Anatropous/Inverted**
  - **Campylotropous**
  - **Amphitropous**
  - **Hemi-anatropous/ Hemitropous**
  - **Circinotropous**

ORTHOTROPOUS / ATROPOUS OVULE

- **Straight and upright from the placental surface**
- **Micropyle, body, chalaza and funiculus are in straight line and above the hilum**

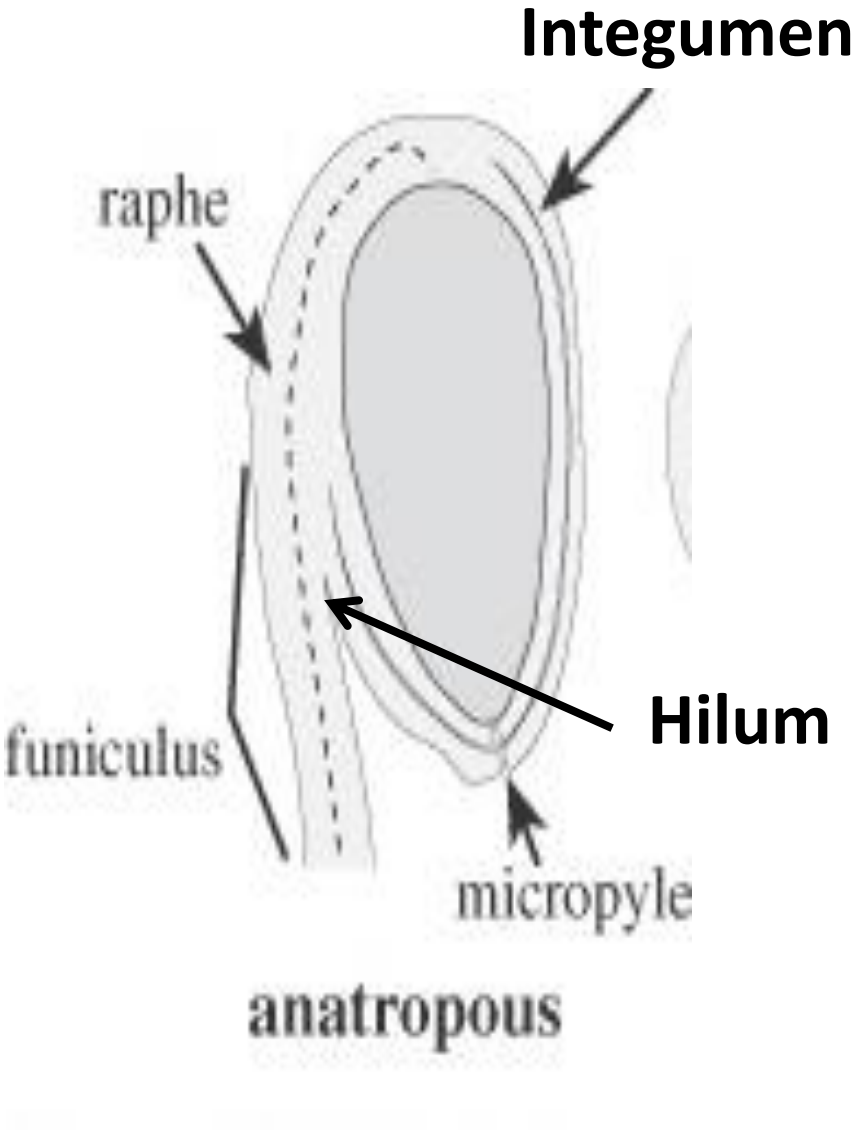
Eg. Polygonaceae

Piperaceae



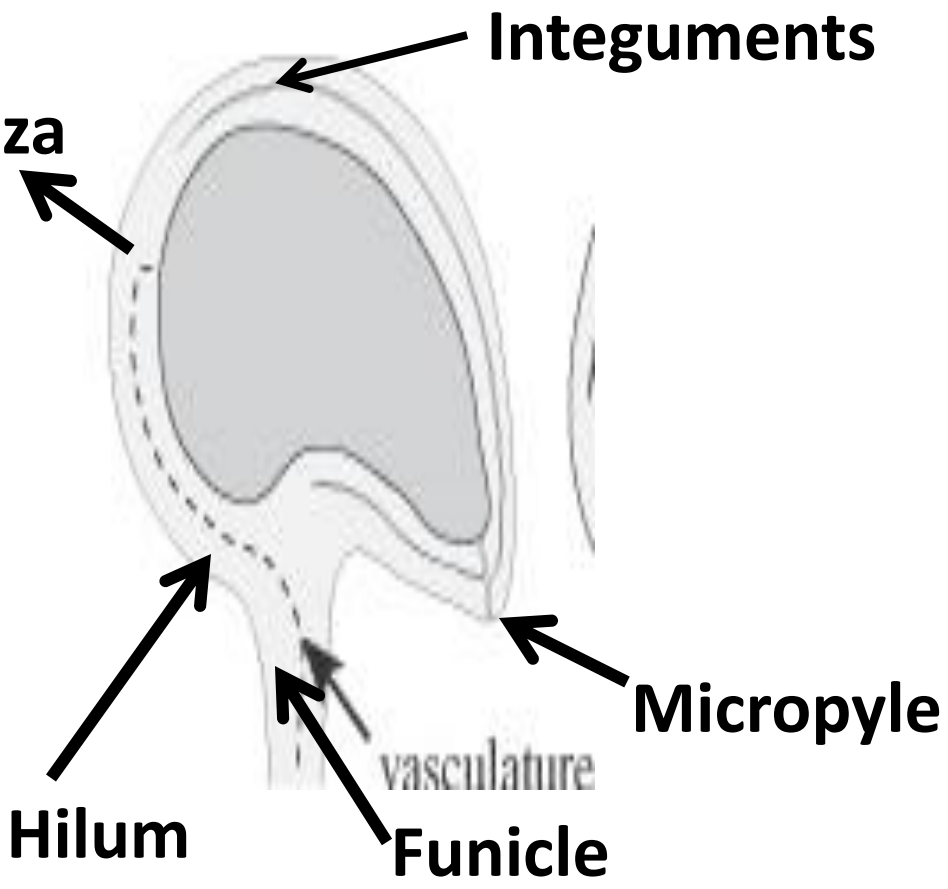
ANATROPOUS/ INVERTED OVULE

- Ovule body bends
- at 180^0
- Thus the micropyle and hilum come close to the funicle
- Eg. Malvaceae, Compositae



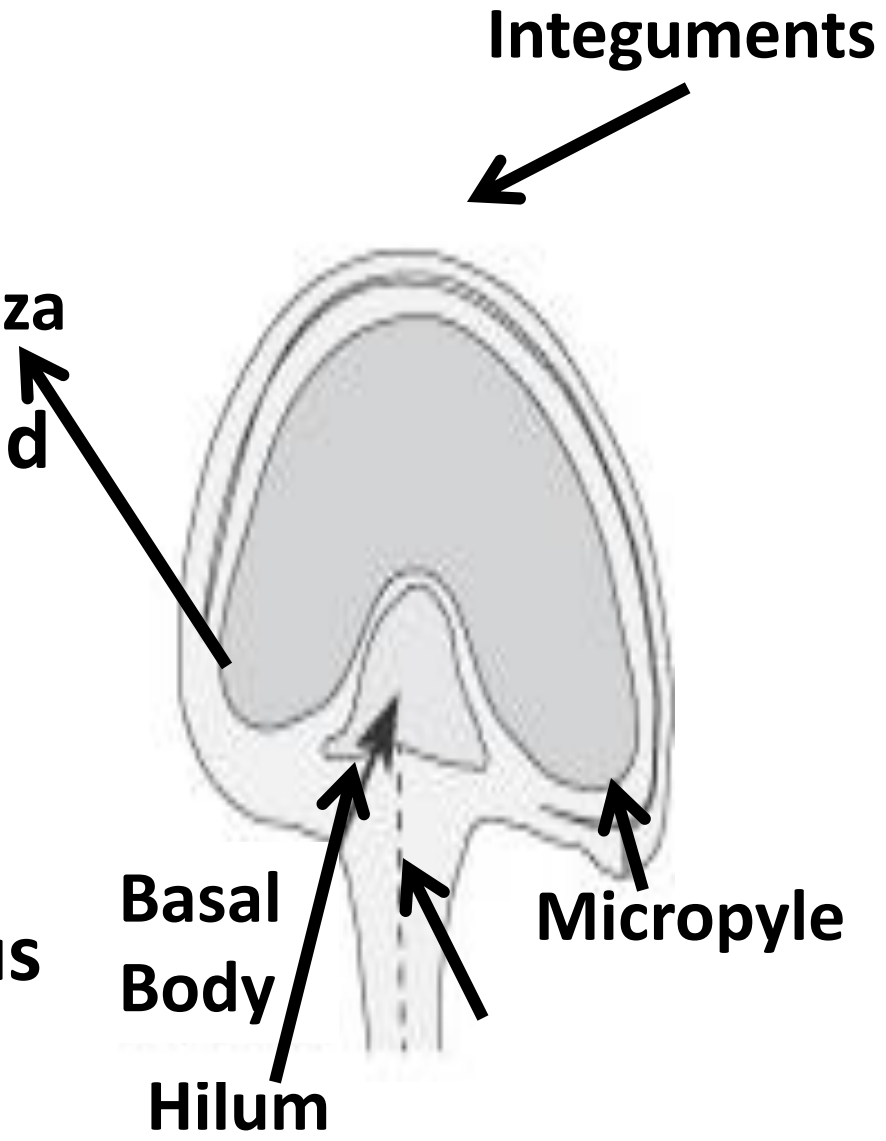
CAMPYLOTROPOUS OVULE

- Ovule body is slightly curved and placed at right angles to the funiculus
- Micropyle and chalaza are not in straight line
- Micropyle lies close to the funicle
- Funicle is right at right angles to the chalaza
- Eg. Leguminaceae
- Cruciferae



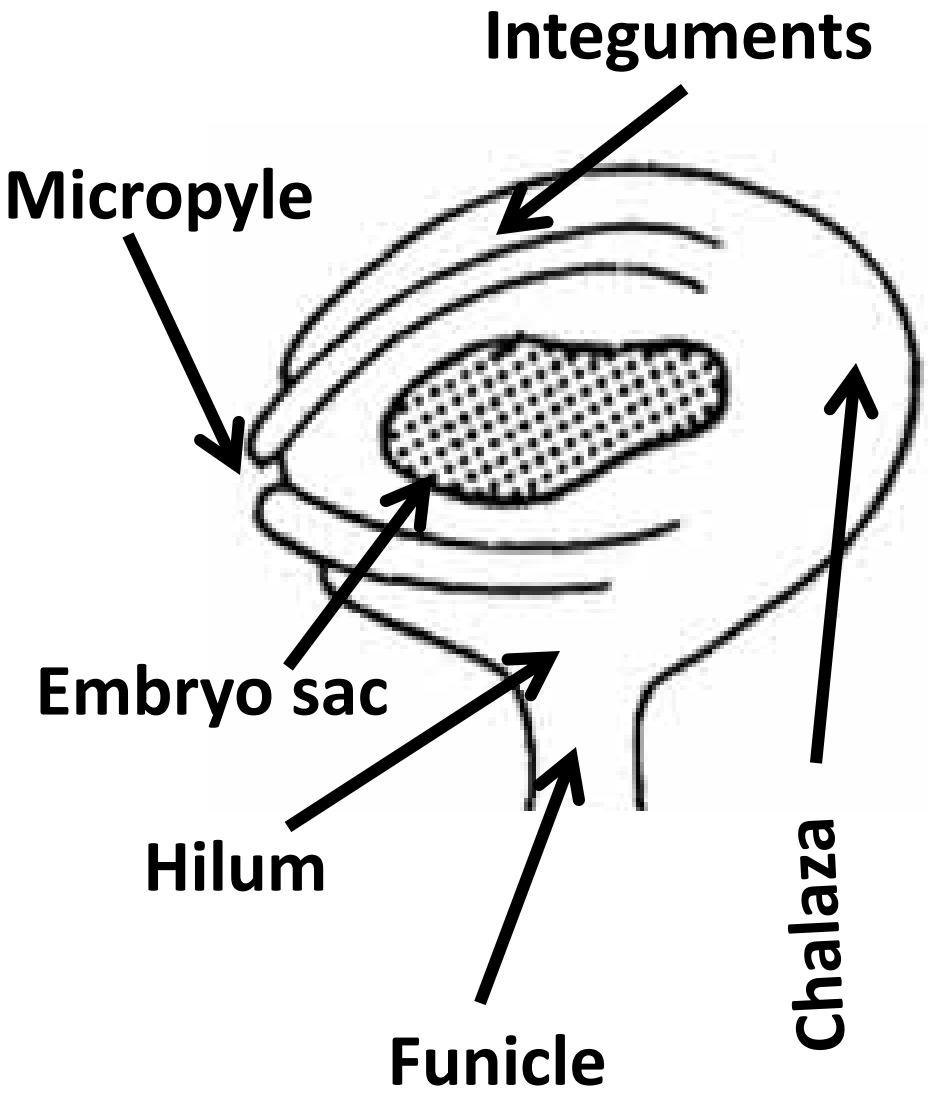
AMPHITROPOUS OVULE

- Ovule is horse-shoe shaped.
- More curved than camphylotropous.
- The curvature is extended to nucellus and embryo sac, which is U-shaped.
- Basally it resembles orthotropous and terminally to anatropous
- Eg. Loganiaceae, Butomaceae



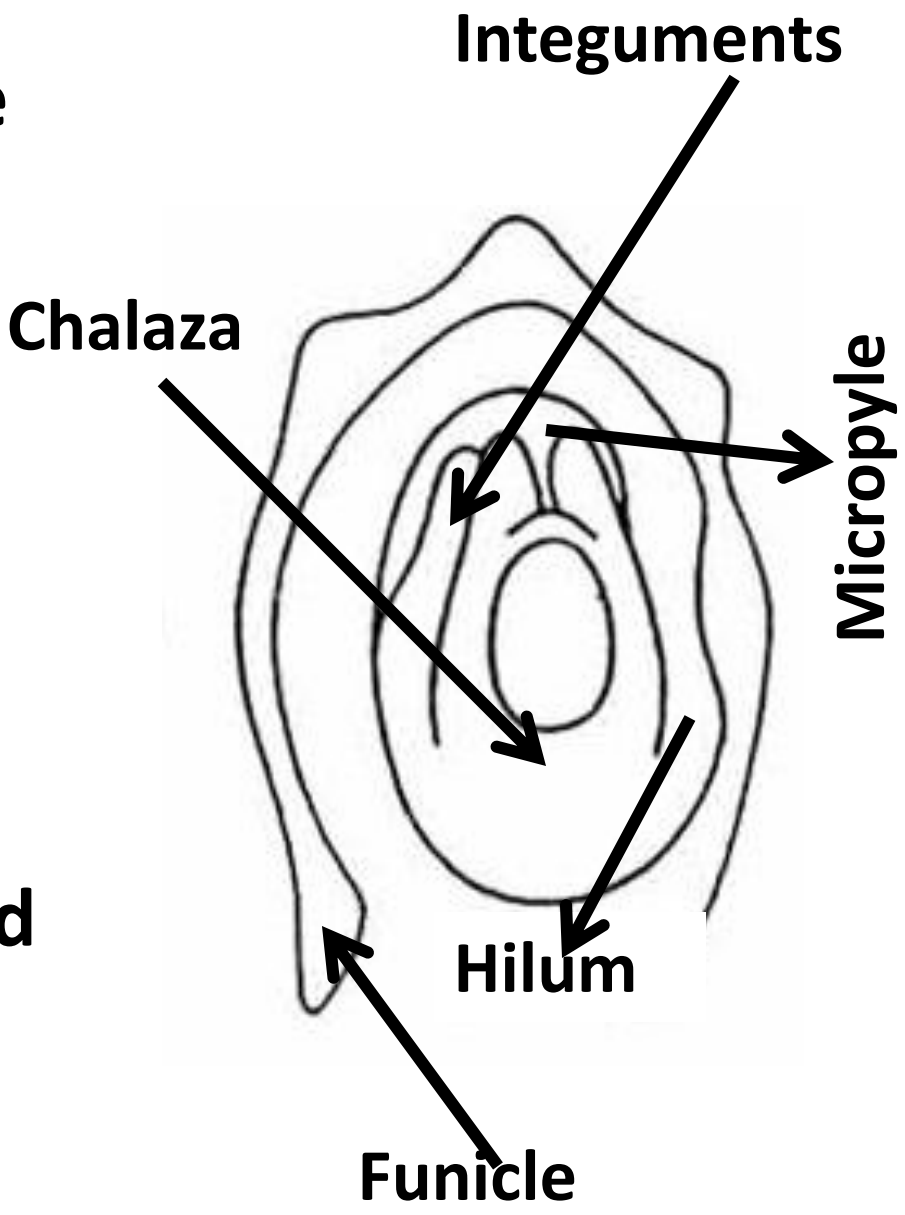
HEMI-ANATROPOUS OVULE

- Ovule half inverted
- i.e. rotated at 90^0
- Right angles to funicle
- Micropyle, embryo sac and chalaza are in straight line
- Micropyle not near the hilum
- Eg. Ranunculaceae members



CIRCINOTROPOUS OVULE

- Funicle is very long, which forms a complete ring around the ovule
- This ovule is formed by unilateral growth
- The orthotropous ovule get inverted to 360^0 by unilateral growth and becomes anatropous
- i.e. the micropyle turned upward again.
- Eg. Plumbaginaceae, Cactacea



DEVELOPMENT OF OVULE

- It is called Megasporogenesis
- Ovule develops from the inner surface of the ovary, on special tissue, the placenta
- On the placenta the nucellus is formed as a spherical structure
- The integuments are formed around the nucellus and completely cover it except at micropylar region

DEVELOPMENT OF MEGASPORE

- **A single hypodermal cell is differentiated, which becomes distinct by its larger size, prominent nucleus and dense cytoplasm**
- **It is named as the archesporial cell/ initial**
- **The development of this cell varies in different ovules**
- **Three types are recognized**

MEGASPOROGENESIS

1. Crassinucellate
2. Pseudo-crassinucellate
3. Tenuinucellate

1. CRASSINUCELLATE TYPE

- The archesporial cell undergoes periclinal division to form outer primary parietal cell and inner primary sporogenous cell
- The primary parietal cell either remain undivided or divided in both plains to form a mass of cells pushing the primary sporogenous cell deep into the nucellar tissue
- The pri. Sporogenous cell thus becomes sub-hypodermal in position and behaves as the megaspore mother cell
- Eg. Myriophyllum intermedium

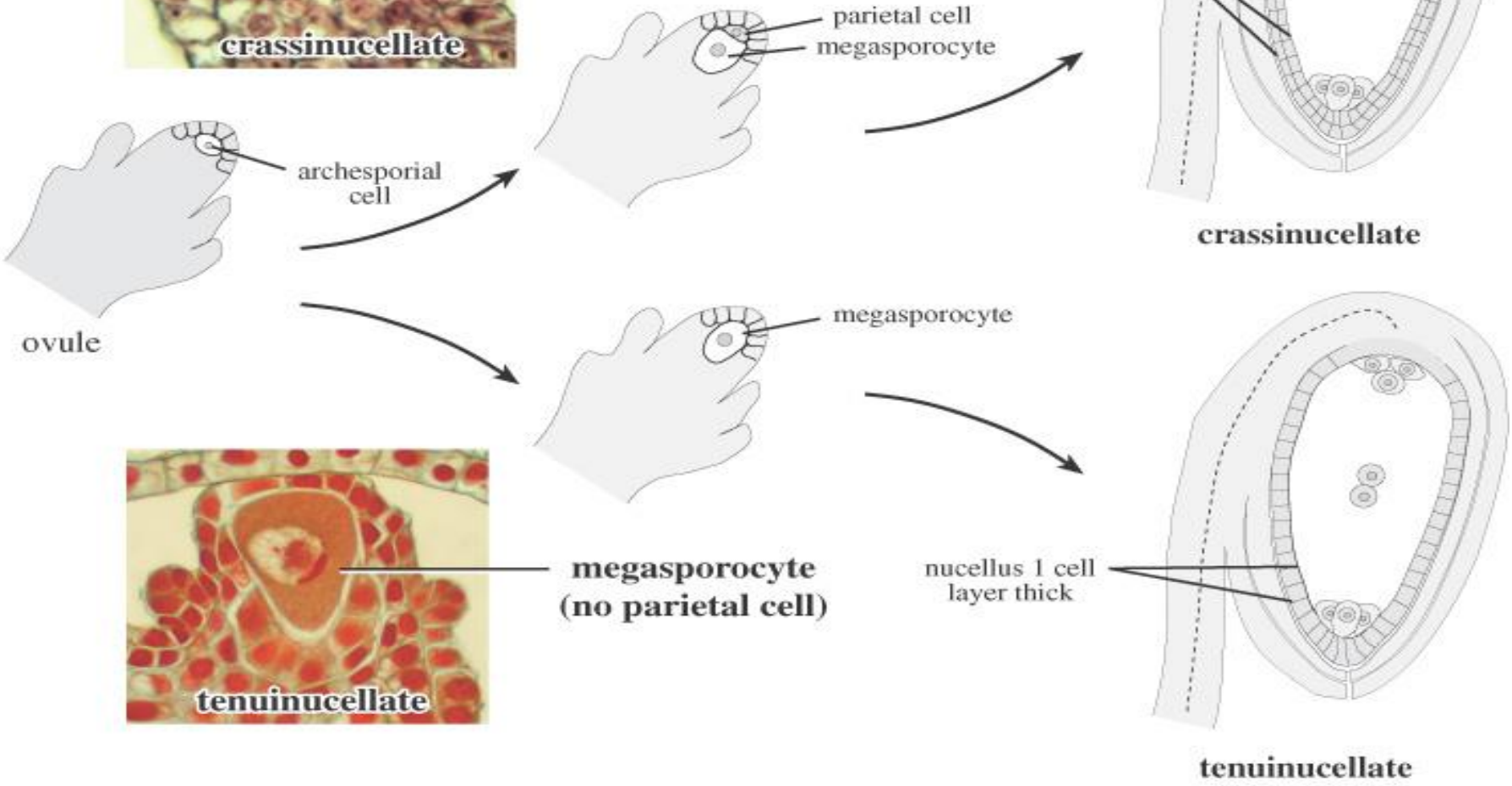
2. PSEUDO- CRASSINUCELLATE TYPE

- Almost similar to former type
- Instead of the division of primary Parietal cell, the nucellar epidermis divide by periclinal division makes the primary sporogenous cell sub-hypodermal
- The primary sporogenous cell acts as the megaspore mother cell
- Eg. Nigella damascena

3. TENUINUCELLATE TYPE

- The archesporial cell directly functions as the megaspore mother cell without division.
- No primary Parietal cell formation
- Eg. Elytraria acaulis

TYPES OF MEGASPORE MOTHER CELL DEVELOPMENT



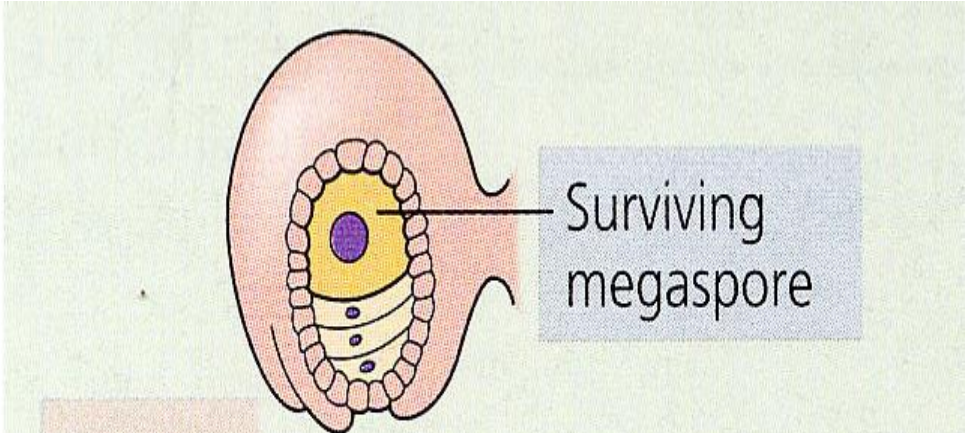
DEVELOPMENT OF MEGASPORE

- The megaspore mother cell is diploid
- It is the last cell of sporophytic generation
- It undergoes meiosis forming 4 haploid cells called megaspore tetrad

– Mostly they are linearly arranged or it can be isobilateral , decussate, T - shaped,

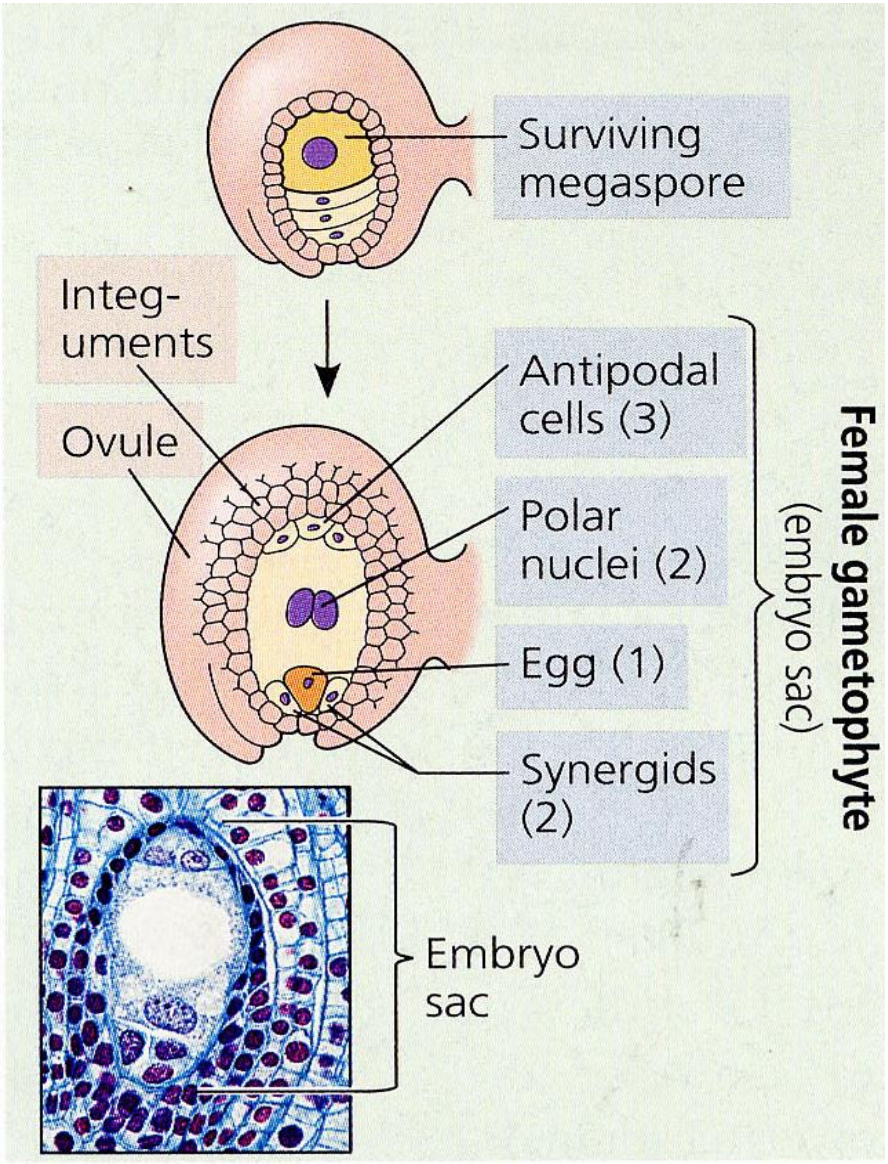
⊥ - shaped and rarely tetrahedral

DEVELOPMENT OF MEGASPORE



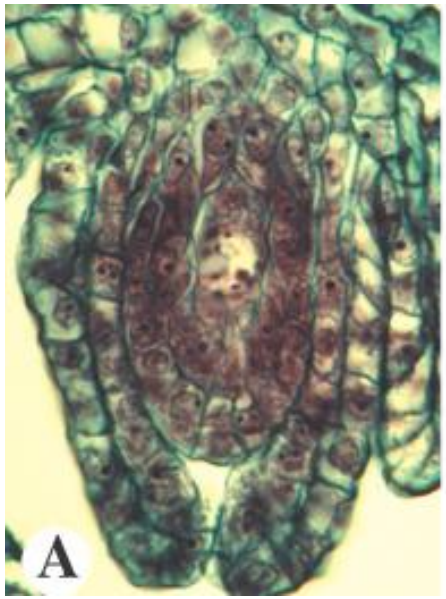
- **In many Angiosperms, only one of the four megaspores towards the chalazal end survives.**
- **Others degenerate and used up by the functional spore.**
- **The functional megaspore deposits callose wall around it, isolating it from others.**

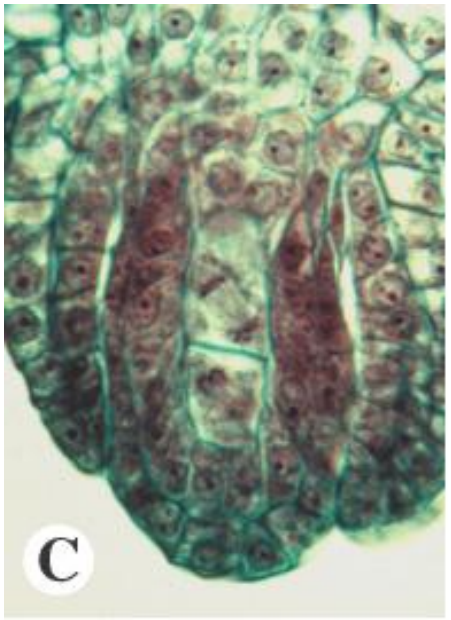
DEVELOPMENT OF MEGASPORE

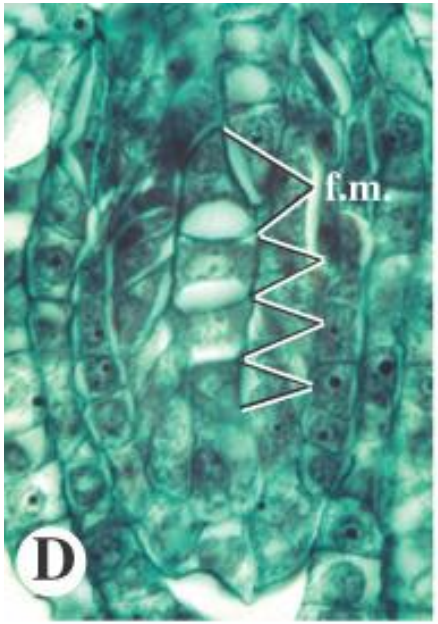


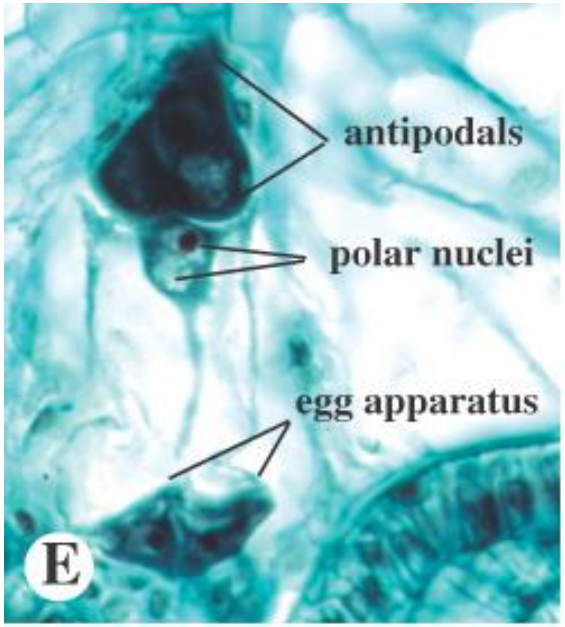
- **This megaspore continues to grow, and its nucleus divides by mitosis three times, resulting in one large cell with eight haploid nuclei, the embryo sac.**

EMBRYOSAC DEVELOPMENT

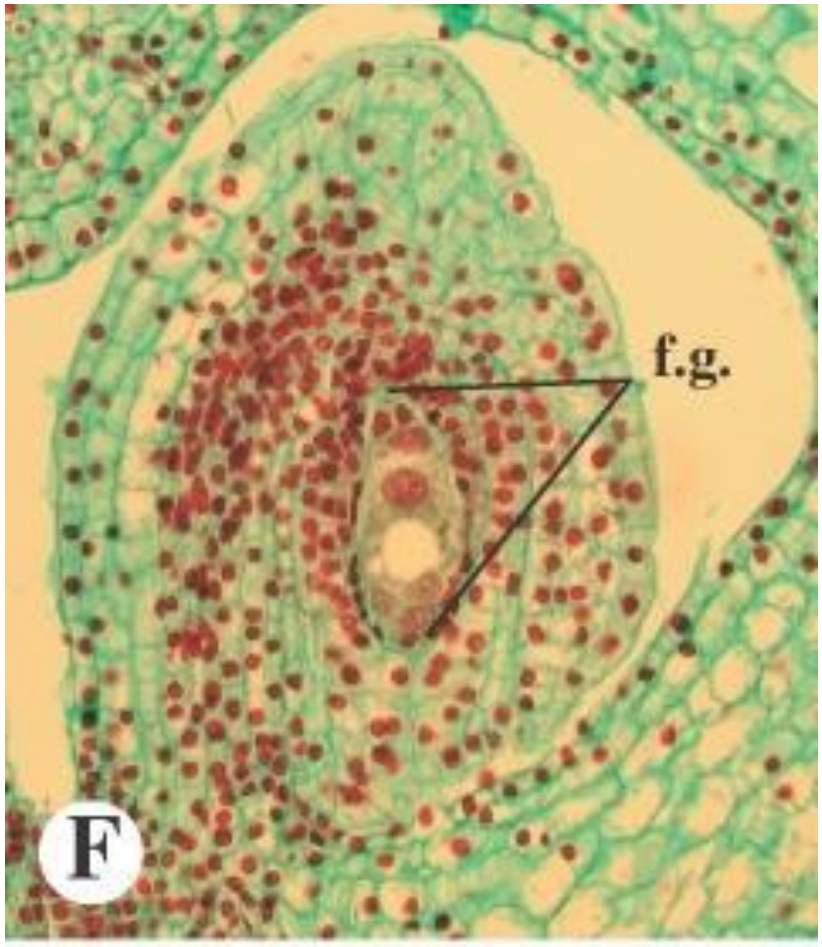


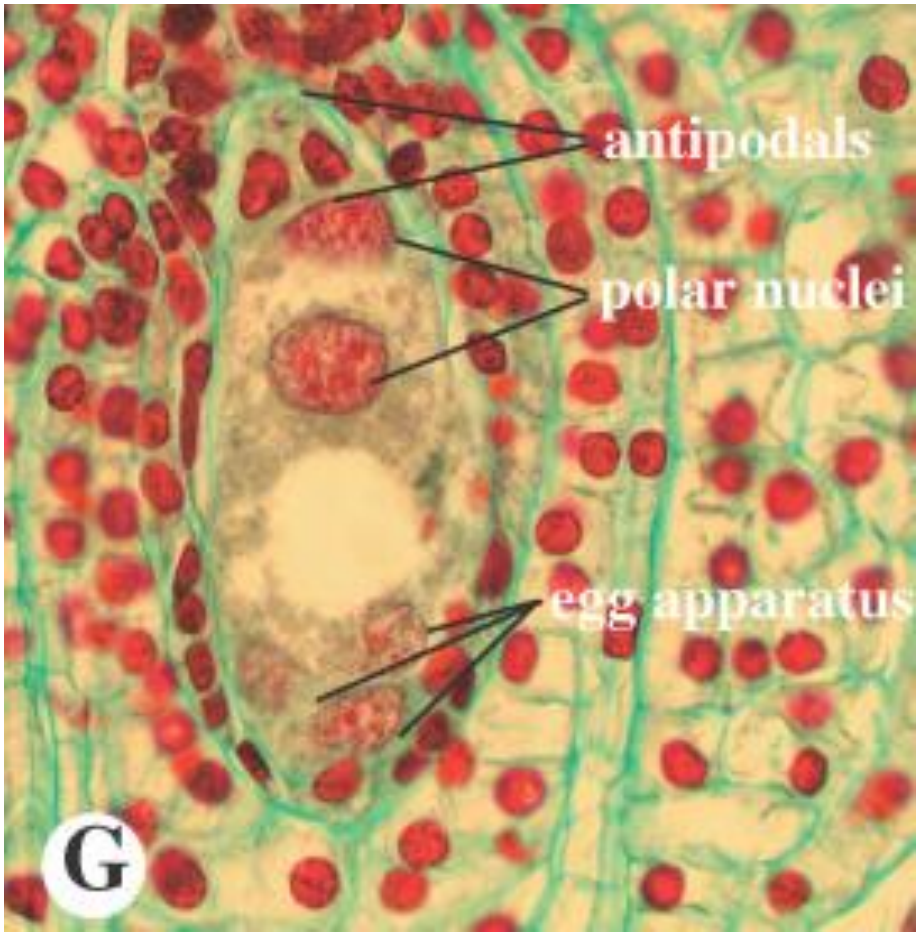






EMBRYOSAC DEVELOPMENT





TYPES OF EMBRYO SAC DEVELOPMENT

- **Based on the Number of megaspores involved in embryo sac formation 3 types of Embryo Sac development observed**
  - **Monosporic**
  - **Bisporic**
  - **Tetrasporic**

TYPES OF EMBRYO SAC DEVELOPMENT

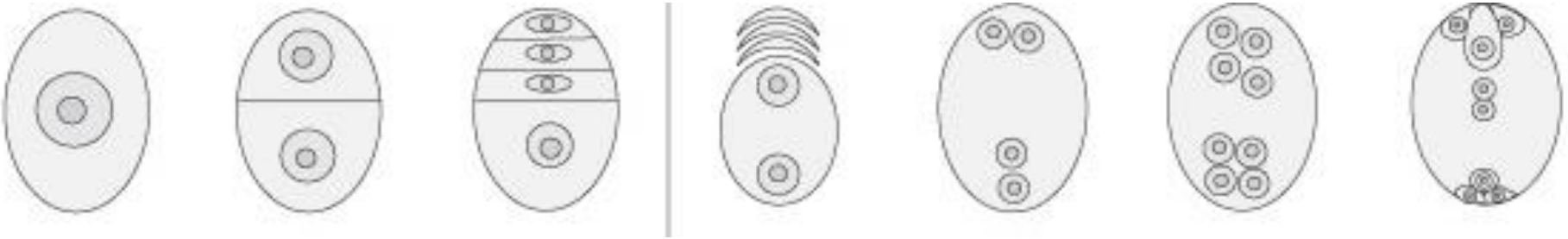
Monosporic embryo sac development

- **Out of 4 only one haploid megaspore takes part in embryo sac development**
- **2 types of Monosporic embryo sac development**
  - ❖ **Polygonum type**
  - ❖ **Oenothera type**

MONOSPORIC EMBRYO SAC DEVELOPMENT

POLYGONUM TYPE

- Commonest & present in 80% Angiosperms
- First noticed in Polygonum divaricatum by Strasburger in 1879
- Among the megaspore tetrads only one chalazal megaspore survives
- It divides mitotically by 3 successive divisions produces 8 haploid nuclei, without wall formation
- They organised as 3-celled egg apparatus, 3 celled chalazal cells and two central polar nuclei which later fused to form the diploid secondary nucleus



MONOSPORIC EMBRYO SAC DEVELOPMENT

OENOTHERA TYPE

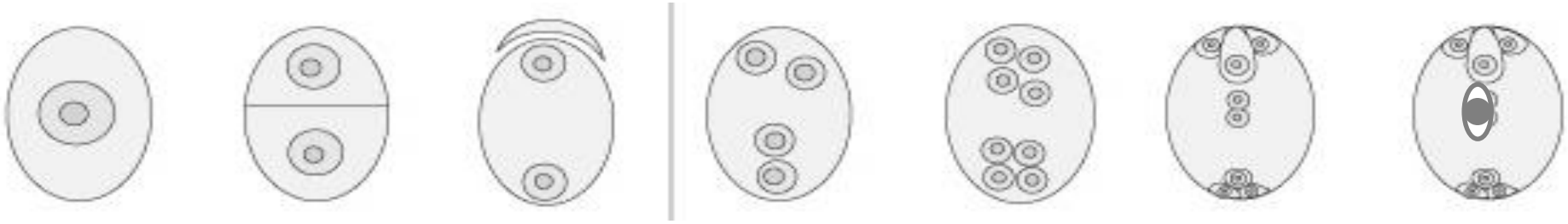
- First reported in Oenothera lamarkiana by Hofmeister in 1849
- The embryo sac developed from micropylar megaspore
- The embryo sac is 4- nucleate and is composed of
- 3-celled egg apparatus and one polar nucleus

BISPORIC EMBRYO SAC DEVELOPMENT

- No tetrad in megaspore development
- From the dyad one degenerates and the other develops into embryo sac

ALLIUM TYPE

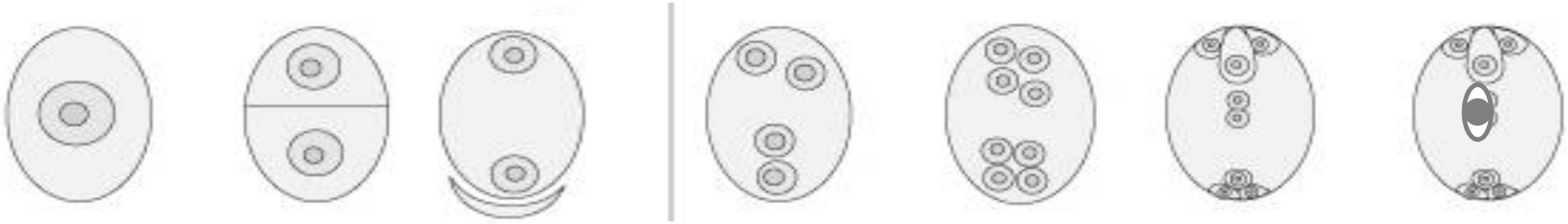
- Reported in Allium fistulosum by Strasburger in 1879
- The functional megaspore is the chalazal one
- From it by three mitotic divisions 8-nucleate embryo sac is formed and latter organised to 7-celled structure



BISPORIC EMBRYO SAC DEVELOPMENT

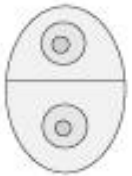
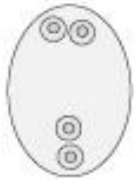
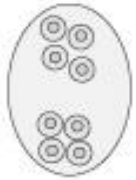
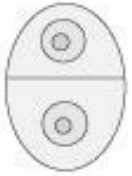
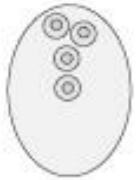
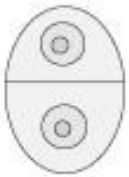
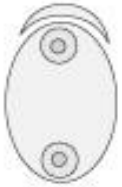
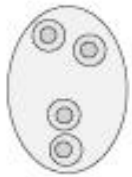
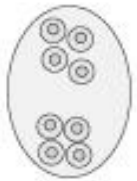
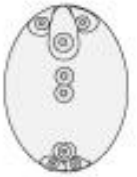
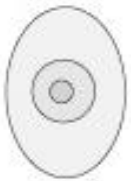
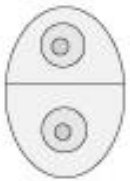
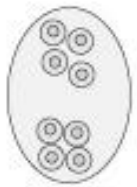
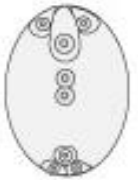
ENDYMION TYPE

- Reported in Endymion hispanicus
- The functional megaspore is the micropylar one
- From it by three mitotic divisions 8-nucleate embryo sac is formed and latter organised to 7-celled structure



TYPES OF EMBYROSAC DEVELOPMENT

MONOSPORIC & BISPORIC

Female Gametophyte Type	Megasporogenesis			Megagametogenesis			
	Mega-sporocyte	Meiosis I	Meiosis II	Mitosis I	Mitosis II	Mitosis III	Mature female gametophyte
Monosporic 8-nucleate *Polygonum* type							
Monosporic 4-nucleate *Oenothera* type							
Bisporic 8-nucleate *Allium* type							
Bisporic 8-nucleate *Endymion type*							

TETRASPORIC EMBRYO SAC DEVELOPMENT

- Meiotic division of MMC is not followed by cytokinesis
- All the 4 nuclei take part in embryo sac formation
- The development of embryo sac from the 4-nucleate coenomegaspore is complicated and the further divisions vary in different species
- Based on the arrangement of nuclei, post meiotic divisions in the coenomegaspore and presence or absence of nuclear fusion various types are recognized
- Two major types, which are sub-divided again into seven types
- The two major types are:
  - Those without nuclear fusion
  - Those with nuclear fusion

TETRASPORIC EMBRYO SAC DEVELOPMENT
Without nuclear fusion

5 types (Two 8- nucleate and three16 nucleated)

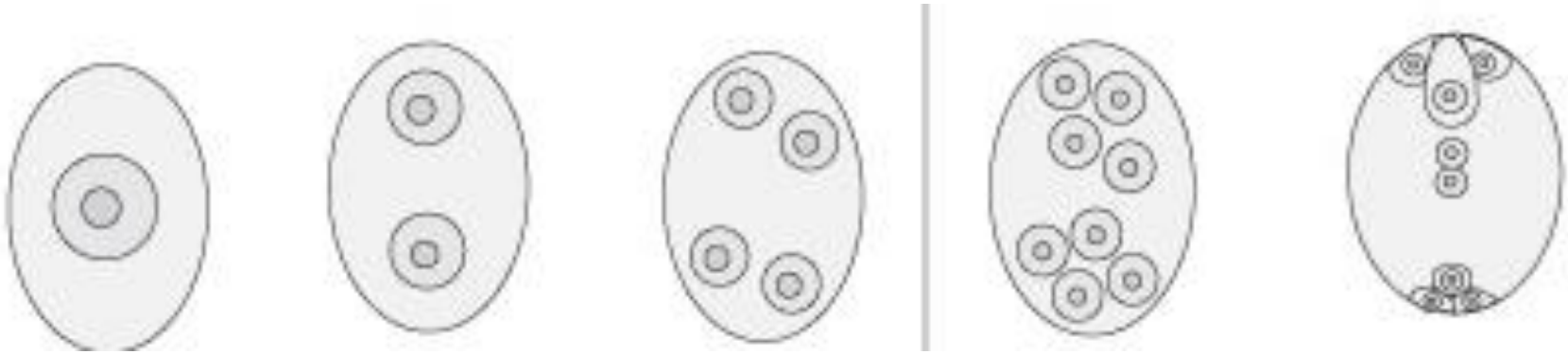
1. **ADOXA TYPE (8- nucleate)**
2. **PLUMBAGO TYPE (8- nucleate)**
3. **PENAEA TYPE (16- nucleate)**
4. **DRUSA TYPE (16- nucleate)**
5. **PEPEROMIA TYPE (16- nucleate)**

TETRASPORIC EMBRYO SAC DEVELOPMENT

8- nucleate without nuclear fusion

1. ADOXA TYPE

- Reported in Adoxa moschatellina by Jansson in 1880
- The 4 nuclei after one mitotic division organised into 3 celled egg apparatus, 2nucleated central cell and 3 celled antipodal

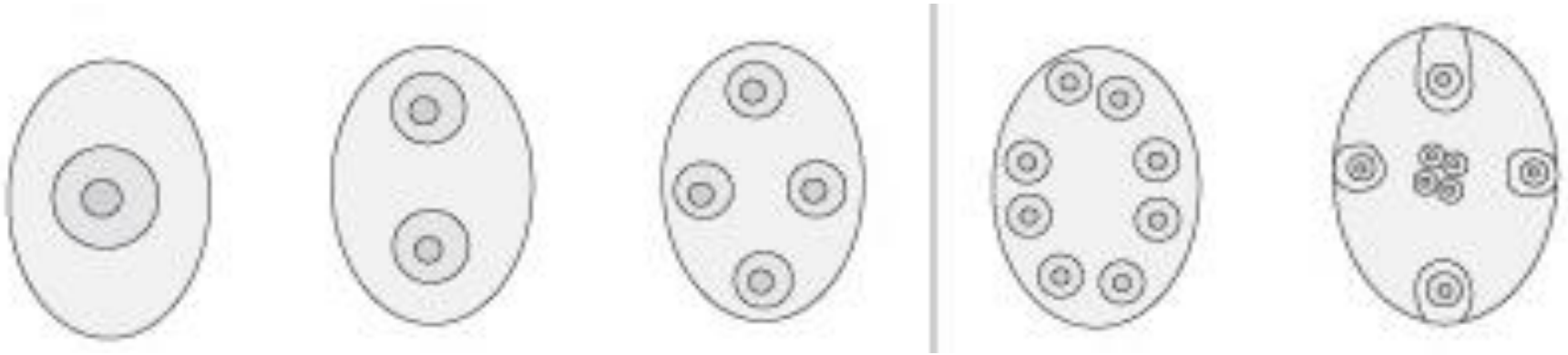


TETRASPORIC EMBRYO SAC DEVELOPMENT

8- nucleate without nuclear fusion

2. PLUMBAGO TYPE

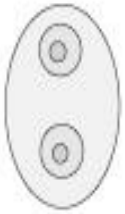
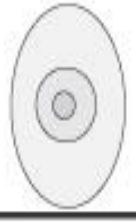
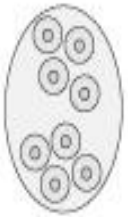
- observed in Plumbago campensis
- Out of the 4 nuclei, after one mitotic division, one uninucleate egg cell, a 4 nucleate central cell and 3 uninucleate peripheral cells are formed



TYPES OF EMBYROSAC DEVELOPMENT

TETRASPORIC

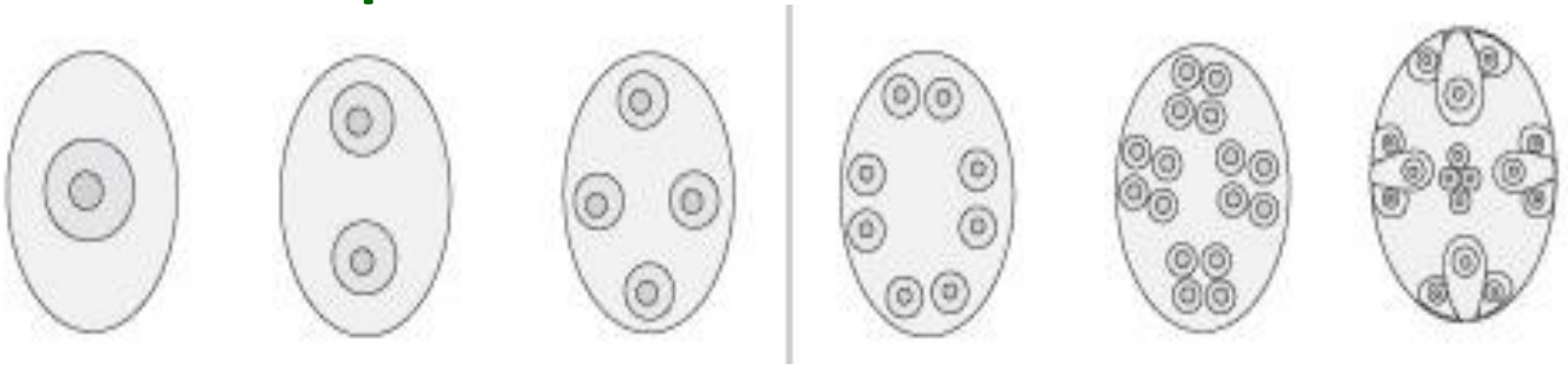
8 Nucleate without nuclear fusion

Female Gametophyte Type	Megasporogenesis			Megagametogenesis			
	Mega-sporocyte	Meiosis I	Meiosis II	Mitosis I	Mitosis II	Mitosis III	Mature female gametophyte
Tetrasporic 8-nucleate *Plumbago* type							
Tetrasporic 8-nucleate *Adoxa* type							

TETRASPORIC EMBRYO SAC DEVELOPMENT 16 nucleate without nuclear fusion

3. PENAEA TYPE

- Reported in Penaea, Brachysiphon and Sarcocolla
- The 4 nuclei by two mitotic division 16 nuclei are formed
- They are arranged in 3+3+3+3+4 condition as 3-celled micropylar egg apparatus, 3-celled chalazal antipodals, two lateral groups of 3 cells and 4 functional polar nuclei at the centre

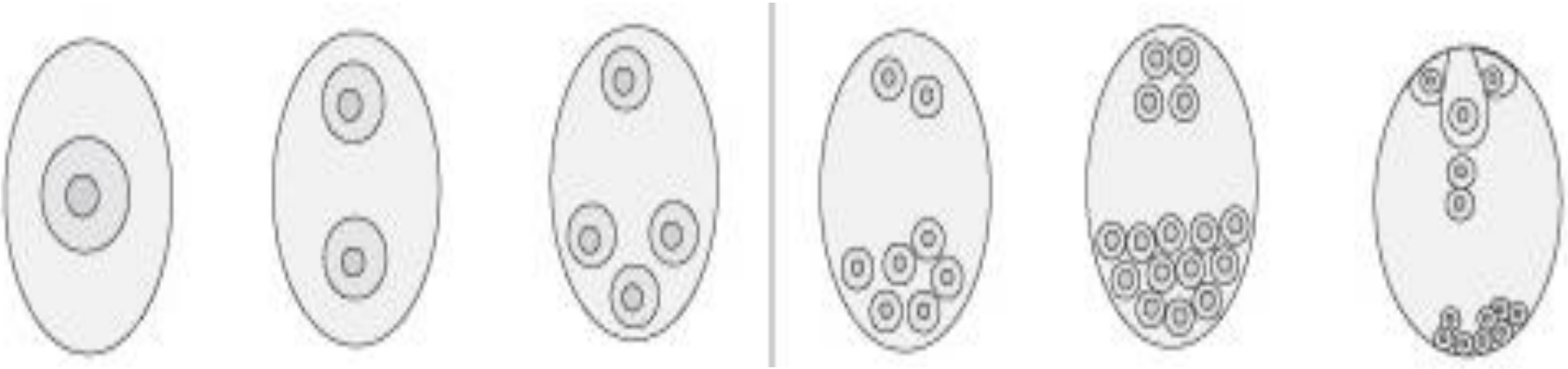


TETRASPORIC EMBRYO SAC DEVELOPMENT

16 nucleate without nuclear fusion

4. DRUSA TYPE

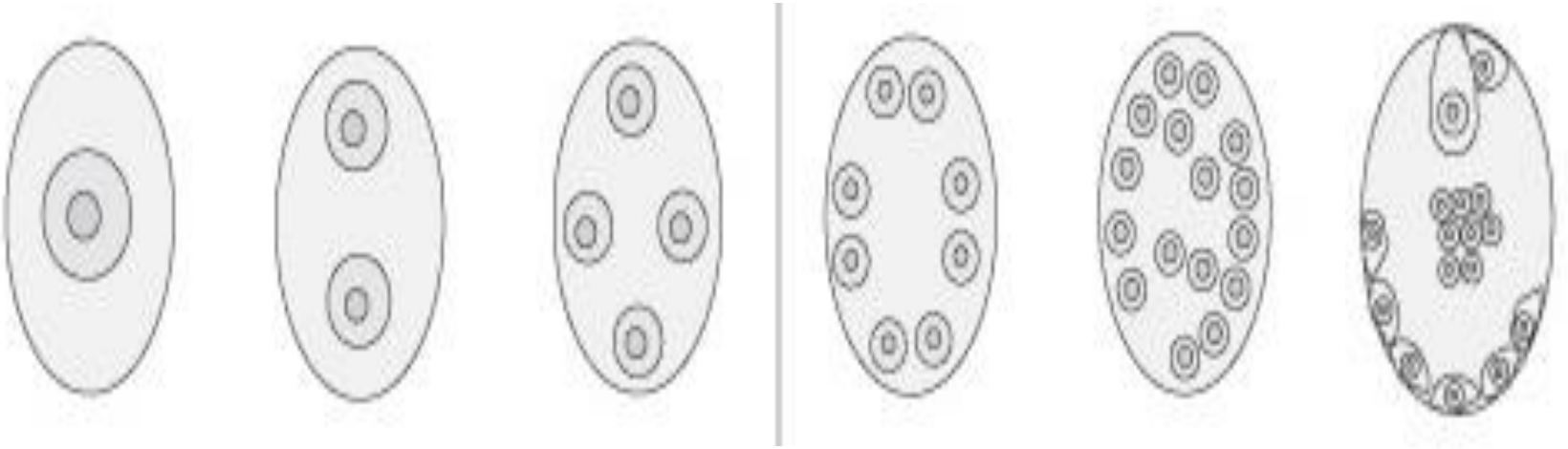
- Observed in Drusa oppositifolia
- 16 nuclei are formed arranged as 3 celled egg apparatus+2polar nuclei +11 celled antipodals



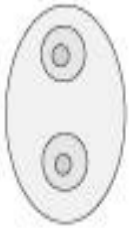
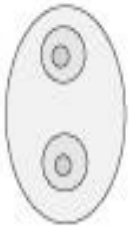
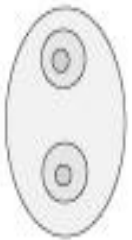
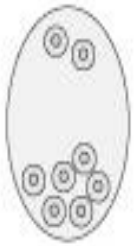
TETRASPORIC EMBRYO SAC DEVELOPMENT 16 nucleate without nuclear fusion

5. PEPEROMIA TYPE

- Reported in Peperomia pellucida
- 16 nuclei are formed arranged as 2 celled egg apparatus, a central cell with 8 polar nuclei and 6 uninucleate peripheral cells



TYPES OF EMBYROSAC DEVELOPMENT TETRASPORIC 16 NUCLEATE without nuclear fusion

Female Gametophyte Type	Megasporogenesis			Megagametogenesis			
	Mega-sporocyte	Meiosis I	Meiosis II	Mitosis I	Mitosis II	Mitosis III	Mature female gametophyte
Tetrasporic 16-nucleate *Peperomia* type							
Tetrasporic 16-nucleate *Penaea* type							
Tetrasporic 16-nucleate *Drusa* type							

TETRASPORIC EMBRYO SAC DEVELOPMENT

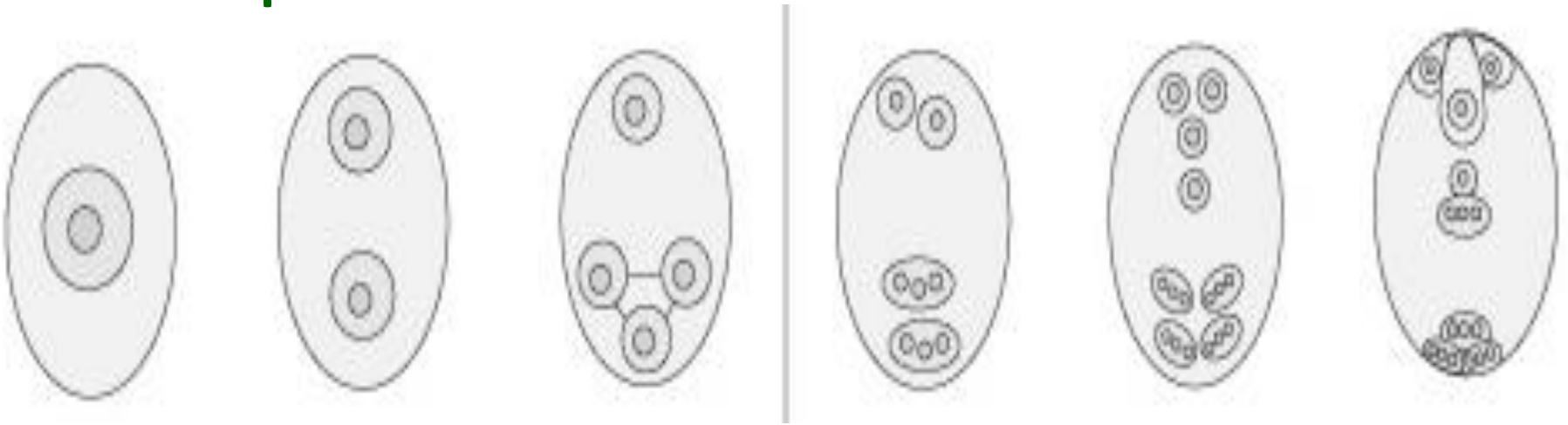
8- nucleate with nuclear fusion

- Out of the 4 nuclei 3 fused to form a triploid nucleus at chalazal end
- One remains as haploid at the micropylar end
- Two variations are reported
  - Fritillaria type
  - Plumbagella type

TETRASPORIC EMBRYO SAC DEVELOPMENT 8-nucleate with nuclear fusion

1. **Fritillaria type**

- Present in various species of Lilium
- Both haploid and triploid nuclei divide twice mitotically to form an 8- nucleate embryo sac
- 3-celled haploid egg apparatus, 3- celled triploid antipodal and two polar nuclei are organized
- One polar nucleus is haploid and the other is triploid

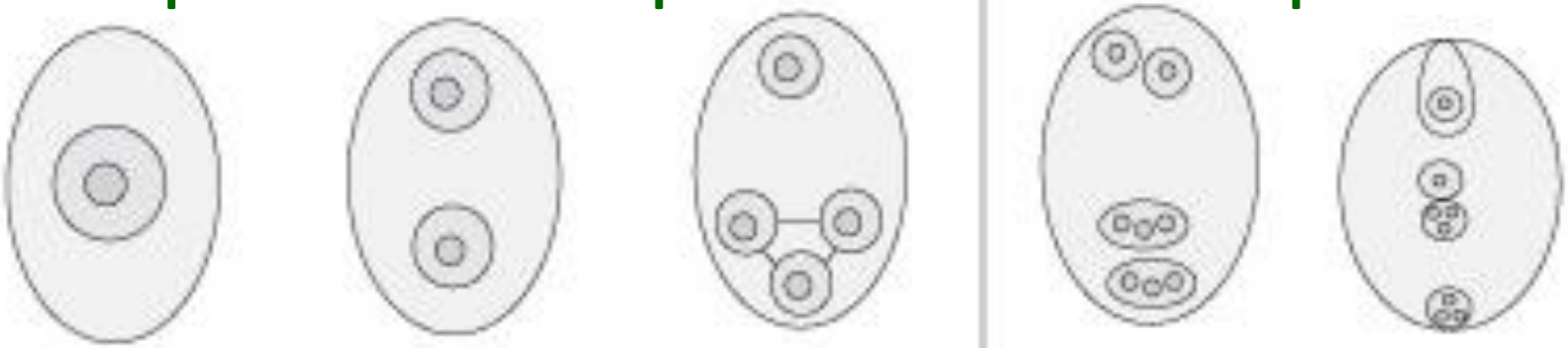


TETRASPORIC EMBRYO SAC DEVELOPMENT

8- nucleate with nuclear fusion

2. Plumbagella type

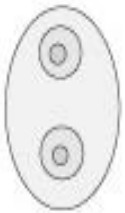
- Reported in *Plumbagella micrantha*
- Both haploid and triploid nuclei divide mitotically to form a 4- nucleate embryo sac
- Out of the 2 haploid nuclei at the micropylar end one remains as the 1-celled haploid egg apparatus
- The other moves to the centre as haploid polar nucleus
- At the chalazal end one haploid antipodal cell is organised and the other haploid nucleus moves to the centre as polar nucleus
- One polar nucleus is haploid and the other is triploid



TYPES OF EMBYROSAC DEVELOPMENT

TETRASPORIC

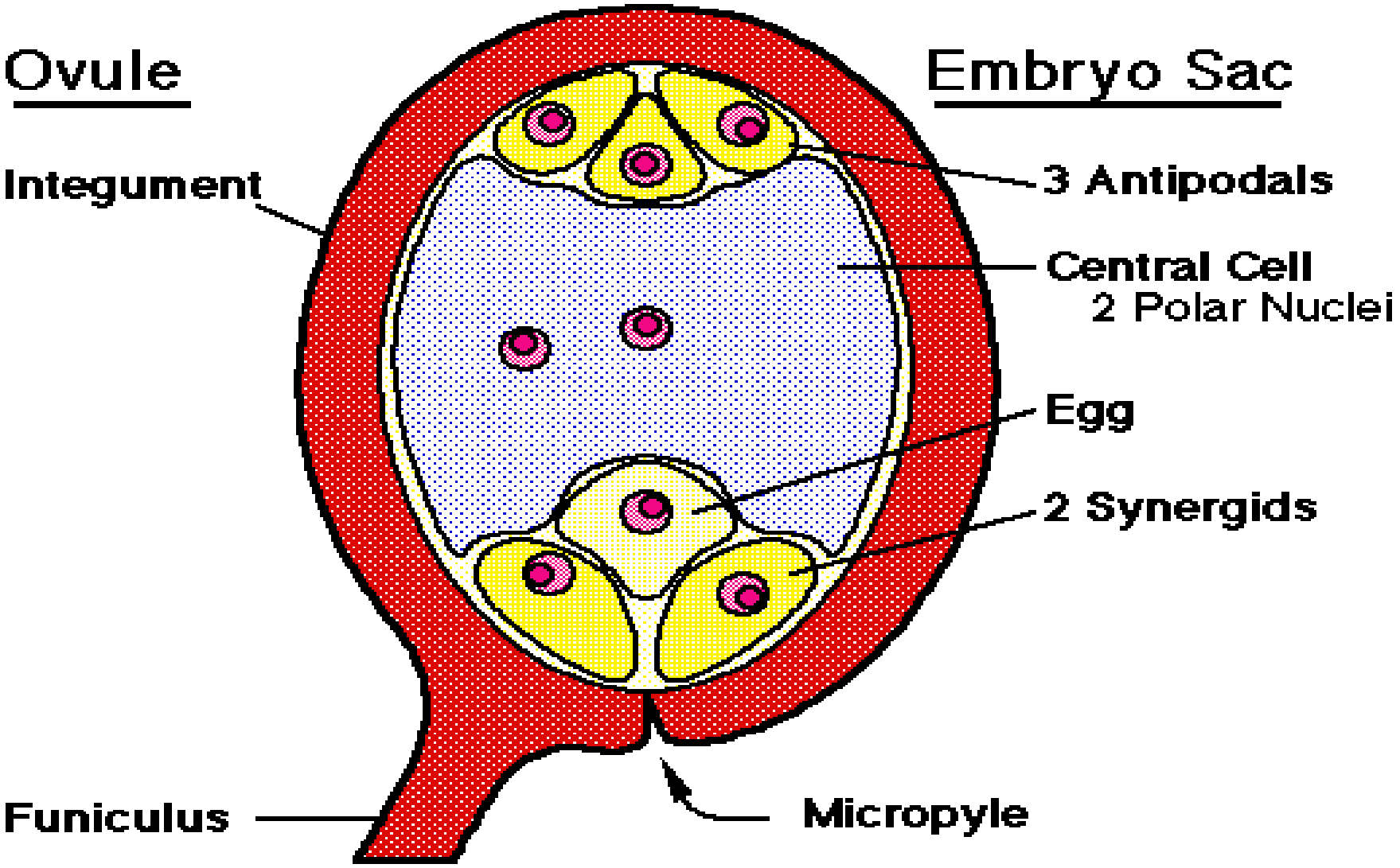
8 Nucleate with nuclear fusion

Female Gametophyte Type	Megasporogenesis			Megagametogenesis			
	Mega-sporocyte	Meiosis I	Meiosis II	Mitosis I	Mitosis II	Mitosis III	Mature female gametophyte
Tetrasporic 8-nucleate *Fritillaria* type							
Tetrasporic 8-nucleate *Plumbagella* type							

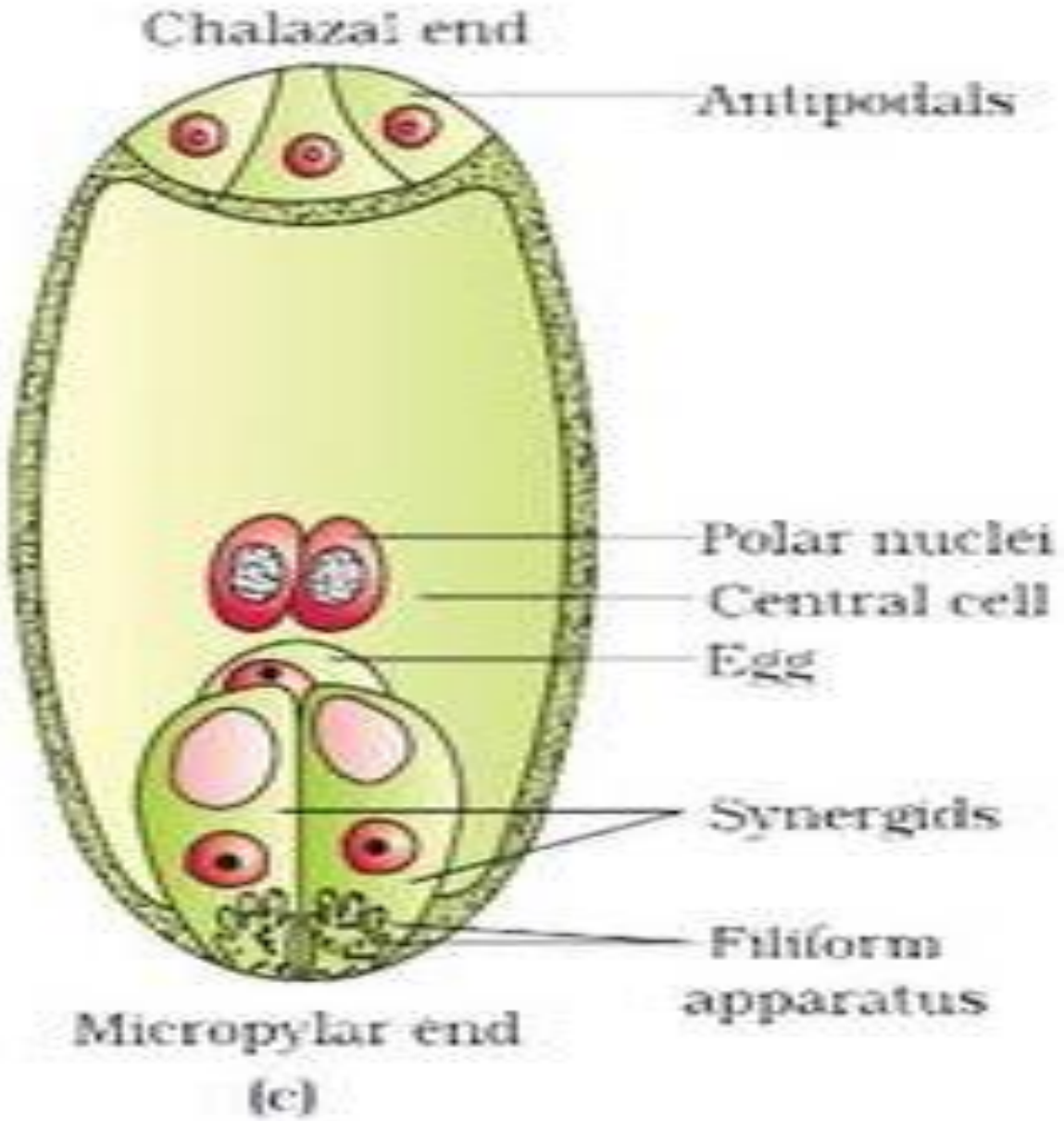
STRUCTURE OF MATURE EMBRYO SAC

- It is ellipsoid with thick, multilayered pecto-cellulosic cell wall, sometimes covered by cutin
- The cell wall is without plasmodesmata
- A mature embryo sac is generally a seven-celled structure consisting of one central cell, one egg cell, two synergid cells, and three antipodal cells
- The central cell is initially binucleate, but later the nuclei fuse to form a diploid secondary nucleus

STRUCTURE OF MATURE EMBRYO SAC



STRUCTURE OF MATURE EMBRYO SAC



EGG APPARATUS

- Situated at the micropylar end of ES
- It has a middle egg cell and two lateral synergids

1. EGG CELL

- Micropylar face, thick cellulosic cell wall
- Chalazal face, only plasma membrane
- Egg cell has plasmodesmatal connections to synergids and central cell

EGG CELL……

- Cytoplasm contains nucleus, plastids, mitochondria & ribosomes
- Dictyosomes few or absent
- Mitochondria have few cristae
- This features reveal its passive metabolic condition
- The egg apparatus without synergids, the egg possesses a prominent projection at the micropylar end, which does the function of synergids

EGG CELL……

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EGG CELL……

- Mature egg cell establishes a definite polarity
- It has cytoplasm and cell organelles towards the chalazal side and a large vacuole towards the micropylar portion

2. SYNERGIDS

- Helpers, that partially enclose the at the micropylar region of embryo sac
- They possess a prominent nucleus, abundant ER, ribosomes, dictyosomes, and mitochondria, which reveal their high metabolic activity
- *Filiform apparatus* with finger like projections and hook like structures are present at the micropylar region

2. SYNERGIDS……

- Filiform apparatus is composed of a central core made of polysaccharide microfibrils, enclosed in a non-fibrillar sheath
- The function is absorption of nutrients from nucellus and their transport
- Plasmodesmatal connections and some times membrane bound vesicular structures are extending between synergids, egg and central cell

SYNERGIDS……

- Opposite polarity with egg is observed in synergids
- The synergids are thought to help in directing the pollen nucleus to the egg cell as part of the process of double fertilization, characteristic of angiosperms.
- One of the synergids degenerate before the pollen tube enters the embryo sac
- Other one is persistent after the male gametes are discharged to the embryo sac
- Haustorial appendages also may develop on the synergids

FUNCTIONS OF SYNERGIDS…

- Absorption of nutrients from nucellus and their transport
- Direct the pollen nucleus to the female gametophyte/Embryo sac
- Haustorial function
- Site for the discharge of male gametes

ANTIPODALS

- At the chalazal end of embryo sac
- Typically 3 antipodals, but the number can vary from zero to 300
- Examples
  - No antipodals in *Oenothera lamarkiana*
  - 20 in Zea mays
  - 300 in *Sosa paniculata*
- Antipodals usually have well defined cell wall
- Cell absent in families such as Orchidaceae

ANTIPODALS….

- Cytoplasm contains plenty of plastids, mitochondria, dictyosomes and ribosomes
- No change till they degenerate just before or after fertilization
- Functions
  - Considered to have nutritive function
  - Control the growth & development of endosperm (some substance in it responsible for it)
  - In some plants like Argemone haustorial function

CENTRAL CELL

- Largest cell of Embryo Sac
- Lies in the centre of Embryo Sac
- Develops into endosperm
- Hence called as endosperm mother cell
- Polar nuclei first fuse to form secondary nucleus, which in turn fuses with 2nd male gamete produces the primary endosperm nucleus resulting in double fertilization
- In some plants like Santalum, haustorium arises from the central cell

CENTRAL CELL……

- Drastic variations found in the number of polar nuclei in the central cell
  - Oenothera-1
  - Penaea & Plumbago -4
  - Peperomia – 8
- Cytoplasm contains many mitochondria, plastids, dictyosomes and ribosomes
- Continuation of cytoplasm of central cell is observed with egg, synergids and antipodals
- No plasmodesmatal connection between central cell and cells of nucellus