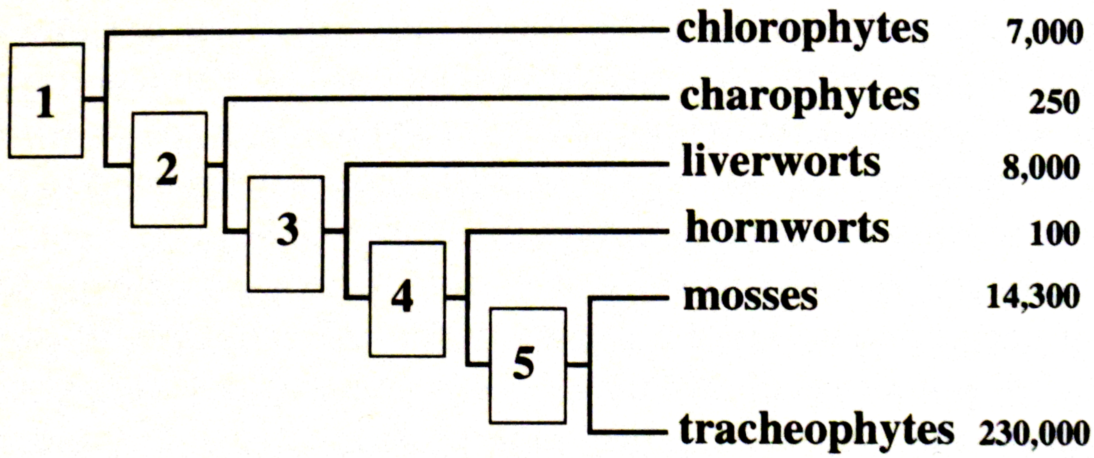



Figure 4.4. Phyletic hypothesis purporting to show the evolutionary relationships among green algae, bryophytes (liverworts, hornworts, and mosses), and tracheophytes (pteridophytes, gymnosperms, and angiosperms). The approximate number of extant species in each group is shown on the right. Some of the characters used to construct the phyletic hypothesis are as follows: 1 = chlorophylls *a* and *b*, carotenoids, starch; 2 = phragmoplastic cell division, glycolate oxidase; 3 = archegonium and antheridium; 4 = indeterminant growth of sporophyte; 5 = water and cell sap conducting tissue system. Adapted from Mishler and Churchill 1984, 1985.

Karl Niklas (1997) The Evolutionary Biology of Plants

## CRITERIA USED TO CONSTRUCT THE EVOLUTIONARY "TREE"

[1] chlorophylls a and b, carotenoids, starch

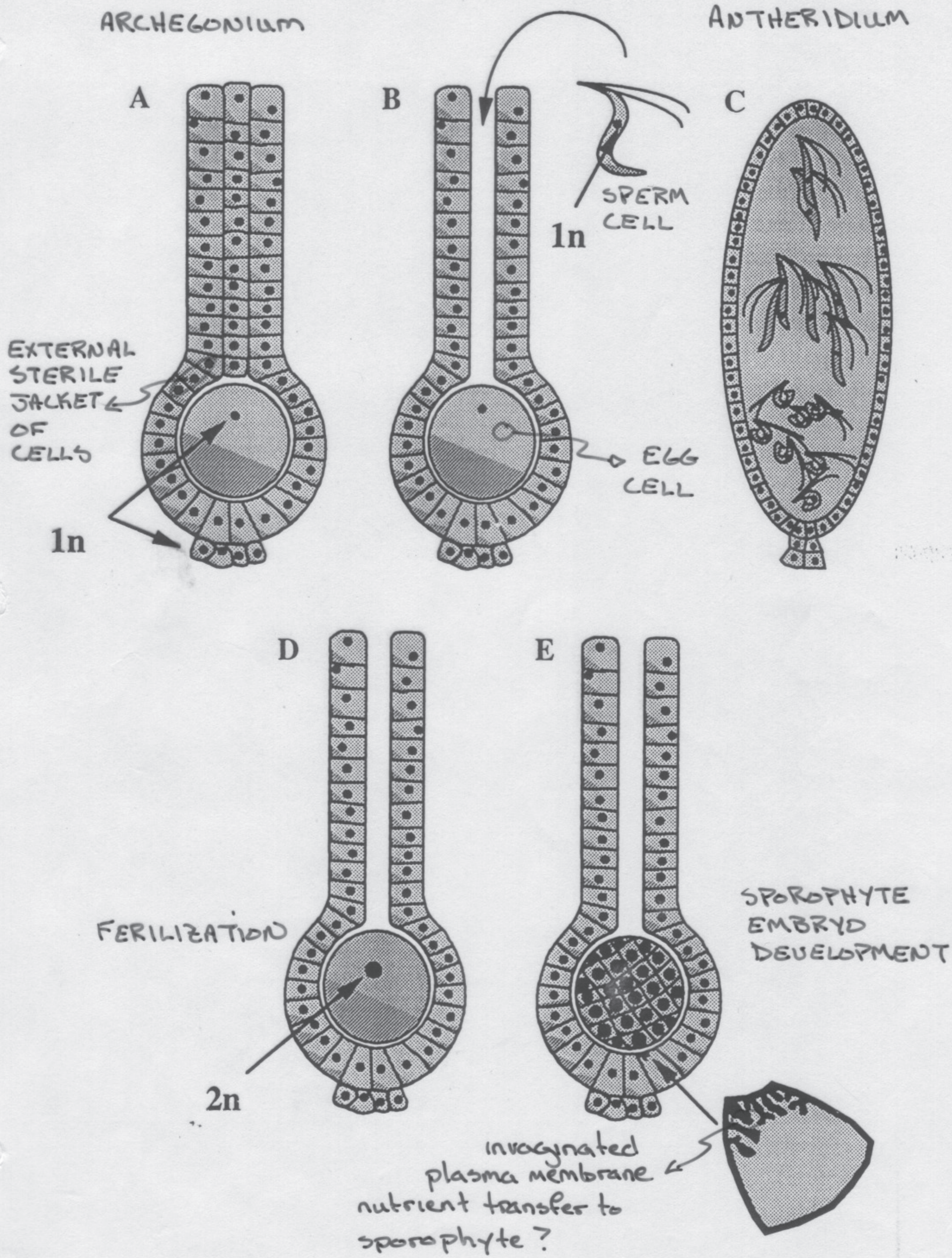
[2] • phragmoplastic cell division
• glycolate oxidase (photorespiration)

[3] archegonium and antheridium

[4] indeterminant growth of sporophyte

[5] water and cell sap conducting tissue system
(vascular tissue: xylem and phloem)

# GAMETOPHYTE



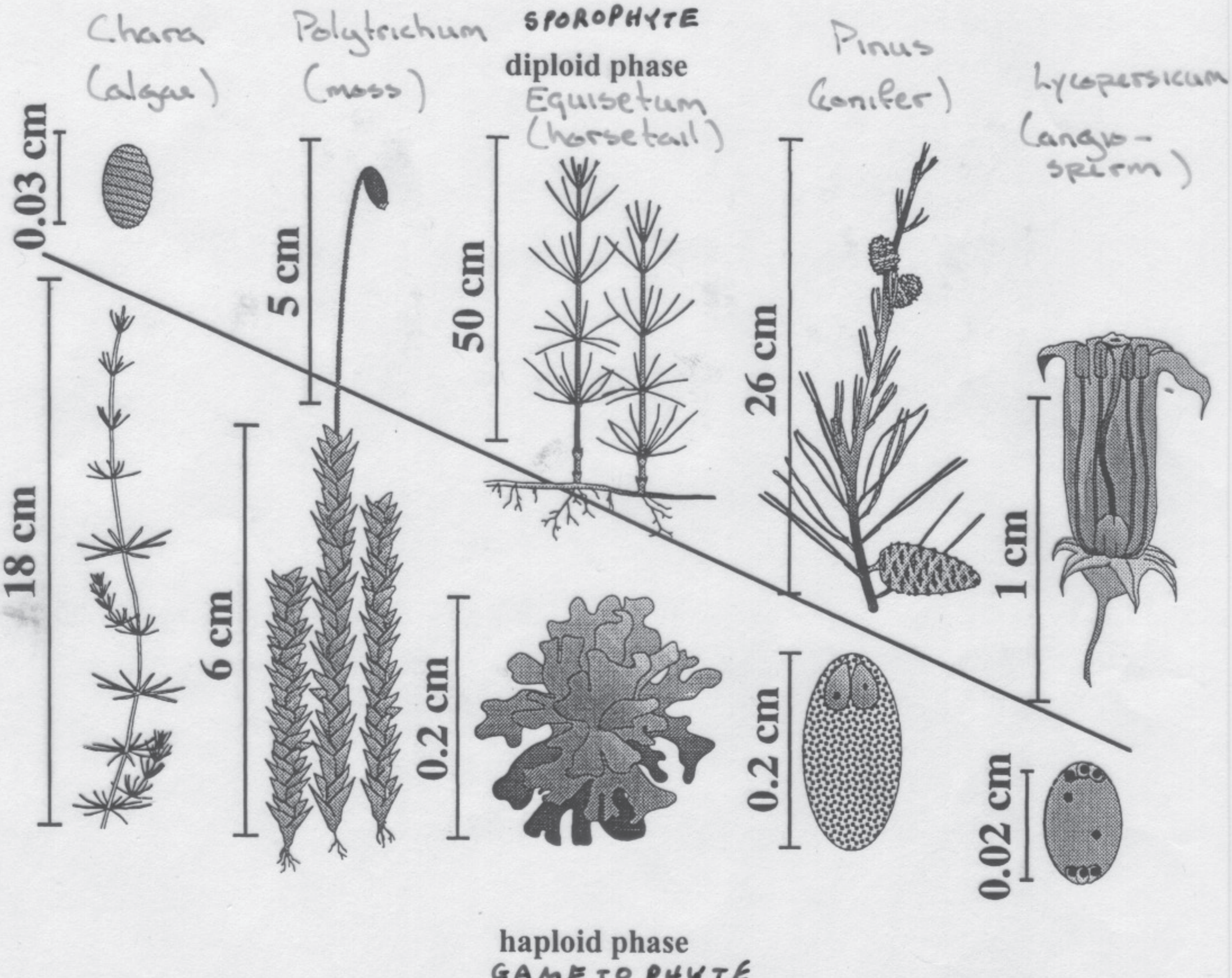



Figure 3.18. Comparisons between the relative size of the diploid and haploid phases in the life cycles of representative plants from progressively more recent lineages (from left to right). The diploid phase in each life cycle is shown above its corresponding haploid phase. The reduction in the size of the haploid phase relative to the size of the complementary diploid phase broadly corresponds to a reduction in the duration of the phase in the life cycle. From left to right: *Chara,* a green alga; *Polytrichum,* a moss; *Equisetum,* a horsetail; *Pinus,* a gymnosperm; *Lycopersicum,* a flowering plant.

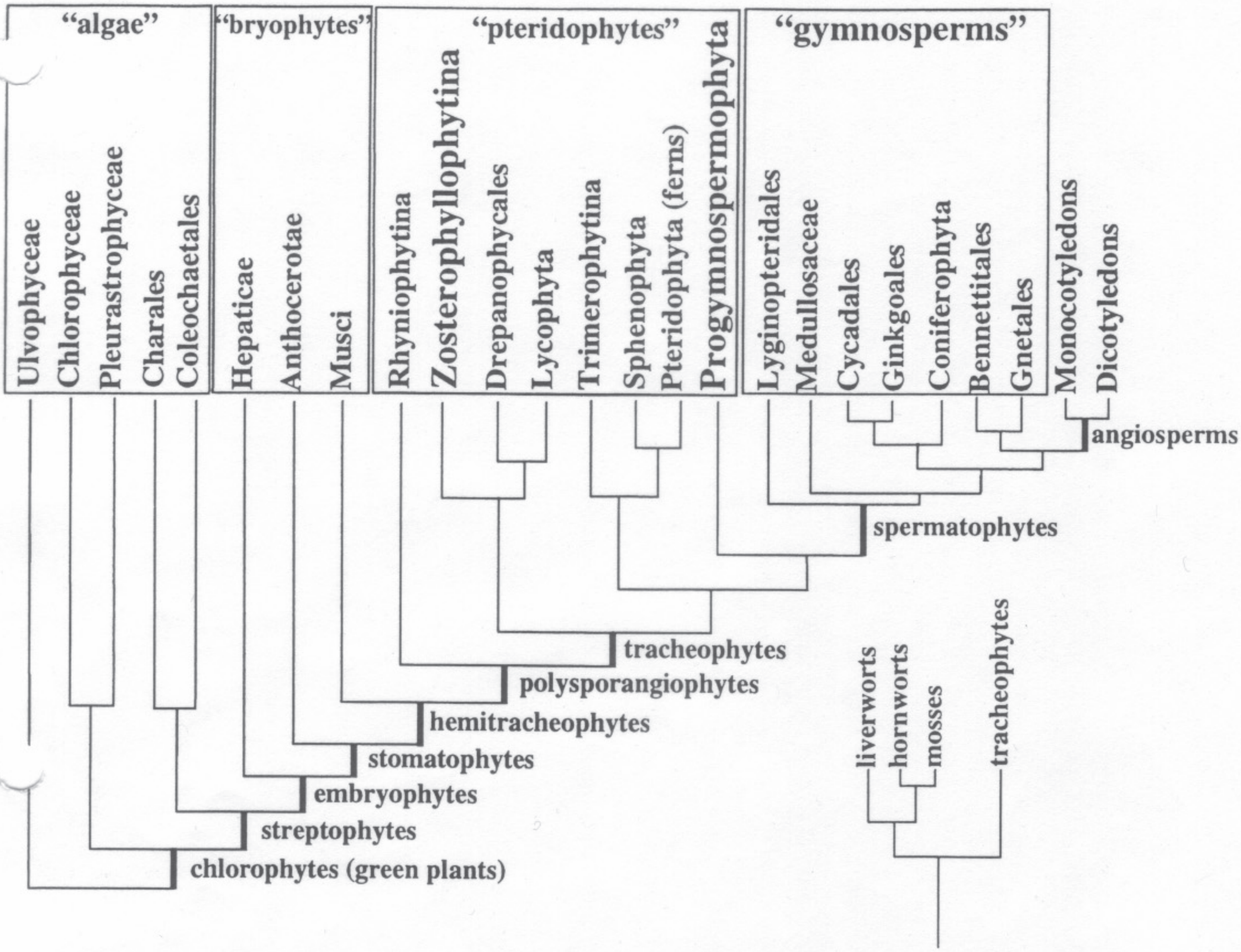
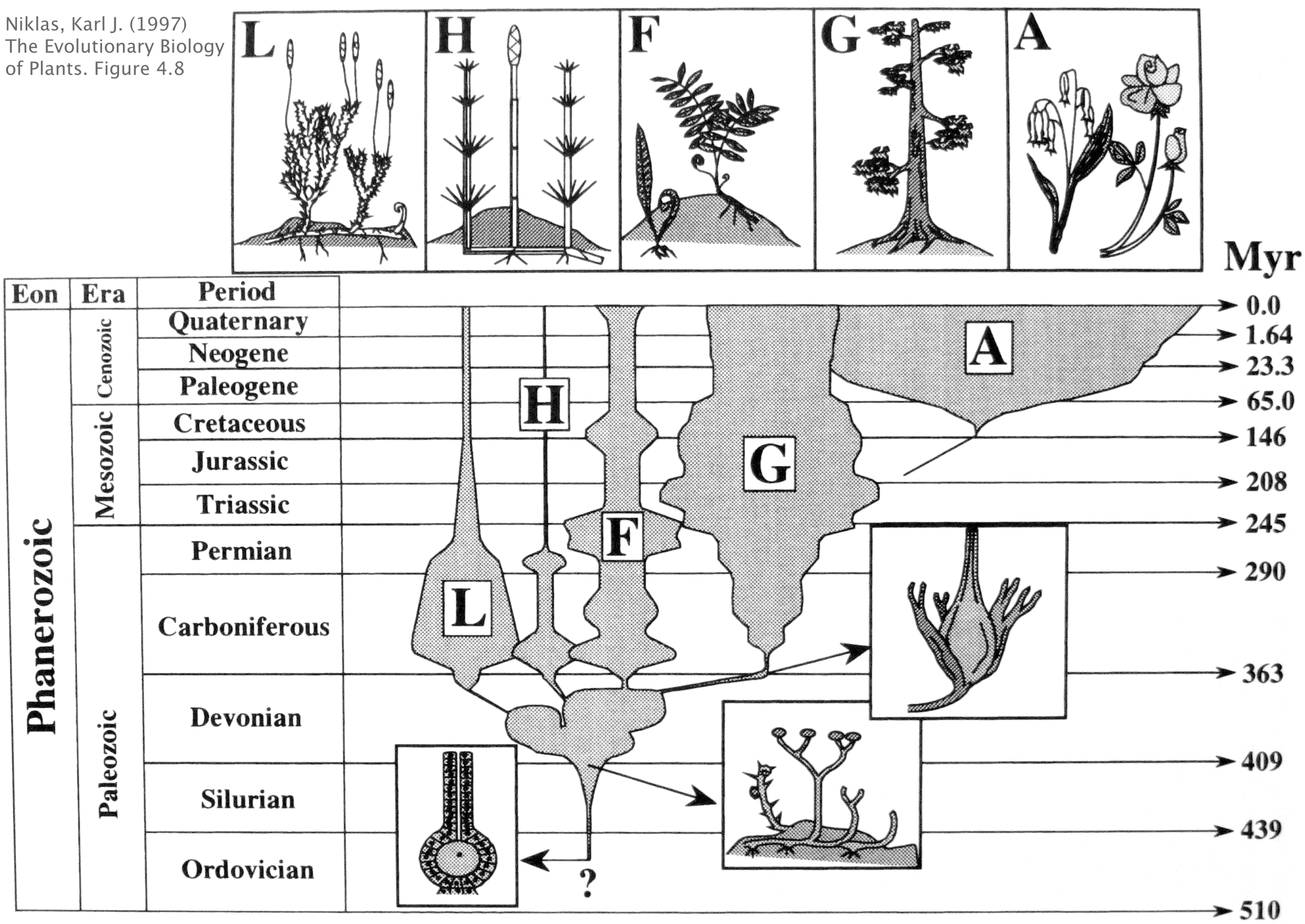



Figure 4.15. Simplified cladogram rendering a phyletic hypothesis for the embryophytes and evolutionarily related green algal lines. Different lineages sharing the same level of morphological or reproductive organization (i.e., evolutionary grades) are grouped in boxes. The informal names for these grades are given in parentheses (e.g., "algae"); formal taxonomic designations are given in boxes (e.g.., Ulvophyceae). Plant groups sharing the same ancestor are indicated by dark vertical links (e.g., chlorophytes). Note that not all the formal taxa are of equal taxonomic rank (e.g., "aceae" designates family rank, "ales" indicates an order, and "phyta" indicates division). According to this cladogram, "bryophytes" are a paraphyletic group (an assembly of organisms that excludes some species that share the same common ancestor with species included in the group). The small cladogram (bottom right) depicts the more traditional view that the bryophytes (Hepaticae = "liverworts," Anthocerotae = "hornworts"; Musci = "mosses") are monophyletic (i.e., Bryophyta) and shared a last common ancestor with the vascular plants (tracheophytes). Adapted from Mishler et al. 1994; Nixon et al. 1994; and Rothwell and Serbet 1994.

Niklas, Karl J. (1997)
The Evolutionary Biology
of Plants. Figure 4.8



# The flowers, the trees, the birds and the bees


**Plant Biology**
**SC/BIOL 2010**

GO
Green

Title: The Botanic Garden. Part II. Containing The Loves of the Plants. A Poem. With Philosophical Notes.

Author: Erasmus Darwin [first published in 1791]

## CANTO I.

Descend, ye hovering Sylphs! aerial Quires,
And sweep with little hands your silver lyres;
With fairy footsteps print your grassy rings,
Ye Gnomes! accordant to the tinkling strings;
While in soft notes I tune to oaten reed
Gay hopes, and amorous sorrows of the mead.—
From giant Oaks, that wave their branches dark,
To the dwarf Moss, that clings upon their bark,
What Beaux and Beauties crowd the gaudy groves,
And woo and win their vegetable Loves.
How Snowdrops cold, and blue-eyed Harebels blend
Their tender tears, as o'er the stream they bend;
The lovesick Violet, and the Primrose pale
Bow their sweet heads, and whisper to the gale;
With secret sighs the Virgin Lily droops,
And jealous Cowslips hang their tawny cups.
How the young Rose in beauty's damask pride
Drinks the warm blushes of his bashful bride;
With honey'd lips enamour'd Woodbines meet,
Clasp with fond arms, and mix their kisses sweet.—

[*Vegetable Loves*. l. 10. Linneus, the celebrated Swedish naturalist, has demonstrated, that ail flowers contain families of males or females, or both; and on their marriages has constructed his invaluable system of Botany.]

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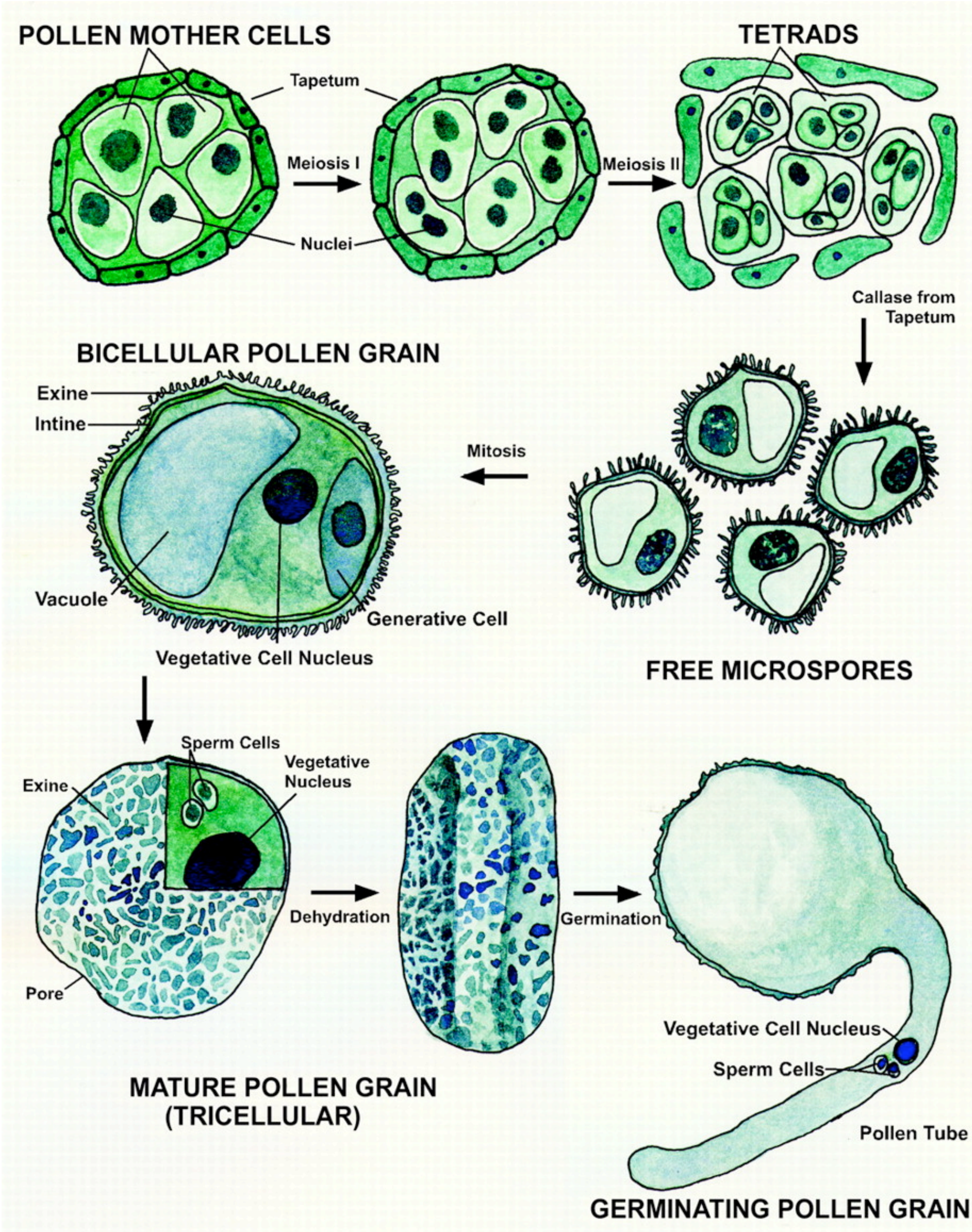
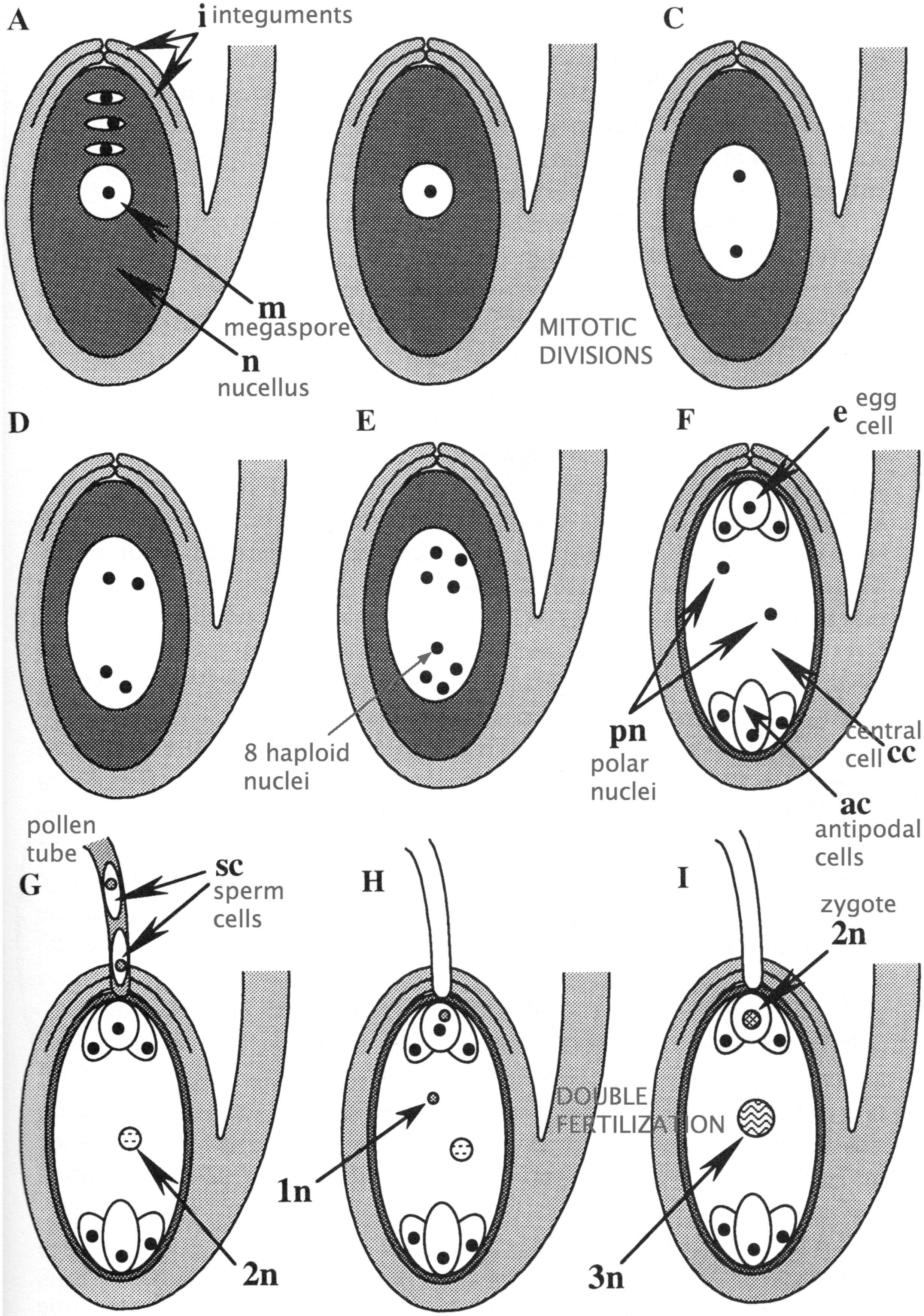
# V. SEXUS.

Initio rerum, ex omni ſpecie viventium (3) unicum ſexus par creatum fuiſſe contendimus.




**McCormick S Plant Cell 2004;16:S142-S153**


A
i integuments
C
m
megaspore
n
nucellus
MITOTIC
DIVISIONS
D
E
F
e egg
cell
8 haploid
nuclei
pn
polar
nuclei
central
cell cc
ac
antipodal
cells
pollen
tube
G
sc
sperm
cells
H
I
zygote
2n
DOUBLE
FERTILIZATION
1n
2n
3n

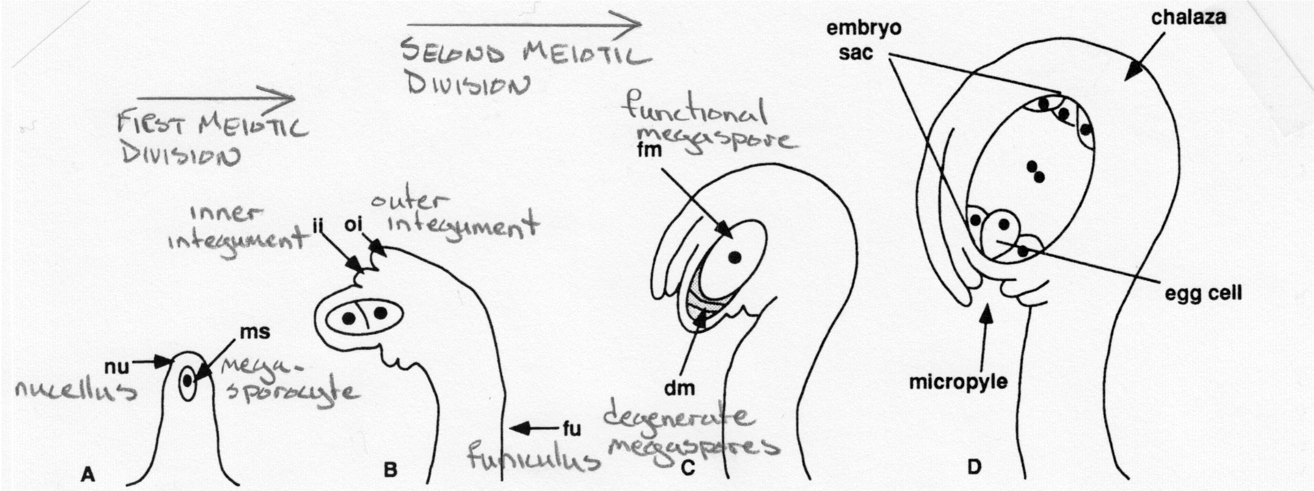



**Figure 1.** Ovule Development.

Stages are shown for an anatropous ovule with *Polygonum*-type embryo sac development. For more details, see text.
**(A)** Ovule shortly after initiation, showing a single megasporocyte (ms). nu, nucellus.
**(B)** Ovule after both integuments have been initiated. At this time, the megasporocyte has undergone the first meiotic division. The axis of the nucellus is transiently perpendicular to the axis of the funiculus (fu). ii, inner integument; oi, outer integument.
**(C)** Ovule after meiosis. The functional megaspore (fm) at the chalazal end has expanded, and the nonfunctional megaspores are degenerated. The axis of the nucellus is now parallel to the funiculus due to unequal growth, primarily of the integuments. dm, degenerate megaspores.
**(D)** Ovule after megagametogenesis. The mature embryo sac contains seven cells and eight nuclei.

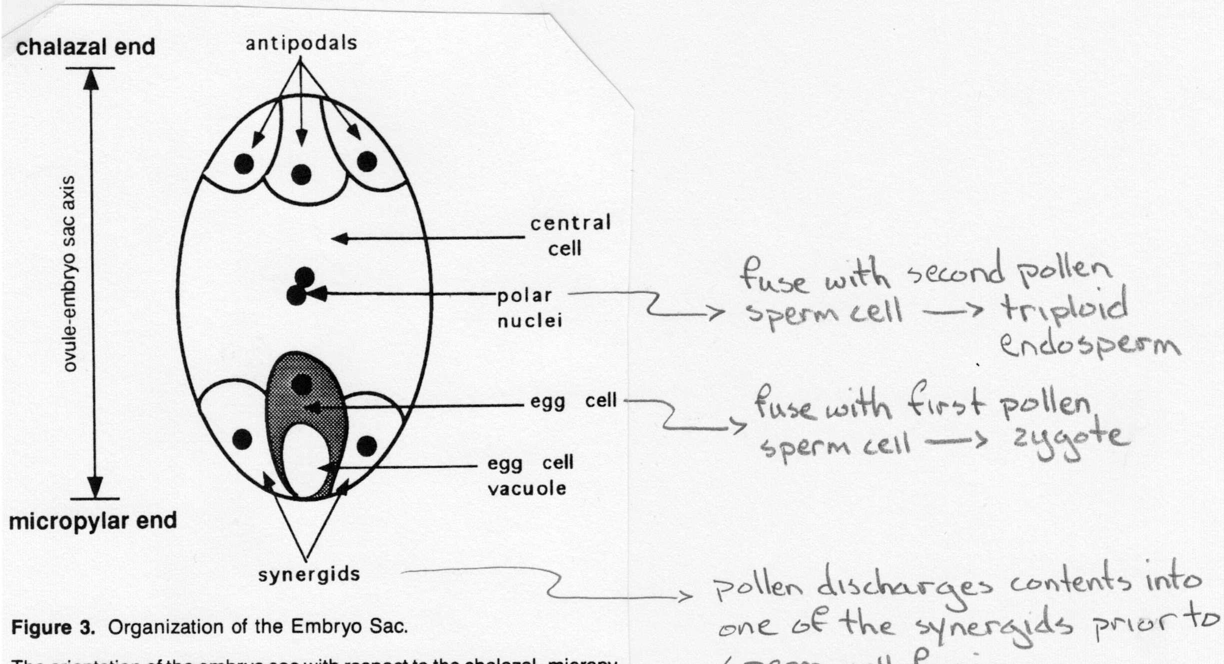



**Figure 3.** Organization of the Embryo Sac.

The orientation of the embryo sac with respect to the chalazal–micropylar axis of the ovule is indicated by the vertical arrow on the left. The egg apparatus, including the egg cell and synergids, is located at the micropylar end, where the pollen tube enters the embryo sac. The central cell contains two nuclei. Three antipodal cells are located at the chalazal end of the embryo sac. The egg cell is actually adjacent to, rather than between, the two synergids. Note the position of the vacuole in the egg cell.

# Sip the Nectar

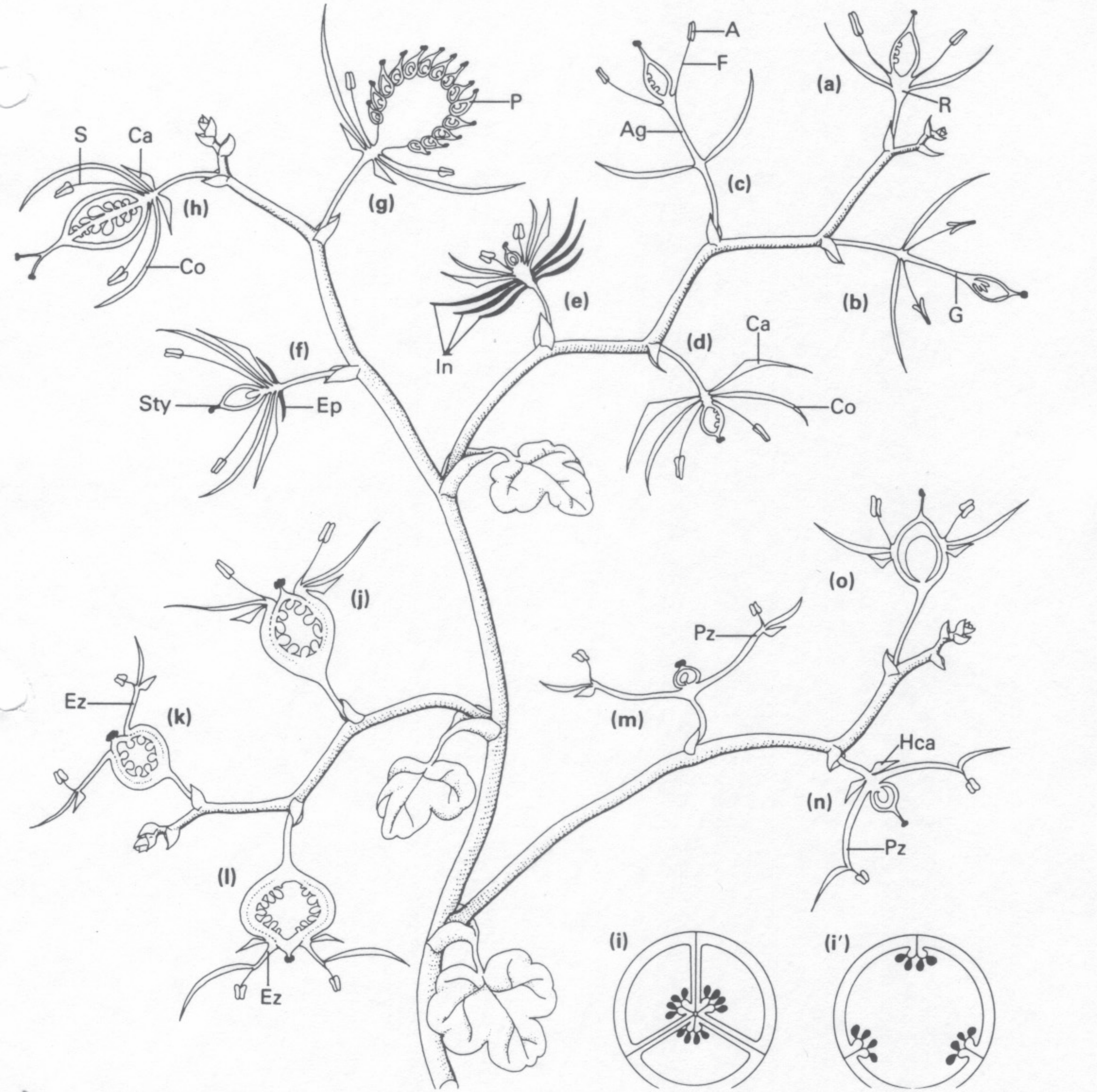
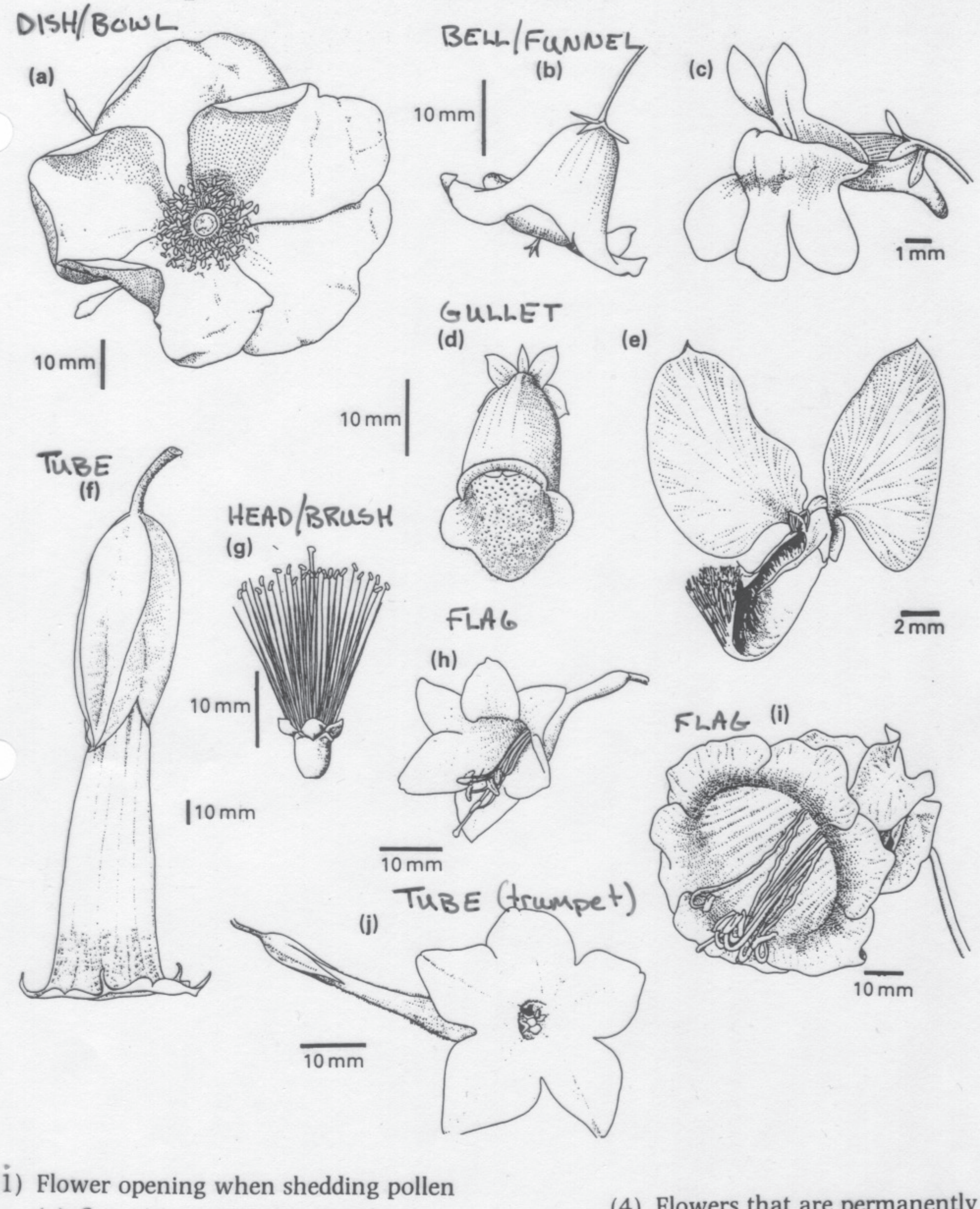



**Fig. 147.** Diagrammatic representation of flower structure. a)–h) superior ovary (g, apocarpous, h, syncarpous); i) trilocular ovary (transverse section); i[1]) unilocular ovary (transverse section); j)–n) inferior ovary; o) partly inferior ovary. A: anther. Ag: androgynophore. Ca: calyx. Co: corolla. Ep: epicalyx. Ez: epigynous zone. F: filament. G: gynophore. Hca: hypogynous calyx. In: involucre. P: pistil. Pz: perigynous zone. R: receptacle. S: stamen. Sty: style.




(1) Flower opening when shedding pollen
- (a) flower inconspicuous (**213b**)
- (b) Flower conspicuous
  - i. dish- or bowl-shaped (**153a**)
  - ii. bell- or funnel-shaped (**153b**)
  - iii. head- or brush-shaped (**153g**)
  - iv. gullet-shaped (**153d**)
  - v. flag-shaped (**153h, i**)
  - vi. tube-shaped (**153f, j**)

(2) Flower opened by visitor when shedding pollen (**153c, e**)

(3) Flower forming a trap for visitors (**152a, b**)

(4) Flowers that are permanently closed and inevitably self-pollinated

(5) Flowers that have a self-pollination mechanism in addition to other mechanisms.

This system applies equally to a whole inflorescence operating as a single floral unit (pseudanthium), such as the capitulum (**141j, 144**) of a member of the Compositae. Any number of similar systems could be devised or refined.

TABLE 3. MAIN BLOSSOM TYPES AND THEIR WAY OF FUNCTIONING

| Function \ Blossom type | Dish | Bell–funnel | Brush | Flag | Gullet | Trumpet | Tube |
|---|---|---|---|---|---|---|---|
| Visual attraction | Diffuse, if any | Corolla or substitute | Diffuse | Standard | Both lips | Margin | Generally supplemented by other parts |
| Alighting | Diffuse | More exact | Diffuse | Carina | Lower lip | Margin | None |
| Guiding | None (or traps) | Some | None | Symmetry, marks on standard | Symmetry, build of lower lip | Towards a central opening | Automatic |
| Displaying of attractant | Diffuse, open | Half hidden, ± centralized | Diffuse, open | Well hidden, entrance to be forced | Well hidden | Hidden | Deeply hidden |
| Pollen deposition and reception | Diffuse, inside | ± central, inside | Diffuse, outside | Sternotribe by carina | Nototribe, in upper lip | Central, inside | Varied |
| Primarily adapted to insect behaviour | Primitive (beetles) | Crawling in (bees) | Alighting visitors with longer mouthparts (bees, butterflies, birds) | Alighting, forcing their way in (higher bees) | Alighting, forcing their way in (higher bees) | Alighting, not crawling in (butterflies) | Hovering or perching on adjacent structures (moths, birds) |

FIGURE 10.1

Pollen binding and germination on the papillae of the stigma in Arabidopsis. Pollen forms a foot (arrow) as it penetrates the cuticle of the stigma and grows in the cell wall of the papillar cell. (From Bowman, J. 1994. Arabidopsis: An Atlas of Morphology and Development. Springer-Verlag, New York, p. 343. Reprinted by permission of Springer-Verlag.)

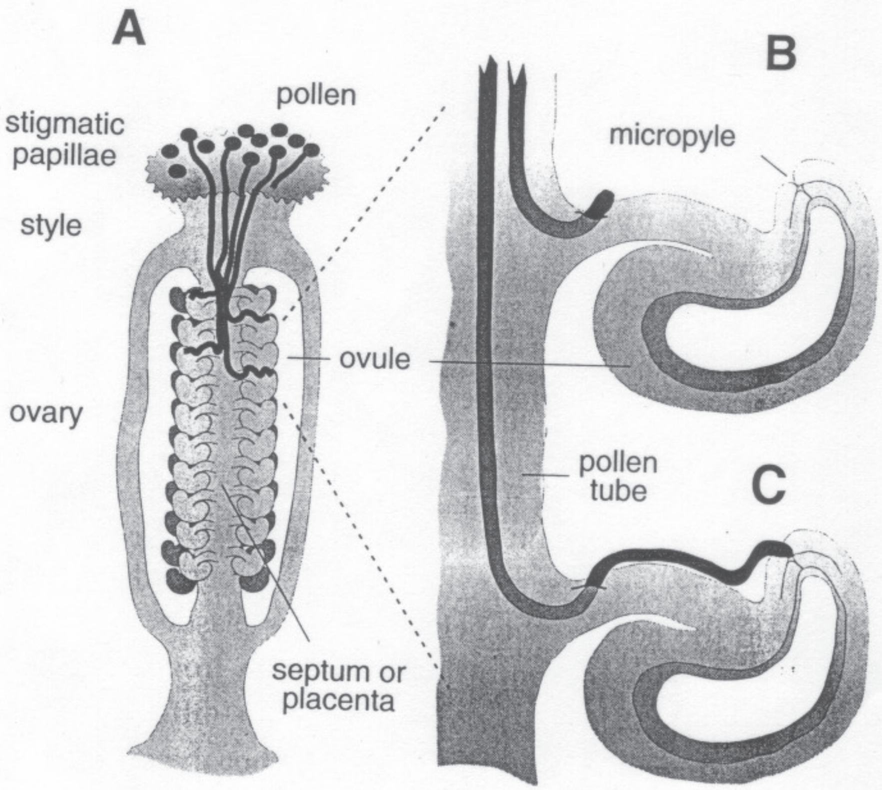
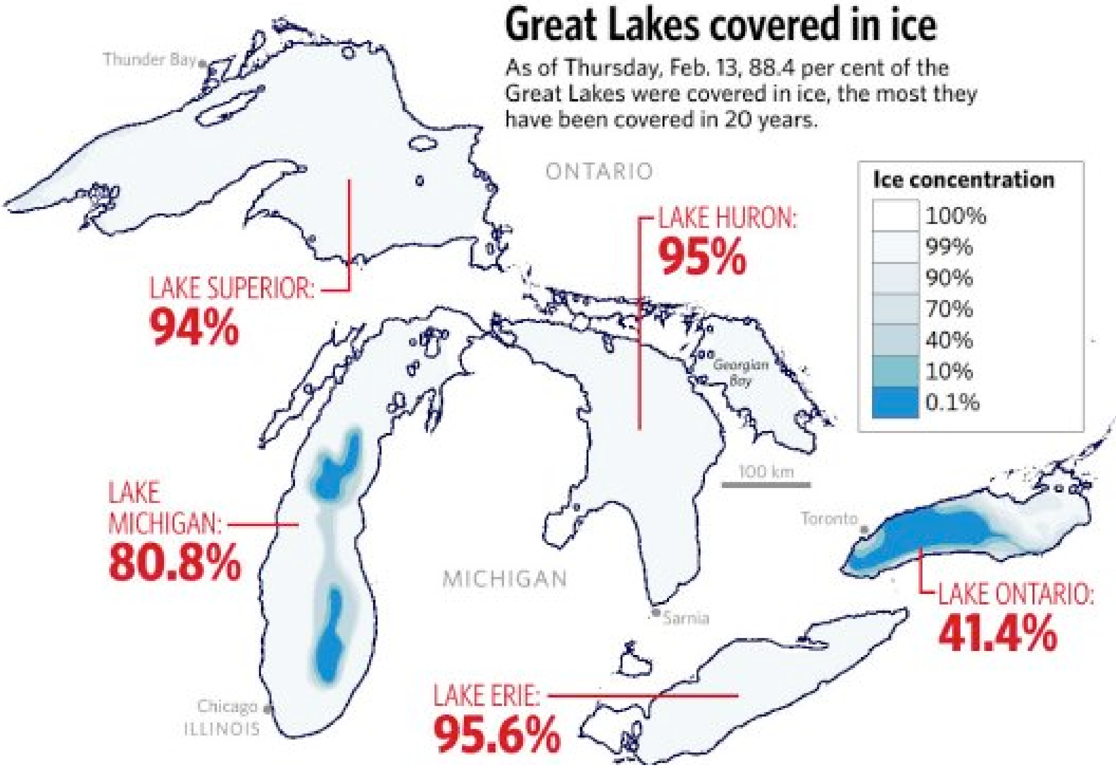


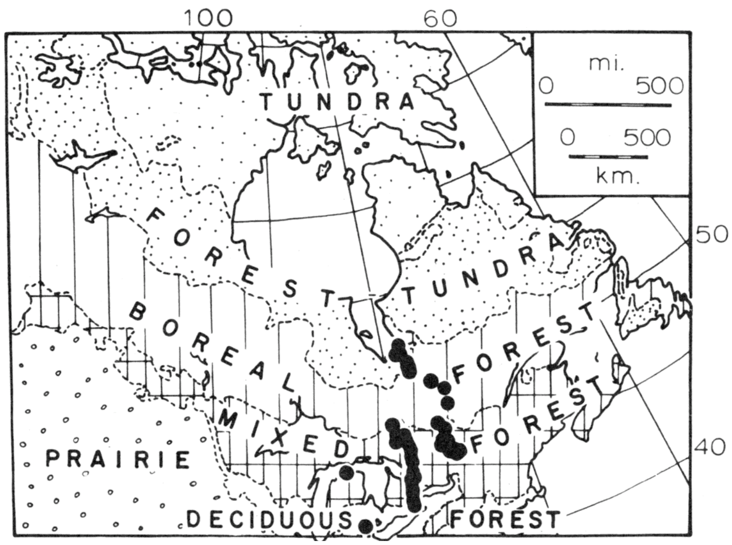

FIGURE 10.3

Pathway followed by growing pollen tubes in Arabidopsis. (A) Pollen germinates on the stigmatic papillae, and pollen tubes grow down through the transmitting tract of the short style. (B) Pollen tube emerges from the septum or placenta, and (C) grows to the nearest ovule and enters the micropyle.



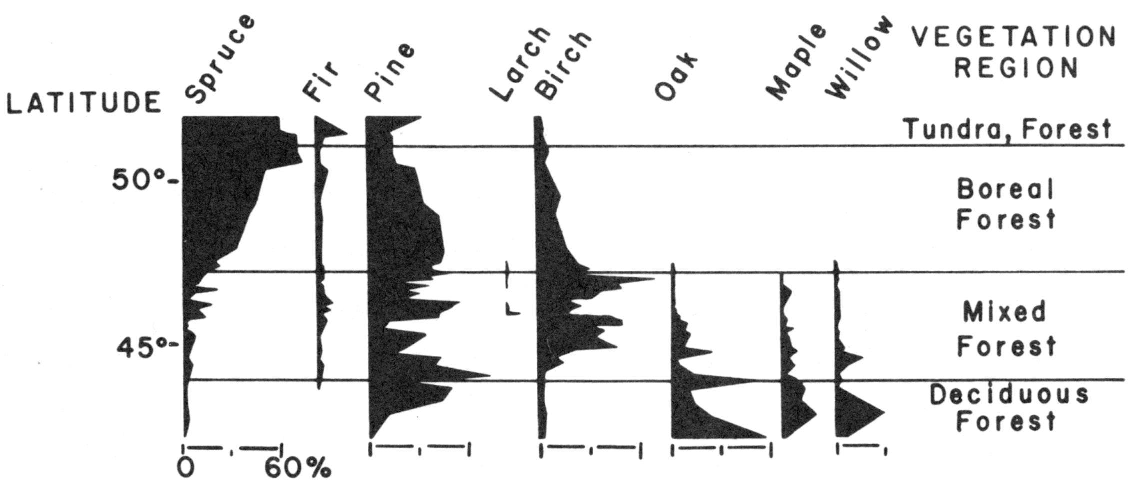

2014: Ice-coverage of the Great Lakes (Toronto Star).
Evidence of Global Cooling? Not so fast….

# Pollen and Climate Change

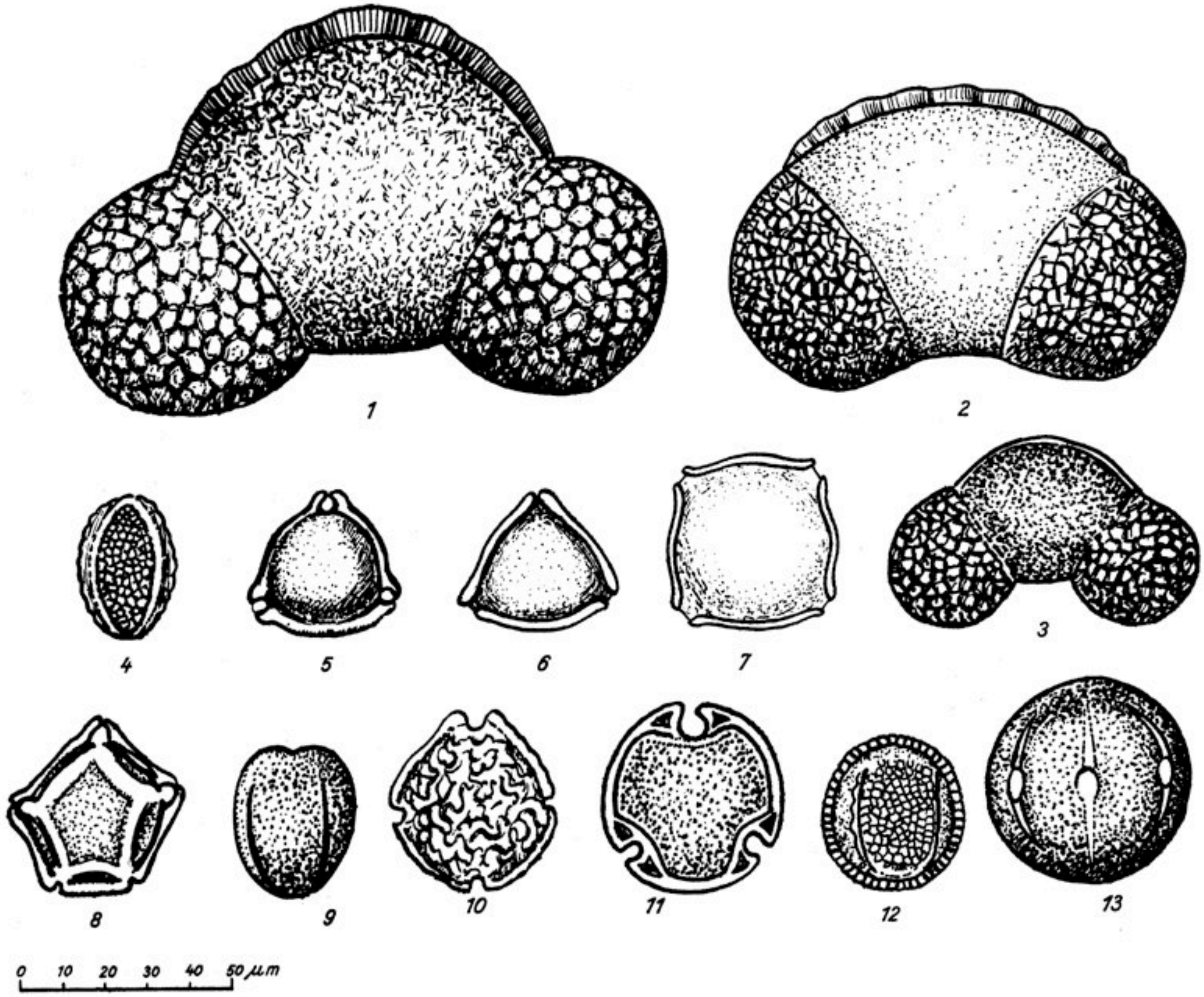



A north-south transect of surface samples of pollen was performed. This way, assemblages of pollen associated with warmer and cooler climates could be established.

The distribution of pollen is defined by representative species: spruce and fir for cool; pine, larch and birch for warmer; maple and oak for warmer still (deciduous forest)




Spurr and Barnes (1973) Forest Ecology. Ronald Press. pp. 460–461.

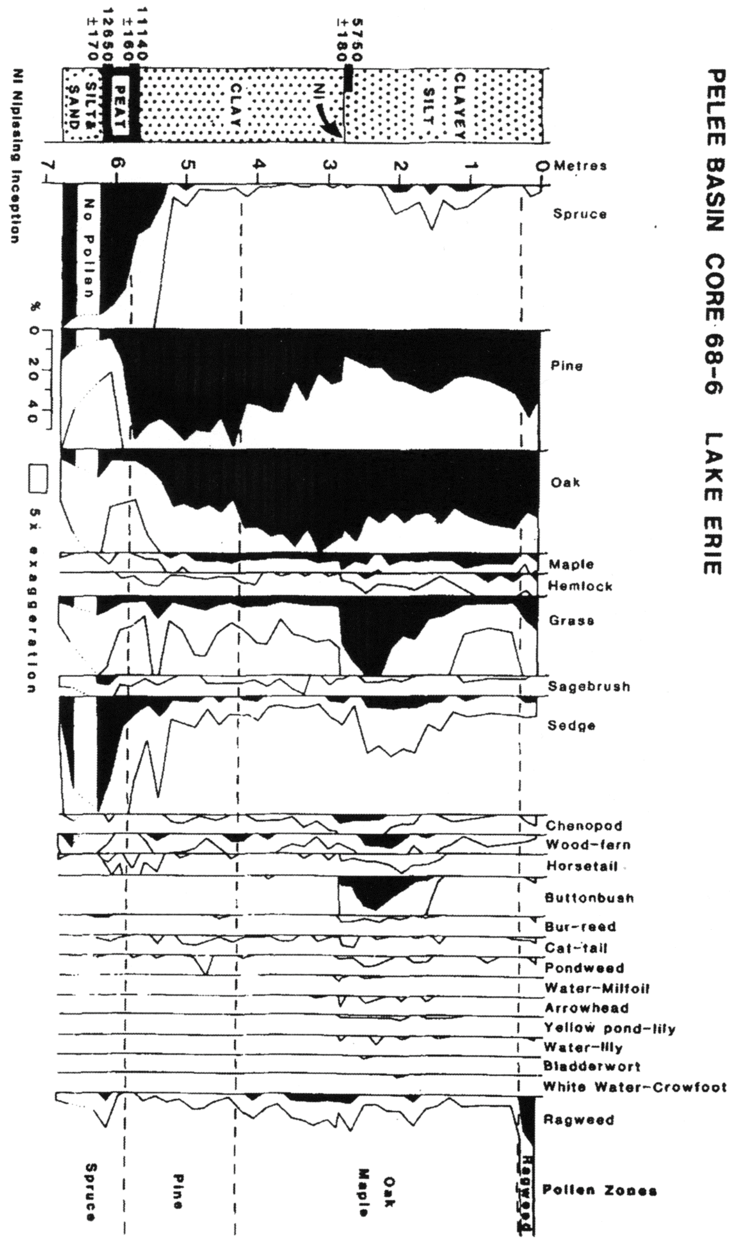



**Pollen:** Pollen mitteleuropäischer Arten: **1** Tanne (*Abies*), **2** Fichte (*Picea*), **3** Kiefer (*Pinus*), **4** Salweide (*Salix caprea*), **5** Hängebirke (*Betula verrucosa*), **6** Hasel (*Corylus avellana*), **7** Hainbuche (*Carpinus betulus*), **8** Schwarzerle (*Alnus glutinosa*), **9** Stieleiche (*Quercus robor*), **10** Flatterulme (*Ulmus laevis*), **11** Winterlinde (*Tilia cordata*), **12** Esche (*Fraxinus excelsior*), **13** Rotbuche (*Fagus sylvatica*)

[Drucken] [Fenster schliessen]

# Pollen and Climate Change

Here are the changes in pollen assemblages over time in Lake Erie sediments. Spruce was dominant 11000 years ago. Maple and oak dominated from *ca* 7000 years ago.

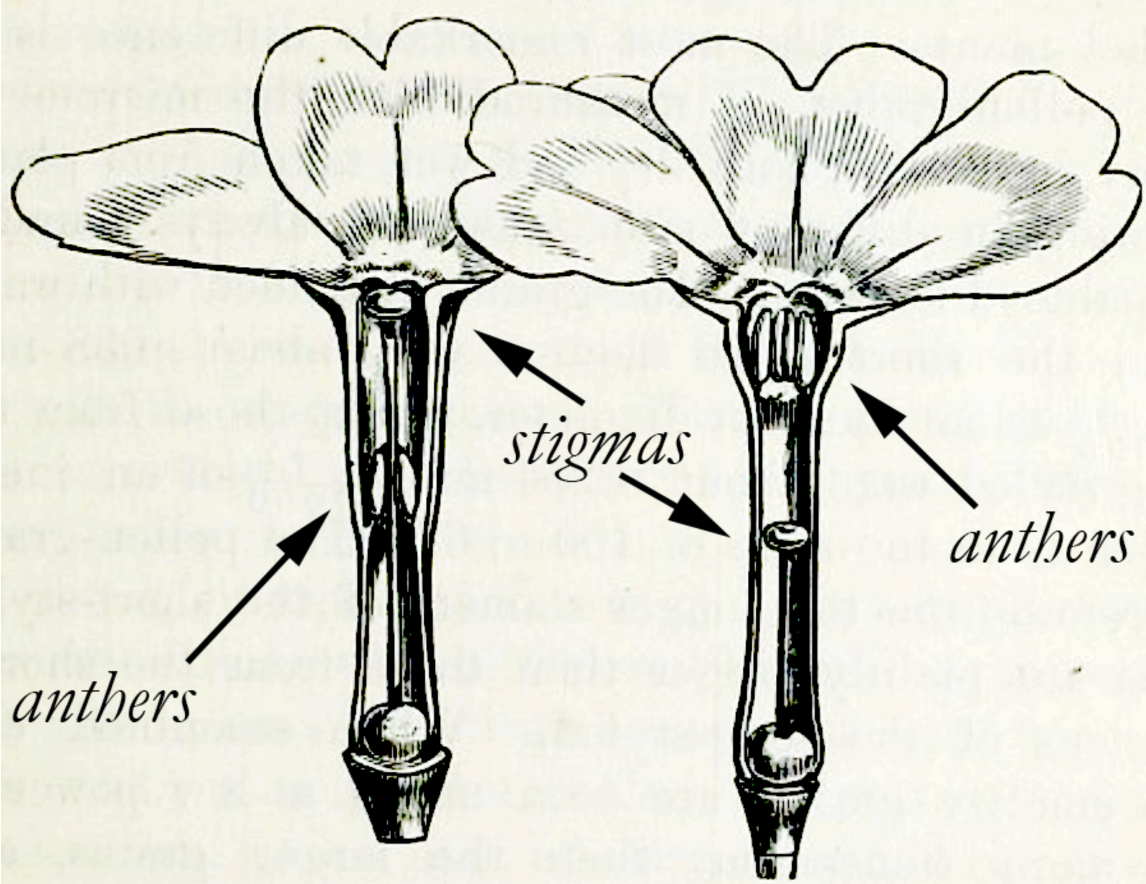



Ragweed appears abruptly only recently, evidence for widespread disruption of the natural vegetation by humans.


Lewis CFM, Andersen TW (1989) Oscillations of levels and cool phases of the Laurentian Great Lakes caused by inflows from glacial Lakes Agassiz and Barlow-Ojibway. Journal of Paleolimnology 2:99–146.

The figure below comes from Charles Darwin's book, entitled "Different Forms of Flowers of Plants of the Same Species" (1877). Darwin engaged in considerable botanical research, much of which was on pollination. At that time, self-fertilization was considered the norm for flowering plants. Darwin explored mechanisms of pollination (especially insect pollination) and mechanisms of out-crossing, which assures that genetic information is shared between two individuals, very important in the context of evolution. This research predated the discovery of Mendelian Genetics.

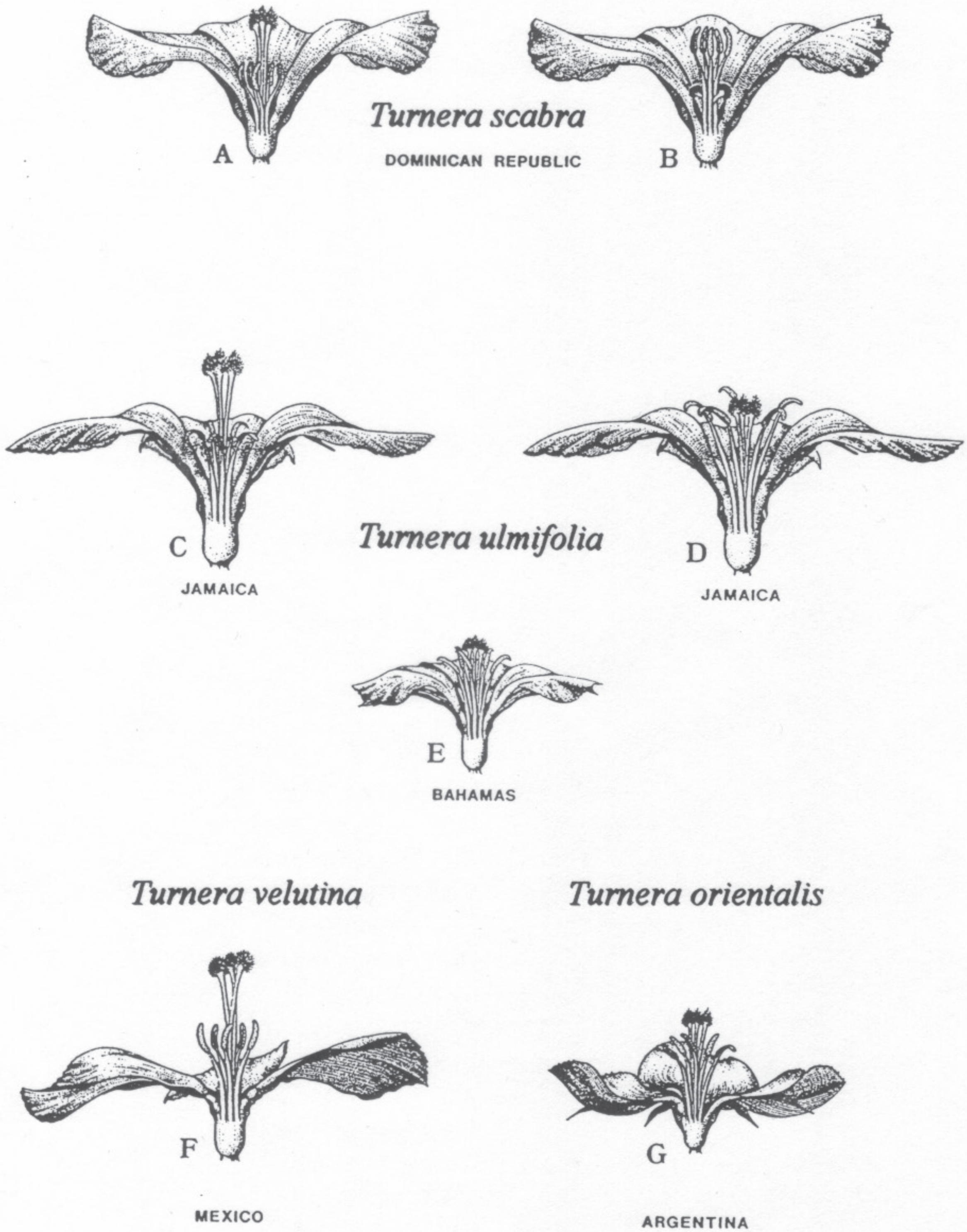
Fig. 1.

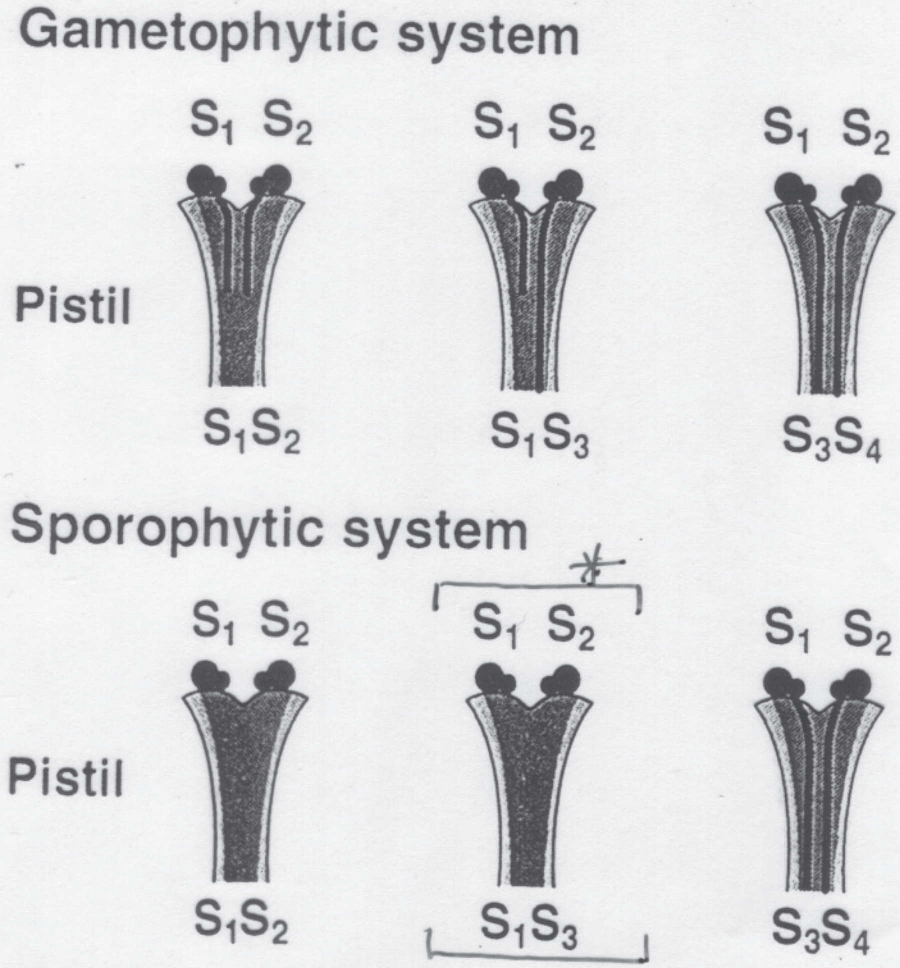



Long-styled form. Short-styled form.

PRIMULA VERIS.

**In *Primula veris* (and other species), there are equal frequencies of long-style and short-style morphs in a population. This morphological difference encourages pollination between two different individuals (one short-style, the other long-style) in the population.**


Turnera scabra
A
DOMINICAN REPUBLIC
B
Turnera ulmifolia
C
JAMAICA
D
JAMAICA
E
BAHAMAS
Turnera velutina
F
MEXICO
Turnera orientalis
G
ARGENTINA




The S-locus controls incompatibility. $S_1$, $S_2$, $S_3$ etc. are different alleles of the S-locus

* if $S_1$ dominant to $S_2$ in pollen and dominant to $S_3$ in pistil.

**Figure 2.** Behavior of Pollen in the Two Major SI Systems.

**(Top)** Behavior of pollen in a single-gene gametophytic system. The pollen parent genotype is $S_1S_2$. When an allele in the individual haploid pollen grain matches either allele in the diploid style tissues, growth of the pollen tube is arrested, usually in the style. For example, both $S_1$ pollen and $S_2$ pollen are inhibited in an $S_1S_2$ style, whereas $S_2$ pollen will grow successfully through the $S_1S_3$ style. When there is no match of alleles (e.g., pollen grains from an $S_1S_2$ plant on an $S_3S_4$ pistil), the pollen tubes of both genotypes grow through the style to the embryo sac.

**(Bottom)** Behavior of pollen in a single-gene sporophytic system. The pollen parent genotype is $S_1S_2$. When an allele in the pollen parent matches that of the pistil (e.g., $S_1S_2$ or $S_1S_3$), pollen germination is arrested at the stigma surface. Where there is no match ($S_3S_4$), the pollen may germinate and grow through the style to the embryo sac. * → The central panel applies only if the $S_1$ allele is dominant to or codominant with $S_2$ in the pollen and if $S_1$ is dominant to or codominant with $S_3$ in the style. If $S_3$ is dominant to $S_1$ in the style, or if $S_2$ is dominant to $S_1$ in the pollen, pollen from the $S_1S_2$ parent will be compatible. (**[Top]** and **[Bottom]** are modified from Anderson et al., 1983; with permission of John Wiley and Sons.)

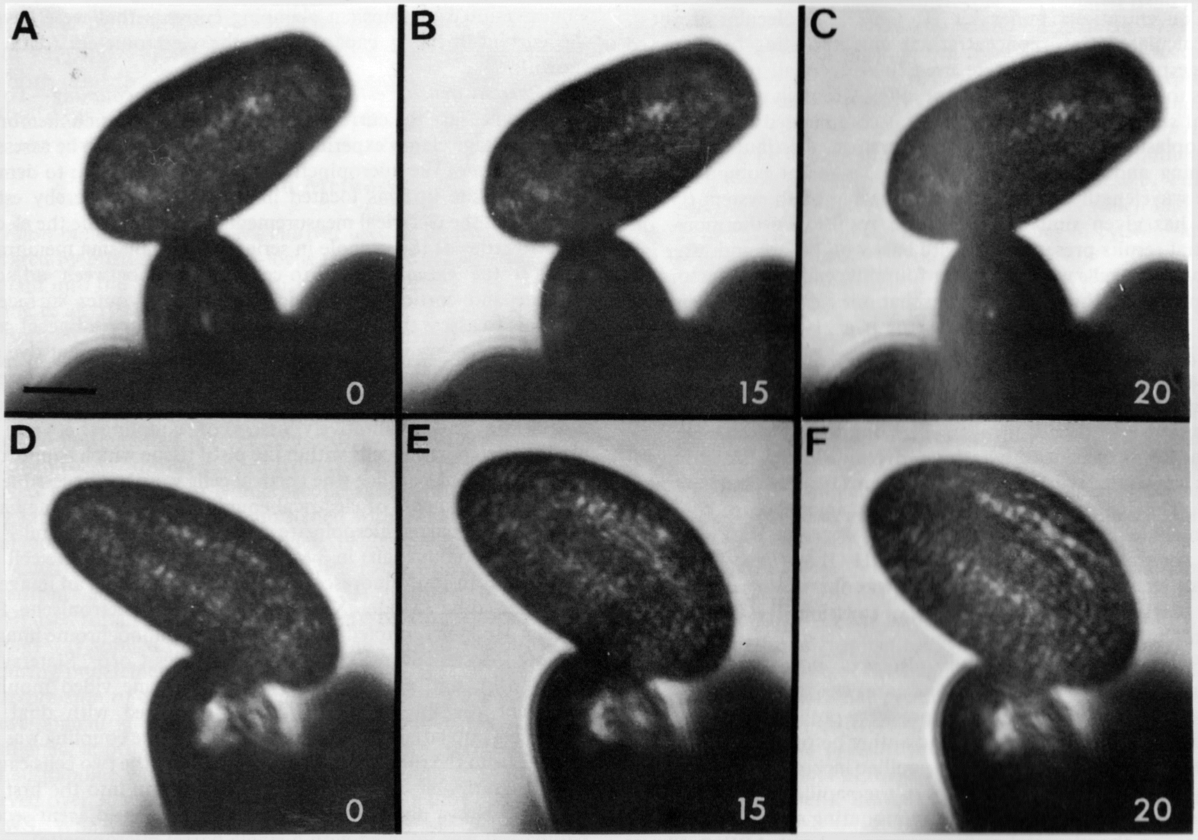



**Fig. 1** The cellular expression of SI in *B. napus*. Incompatible W1/W1 (A–C) pollination produces no pollen grain hydration, even 20 min after pollination, whereas a compatible combination (WS/W1, D–F) shows initiation of swelling after 15 min and substantial hydration by 20 min. Times (min) in lower right hand corner, Scale bar = 10 $\mu$m.

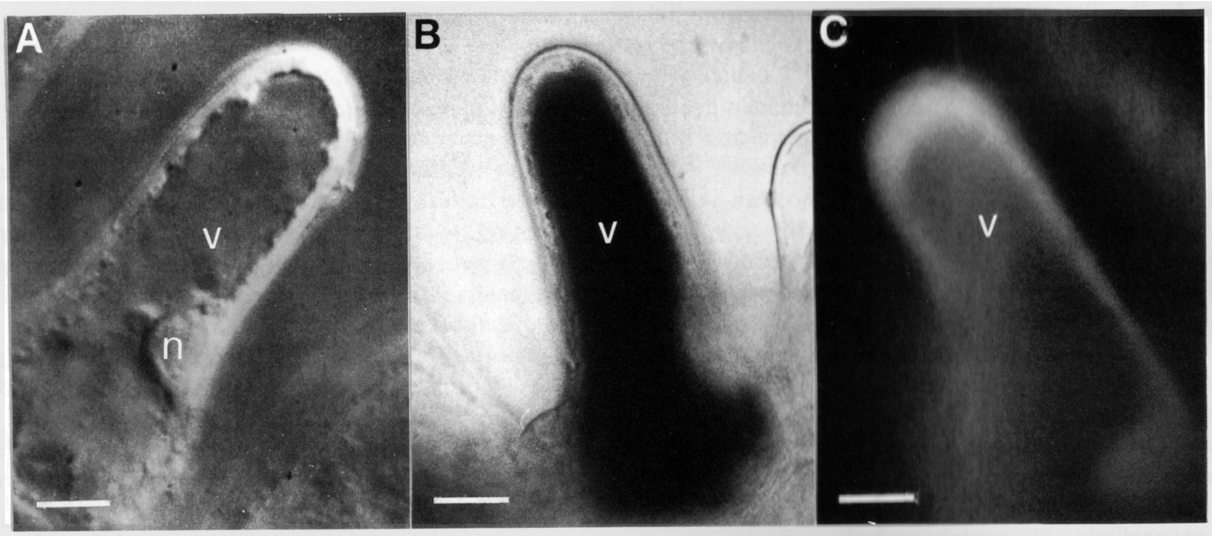



**Fig. 2** Location of impalements in the cytoplasm of papillae. In the papillae, the cytoplasm forms a thin layer around the periphery of the cell (DIC image in A) which surrounds the large central vacuole (neutral red stained in B). Microinjected fluoroscein remains localized in the peripheral cytoplasm, especially concentrated around the site of injection, near the cell apex (C). n = nucleus, v = vacuole. Scale bars = 9 $\mu$m (A), 7 $\mu$m (B) 12 $\mu$m (C).

*Plant Cell Physiol.* 40(1): 60–68 (1999)


# Semi-Automatic Laser Beam Microdissection of the Y Chromosome and Analysis of Y Chromosome DNA in a Dioecious Plant, *Silene latifolia*

**Sachihiro Matsunaga, Shigeyuki Kawano, Takeshi Michimoto, Tetsuya Higashiyama, Shunsuke Nakao, Atsushi Sakai and Tsuneyoshi Kuroiwa**

*Department of Biological Sciences, Graduate School of Science, University of Tokyo, Hongo, Tokyo, 113-0033 Japan*

DIOECIOUS : male (♂, staminate) and female (♀, pistillate) on different individuals.

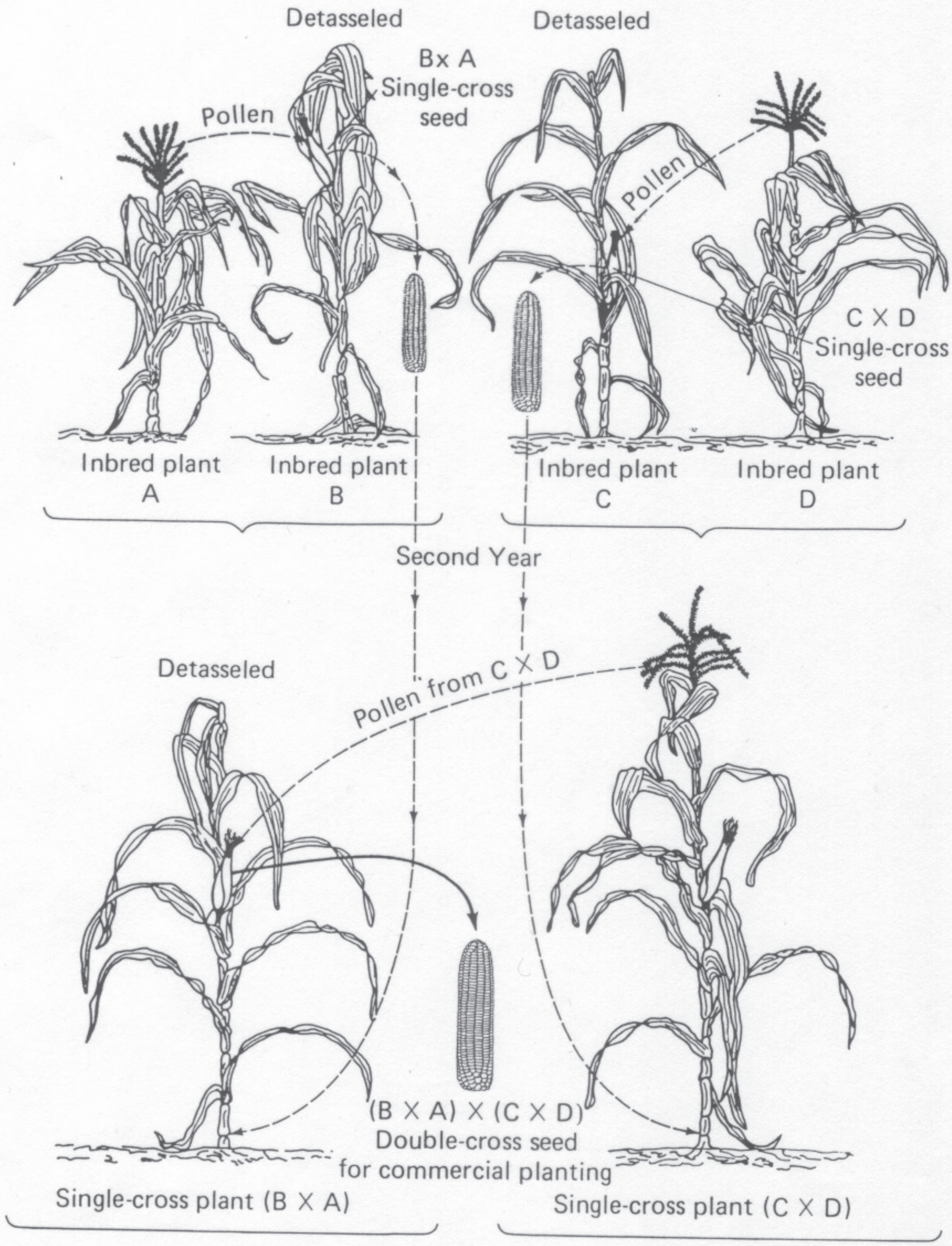
BISEXUAL : male and female on the same plant.

→ HERMAPHRODITE : ⚥ flowers

MONOECIOUS : separate ♀ & ♂ flowers

TABLE 1
The Distribution of Sex Forms among Species of the British Flora*

| *Sex form* | *Families* | *Genera* | *Species* | |
|---|---|---|---|---|
| Completely hermaphrodite | 63 | 468 | 2080 | 92.0% |
| Completely monoecious | 6 | 28 | 122 | 5.4% |
| Completely dioecious | 6 | 15 | 54 | 2.0% |
| Hermaphrodite + monoecious | 4 | 1 | — | — |
| Hermaphrodite + dioecious | 7 | 9 | — | — |
| Monoecious + dioecious | 2 | 2 | — | — |
| Hermaphrodite + monoecious + dioecious | 3 | — | — | — |
| *Total* | 91 | 523 | 2256 (approx.) | |




Crossbreeding for production of hybrid corn. Courtesy U.S. Department of Agriculture.

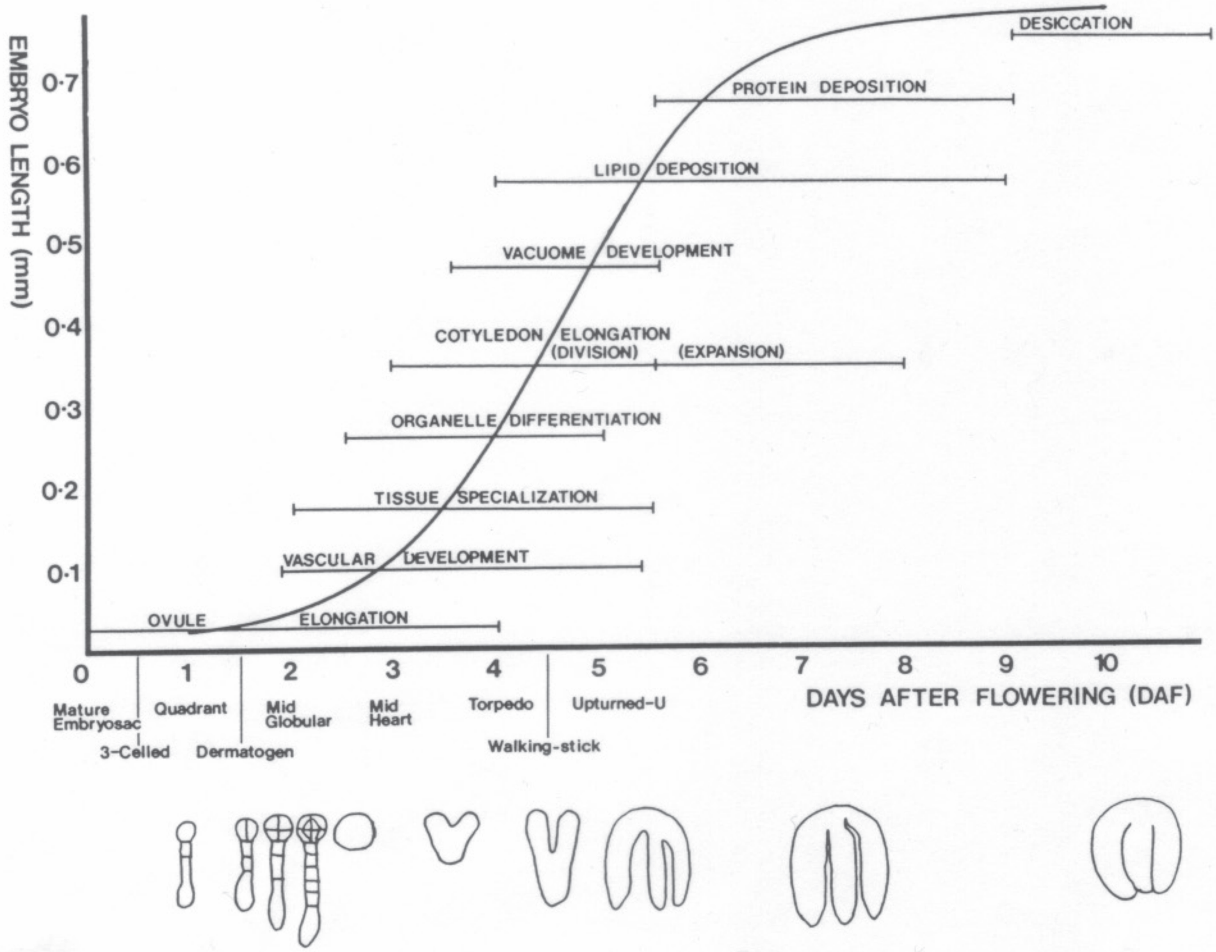



**Figure 1.** Summary of embryogenesis of *Arabidopsis*. Stages of embryo development and cellular differentiation within the developing embryo related to days after flowering. Flowering is defined as the time the length of the medial (long) stamens exceeds that of the gynoecium. It is essentially the time of pollination [stage 14, as defined by Müller (1961) and Smyth et al. (1990)]. Plants were grown under continuous lighting at 25°C and 70% humidity, and embryos examined were taken from the middle of the silique of the third to seventh flowers on the main flowering stem (Mansfield et al., 1991).