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HUNTIA 15(2) 2015

Pollen development, membranes and features of the nucleus in *Tradescantia* and related genera; a translation of Wilhelm Hofmeister's 1848a paper "Ueber die Entwicklung des pollens"

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Abstract

Wilhelm Hofmeister (1824–1877) was largely a self-educated scientist who made great progress in his early career, publishing the work described in this paper a little after his 24th birthday. He worked alone in his spare time while supporting himself in business with his father, publishing and selling books and music scores. Even so, he was able to earn a reputation for experimental botany, revealing, in this case, pollen development, and was as influential as many established professional scientists. Hofmeister did more than observe and draw. He followed the developmental process of anther cells, gaining an idea of development over time. Early histochemical methods were also used to confirm ideas, such as the physical nature of cell and nuclear membranes, contributing to basic ideas of the nature of the cell and cell compartments. This was during a time when cell theory was a fragile new idea and spontaneous generation a persistent theory of life.

Hofmeister observed formation of the cell plate, appreciating its involvement in cell division. Chromosomes were observed after precipitation from suspension by treatment with water or dilute acid, though in those early years he did not understand their great significance for inheritance, only confirming the observations of Nägeli but recording their occurrence beautifully. This paper describes his early work on pollen development in *Tradescantia, Siderasis, Campelia* and *Commelyna* (Commelinaceae), which was published in the *Botanische Zeitung* (Botanical newspaper), a rapid publication more closely resembling a modern newspaper than a modern scientific journal.

Introduction

The year 1848 is better known for destruction and bloody revolutions than for gentle scientific discovery (Sperber 1994). Regimens from most of Europe and parts of South America were convulsing amidst violence, including the Kingdom of Saxony, though very unevenly in that country. For example the political capital of Saxony, Dresden, was in a destructive political ferment, which ended with fighting on the streets in May 1849, and ironically one prominent revolutionary (Wilhelm Richard Wagner, 1813–1883) involved himself in destruction which included that of the Dresden Old Opera Building. In contrast, the largest city, Leipzig was much less affected by violence (Robertson 1960), and because of that, more productive and peaceful lives of merit could continue in the background of turmoil. One of these lives was that of Wilhelm Friedrich Benedikt Hofmeister (1824–1877), self-taught botanist (Witty 2014).

It is surprising to a modern generation universally accepting that the basic unit of life is the cell to know that cell theory was established only in the decade before Hofmeister's work on pollen, after many decades of research (reviewed in Karling 1939 and Conklin 1939). Hofmeister worked very early in the field of experimental botany and because of that the list of ideas he could *not* know is impressively long. Nathanael Pringsheim's work on plant fertilization (1856, reviewed in Troyer 1992), the theory of evolution (Darwin 1859), Mendel's work on the logic of inheritance (1866), meiosis (Strasburger 1888, van der Ploeg 2000),

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alternation of chromosome numbers, reduction and doubling during alternation of generations (Strasburger 1894; Steil 1939), chromosome theory (Sutton 1902; Crow and Crow 2002) and sophisticated histochemical stains (Perkin 1863; Kornhausser 1930; Clark and Kasten 1983), all as reviewed in Kaplan and Cooke (1996) and Raven et al. (2005), were yet to be known.

However, there were many well-established ideas that Hofmeister could have known and by which he could have been guided. Camerarius (1665–1721) showed experimentally that plants have two genders (Johnson 1915). Kölreuter (1733–1806) and others showed that pollen contained a male gamete (reviewed in Ducker and Knox 1985).

Most authors refer to Schleiden (1804–1881) as an influence in the early work of Hofmeister (described in Witty 2014). Schleiden's observations led to the first widely influential theories on plant cells (Strasburger 1895). However, his influence on Hofmeister was a negative one compounded from Schleiden's powerful assertion of matters inconsistent with what Hofmeister and others could see with their own eyes (Morton 1981) and Schleiden's cutting nature (Mayer 1939). Some words of Julius von Sachs (1875) illustrate this point.

> Endowed with too great love of combat, and armed with a pen regardless of the wounds it inflicted, ready to strike at any moment, and very prone to exaggeration, Schleiden was just the man needed in the state in which botany then was. His first appearance on the scene was greeted with joy by the most eminent among those who afterwards, contributed to the real advance of the science, though their paths it is true diverged considerably at a later period, when the time of reconstruction was come. If we were to estimate Schleiden's merit only by the facts which he discovered, we should scarcely place him above the level of ordinarily good botanists; we should have to recon up a list of good monographs, numerous refutations of ancient errors and the like [few peer reviewed papers of experimental results]; the most important of the theories which he proposed, and over which vigorous war was waged among botanists during many years, have long since been set aside. His true historical importance has been already intimated; his great merit as a botanist is due not to what he did as an original investigator, but to the impulse he gave to investigation, to the aim and object he set up for himself and others, and opposed in its greatness to the petty character of the text-books. He smoothed the way for those who could and would do great service (translation cited in Conklin 1939).

One of the particular spurs to Hofmeister's action was that Schleiden clung to the idea that fertilization in plants was similar to that imagined by van Leeuwenhoek in animals; that plant embryos originated as vesicles formed in the tip of the pollen tube and deposited in a passive embryo sac for development. Schleiden's work of 1843 was briefly reviewed in Johnson (1915) and Larson's (1930) papers. Schleiden must have continued to believe this long after the work of Hofmeister (1847; Witty 2014) and others because a similar passage appeared in quite late editions (Schleiden 1861). Hofmeister's (1847) own work contradicted Schleiden and showed pollen contacting the egg within the embryo sac of plants (reviewed and translated in Witty 2014), and it concluded that this action of the pollen tube stimulated development of the embryo, but was not entirely responsible for it. This work skillfully supported the work of Amici (1847). Hofmeister also contradicted Schleiden's watch glass theory, i.e., that the nucleus produces a nuclear membrane which subsequently produces the cell which surrounds it, like a watch glass surrounding the bulk of a pocket watch (Kasten 1983). Hofmeister preferred to assert "I think daughter nuclei form by accumulation of unknown protein-like substances of two groups in the center of the mother cell, that individualize in the form of the oblate elliptical spheroids . . . ," a phrase consistent with modern molecular genetics.

As this and the two subsequent papers (Witty 2015b, c) I have translated from Hofmeister's 1848 contribution to *Botanische Zeitung* (Botanical newspaper) show, Hofmeister was an excellent microscopist and observed several phenomena important to cellular details of fertilization in plants, though because of a lack of theoretical framework he could not name or understand them all (Coleman 1965). He saw and accurately described the independence of the cell membrane from the cell wall, the separate existence of the nuclear membrane, disappearance of the nuclear membrane and nucleoli before cell division and phenomena tantalizingly similar to condensation of chromosomes and cell plate formation (Larsen 1930). In the 1840s cell origin exclusively from preexisting cells was a new idea, and spontaneous generation, at least under some circumstances, was still a strong rival (Karling 1939; Debre 1998). Hofmeister made clear observations that supported cell theory but also made remarkably clear illustrations of the next critical phenomenon, which was how the process of cell division was achieved, i.e., the sequence of events of the process: loss of nucleoli and nuclear membrane breakdown (prophase of meiosis); condensation of chromosomes; separation of chromosomes into two groups; new nuclear membrane formation and finally formation of the cell plate and two daughter cells to complete cell division. Generally, the sequence of events for cell division is easy to see in his work, though there are some ideas of Hofmeister, with which we don't agree today, for example free and membrane-bound nucleoli.

Knowing something of how Hofmeister achieved this is important, and therefore reading his papers, in translation if need be, is a benefit to botanists. That is why, with my limited talents, I have tried to translate the sense of Hofmeister's work and his conclusions. If I have mistranslated Hofmeister, this quotation may console the reader:

> Some other Man, in my Place, would perchance, make you twenty Apologies, for his want of Skill, and Address, in governing this Affair, but these are *Formal* and *Pedantique Fooleries*... This *Abstract*, such as it is, you are extremely welcome to; and I am sorry it is no better, both for your sakes and my own: for if it were written up to the Spirit of the *Original*, it would be one of the most valuable Presents that ever any private Man bestow'd upon the Publick (adapted from Roger L'Estrange and cited in Campbell 1969).

In translating Hofmeister I also wanted to preserve his style, which is similar to 19th-century botany journals and newspapers in general. These publications were much less precise and polished than journals of the 21st century and have quite an elaborate system of parallel footnotes and references, undoubtedly related to the cumbersome and difficult process of typesetting by hand. It is as if Hofmeister published a draft and then responded to criticism by adding corrections to the draft, which was too expensive to rewrite after the type was set. For example, I have preserved Hofmeister's unusual use of em dashes, which he often employed at the end of a sentence, although they may seem random or extraneous to a modern editor or reader. Hofmeister's original three articles appeared in the 9 June and 15 and 22 September issues of *Botanische Zeitung* in 1848. Instead of combining the translations into one article in *Huntia*, I have tried to preserve the flavor of the original presentation by doing three separate articles that are interspersed with the other articles in this issue.

On the development of pollen

By W. Hofmeister

Hereto Pl. 4 [see Fig. 3 for all figures cited in the translation below]

Few plant developmental processes have been the subject of as many studies as that referred to in the heading of this paper. Most research dealt almost exclusively with solving the question of the manner in which membranes of special mother and pollen cells arise. On the other hand, behavior of the nucleus of the mother cell and those of the special mother and pollen cells, phenomena that have observable nucleoli, only sparse data and conjecture, which more accurate observation can not confirm, is seen even in later communications. The research presented in what follows is directed to ascertaining the relationships just referred to.

1. Commelinaceae*)

Anthers withdrawn from young ½''' [*Ligne* or Line, a nonstandard unit of length, 1⁄12 inches] long flower buds of *Tradescantia virginica* [*Tradescantia virginiana*] appear as rounded cellular bodies with four shallow longitudinal projections, which suggest four compartments, along with very short stalks, the first hint of subsequent filaments seated on the receptacle. If you open the compartments with a carefully performed cut and apply gentle pressure, a thoroughly cohesive tissue of soft-walled cells with fine-grained contents and rather large central nuclei detaches. There are usually four or five nucleoli floating in the viscous semitransparent liquid contents of the nucleus (Fig. 1; Hofmeister's figures are found in plate 4 of the original and figure 3 of this paper).

The fixed relationship of these cells, the mother cells of pollen, is soon abolished by additional growth of the anther. Placed under water, they isolate themselves immediately. Even at this moment there are up to six nucleoli in each nucleus, but with more development they decreased except for one whose diameter was larger by three or four times than any in figure one (Fig. 3). It seems that one of those nucleoli increased in size constantly, while the rest were absorbed. This conjecture is supported by the fact that in rare cases where the nucleus of advanced mother cells contain two to three nucleoli, one is larger by far than the others (Fig. 2a). The liquid content of the freed mother cell appears very sensitive to the action of water, even chemically pure water. A few moments after the specimen has been placed in water on a slide, a part of that liquid coagulates—(a protein-like substance, which it contains, probably breaks down because it is dissolved in a less soluble compound),—this forms the center of the nucleus, depending on the degree of development of the cell, as either a sharply defined spherical lump (Fig. 2b) or an irregular heap of granules (Figs. 4, 7b [*sic*]) of a yellowish, translucent, semisoft mass, surrounded by water-clear liquid. After its contents clot, the nuclear membrane appears clearly, especially when, as often happens, it is uniformly filled with mucilage and shrivels into a ball of grained jelly-like substance that slowly retreats from the wall of the nucleus (Figs. 2 and 2b, 6 and 6b).

The process just described for nuclei of young cells of higher plants has often been observed, but not fully recognized (Nägeli calls it "contraction of the nuclei," see Schleiden and Nägeli, *Zeitschrift für Botanik,* issue 1, p. 63) [Nägeli 1844], and provides evidence of the independent existence of a membrane of the cell nucleus, which acts on the contents in a similar manner as the cellulose wall of the cell to its cell membrane. After coagulation of the liquid contents of the nucleus a large nucleolus very often grows outside the coagulum. On the nucleolus of older mother cells there is clearly a membrane, much coarser than that of the nucleus, and a different fine-grained content (Figs. 6b, 6c). On the other hand, for less advanced stages of development, the nucleoli appear as elongated rounded masses of a very thick mucus, which are located in one or two cavities and a membrane is not directly observed (Figs. 4, 4b). The outline of nucleoli of such nuclei can be under the influence of water yet suffer no change but are always hazy and indistinct as is expected from objects lying in a turbid liquid. The cavities inside them can be perceived much more often (Fig. 3).

Cell, nucleus and nucleolus constantly increase in size, the former the least, the latter the most. The diameter of the nucleus, which in earlier stages was ½ of the mother cell diameter, grows up to ⅞ of the cell, and the longitudinal diameter is up to ¼ of the nucleus. The membrane of the nucleus and its nucleolus are always similar while the contents of the cell are increasingly thinner; the nucleus and the nucleolus are similar and contain the majority of larger granules while the cell sap is liquefied. Finally, the nucleolus disappears entirely about the same time it is observed that the nuclear membrane is reabsorbed.

The mother cell, placed into contact with water at this stage of development, immediately formed a sphere by expansion on all sides. Protein-like substances, the former contents of the nucleus, are in the center of the cell, even after the liquefaction of the nuclear membrane. The only numerous little granules of the cell sap are in the immediate vicinity of the cell wall, pretty much the entire contents of the cell appear as a homogeneous, turbid, mucilaginous liquid. The size of individual particles that cause turbidity does not reach the limit of microscopic vision.

While the mother cells appeared in this state with such a tearing speed, none of the others absorbed water. The majority of preparations coagulate before it is possible to bring the object into focus with the microscope. One then finds arranged in the cell a number, often quite large, of irregular clumps (Figs. 9b [*sic*, Fig. 10], 12b). This is the phenomenon that Nägeli [1844] referred to as (*Zur Entwickelungsgeschichte des Pollens bei den Phanerogamen,* p. 34) "formation of transient cytoblasts in the mother cell." If one follows the appearance and visual changes of the albuminoids in slower coagulation of the cell contents, it is initially seen that in the apparently homogeneous liquid content of the cell, spherical drops of a light and more strongly refracting substance are visible (Figs. 10a [*sic*], 12a [*sic*]) that within a few seconds alter to clumps of firmer translucent mass (Figs. 10b, 12b).

When the endosmosis of water slows down because a fluid such as ammonium carbonate is added to the slide, it is sometimes possible to cause accumulation of protein-like substances in the center of the cell in the form of an irregular spheroid clinging to the cell wall (Fig. 9).

In compartments of the same anther whose mother cells behave as just described, there are also usually mother cells with two free nuclei (Fig. 13). These flattened elliptical spheroid nuclei are equal to the first, and they occupy the greater part of the cell's volume. Their substance refracts light in almost exactly the same way as the contents of the mother cell, and they are only with difficulty distinguishable from cell sap. The best indication of this type are the very small granules of the latter, which no longer accumulate on the periphery of the cell but at a kind of belt at the equator. Young daughter nuclei do not contain nucleoli, and they often go through all stages of their development without forming any permanent internal structures. No membrane can be seen in the newly formed nuclei, either directly or inferred from the phenomena that occur after coagulation of the proteinaceous substances of nuclei: but there are two heaps of albuminoid clumps obtained by coagulation, which are free in the cell (Fig. 14). More developed individuals show an enveloping membrane and contain up to ten relatively very small nucleoli (Fig. 15). There are certainly two ellipsoidal nuclei in mother cells at the stage which immediately follows that shown in Figs. 8–12. A very large number of observations of *Tradescantia virginica*, *subaspera* and *fusca* [*Siderasis fuscata*], the closely related *Campelia zanonia* [*Tradescantia zanonia*] and *Commelyna coelestis* [*Commelina coelestis*] were made, and no intermediate phenomena can be seen. Absolutely nothing is seen of a nucleolus in the sense of Schleiden's theory, i.e., an organized body of greater density that acts as the center of attraction for the substance of nascent nuclei.—I think daughter nuclei form by accumulation of unknown protein-like substances of two groups in the center of the mother cell, that individualize in the form of the oblate elliptical spheroids themselves, and later towards the outside as a membrane inside which structures of dense materials are produced and confined.—On the more detailed nature and significance of the latter, the nucleolus, hardly anything is likely to be determined in this case with current instruments.—Certainly Nägeli's conjecture about the nature of the process of forming future special mother cell nuclei (Schleiden and Nägeli, *Zeitschrift für Botanik,* issue 1, p. 48) in *Tradescantia* finds a most decisive refutation. The fact that in many other genera from families that have little in common with the rest of the Commelinaceae, development of these nuclei does not differ materially from that in *Tradescantia*, *Campelia* and *Commelyna*, I will show in the sequel to this paper [Witty 2015b, c]. I assume that here is the radical difference between the mode of formation of higher cryptogam spores and the pollen of phanerogams.

Without any observable transition state, a very fine line parallel to the major axis of the nuclei appears abruptly, which is the first appearance of the dividing wall separating the mother cell into two halves and forming *special mother cells of the first degree* (Fig. 17). The diameter of the dividing wall increases later, often considerably (Fig. 23);—but even then it always appears as a homogeneous glass-like mass in which no indication of a dividing line or a thickening layer can be perceived.

The vital process of the special mother cell nuclei of the first degree is completely similar to the mother cell nuclei. The membrane of the daughter nucleus is reabsorbed and a very delicate cell wall appears, bisecting the mother cell, which increases in thickness a little later. The liquid content of the nuclei of the special mother cells coagulates easily, either during the existence of the nuclear membrane, or after it has disappeared (Fig. 19). The nucleus of the special mother cell of the first degree, after resorption of the membrane of the same two smaller nuclei, has elongated elliptical spheroids, still showing a membrane (Fig. 20), which contain no nucleolus shortly after their formation (Fig. 22). After further development one or a few small nuclei appear (Fig. 23) later with an enveloping membrane.

Between these two nuclei, again quite suddenly, and also parallel to the major axis of the nuclei, a delicate line appears, the cell wall, which bisects the special mother cells of the first degree. The four special mother cells of the second degree are thus formed.

In the predominantly large majority of cases, the formation of the special mother cells is in the manner just described, so that two are in the same plane. There is, however, although very rarely, in *Tradescantia* a tetrahedral arrangement of the special mother cells (Fig. 25), a spatial relationship that can only occur as a result of the simultaneous emergence of the four cells [*sic*] and that necessarily excludes the occurrence of special mother cells of the first degree [*sic*]. As early as 1842 Nägeli knew *Alcea rosea* is a plant in which four of the special mother cells form at once in a generation, as well as in two successive generations. I have found the simultaneous occurrence of both modes of formation occur in *Passiflora*, *Pinus*, *Abies* and *Iris*. This difference in the course of development seems to be of little significance. On a specimen of *Campelia zanonia*, with vegetation that had been deprived of light and air in a musty corner of a greenhouse, I found a very different and diverse arrangement of special mother cells. I have depicted some of these no doubt pathological states as Figs. 28 and 29. From Fig. 28 it appears that even in this case, the formation of primary special mother cells has taken place.

Of the prominent ridges on the inner wall of mother cells, which occur in many dicotyledons with so much clarity, there is no trace in the Commelinaceae.

Upon examination of special mother cells in saturated salt solutions, I observed several times that the cell contents of the cell membrane are not uniformly dense and adherent, but rather, in the form of a rounded tube, limited to the outside of a distinct membrane, the dividing cell walls barely touched at some points (Fig. 24). Subsequently I replaced the liquid of the slide with abundant water, and this tube expanded out and completely filled the cell space.—I believe that this is by no means an isolated phenomenon—subsequent to this paper, I'll communicate similar, yet more convincing material,—as a new support of the view that it is the mucus layer that defines the exterior of young cell contents—the cell membrane—is an independent body.—No observation is contrary to the view that separation is achieved by a specific material on the entire outer surface of the cell membrane, not the thickened layers of the walls adhering to the special mother cells, perhaps after a mild contraction of the inner membrane of the pollen cell. At a certain stage of development of *Campelia zanonia,* when the specimen is under water, the walls of the special mother and mother cells burst, and from the crack emerges a portion of the delicate membrane of the pollen cell, like a bubble (Fig. 27). It is in this case particularly easy to convince yourself that the central nucleus of the special mother cell, which is persistent for the pollen cell, often contains no fixed structures.—From the occurrence of two nuclei in the special mother cells of the first degree until the release of the pollen cell, external factors never show any phenomenon that suggest dissolution of the central nucleus of the special mother cell or formation of pollen cell nuclei by "parietal cell formation." At no stage of development is the nucleus missing, even during liquefaction of the special mother cell walls. There is only one difference between initial and later stages, which is that in later stages there is usually only one nucleolus, although a fairly large one, it can be attached to the membrane and its contents are different. In consequence of the nature of its development in the shape of a spherical quadrant, the young pollen cell takes the form of a kidney immediately after its liberation (Fig. 30). A layer of mucus coats its inner wall, and the nucleus is embedded in this mucus layer (Figs. 30, 31); it is parietal in the sense in which Nägeli uses this expression.—That this position of the nucleus is always a later state associated with differentiation of the cell, even in formation of endosperm cells the nucleus is always central, probably requires no farther discussion. Nägeli himself, who earlier conjectured that "the free core of the special mother cell of the pollen cell would be the nucleus" (Schleiden and Nägeli, *Zeitschrift für Botanik,* issue 1, p. 63), has recently stated (the same journal, issues 3 and 4, p. 50) the presence of parietal cell formation in the sense of the original version of Schleiden's theory is generally disputed. In further development of the pollen cell a frothy mucus appears in their interior (Fig. 32), and the nucleus returns to the center of the cell. When the exine projections appear, the nucleus can no longer be seen; the pollen grain begins to contain oil droplets that increase in number until its maturity.

Explanation of figures

Figs. 1–25. *Tradescantia virginica*.

1. Two mother cells at the time when all the mother cells of an anther compartment form a coherent firm tissue.

2[a]. Mother cell from a slightly older anther. The contents of an anther compartment, placed under water, appears to the naked eye as a milky liquid because mother cells are immediately released.

2b. The same mother cell after brief incubation in water. The liquid content of the nucleus is coagulated, and the cell sap shows a greater number of solid grains than before.

3. Further developed cell, contents unchanged.

4. A similar cell with clotted contents.

4b. The nucleolus of the same cell, more strongly magnified.

5 and 6. Mother cells shortly before the resorption of the nuclear membrane.

6b. The same cell as illustrated in figure 6, after clotting of the liquid content of the nucleus.

6c. The nucleolus of a single mother cell, at the same stage of development.

7. Mother cell with coagulated contents. The membrane of the nucleus is not directly observed.

8. Mother cell following resorption of nuclear membrane, contents unchanged.

8b. The same cell, treated with sugar solution. The cell membrane withdraws from the cell wall.

9. Mother cell in a solution of ammonium carbonate. The albuminous material of the cell lies next to the cell wall.

10. Mother cell after a short exposure to distilled water showing refractive spherical droplets.

10b. The same cell, treated with aqueous tincture of iodine. The cell membrane contracted as the coagulation of albuminous material proceeded.

11. Mother cell, unaltered

11b. The same cell, after two minutes in water. A number of coagulated clumps are located in the center.

12. Mother cell, after a short exposure to water. Coagulation of albuminoids is beginning.

12b. The same cell, half a minute later. Coagulation is complete.

13. Mother cell with two newly formed nuclei, unchanged.

14. A similar cell with coagulated contents. No sign of a membrane enclosing the two granule clusters.

15. Mother cell with two nuclei, further developed.

16. A similar cell, treated with very dilute acid. The cell membrane is pulled back from the cell wall.

17. The first appearance of the dividing cell wall.

18. Complex of two special mother cells a little later.

19. A similar cell from a slightly older bud after a short exposure to water. The contents of the cell are coagulated, a nuclear membrane is no longer noticed.

20. Two newly emerging nuclei are seen in every special mother cell. The axis of the upper cell nucleus diverges from those of the lower by 90°. No solid material develops in the nuclei.
21. From the same anther. The contents of the cells are coagulated. No indication of a membrane enclosing the young nuclei.
22. Very small nucleoli appear in the nuclei. Prepared from the same anther as 20 and 21.
23. Complex of two special mother cells with greatly thickened septum. The axes of all four nuclei are parallel.
24. The four special mother cells are formed, the object is in a dilute solution of ammonium carbonate, cell membranes are contracted [a fourth cell is assumed, out of the plane of focus].
25. Tetrahedral arrangement of the special mother cells.

Figs. 26–32. *Campelia zanonia*.

26. Complex of four special mother cells slightly swollen by water, but in other respects unchanged.
27. Lower half of a complex, a little later. A portion of the delicate membrane of the pollen cell emerges like a bubble from the gap in the wall of the mother and special mother cell. The nucleus of the right-hand pollen cell has remained in its original place and the left-hand-side nucleus moved into the sac. In the latter are very small nucleoli.
28. Complex of three special mother cells.
29. — of four —

(Pathological states)

30.–32. Various stages of freed pollen grains.

All objects are drawn at a magnification of 500 times and in their correct relative size.

The appearance of *Tradescantia*, *Campelia* and *Commelyna* are similar to each other and a representation of the same stages of development of these species is superfluous. In *Commelyna* and *Campelia* investigation is made easier by limited solid substances contained in cells and made difficult by the small size of the organs.

Leipzig, 15 February 1848.

(To be continued.)

Footnote of Hofmeister 1848a

*) Commelyn, a Welsh name, is written with a *y*. [The modern spelling is Commelinaceae].

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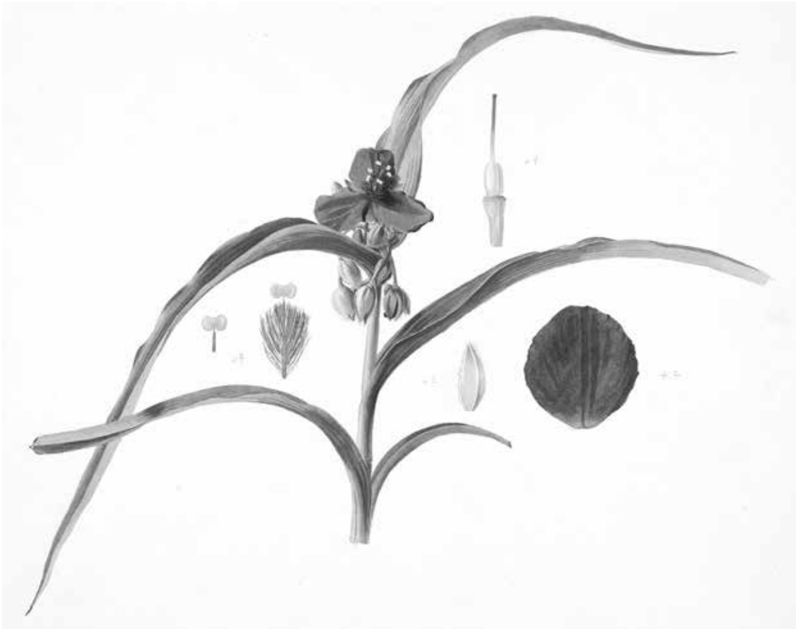

Figure 1. Gross anatomy of *Tradescantia virginica* [*Tradescantia virginiana* Linnaeus], watercolor on paper by Frederick Andrews Walpole (1861–1904), 1897, 25.5 × 30.5 cm, on indefinite loan from the Smithsonian Institution, Hunt Institute for Botanical Documentation Art accession no. 4320.

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Schleiden, M. J. 1861. Grundzüge der Wissenschaftlichen Botanik, ed. 4. Leipzig: Verlag von Wilhelm Engelmann. [P. 521: "Demnächst erscheint das Ende des Pollenschlauchs innerhalb des Keimsacks als ein längerer oder kürzerer, cylindrischer oder eiförmiger Schlauch, der nach der Höhle zu rund geschlossen ist, nach der Spitze des Keimsacks offen in den Pollenschlauch ausläuft;

Figure 2. Gross anatomy of *Campelia zanonia* [*Tradescantia zanonia* (Linnaeus) O. P. Swartz], watercolor on paper by an unknown artist for the Royal Spanish Exploring Expedition of 1787–1803, Torner Collection of Sessé and Mociño Biological Illustrations, Hunt Institute for Botanical Documentation Art accession no. 6331.0855.

das Ende schwillt bald an, entweder so, dass das hieraus hervorgehende Bläschen (Keimbläschen) der ganze im Innern des Keimsacks enthaltene Theil des Schlauchs ist, oder so, dass zwischen diesem Bläschen und der Spitze des Keimsacks noch ein längeres oder kürzeres, cylindrisches Stück, der Keim- oder Embryoträger (filamentum suspensorium, filament suspenseur, Mirbel) zurückbleibt." "Soon the end of the pollen tube appears within the embryo sac as a longer or shorter, cylindrical or egg-shaped tube that is enclosed by that cavity, at the top of the embryo sac the pollen tube terminates, the tip quickly swells and vesicles are released (germinal vesicles) [future embryo], the whole interior of the embryo sac contains portions of the tube, or between the vesicles and the tip of the germ sac a longer or shorter, cylindrical piece of the egg or suspensor (*filamentum suspensorium*, *filament suspenseur*, Mirbel) remains."]

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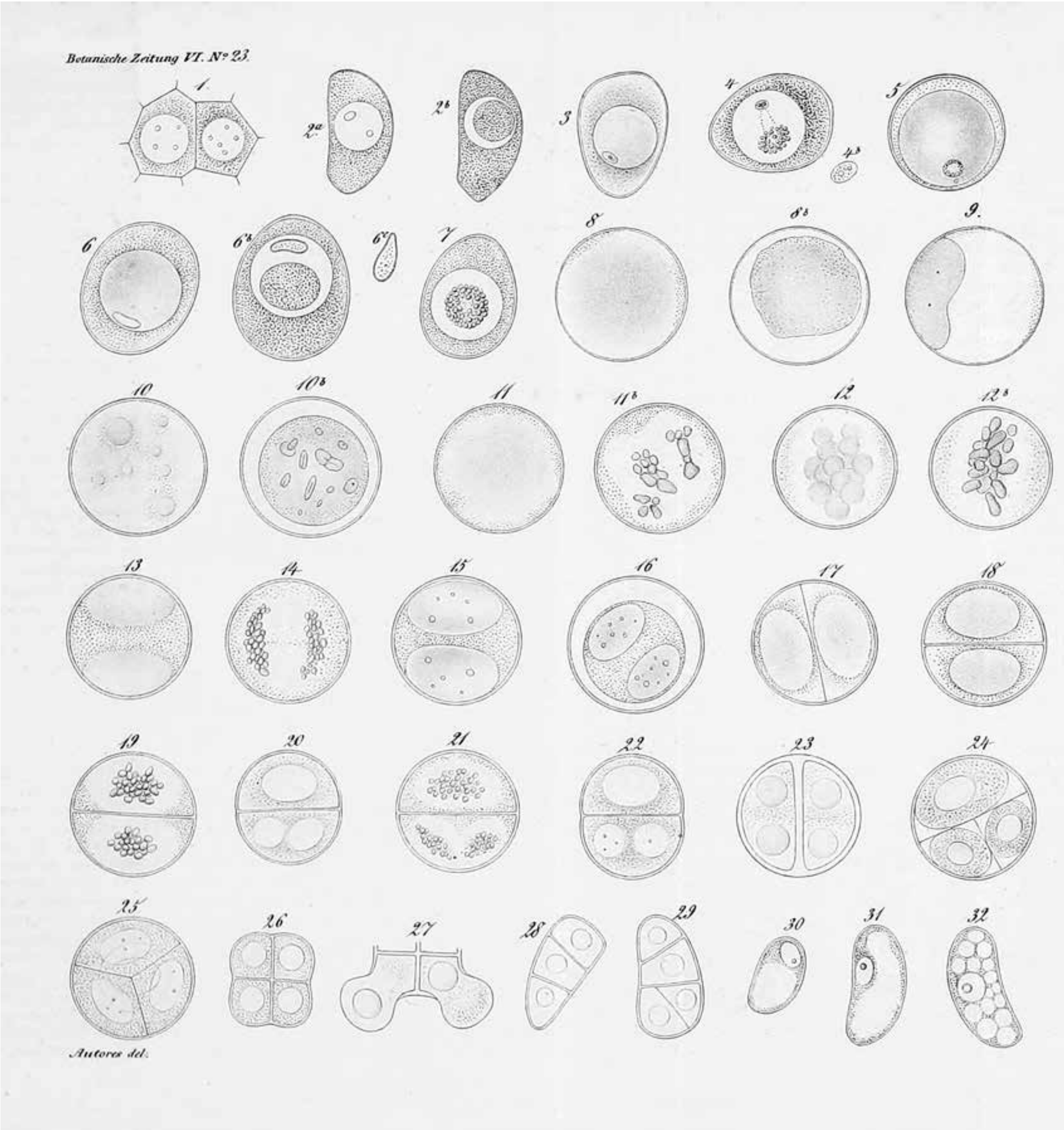

Figure 3. Plate 4 of Hofmeister 1848a. Image courtesy Biodiversity Heritage Library (http://www.biodiversitylibrary.org) and the LuEsther T. Mertz Library at the New York Botanical Garden.