Barley tales

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What does it mean for a scientist and artist to work together to create works that are a true fusion of their research and how can this experience feed back into broadening an appreciation and understanding of the world around us? A tale of how a meeting between an artist and microscopist led to a series of joint events for the Max Planck Day at their Institute for Plant Breeding Research (Max-Planck-Institut für Pflanzenzüchtungsforschung, MPIPZ) in Cologne.

Rob Kesseler: The artist's tale

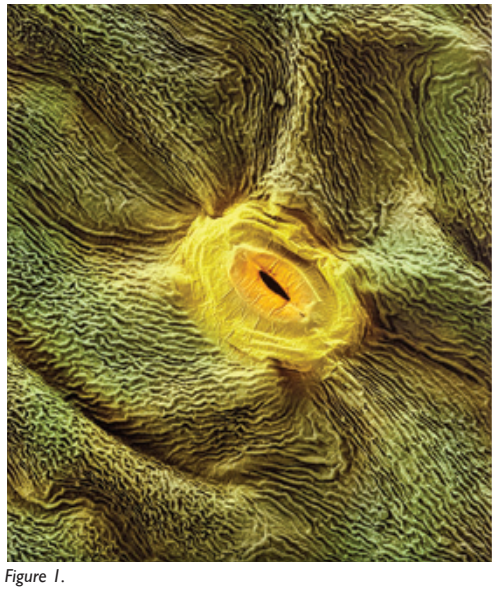
Opportunity

To be the invited speaker at the 2015 International Congress of Botanical Microscopy in Exeter was a great honour, even more so given that I am an artist with limited formal scientific training. My presentation revealed the extensive work I have done in the field of Scanning Electron Microscopy (SEM), creating a new aesthetic dimension through hand colouring the black and white images to reveal plant specimens, pollen, seeds, fruits and leaves in ways that go beyond the conventions of scientific imaging. This work sits on top of a vast canon of botanical art and illustration that continues to attract audiences. I have always believed in the possibility of creating work that fuses contemporary science and art practice to create powerful mesmerizing plant portraits that captivate the viewer and reveal the wonders of plant specimens too small to be seen by the naked eye. My presentation was well received by the assembled audience of eminent microscopists from around the world who were struck by the fact that I had attended all the presentations over the previous three days. For me this was a privilege and a necessity; if my work is to be respected by the scientists I collaborate with, it is an essential part of my practice that I engage with the discipline in a meaningful way.

I made reference to an exhibition I was preparing with the Hunt Institute for Botanical Documentation at Carnegie Mellon University in Pittsburgh, USA (Roy 2017). The exhibition paired my SEM images of plant specimens alongside botanical wall charts from Carl Ignaz Leopold Kny's (1874-1916) series *Botanische Wandtafeln* (Berlin, Paul Parey, 1871911), (Figure 1). The long neglected educational wall charts struck a chord with Ulla Neumann (CeMic, Max Planck Institute for Plant Breeding Research) who appreciated their artistic sensibility; she even has one hanging in her office. A mutual passion for the science and art of botanical microscopy was quickly established between us resulting in an invitation to give a lecture to the teams at the Max Planck Institute. Their enthusiastic response emboldened us to explore other possibilities of collaboration.

Co Cultures

In my role as Chair of Arts Design and Science at the University of the Arts London, under the banner of Co Cultures I have created opportunities for art and design students and schools to experience first-hand the spectacular world that microscopes reveal [www.cocultures.com]. Recognizing this potential of art and science collaboration to engage new audiences, Ulla Neumann enthusiastically invited me to take part in the Max Planck Day the following year, celebrating the 70th anniversary of the foundation of the Max Planck Society, the 160th birthday of Max Planck and the 100th birthday of his Nobel Prize award. The Max Planck Day is an opportunity for local communities when the Institute throws open its doors to show and talk about the important work it does through a series of lectures, workshops and tours of the facilities.



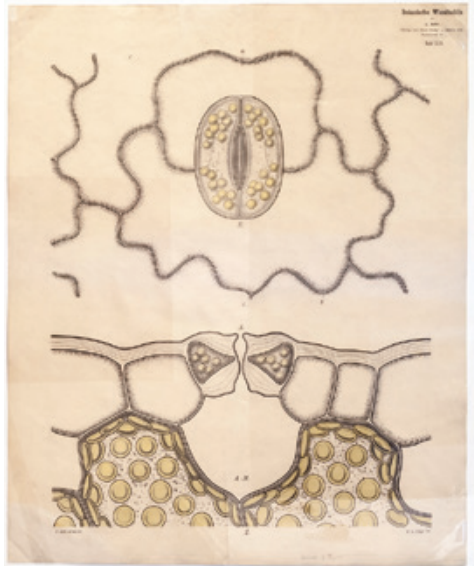


Figure 1.

In July 2018 I visited the Institute and met with Ulla Neumann and PhD student Marine Przybyl (Ivan Acosta Group) to develop a strategy for the event in September. Our contribution to the day would be a microscopy workshop and joint lecture to reveal our contrasting approaches to working with barley. I was particularly keen to show how various modes of artistic expression could be employed to reveal new ways of extending images of art and science. Their work using mutant collections and natural variation in barley presented an interesting challenge, and a visit to the greenhouses, show garden and barley fields around the Institute yielded a fine collection of fresh specimens and the raw material for me to work on. Together we prepared pollen and flower samples for examination in the SEM. The anticipation of what will be revealed through magnification always gives an adrenaline rush and one is never disappointed. This time was no exception and using the Zeiss Supra 40VP through the direction of technician Rainer Franzen I quickly harvested a memory stick full of images to work on over the summer in preparation for our joint lecture.

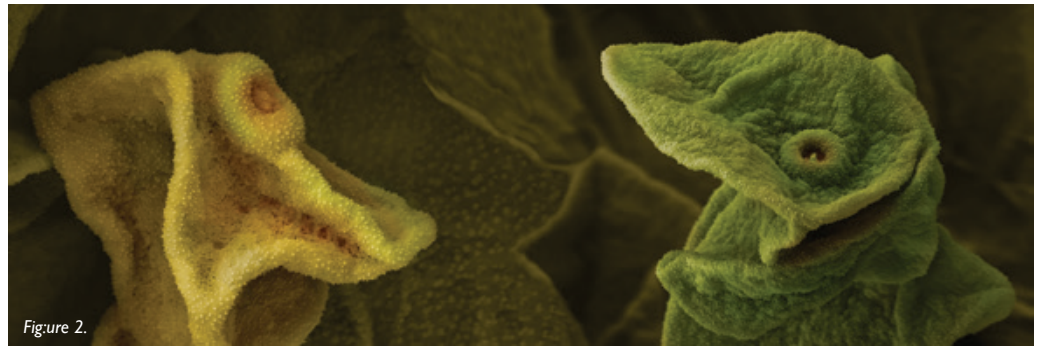


Fig:ure 2.

Mutation

There is a tendency in modern society to demonise science, especially plant science, mythologizing its practices and the consequences of its research. A mixture of genuine concern for our planet liberally sprinkled with inaccurate and misleading media articles breeds suspicion. Within this context the spectre of mutation has many negative connotations, but mutations in the plant world happen as a natural consequence of evolutionary and environmental factors. The SEM images of mutant barley pollen appeared on screen like familiar characters. The artist Jean Arp (1886-1996) once remarked that art usually shows an absurd resemblance to the aspect of something else. The image (Figure 2) features two mutant barley pollen grains and plays on our human instinct to look for the identifiable within the inexplicable. In this case the pollen grains appear like bizarre animated characters from a Star Wars movie.

The character of John Barleycorn in the popular song is a personification of the important cereal crop barley and of the alcoholic beverages made from it, beer and whisky. In the song, John Barleycorn is represented as suffering indignities, attacks and death that correspond to the various stages of barley cultivation, such as reaping and malting. In pagan European culture it was believed that the spirit of the corn lived amongst the crop, and that the harvest made it homeless. During harvest "corn dollies" were made and ploughed into the first furrow of the new season.

Modern science may have superseded popular mythology but it continues to confront us with

Figure 3.

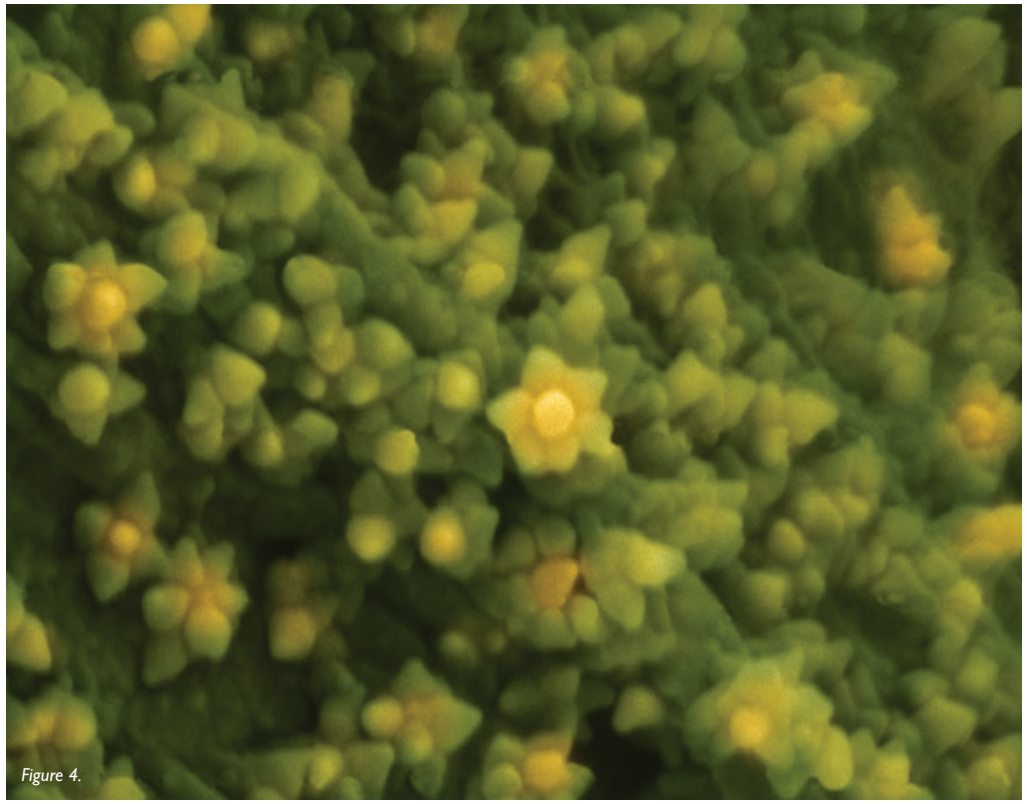


Figure 4.

awesome and disturbing images of the living world. The image of barley flower resonates with the Barleycorn myth, a scientific surrogate for a contemporary corn dolly (Figure 3).

Other images resonated with a personal interest in pattern and structure in plant morphology. The tapetum, the innermost cell layer of the anther wall, surrounding the barley pollen grains, is covered with Ubisch bodies, small acellular structures whose function remains unclear (Wang et al., 2003; Gómez et al., 2015). At high magnification (X40K), however, these bodies of the mutant appear to develop and evolve into delicate and ethereal six-petaled floral forms (Figure 4).

Fusion

Time didn't allow for the development of any Transmission Electron Microscopy (TEM) images but as we felt it was important to create artworks that were a true fusion of our respective approaches, Ulla gave me some of her stained sections of anthers and other TEM images to take away and work on. Like mutation, the word stain has many negative connotations: *discolour, blemish, spoil, defile, pollute, contaminate,* but to the artist its meanings have a more positive familiarity: *colour, tint, dye, tinge, shade,* whilst to the scientist, it is a fundamental component of histological sample preparation. Toluidine blue O being a particular favourite of mine.

One of the earliest photographic processes, Cyanotype was developed in 1842 by Sir John Herschel (1792-1871) and used by Anna Atkins (1799-1871) to produce some of the first plant photograms. A non-lens-based process, it has been enjoying a revival as a popular form of artistic expression, its immediacy and subtle ethereal abstraction are particularly appealing. Subsequently it was taken up by engineers and architects as a reproductive drawing process that we know now as blueprints. A light-sensitive solution of ammonium citrate and potassium ferricyanide applied as a coating to the paper on which plants have been placed and exposed to sunlight produces a distinctive blue tonal image. A sheaf of wild type (Bowman) barley collected from outside the greenhouse provided the material to work with. Placed quite randomly on the prepared paper, the familiar stalks and spikes of the barley were exposed to sunlight before washing out to reveal evocative white silhouettes against a deep blue background.

These initial images were paired up with Ulla's stained sections of anthers, juxtaposing our two ways of working with the same material (Figure 5). To create a more cohesive body of work, the two types of image were literally overlaid to produce a rather mysterious composite combining different orders of magnification, the stained sections floating in and out between the ears of barley (Figure 6).

Old masters

Scientific research builds on centuries of accumulated knowledge, the arts likewise cannot escape the myriad of paintings and sculptures that populate our museums and galleries. The landscape tradition has long been a source of inspiration for painters, and in particular the food crops that sustain us. Driving through the fields of barley surrounding the Max Planck Institute, the iconic painting Wheat Fields with Cypresses (1889) by Vincent Van Gogh sprang quickly to mind (Figure 7). We view such landscapes now with a more informed eye; the fields contain complexities of life too small to be seen with the naked eye. The challenge to represent what is seen together with what is known resulted in a collection of images in which TEM micrographs of tapetum cells and pollen grains were woven back into the landscapes from which they originated - graphic notations, micro abstractions (Figures 8, 9). The series was completed with another evocative allusion to Van Gogh's Starry night. Extending the overlaid format, stained sectioned images were chromatically inverted and presented against straight photographic images of barley (Figure 10). The samples floated like stars in a distant galaxy, a poetic fusion of science and art.

Ulla Neumann: The microscopist´s tale

First contact

In 2015, I attended the 10th RMS Botanical Microscopy Meeting in Exeter. For dedicated plant microscopists, this meeting, which takes place every four years, is a true highlight as it combines state-of-the-art microscopy with the latest developments in plant cell biology. Since my first meeting in 1999, I have attended all but one meeting and immensely enjoyed the shared enthusiasm for plant cell biology and the informal atmosphere.

One of the keynote speakers of the Botanical Microscopy Meeting in 2015 was Rob Kesseler who is well known to plant microscopists for his stunning hand-coloured micrographs of pollen, fruits and seeds. In addition to his amazing presentation entitled "Convergent Territories – new opportunities in Art & Science", it was mainly his sheer presence throughout the total length of the meeting that really struck me – surely, very few (if any) plant cell biologists would attend a full three-and-a-half days meeting of professional artists. The enthusiastic reception of Rob's presentation by all conference attendants triggered my idea to invite Rob to the MPIPZ in the summer of 2017 to present his work at the interface of Art and Science. His presentation was part of our Institute's weekly Site Research Seminar series and again, his presentation was very well received, and by a much broader audience than is usually attracted by the life science seminars.

Collaboration

Rob's visit to our institute strongly encouraged me to initiate a collaboration with him on one of the research topics of our Institute. Being an expert in transmission rather than in scanning electron microscopy myself, ever since Rob's presentation at the Exeter meeting, I was intrigued by the question what the artistic output would be if Rob worked on TEM as well as SEM images. So I started to look

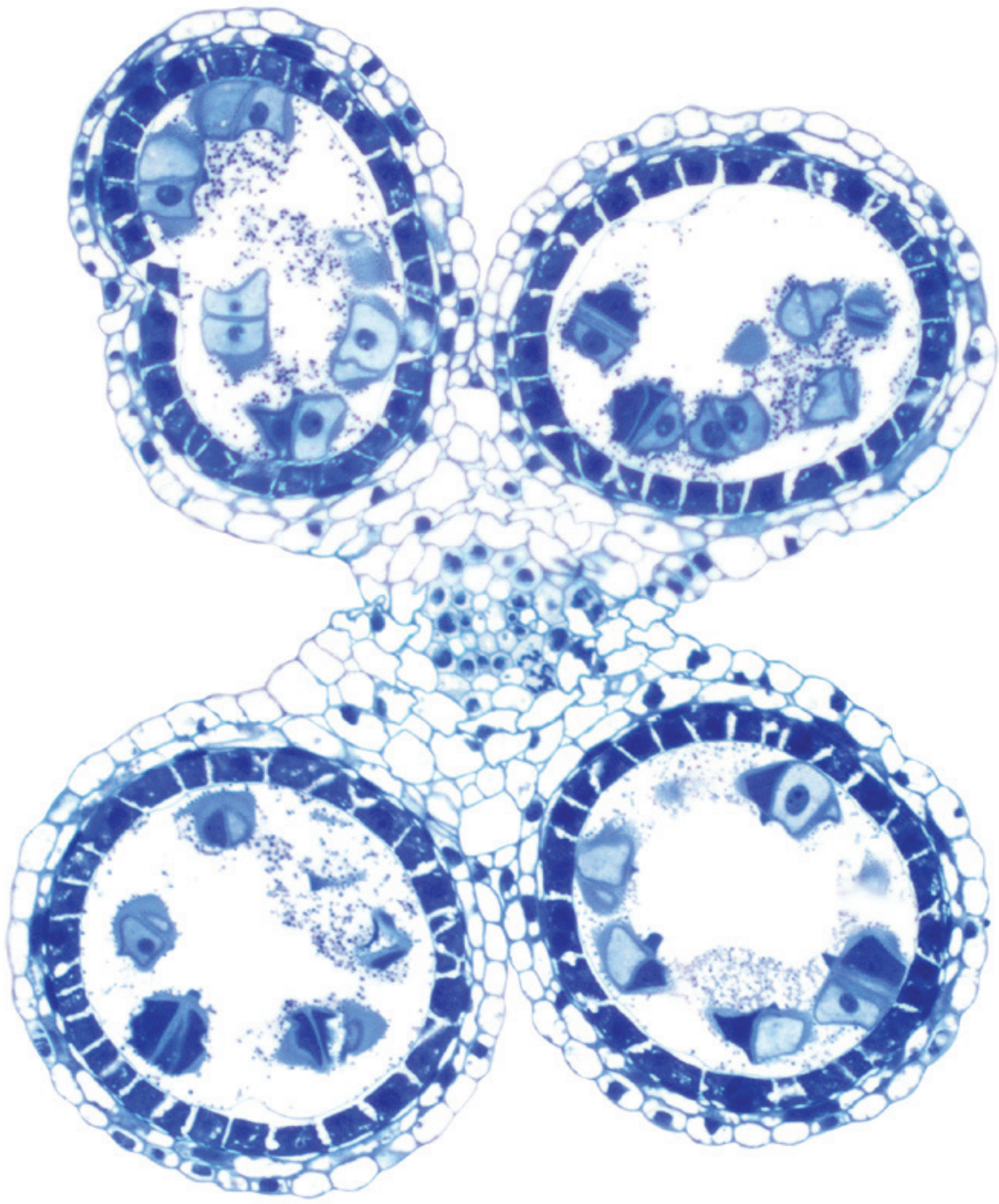


Figure 5.

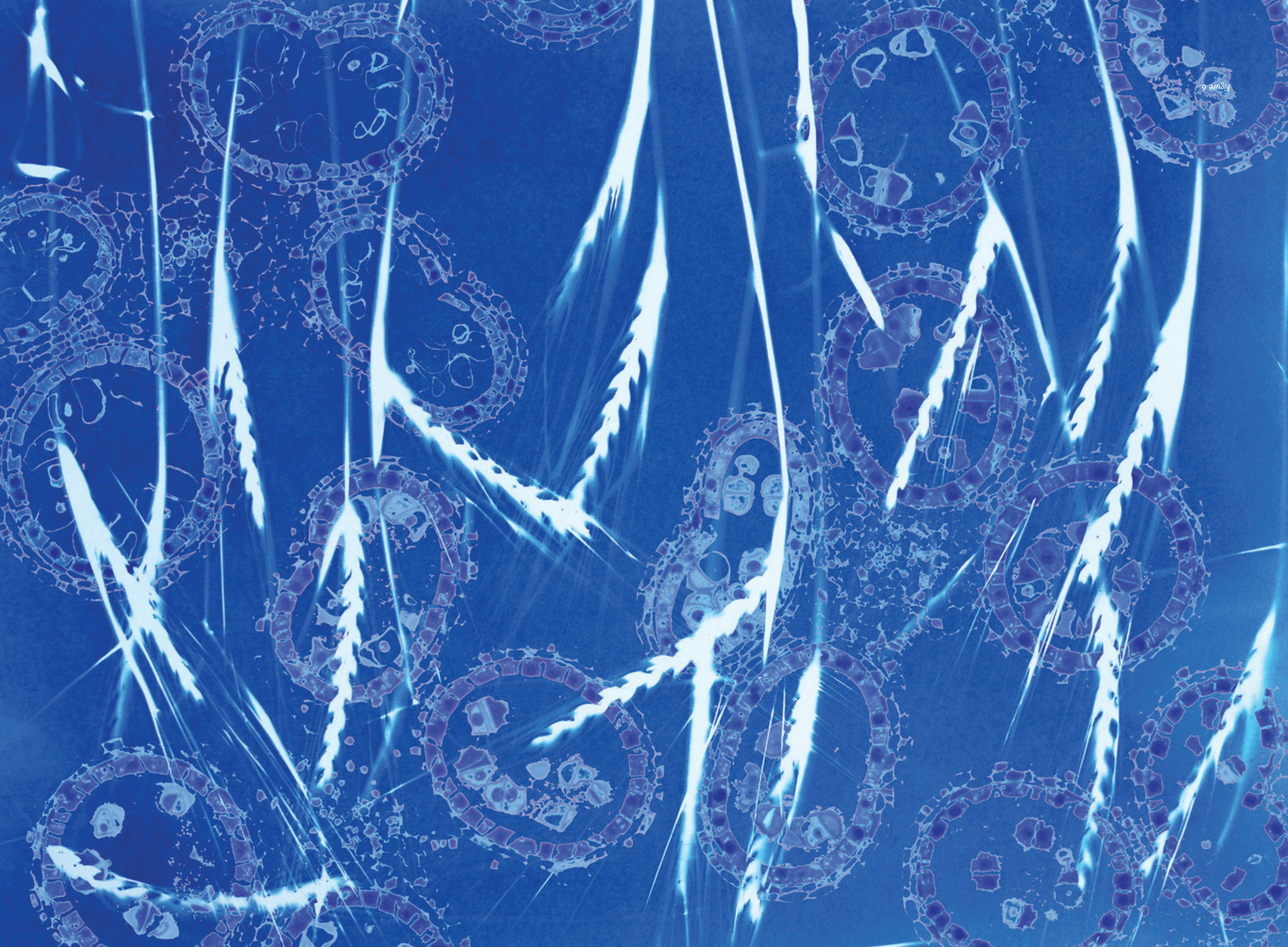


Figure 6.

Figure 7.

Figure 8.

Figure 9.

out for a research project suitable for collaboration between Rob and myself. In a large research institute as the MPIPZ, some projects make intense use of the different microscopy techniques available. In 2017, one of these projects was by PhD student Marine Przybyl from Ivan Acosta's group on male reproductive development in barley.

The reproductive organs of self-pollinating species, such as barley, comprise a female and male organ, named pistil and anther, respectively, and are synchronized in development for successful reproduction.

Today, higher crop yields are achieved by the production of hybrid seeds. Compared to their parental lines, higher yields result from the benefit of hybrid seeds - the so-called `heterosis effect` or `hybrid vigour`. However, for the production of hybrid seeds, one parental line needs to be efficiently `emasculated´, which is a complex task as pistil and anthers are synchronized in development. Therefore, Marine Przybyl studies genetic factors which control anther development in barley in order to identify new targets and simplify large-scale crosses for the production of hybrid seeds. These genetic factors were identified from an existing barley collection consisting of 252 mutants which are mainly affected in anther development and consequently are male sterile (Druka et al., 2011; Franckowiak and Lundqvist, 2012; USDA Germplasm Database). A large part of this male sterile mutant collection, including the mutants she investigates, resulted from natural variation representing mutants which spontaneously occur in the field.

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Figure 10.

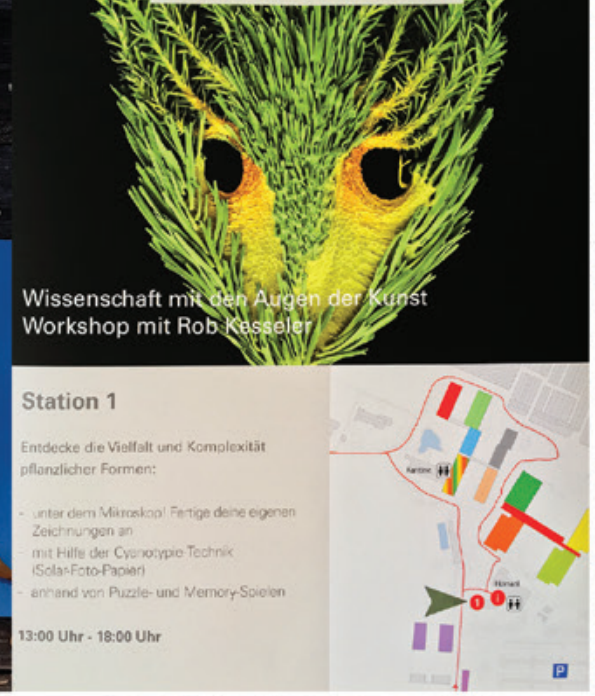

Wissenschaft mit den Augen der Kunst
Workshop mit Rob Kesseler
Station 1
Entdecke die Vielfalt und Komplexität pflanzlicher Formen:
- unter dem Mikroskop! Fertige deine eigenen Zeichnungen an
- mit Hilfe der Cyanotypie-Technik (Solar-Foto-Papier)
- anhand von Puzzle- und Memory-Spielen
13:00 Uhr - 18:00 Uhr


Figure 12.

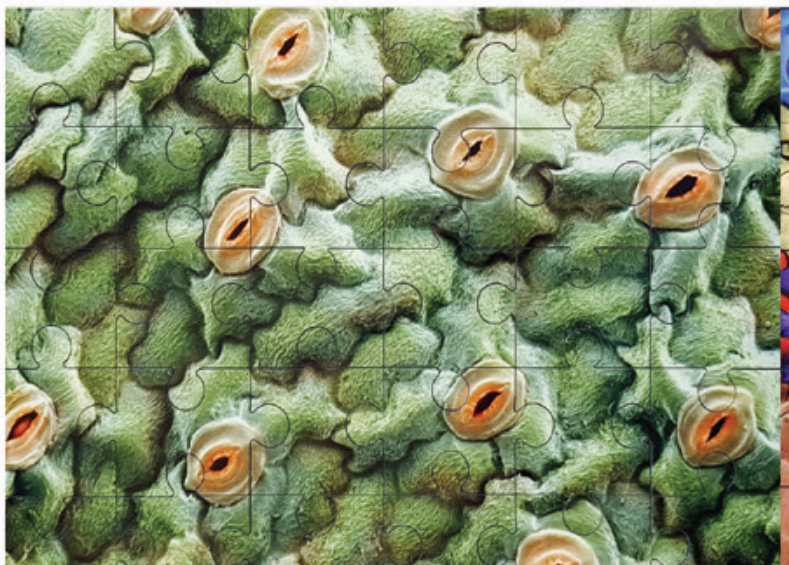
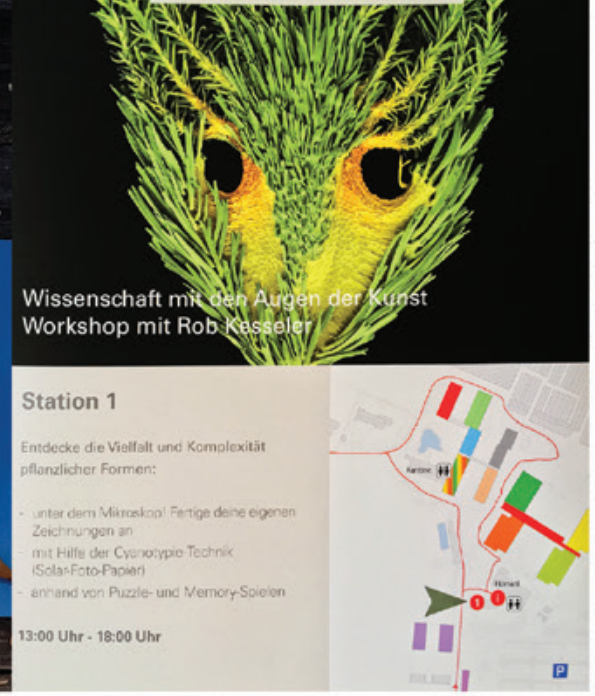


Figure 10.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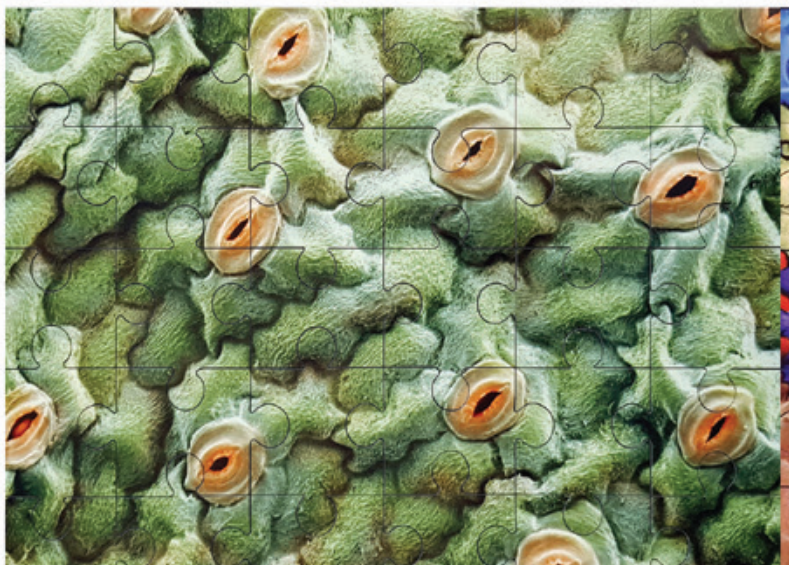

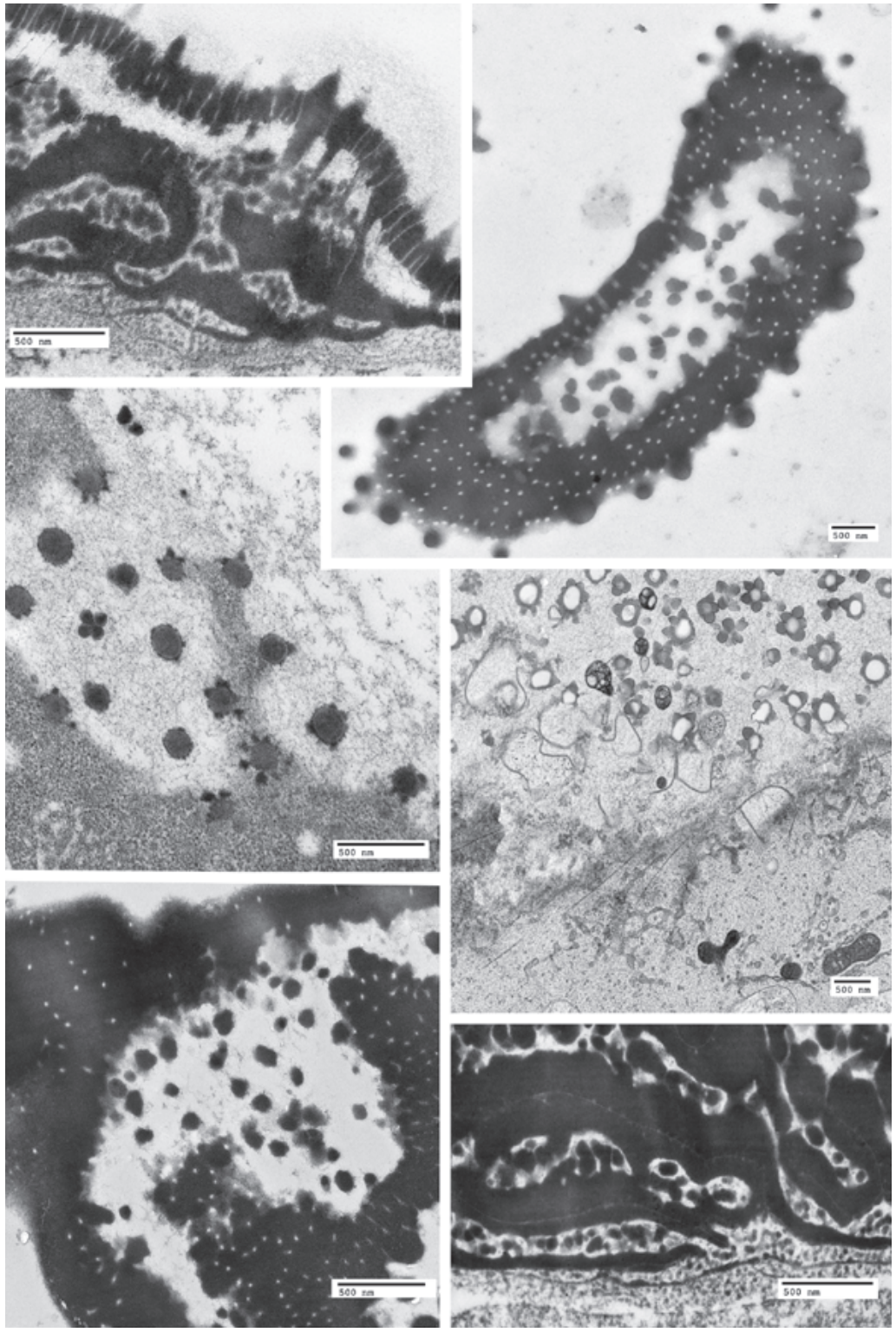

Figure 11.

In addition to genetic and physiological analyses of wild type and mutant barley plants, an important part of the project is to describe anther development including morphological, anatomical, histological and cytological features with a special focus on the tapetum and the developing pollen grains. To this end, we use microscopy techniques over multiple scales ranging from stereo microscopy over bright field to scanning and electron microscopy. We combine and correlate all the results in order to "get a better picture" of the samples, both literally and figuratively speaking. Barley anthers are very attractive but at the same time very challenging samples to work with. Employing both conventional chemical fixation as well as high pressure freezing combined with freeze substitution, we realized that especially the tapetum is a very sensitive tissue and prone to artefacts by any sample preparation technique. Yet, when well preserved, tapetum cells are most fascinating due to their wealth of endomembrane compartments and the drastic changes these cells undergo through anther development. The cell walls of developing pollen grains and the tapetum cell wall decorated with Ubisch bodies are great examples for the stunning complexity of plant structures, revealed by transmission electron microscopy of ultrathin sections cutting through the wall at different angles (Figure 11).

After sending Rob some of my TEM images of barley samples, he welcomed the opportunity to collaborate with us. Communicating our research to audiences beyond the scientific community has become an important part of our responsibility to increase understanding of the vital work we do. To this end we constantly need to explore new ways of expression and engagement and the upcoming Max Planck Day in September 2018 offered the perfect occasion to celebrate our collaboration in a more public context.

The fruits of 'cross-pollination' between science and art

Puzzle patterns and prints

When the Max Planck Day finally arrived on September 14th 2018, Ulla, Marine and I had a rich programme to offer! Many ideas resulting from fruitful discussions between the three of us materialized into a hands-on microscopy work station (Figure 12). In addition to providing fresh samples from the MPIPZ show garden and the fields surrounding the institute, we had invited all researchers of the institute to provide different samples that would allow the Max Planck Day visitors to explore the hidden world of plants with stereo and bright field microscopes. In addition to brief scientific descriptions of the samples, we had a range of drawing tools at hand and I encouraged and assisted people in drawing, the art of looking with one eye through the microscope and one down on the drawing proving quite a fascinating challenge. For younger visitors, we had prepared jig-saw puzzles from micrographs, including some of my hand-coloured SEM images of leaf structures and seed coatings. Our memory games with images representing the plethora of plant breeding research of our Institute also drew a lot of attention and presented a perfect opportunity to discuss what the images were and how they are used within our research. The cyanotype technique was also a huge success, it encouraged visitors to select plant specimens and really examine their structures to generate beautiful blue and white silhouettes, a mixture of Art & Science and a souvenir to take home of their day at the MPIPZ. Finally, Ulla and I gave a lecture explaining our different yet complementary approaches to studying and visualising plant samples entitled "to Know and to Show – cross pollination of science and art". It was a perfect conclusion to an enriching day and a confirmation of the value in interdisciplinary collaboration.

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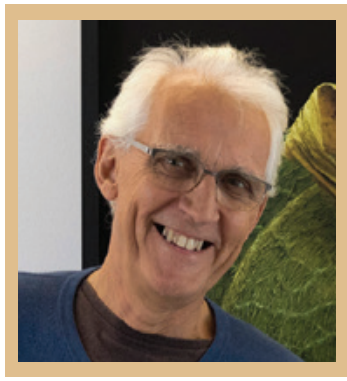

Rob Kesseler is a visual artist and Chair in Arts, Design & Science at the University of the Arts London. A former NESTA Fellow at Kew and Research Fellow at the Gulbenkian Science Institute, Portugal, he collaborates with botanical scientists and molecular biologists to explore the living world at a microscopic level. He exhibits internationally with recent shows in America, Chile and Greece and has published an award winning series of books on Pollen, Seeds and Fruit with Dr. Madeline Harley and Dr. Wolfgang Stuppy of Kew.

Ulla Neumann was born in Koblenz. Before becoming the TEM specialist in the Central Microscopy service group of the MPIPZ in 2008, she has lived and worked in Marburg, Paris, Oxford and Hannover. She is interested in all aspects of botany but most fascinated by the complexity and beauty of plant cells as revealed by any microscopy technique.

Marine Przybyl of French and German origins was always fascinated by plants and studied horticultural sciences in Hanover for her undergraduate degree. To intensify her special interest in crops she completed her master studies in ´Molecular Crop Science´ at the University of Bonn. Currently, she works on her PhD thesis on male reproductive development in barley in the group of Ivan Acosta at the MPIPZ.