# The Living Canvas: Interactive Chloroplasts

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## Abstract

"*The Living Canvas*" is a science/art/educational exhibit in which aesthetic experience is the vehicle to examine photosynthesis in the context of its central role in life on Earth. The artwork is a series of visually compelling, exhibition-quality images created by light-dependent positioning of chloroplasts in leaf cells. The "Living Canvas" will give visitors the opportunity to examine the results of how leaf cells act as a living canvas as chloroplasts move in response to light and how the process was used to create the art on living canvases. The exhibition incorporates live leaves, high definition imagery, digital painting and interactivity to reveal the process of chloroplast movements as they occur from the level of a single cell up to how those subcellular changes affect the optical properties of whole leaves to maximize photosynthesis. The experience is designed to stimulate a sense of intrigue and awe in ways that are intended to enhance the visitors' awareness of plant life and their relationship to plants in their environment.

**Keywords**: Fine arts; Photosynthesis; Plant biology; Chloroplast movements.

**Index Terms**: H.5.2 [Information Interfaces and Presentation]: User Interfaces-Graphical user interfaces (GUI)

## 1 The Living Canvas

"*The Living Canvas*" is an art and science collaboration that resulted in an interactive science/art/educational exhibition in which aesthetic experience is the vehicle to examine a particular scientific phenomenon -photosynthesis- in the context of its central role in life on Earth. Photosynthesis is the light dependent process by which plants reduce carbon dioxide from the atmosphere into complex carbon compounds that constitute their biomass. "*The Living Canvas*" experience is designed to stimulate a sense of intrigue and awe in ways that are intended to enhance the visitors' awareness of plant life and their relationship to plants in their environment.

This collaboration resulted in a series of visually compelling, exhibition-quality images created by light-dependent positioning of chloroplasts in leaf cells alongside applications highlighting photosynthesis in experiential touch-screen interactive tables (4x7 feet). Together, these presentation modules give visitors the opportunity to examine the results of how leaf cells act as a living canvas as chloroplasts move in response to light and how the process was used to create the art on living canvases. The exhibition incorporates a number of assets, including high definition imagery and time-lapse movies that reveal the process of chloroplast movements as they occur from the level of a single cell up to how those subcellular changes affect the optical properties of whole leaves to maximize photosynthesis. The work premiered at the Indiana University Grunwald Gallery of Art from August 30 to October 11, 2013. The exhibit is appropriate for installations in a variety of venues, including botanic gardens, art spaces, and museums. A companion website is also being developed.

## 2 Interacting with Chloroplasts

"*The Living Canvas*" examines live leaf structures and monitors the movement of chloroplasts in response to light. This scientific phenomenon is harnessed as images in live leaves that appear as a result of the final location of chloroplasts. We use processes of photosynthesis as an artistic medium to visualize a scientific process embedded in the leaf itself. Rather than using numerical data to describe the movements of chloroplasts we monitor their movements visually by recording their hue patterns.

By manipulating light, we coax chloroplasts to align themselves in the leaf cells according to light patterns we provide. The chloroplasts provide varying shades of green based on their positions in the leaf cells so their photosynthetic activity is apparent as the green hues congregate to become images within the leaf. The chloroplasts operate as a type of biological paint during the photosynthetic process and allow us to observe the evidence of their movements over time.

Figure 1. A gallery visitor holds a green coleus leaf that has undergone our photosynthetic process and has embedded in the live leaf the image of an artist painting at an easel that is in the shape of a leaf.

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Figure 2. "*Towards the Edge of the Horizon*" Margaret Dolinsky, Roger Hangarter 2013. Live leaves on digital canvas. Here the process of photosynthesis is utilized as an artistic medium where images can appear in the surface of nicotiana leaves.

In the experimental and artistic process we are ascertaining data changes in response to specific light sources provided to the live leaf. In effect, our science generates an artistic process whereby the live leaf is experiencing a photosynthetic episode as it happens in nature. In Figure 1 a green coleus leaf is held up and shows the image of an artist painting on an easel that is in the shape of a leaf.

## 3 Exploring Light Phenomena as Art

This art and science collaboration explores light phenomena relating to photosynthesis to create art within living leaves as an art medium. Here a virtual reality artist (Dolinsky) works with a plant biologist (Hangarter) to use light to control the position of chloroplasts in the cells of live leaves, a fundamental process in all green plants.

Using hand drawn imagery and light, leaves can become living easels to display patterns and drawings. Through light-dependent chloroplast movements and leaf structural properties, the leaves can be coaxed into producing varying shades of green hues that formulate clear and recognizable images, and even animations. The resultant ephemeral imagery is embedded within the live leaf structure and can be readily shifted by changing the way light impinges on the leaf surface. The leaves are incorporated into paintings through a digital canvas.

The drawings and paintings created by Dolinsky are the result of hypnopompic imagery that are created in sketchbooks, either paperbound or electronic, using Jung's process of active imagination. Her images often consists of whimsical portraits that reveal the intimacy of complex relationships. The artwork is then scaled and printed on transparency film which is placed over suitable leaves. The masked live leaf is then irradiated with bright white or blue light to induce the chloroplasts to move. In areas that are shaded, the chloroplasts will accumulate along the top and bottom of the cells in the leaf. In areas that receive bright light (clear areas of the transparency), the chloroplasts move to the edges of the cells.

After the light exposure and removal of the transparency, the image will appear in the leaf when illuminated correctly (back light or reflected light depending on the plant species). The leaf is then digitally photographed at high resolution. The resulting digital images are incorporated into digital paintings and the resulting works are then displayed on a flat panel monitor. They can also be printed onto backlight film for mounting and display on a framed backlight box. An example of the images in nicotiana leaves are shown in Figure 2 with the piece, "*Towards the Edge of the Horizon*" by Margaret Dolinsky and Roger Hangarter created in 2013.

## 4 Interactive Exhibits

This collaboration also incorporates interactive touch screens that invite visitors to experience our art studio and science laboratory virtually. Visitors control drawings, leaves and studio/laboratory set ups in order to generate animations and manipulate microscopic imagery. One of the aims of our exhibition is to allow visitors experience what is occurring on the cellular level during photosynthesis and how that drives the art process. See Figure 4.

By interacting with high resolution microscopy images and time-lapse movies, the process of chloroplast movements is revealed as they occur from the level of a single cells to whole leaves. The resultant images also show how the subcellular changes affect the optical properties of leaves, which relates to how chloroplast positioning maximizes photosynthesis.

This presentation will give visitors the opportunity to examine the results of how chloroplasts act as living pixels that move in

Figure 3 "*The Living Canvas*" was a part of the "Imagining Science" exhibition at the Grunwald Gallery of Art, Indiana University in 2013. Artwork was created using chloroplast movements in live leafs and the photographs were collaged with paintings. The artworks shown include (from left) "*Monsieur et Madame des Chloroplastes*," "*Illusions of Desire*," "*Sous La Lune*," and "*Towards the Edge of the Horizon*."

response to light and render the art in a living canvas. The exhibition will display a number of high resolution art images created in living leaves to illustrate the dynamic biology of green plants.

## 5 Creating an Image on a Live Leaf

One of the interactive artworks explains the artistic process and the science behind "*The Living Canvas*." It allows the visitor inside the artistic studio to choose an image and a leaf and take them through our process.

Through visual cues where the activity is highlighted in a pulsing graphic, the visitor is guided through each step in the process, beginning by providing water for the recently clipped, but still living canvas (leaf). The visitor is then presented with a collection of drawings, from which one may be chosen and placed on the exposure table. A corresponding leaf then glides into place under the drawing. A pulsing sun directs the user to shine light on the leaf, resulting in a time-lapse video of the image as it appears in the leaf as its own chloroplasts are repositioned in response to light.

Visitors can repeat the process multiple times to see various images and leaf combinations. See Figure 4 and 6 for visitors manipulating the interactive artwork that allows them to see the artistic medium in process. This helps explain to visitors how the images were generated and helps explain the science behind the visualizations. For visualizations, see Figures 2, 3, 5, and 7.

Figure 4. Visitors manipulate leaves, drawings and light source to simulate the photosynthetic process as an artistic medium.

## 6 Manipulating the Movement of Chloroplasts

Another interactive artwork explains the movement of chloroplasts by displaying microscopy video of chloroplasts moving inside actual plant cells. Visitors' touch acts as a light source so that the chloroplasts move and align themselves accordingly when they sense the light source. Visitors can zoom in and out of the cells and

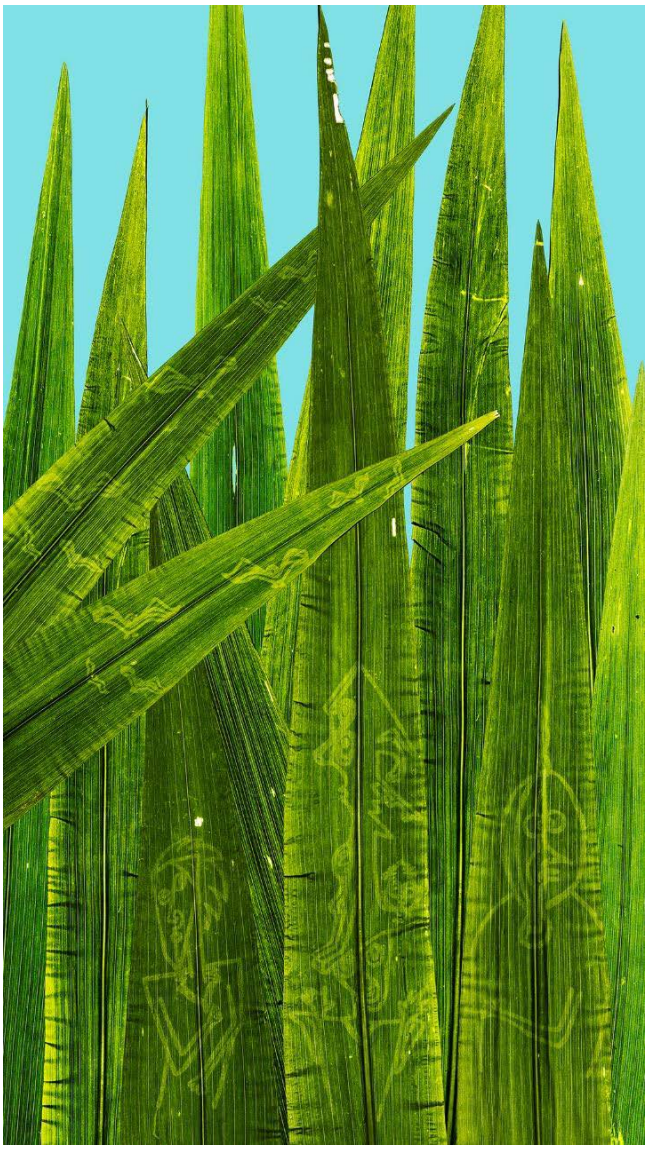

Figure 5. "*Harvesters of the Sun*" Margaret Dolinsky, Roger Hangarter 2013. Live leaves on digital canvas. Our scientific process embeds Dolinsky's art in live corn leaves by directing chloroplast movements.

create a matrix of chloroplasts that simulates the chloroplasstructure in a live leaf. As the visitor zooms farther out, the matrix grows, showing more videos at each level. At the lower zoom levels, so many chloroplasts are visible that the visitor can actually draw live sketches on the simulated leaf surface. See Figure 6 where visitors are touching the plant cells as if introducing light to the chloroplasts. The chloroplasts then react by realigning themselves and changing the hue of the cell structure and changing the shading of green at that location within the leaf.

## 7 Conclusion

Scientific visualization comprises a new data stream in "*The Living Canvas*" where the location of chloroplasts within live leaf cells are monitored by causing them to move and to verify their movement by creating specific formations that result in visual imagery on the leaf surface. The images created in the leaves are photographed and sometimes combined with digital paintings to create more complex art images. These images are best shown on flat panel monitors as the luminescence of the screens is reminiscent of the light that is required for the photosynthetic process. The images in the flat panels work well with the interactive table artwork because they reveal the photosynthetic process both as an artistic media and as a scientific phenomenon. "*The Living Canvas*" is the scientific visualization of a scientific process in its natural habitat - the living leaf.

Figure 6 Gallery visitors interacting with the artwork are touching the plant cells as if introducing light to the chloroplasts. The chloroplasts then react by realigning themselves and changing the hue of the cell structure and changing the shading of green at that location within the leaf.

## 8 Acknowledgements

We would like to thank the Advanced Visualization Lab and David M. Reagan for working with us to realize our vision of the interactive tables. The interactive applications were created using a combination of commercial-off-the-shelf multi-touch hardware and custom software. This exhibition uses IQ-Tables, multi-touch tables designed and built by Indiana University's Advanced Visualization Lab.

The Advanced Visualization Lab is part of the Research Technologies division of the University Information Technology Services. Research Technologies is a Pervasive Technology Institute Cyberinfrastructure and Service Center.

Each IQ-Table consists of a 55 inch display and a small computer embedded in a portable travel case. Affixed to the display is multi-touch overlay capable of detecting up to 12 simultaneous touch points. See Figure 5 for an image of the tables in the Grunwald Gallery of Art at Indiana University.

The two touch applications were developed using the Open Exhibits multi-touch framework. Open Exhibits allows the creation of multi-touch, multi-user applications using a combination of ActionScript and the open standards CML (Content Markup Language) and GML (Gesture Markup Language). These applications are then deployed using the Adobe Flash player.

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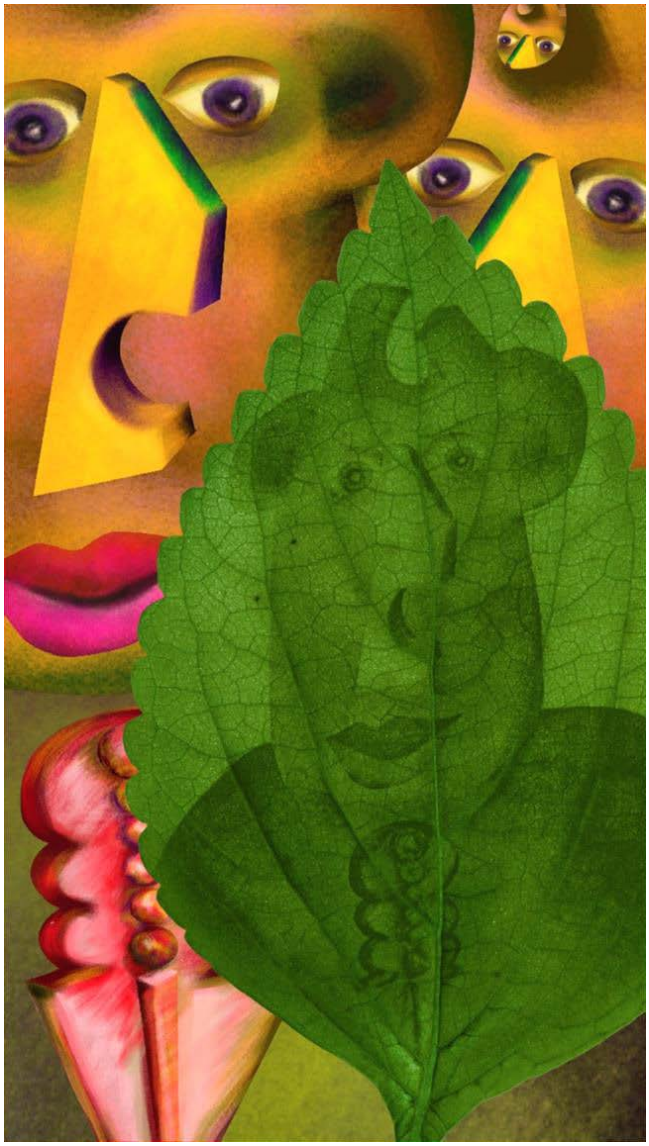

Figure 7. ”*Monsieur et Madame des Chloroplastes*” Margaret Dolinsky, Roger Hangarter 2013. Live leaves on digital canvas.