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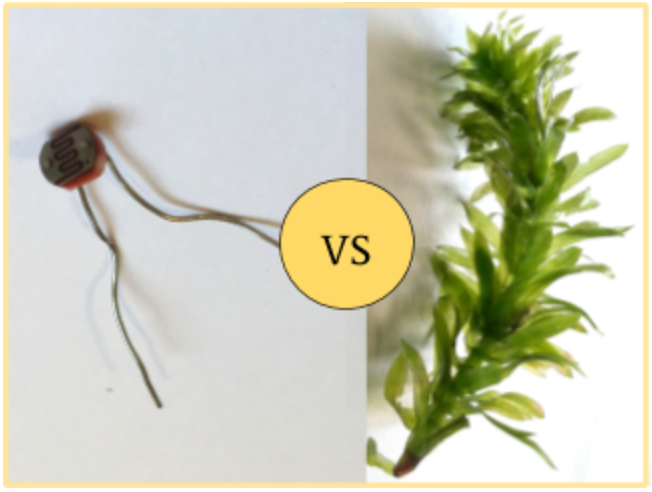
Biological and electronic sensors: How light intensity is perceived by *Egeria densa* chloroplasts and photoreceptor LDR ?

To feed ourselves, we eat nutrients contained in food, and our body uses these different components to stay alive. Plants also need elements to grow and develop during time, and their main source of energy is… **light**.

Indeed, with a process called photosynthesis, the light emitted by the sun is transformed by little organelles (a cell sub-unit) called chloroplasts, into chemical energy.

This chemical energy is stored by the plant to grow. Creating energy with chloroplasts release heat. Too much heat can be dangerous for the cell. When there is too much light, scientists have shown that chloroplasts move away from the light to decrease the production of chemical energy and heat [1]. We call this phenomena **light avoidance** or negative phototaxis. We considered this movement as a response to light for the cell.

We want to compare this biological sensor with a mechanical sensors. In our researches, we confronted chloroplast characteristics and a light dependent resistor of arduino.



[1] Kasahara, Masahiro, Takatoshi Kagawa, Kazusato Oikawa, Noriyuki Suetsugu, Mitsue Miyao, and Masamitsu Wada. "Chloroplast Avoidance Movement Reduces Photodamage in Plants." *Nature* 420, no. 6917 (December 19, 2002): 829–32. doi:10.1038/nature01213.

*Egeria dens*First Candidate - the aquatic plant

- an aquatic plant, usually used to produce oxygen in aquarium, grows fast and as any plant has many chloroplasts ready to produce energy.

Our research aim is to *Egeria dens*identify the movement of chloroplasts in cells of in function of the light intensity. Then, compare the time response and the range with a light dependent resistor with arduino.

To observe the leaf under the microscope and see the chloroplasts in it, we have to get only one layer of cell. We tried many techniques, but the better one is scratching the leaf with a scalpel. If you want to know more how to do a microscope slide of an aquatic plant and use a microscope, look this lesson, made by a biology teacher. The slides are sequentially reserve in a dark place during 20 minutes with aluminum.

In scientific research, it is important to do several times the same experiment. : it is called **replication**.

So we observe six different slides. We tested three different light intensity : low, medium and high. (We used the microscope light). We expose the slide during 10 minutes, taking picture every minute. At the end we can compile all our pictures into a timelapse as shown here.

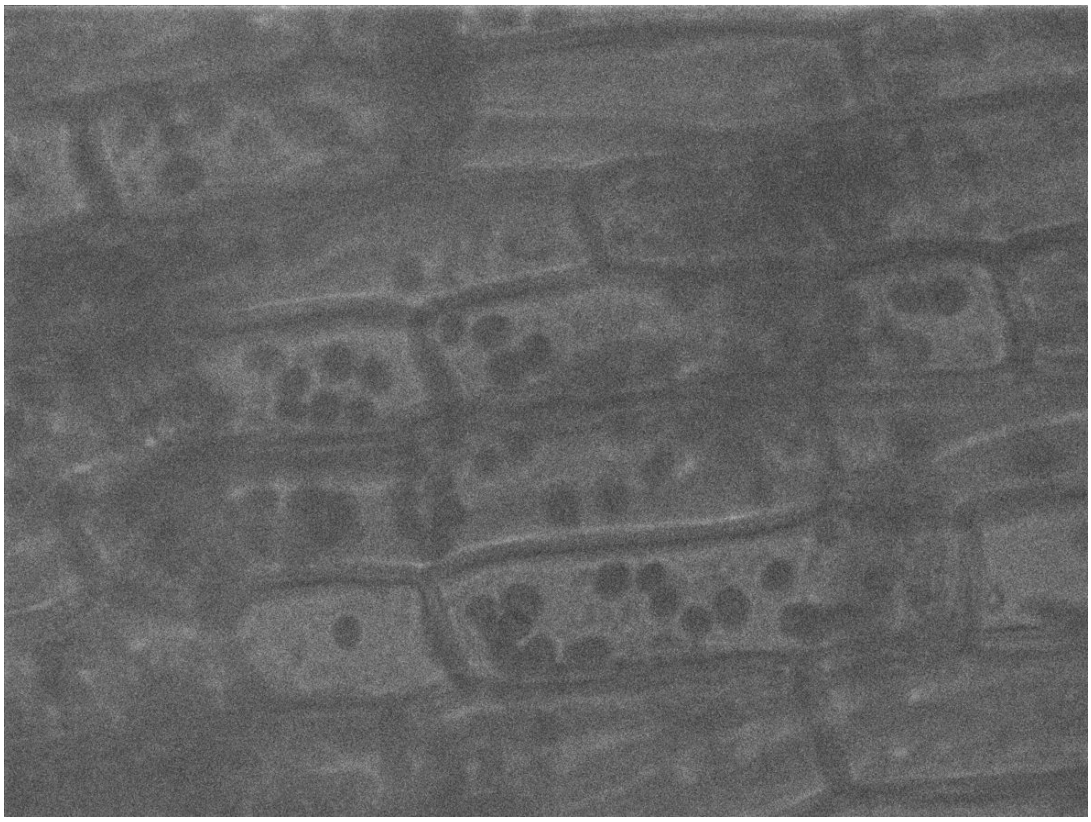


Figure 1 : This timelapse presents the observation of

cell under microscope x63 at medium light during 10 min. We can see some chloroplasts slightly moving in the cell. But almost none of them move themselves.

Our study shows that most of chloroplasts didn't move after 10 minutes of light exposure.
We imagine two hypothesis to explain this non-movement :

- the time response of chloroplasts is very slow, so no movement was able to be seen in only 10 minutes.
- The light was not enough intense to activate the movement mechanism.

In conclusion, chloroplasts seems to have a very long time response and a range of detection quite high.

Second Candidate - the arduino device

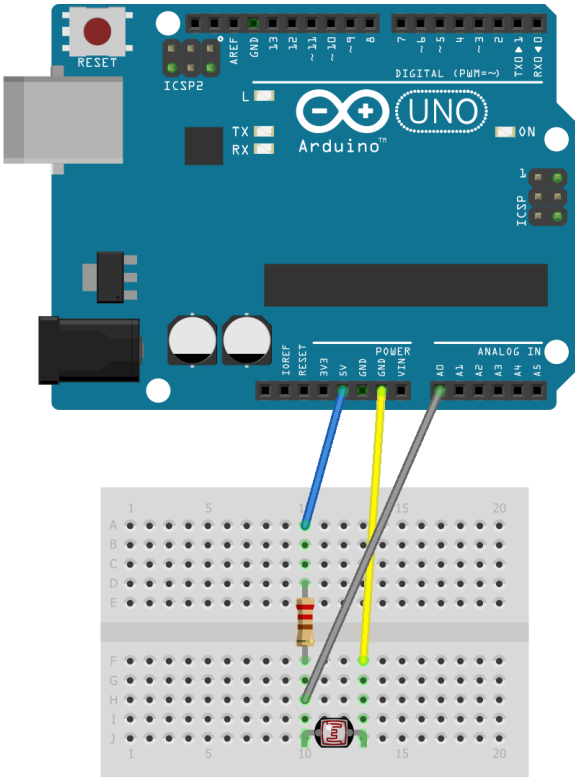
Light Dependent Resistor (LDR) are electronic sensor which modifies the voltage in electric cable when exposed to light. The voltage variation is interpreted by an **arduino device** and printed on a computer. Let's look at our arduino arrangement on this right.

We exposed the LDR to the same condition than the layer of cell : low, medium and high light intensity.

We have shown in our results that the electrical response is extremely sensitive at very low light intensity. However, the LDR sensor seems to be saturated in high intensity of light.

It means that the sensor is dazzled and can't quantify accurately the light intensity. In addition, we made two replicates of the measurement. We noticed that the two were quite different, up to 20% of variation.

LDR is sensible to low light but get saturated quickly. It is also not very precise, giving high variation.



Final verdict :

After observations and data analysis, we can conclude several statements :

- chloroplast reactions to light are much more unpredictable than we thought.

The light intensity doesn't seem to increase significantly chloroplast movements. Other phenomenons occur inside on cells, particularly in aquatic plant ones which complicate the observations of chloroplasts.

- LDR photoreceptor on the other hand is very sensitive on low light intensity, but saturated quickly. But it is definitely more constant than chloroplasts if your only goal is to quantify light intensity changes.

Further experiments should be done to explore chloroplast potentiel. Look this video to see movement of chloroplasts in another aquatic plant .

But before them, we officially declare LDR photoreceptor winner of the tense competition, in which biology competed electronic.

We made a beautiful power point, if you need more information on the protocol we used to compare these two sensors. To go deeper on what we did, go on GitHub ! And finally, we tweeted all among our experiments, get a look on our storify.

Bibliography :

Videos

- Aquatic plant slide and microscope observations : "Elodea Plant Cells: How to Prepare a Wet Mount Microscope Slide - YouTube." Accessed January 23, 2017. https://www.youtube.com/watch?v=b6_SuhG_VPM&list=PLYAHG0tkFsN056qsZwV-nYSnoueNdDqKs.
- Chloroplast movements : "Elodea under the Microscope - YouTube." Accessed January 23, 2017. https://www.youtube.com/watch?v=A0fjWhFN-EI.
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Scientific articles

- "Chloroplast Avoidance Movement Is Not Functional in Plants Grown under Strong

Sunlight - Higa - 2016 - Plant, Cell & Environment - Wiley Online Library." Accessed January 20, 2017. http://onlinelibrary.wiley.com/doi/10.1111/pce.12681/full.

- Kasahara, Masahiro, Takatoshi Kagawa, Kazusato Oikawa, Noriyuki Suetsugu, Mitsue Miyao, and Masamitsu Wada. "Chloroplast Avoidance Movement Reduces Photodamage in Plants." 420, no. 6917 (December 19, 2002): 829–32. doi:10.1038/nature01213.

- "Chloroplast Avoidance Movement Reduces Photodamage in Plants : Article : Nature." Accessed January 20, 2017. http://www.nature.com/nature/journal/v420/n6917/full/nature01213.html.

- "Phototropin-Related NPL1 Controls Chloroplast Relocation Induced by Blue Light : Article : Nature." Accessed January 20, 2017. http://www.nature.com/nature/journal/v410/n6831/full/410952a0.html.

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- « Induction of Cytoplasmic Streaming and Movement of Chloroplast Induced by L-Histidine and its Derivatives in Leaves of Egeria densa ». 32, n° 2 (1 mars 1991): 253‑60. doi:10.1093/oxfordjournals.pcp.a078071.

You can see our other document in the Github of Biosensors :
https://github.com/learningthruresearch/Biosensors2017