"MUTANTS PLANTS" WORKSHOP PROTOCOL

DIDACTIC GUIDE FOR RESEARCHERS AND INSTRUCTORS TO CONDUCT A SCIENCE WORKSHOP WITH GROUPS OF SCHOOL STUDENTS AGED 10 TO 14

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The workshop "Mutant Plants" was designed jointly by the Centre for Research in Agricultural Genomics (CRAG) and the Research Centre for Scientific and Mathematical Education (CRECIM) from the Autonomous University of Barcelona (UAB), both located in Barcelona (Spain). This workshop was created thanks to the financial support of the Spanish Foundation for Science and Technology (FECYT) and the Severo Ochoa program of Excellence Centres, both from the Spanish Ministry of Economy, Industry and Competitiveness.

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**The approximate duration of the workshop is 2h30 min.*

1. ABOUT THE “MUTANT PLANTS” WORKSHOP

The “Mutant Plants” workshop pursues the dual aim of **promoting scientific vocations** and **publicizing the importance of Plant Science to meet current and future societal challenges**. This workshop was created in a collaborative work between a scientific institution –CRAG–, a group of experts in STEM education –CRECIM– and a primary school –CEIP Joan Maragall, Sant Cugat del Vallès–, following the Responsible Research & Innovation (RRI) principles.

Also following the RRI principles, the “Mutant Plants” workshop uses an inquiry-based learning model, in which the students act as “real” scientists. In this sense, the students are asked to help to two CRAG researchers – Soraya Pelaz and Jaime F. Martínez– in finding and analysing the phenotype of the mutant plants they are working with. This design supports the development of attentive observation, critical thinking, and collaborative skills in the students.

Soraya Pelaz is an ICREA research professor at CRAG since 2003. Her group studies how plants know when to flower in response to external and endogenous signals and the genes responsible for the flower development. Lately they have focused on trichomes as putative biofactories for anticancer and antimalarial compounds, generating hairy plants of species known for their anticancer properties. In our workshop, we use a hairless mutant of *Arabidopsis*, which has a mutation in the *GLABRA2* (*GL2*) gene that is responsible for trichome initiation. Specifically, we use the allele *gl2*-1

Jaume Martínez is an ICREA researcher professor at CRAG since 2003. His group studies how plants respond to vegetation proximity, which elicits a bunch of responses known as the shade avoidance syndrome (SAS), which are mediated through the phytochrome photoreceptors. In our workshop, we use an *Arabidopsis* mutant deficient in phytochrome B (*phyB-9* allele), which has an impaired perception of light.

A video on the workshop can be seen here.

The workshop can be done exactly as it is proposed in this protocol, or be adapted to your institution’s lines of research.

About the Centre for Research in Agricultural Genomics (CRAG)

The Centre for Research in Agricultural Genomics (CRAG, https://www.cragenomica.es/) is a centre that takes part in the CERCA system of research centres of the Government of Catalonia, and which was established as a consortium of four institutions: the Spanish National Research Council (CSIC), the Institute for Agri-Food Research and Technology (IRTA), the Autonomous University of Barcelona (UAB) and the University of Barcelona (UB). CRAG's research spans from basic research in plant and farm animal molecular biology, to applications of molecular approaches for the breeding of species important for agriculture and food production in close collaboration with industry. CRAG has been recognized as "Centro de Excelencia Severo Ochoa 2016-2019" by the Spanish Ministry of Economy, Industry and Competitiveness.

About the Research Centre for Science and Mathematics Education (CRECIM)

The Research Centre for Science and Mathematics Education (CRECIM, www.crecim.cat) is a Centre of the Education Sciences Faculty in the Autonomous University of Barcelona. The centre is dedicated to research in the Science Didactics field and STEM (acronym for Science, Technology, Engineering & Mathematics) disciplines. It has extensive experience in research projects development and in offering educative evaluation and didactic counselling to institutions.

About the Spanish Foundation for Science and Technology (FECYT)

The Spanish Foundation for Science and Technology (FECYT, https://www.fecyt.es/en) is a public foundation dependent on the Spanish Ministry of Economy, Industry and Competitiveness. Its mission is to drive forward science, technology and innovation, promote their integration and proximity to Society and respond to the needs of the Spanish Technology and Business System.

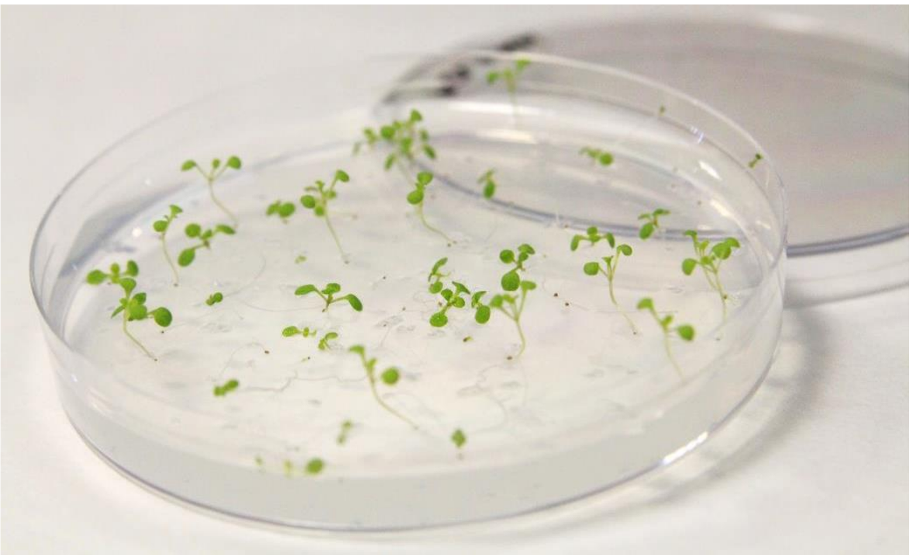
The Foundation is focused on increasing the interest of the Spanish citizens in Science, as well to give visibility to the scientific –technical and innovation results financed with public funds.

2. SHORT DESCRIPTION OF THE "MUTANT PLANTS" WORKSHOP

This workshop is meant to be done with a group of primary school students (aged 10 to 14) who visit a research centre. In this protocol, we explain how we do it at CRAG, with a group of 24 pupils and 4 CRAG researchers, who act as instructors. The whole activity takes approximately 2 hours. After the workshop, the students are divided in 2 groups to visit CRAG's installations (including the greenhouses and laboratories).

A specially designed *NOTEBOOK* is used throughout the workshop as a didactic guide that the students fill in. The rest of the material needed for the workshop is detailed below in this document (*8. MATERIAL*). The students are divided in 4 "research groups" (6 people/each group) that sit around the same table. Each of these groups has an instructor (usually a young researcher) assigned.

In the first part of the workshop, the students discover three model plants: rice, Micro-Tom tomato and *Arabidopsis thaliana*. In the second part of the workshop, the students work with *in vitro* grown arabidopsis seedlings and use binocular lenses. In this second part of the workshop, CRAG researchers Soraya Pelaz and Jaime Martínez, who appear on video, propose a challenge to the students. After introducing themselves and their research projects, these two researchers ask the students to help them in identifying mutant plants that are mixed with wild-type plants. In particular, Martínez asks to identity those mutants that "cannot see properly" and Pelaz asks to identify those mutants that are "bald". Two of the "student research groups" work in identifying the "bald" mutants, and the other two groups work in identifying the mutants that "can't see properly". After this, the whole group of 24 students share their conclusions, and practical applications for these discoveries are imagined and discussed. At the end of the workshop, the students meet the CRAG researchers Soraya Pelaz and Jaime Martínez, who check on the work they have done.



We propose this workshop to be carried out at any interested Research Centre, adapting the protocol to its advantage.

3. PROPOSED EDUCATIONAL MODEL

In the following sections of this Didactic Guide, you will find a detailed description of the workshop activities as well as recommendations for the instructors that altogether propose an educational model by which the students construct the knowledge for themselves. This model (known as dialogical and social-constructivist) is opposed to the knowledge transmission model, in which the instructor gives the "correct" answers to every question.

Thus, this workshop is based on the following Modelling cycle (Garrido 2016[1], based on Baek et al. 2011[2]; Clement 2008[3]; Hernández et al. 2015[4]; Schwarz et al. 2009[5]; Windschitl et al. 2008[6]):

1. **Recognize the need of a model. To explain or act upon a phenomena**
2. **Express/use an initial model: Think individually.** We will find out what the students already know about the subject. During this phase, it is important to confirm what they really understand through precise questions. (E.g.: they may know the term "phototropism" but they may not understand entirely its meaning).
3. **Evaluate the model: analyse the level of adjustment with reality/testing the model**. Students will question their own initial ideas thanks to the experimentation. To do so, they will have to follow the protocol we propose. We should help them by asking them questions (E.g.: What has happened and why?).
4. **Review the model: sophisticate and improve inadequate specific aspects of the model with the help of other's ideas.** Students will sophisticate and improve specific aspects of their model to increase the descriptive, predictive and explanatory power of their own model. To do so, they will have to follow the protocol we propose. We should help them by asking them questions (E.g. How can you explain that…?).
5. **Express a final consensus model:** We will put together all the results, debate and help the students interpret and clarify their key ideas from the workshop. The question to answer is "What have we learned today?"
6. **Use the model to predict or explain new phenomena:** The students will play with their imagination and will be asked to apply what they have learned to help solving current societal needs.

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[1] Garrido, A. (2016). Modelització i models en la formació inicial de mestres de primària des de la perspectiva de la pràctica científica [Models and modelling practices in primary-school initial education from the Scientific Practices perspective]. Doctoral thesis. Universitat Autònoma de Barcelona, Barcelona, Spain.

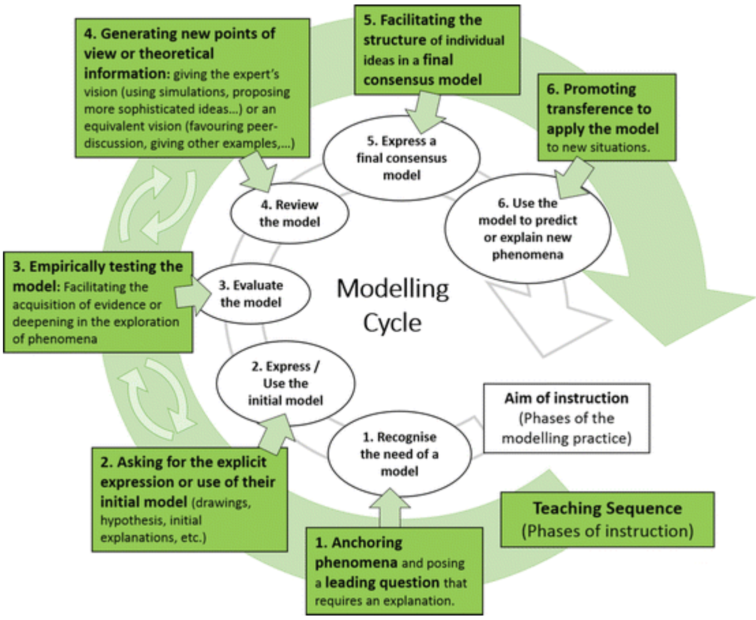
[2] Baek, H., Schwarz, C., Chen, J., Hokayem, H., & Zhan, L. (2011). Engaging elementary students in scientific modeling: The MoDeLS fifth-grade approach and findings. In M. S. Khine & I. M.Saleh (Eds.), Models and modeling (pp. 195–218). Dordrecht: Springer.

[3] Clement, J. J. (2008). Student/teacher co-construction of visualizable models in large group discussion. In J. J. Clement & M. A. Rea-Ramirez (Eds.), Model based learning and instructionin science (pp. 11–22). Dordrecht: Springer.

[4] Hernández, M. I., Couso, D., & Pintó, R. (2015). Analyzing students' learning progressions throughout a teaching sequence on acoustic properties of materials with a model-based inquiry approach. Journal of Science Education and Technology, 24(2–3), 356–377.

[5] Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., et al. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. Journal of Research in Science Teaching, 46(6), 632–654.

[6] Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. Science Education,92 (5), 941–967



Modelling cycle followed in this workshop (Garrido 2016)

We will value the **Comprehension** of the students above the Correction. For this purpose, we will limit the specific vocabulary, using analogies and giving the students time to think, propose and rethink their own ideas.

4. GOALS AND CONTENTS

Goals	Contents ABOUT science	Contents OF science
1. **Function approximation/ utility of the** science and the way of being a scientist, acquiring a **positive and realistic vision of the scientific activity and of the scientists.** 2. **Recognising** characteristic aspects of plant research like the use of **model organisms**. 3. **Introduction to the idea of mutation,** being able to identify its **expression** and **represent** it clearly. 4. **Argue based on proof.** 5. **Proper use of the lab material.**	1. **Nature of the scientific activity:** Scientists are "normal" people who perform a pleasant/interesting activity. Scientists propose hypothesis, they have curiosity and creativity, observe in detail and take notes (They are hard workers), argue their ideas with colleagues (Team working) and they get conclusions from their observations (based on proof). 2. **Utility of research:** Scientists research to create new knowledge and/or to get useful products for the society. 3. **Use of model organisms and plant research:** Scientists use some specific plants (model organisms) for research, because they know them better, they grow faster and they are easier to manipulate.	1. **Mutation and expression:** Mutant plants are different from normal plants because scientists or nature have changed something in them before growing (E.g.: bad vision of the light, absence of "hair", etc.). Afterwards, when plants grow, we can detect that the mutant plants have some different aspect compared to the non-mutant plants, the difference is related to the change (E.g.: The plants are higher or smaller, they are hairier or hairless, etc.). 2. **Reasoning:** Affirmations justification/ Decisions about mutant plants based on proof (E.g.: Observation of different morphology between plants) and scientific knowledge (E.g.: Plants grow/ get taller to search for the light). 3. **Lab material use:** Proper use of binocular lens, model plants and Petri plates. 4. **Representation of the observations:** Clear representation of the significant differences between mutant and non mutant plants, observed through the lens.

5. THE WORKSHOP IN DETAIL

The 24 students are divided in 4 "research groups" of 6 people. Each group sits around one table and is supervised by one instructor (one main instructor and three supporting instructors). The main instructor will be responsible for supervising his or her assigned students, as well as conducting the whole workshop, with the help of an auxiliary PowerPoint presentation (*MATERIAL*), and paying attention to the timings. The three supporting instructors will supervise the three remaining student groups and will guide them when working in small groups is required.

PART 1. Observation of the plants (15min)

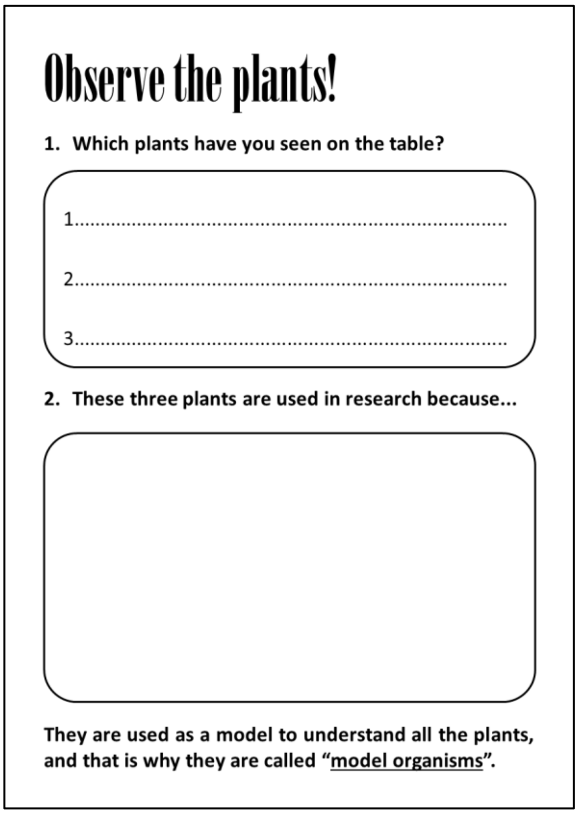
1. **PRESENTATION OF THE RESEARCH CENTRE (1 min):** Presentation of the instructors and the research centre. Emphasise the different kind of people working there: ages, nationalities, type of work (lab work, informatics, etc.)

2. **IDENTIFICATION OF THE MODEL ORGANISMS (10 min):** We show 3 plants to the students, without identifying them, and we ask the students to explain what plants do they know (if they have a garden). In small groups, the students think which plant is each one, with the help of their instructor. The instructor can give some clues:
   a. **Tomato plant** leaves have a characteristic smell, they can touch them. In addition, the instructors can help them look for some aspects: flowers, fruits, hairy shoot, etc.
   b. **Rice plants** can be identified by their seeds (rice) if they have some. If not, the instructors can help the students by asking them where do they think these spiky plants grow (near water) and if they remember some food that grows where there is a lot of water.
   c. The students have probably never seen an **Arabidopsis plant.** The plants should have flowers and fruit.

   Back to the bigger group. The students share the name of the plants they have identified. With the PowerPoint presentation, we help them identify each plant. We can explain that Arabidopsis is a "weed" very usually found in the fields. The students write the answers in their notebooks (**Question 1**).

3. **CONSIDERATIONS ABOUT MODEL ORGANISMS (4 min)**: We explain to the students that research groups work with those plants and we ask them: "What characteristics do you think a plant has to have to be "suitable" for research?" The students share their ideas with the group. We can help them get to the main characteristics of model organisms: they are plants that grow fast, are smaller than other plants, the researchers know them a lot, etc.

   The students should complete the **Question 2** in the notebook with their own words.



Observe the plants!

1. **Which plants have you seen on the table?**

1.………………………………………………………………

2.………………………………………………………………

3.………………………………………………………………

2. **These three plants are used in research because...**

They are used as a model to understand all the plants, and that is why they are called "<u>model organisms</u>".

PART 2. The scientists need us (20 min)

4. **PRESENTATION OF THE SCIENTISTS' VIDEO (10 min):** The instructor tells the students that they are going to help two researchers with their work and shows them the video (*MATERIAL*).

In the video, the scientists first present themselves and give a brief personal introduction (name, place of residence, hobbies, etc.). Then, they explain which the main characteristics to be a scientist are. They explain what does plant research mean and their research projects (light sensing and leaf hair appearance). They mention the idea of mutation and detecting differences between mutant and non-mutant plants. Finally, they confess that they accidentally mixed up mutant and non-mutant plants in Petri dishes and ask the students to help them identify the mutant individuals.

5. **PREPARATION OF THE METHODOLOGICAL PART OF THE WORKSHOP (10 min):** The instructor, in small groups, **prepares the students for the task** that they will be performing after the break. To do so:

a. The instructor exposes the Petri dishes without plants (only agar), letting the students touch the medium, and asking what do they think the medium contains to be able to grow a seed (water and mineral salts). Some clues could be: "Where do plants normally grow?, What do plants need to grow?" The instructor explains that scientist grow the plants in agar to be able to see them better. The students should know that the Petri dishes are fragile and that they shouldn't touch those that contain plants.
b. The instructor shows the students how to use a binocular lens and lets them look at different objects, leaves or an opened arabidopsis fruit. The instructor has to show the students how to focus, use the light, place the sample, etc. All the students should try to focus at least one time.
c. **The students are distributed in two groups**: two tables (12 students) will help one researcher (hairless plants) and the other two tables will help the other researcher (plants that don't see the light).

BREAK TO HAVE BREAKFAST (15 min)

When the students get back from the break, there will still be 1h of workshop ahead and the students should be prepared to work in groups.

PART 3: We research as scientists! And we analyse the results! (40 min)

6. **REMINDER OF THE MATERIAL AND THE ATTITUDE (2 min):** The students come back to the workshop space and put on the disposable lab coats. The principal instructor reminds them of the importance of being tidy and respectful with the material. We should also encourage them to be very observant and annotate the things they see.

7. **PREDICTIONS PROPOSAL (5 min):** Before working in small groups, the main instructor asks the students to predict what do they think they will see in the different Petri dishes. The students have to predict how do they expect the different mutants, hairless and "bad sight" plants, look like. It is very important to let them say whatever they think and don't correct them in any way. All the predictions are written down in a blackboard for everyone to see.

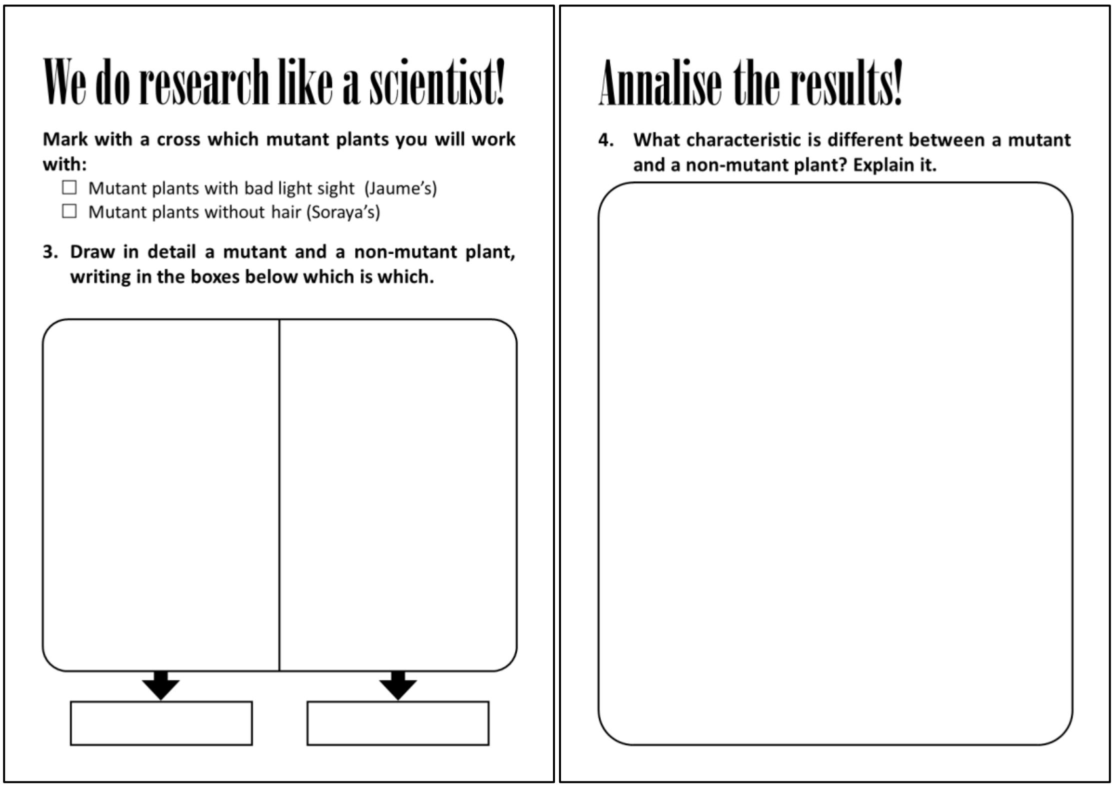
8. **DISTRIBUTION OF THE PETRI DISHES (3 min):** The instructors distribute the dishes depending on the plants their students will work with (two groups will work with "hairless" plants and two with "bad light sight" plants), reminding the students that every dish has mutant and non-mutant plants and that they have to mark the mutant ones. The students should mark the plants they will work with before **Question 3** of the notebook:

   a. **Mutant plants with bad light sight (Jaume's project)**: for Petri dishes grown in the light, mutant plants are taller than non-mutant plants. For Petri dishes grown in the dark, there are no differences between mutant and non-mutant plants (both are tall and white).
   b. **Mutant plants hairless (Soraya's project)**: the non-mutant plants have trichomes ("hairs") on their leaves, while the mutant plants are hairless.

9. **OBSERVATION OF THE PLANTS AND DRAWING (30min):** In small groups, every student uses the lens and draws in detail what he or she sees in the Petri dishes (**Question 3**) and writes the answer to the **Question 4**. When all the students of a group agree that they have found a mutant plant, they identify it with a permanent marker (they can draw a circle on the bottom of the Petri dish). During this activity every research group has an **instructor that should help them** in the following way:

    i. **Hairless plants**: The difficulty of this part lies in being able to properly focus the samples with the lens. The instructor should help the students at the beginning, letting one student focus a sample and asking another student to look at the same sample and identifying the first plant. After this, the students should take turns looking through the lens and marking the Petri dish, as there are several mutant plants. When they are not looking through the lens, they should be drawing the plants they have seen in the notebook and answering to the **Questions 3** and **4**. The instructor can also help them decide whether a plant is mutant before marking it, to assess their work. In some occasion, the students may be confused because some of the leaves of the plant have hair ("real leaves") and some don't (cotyledons). Then, the instructor should explain them the reason why: these specific leaves (the cotyledons), are the ones wrapping the seed and they are not "real leaves", so that's the reason why they don't have any hairs. Technical words, such as trichome (for "hairs") or cotyledons (for "fake leaves"), should only be used in case the instructor judges it necessary. When it is fitting, the instructor can help the students with some photos showing a hairy plant seen under the lens to see the amplified trichomes (*MATERIAL*).

    ii. Plants with bad light sight: In this dish, mutant and non-mutant plants can be distinguished without the lens, but the difficulty lies in knowing which ones are mutant and which aren't. The mutant plants are taller because they are looking for the light, and their leaves are green because they can see the light a little bit. The instructors should **not give the solution** to this problem, but they should guide the students with questions like: *If a plant doesn't see the light, what will it do to get more light? When a plant grows near a window, towards what direction does it grow?* After this debate, they should answer **Questions 3** and **4** of the notebook. Even with these questions, the students may not get that the mutant plants are the taller ones and the instructor should now show them the second dish.



OBSERVATION AND DRAWING OF THE SECOND PETRI DISH (<u>optional: only for the groups working with the bad light sight plants</u>, included in the time from section *9*):

The instructor distributes a second Petri dish and tells the students that this one also has mutant and non-mutant plants, but it has been grown in the dark, so they should consider that neither plants were able to see the light. This dish can be observed at plain sight, as the students can easily see that the plants are very tall and white. The instructor should encourage the students to rethink their previous idea about which plants were the mutant ones in the Petri dish grown with light by asking the following questions:

- 1st) Helping the students think why there are no differences between mutant and non-mutant plants (**Question 6**). Model questions: *Why are all the plants white*? *What happens to the plants when they get out of the dark?* As a last resource, the instructor can show a picture (*MATERIAL*) illustrating a plant emerging from the soil and becoming green with the light from the sun (photosynthesis). They should get the conclusion that all the plants from this dish behave as if they were blind, mutant or not.
- 2nd) Helping the students to rethink their answers to **Questions 3** and **4** given the new information from this dish (the plants, even without any light, grow really tall). The main goal is for the students to be able to **reinterpret which plants from the first dish where mutants and non-mutants** (**Question 7**). The instructor can ask some questions like: *How can the plants be so long? The plants from the first dish where also tall? Which were the mutants? Do you all think the same?* With this part, the students should be able to acknowledge that a plant that sees the light poorly or has grown under dark conditions grows taller in search for the light. They should answer **Questions from 5 to 7**.

Optional

If you work in the group with the plants with bad light sight, answer questions 5, 6 and 7.

5. Draw what you see in the new Petri dish.

6. Have you seen any differences between the plants in this Petri dish? How are they now?

7. This plants haven't seen the light. Seeing how they grew makes you rethink which ones were the mutants in the first Petri dish?

Revise your answers for questions 3 and 4.

PART 4. Getting conclusions (15 min)

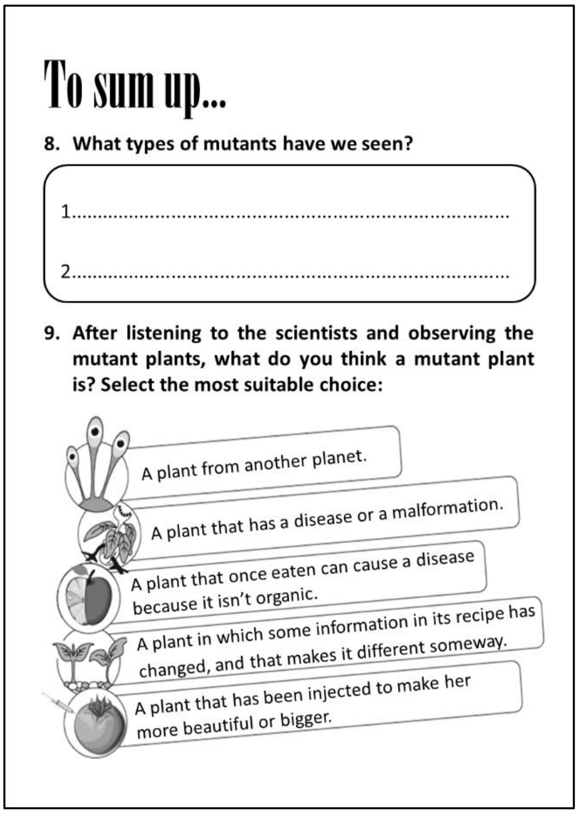
10. **SHARING THE RESULTS (10 min)**: all together, the students share their results from the different mutants (hairless and bad light sight) and explain to their schoolmates what have they answered in **Question 4**.

    Following the PowerPoint presentation, the main instructor shows the students what the other research groups have seen in their Petri dishes. The students are shown photos of mutant and non-mutant plants of both mutant varieties, so they have the opportunity to know what the other groups have studied. The instructor asks if they have had any difficulties knowing which plants were mutants and the students should explain. If there is time left, the research groups can look at the dishes from the other groups. After the debate, the conclusions should be:

    a. **Plants with bad light sight:** These plants grow taller because they are looking for light. The same plants grown under dark conditions can't be identified as mutants or non-mutants because they behave, or grow, the same way. Using an analogy with humans (blind and not blind people in a dark or illuminated room) can help understand this. Students should also understand that the plants are green because of the light and the photosynthesis.

    b. **Hairless Plants**: It should be clear that scientists have modified the plant "recipe" to make a plant without hair, being that non-mutant plants have hair. The "recipe" could also be changed to make plants with more hair.

11. **DRAWING CONCLUSIONS (5 min):** Each student should answer **Questions 8 and 9** of the notebook. They share their answers with the whole group and debate until they get a consensus and a justification of the answers. The instructor should only guide them, and remember them some important details they might be missing. The group has to get to the **conclusion that mutant plants,** although they are the same type of plant as non-mutants, **have different information in their instruction book or "recipe" and that makes them different from the others**.


To sum up...

8. What types of mutants have we seen?

1...

2...

9. After listening to the scientists and observing the mutant plants, what do you think a mutant plant is? Select the most suitable choice:

- A plant from another planet.
- A plant that has a disease or a malformation.
- A plant that once eaten can cause a disease because it isn't organic.
- A plant in which some information in its recipe has changed, and that makes it different someway.
- A plant that has been injected to make her more beautiful or bigger.

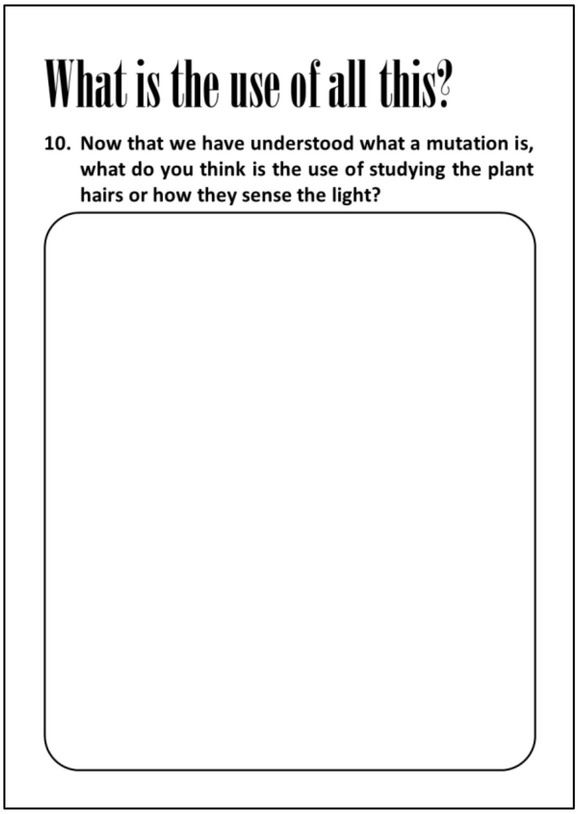
PART 5. Thinking applications of this research: "What is the use of all this?" (25 min)

12. **RESEARCH APPLICATION:** The instructor asks **Question 10** to the whole group, asking what insights might come from having such an accurate knowledge about plants. *What benefit does it have knowing that much about plants? What is the use of controlling that the plants may see more or less the light, or to have more or less hair?* The students answer the questions and debate, and the instructor should guide to answers with real application.

    Some ideas:

    - **Light:** Plants adapt their development and growth to light conditions. For this reason, it is very important for them to be able to sense the light. If scientists made plants that had bad sight, the plants could grow faster (interesting for food plants and garden plants), or they could be grown close to each other as the shadow wouldn't affect them. If, instead, scientists were able to make plants with super light sight, plants would grow slower and shouldn't have to be cut as often (house grass). In any case, **knowing how a plant grows is very useful for future applications**.

- **Trichomes**: Inside the plant hairs, very useful substances are produced, like medicines or fragrant compounds. For example, in the mint hairs there is menthol, a substance with a fresh flavour. Nowadays, Soraya is working in a project to make mint plants more hairy and, in addition to producing the compounds they usually produce, they would also produce a medicine for treating cancer. Keep in mind that one of the main goals of the workshop is that the students can know real projects carried out by real researchers.


What is the use of all this?

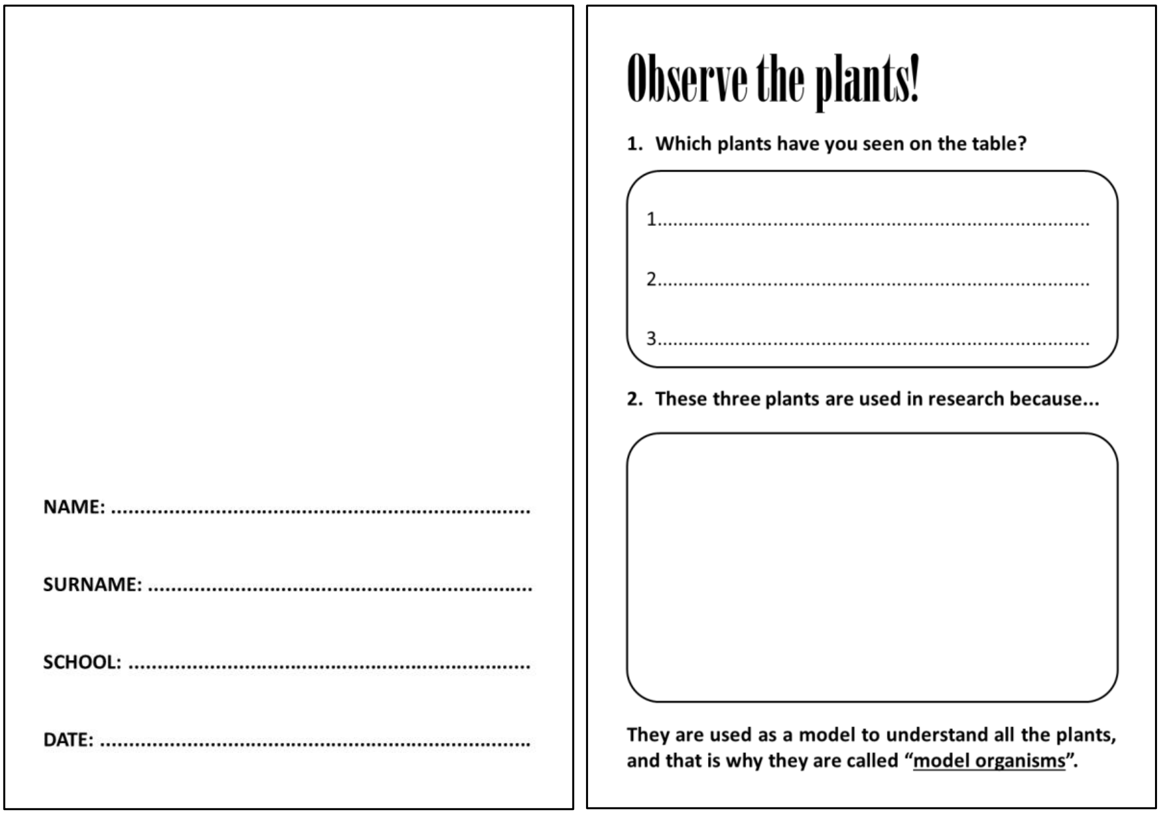
10. Now that we have understood what a mutation is, what do you think is the use of studying the plant hairs or how they sense the light?

PART 6. Bringing the Petri dishes to the researchers (and visiting a lab and the greenhouse) (20 min)

13. **GOING TO MEET THE RESEARCHERS AND BRINGING THEM THE PETRI DISHES WITH THE MARKED MUTANTS**. The students are divided into two groups; the first group brings the Petri dishes to the lab where the researchers are waiting for them, and they thank the students for their work and check if they correctly marked the mutant plants. The other group goes to visit the greenhouse in the building. Once finished this first part, the two groups swap and the visit reaches its end.

6. NOTEBOOK

To assemble the notebook, print the *Notebook_english.pdf* document double-sided, fold it in half and staple it in the spine. You can also print and add the cover (*Notebook_cover.pdf*) before stapling the notebook.



NAME: ....

SURNAME: ....

SCHOOL: ....

DATE: ....

Observe the plants!

1. **Which plants have you seen on the table?**

1...

2...

3...

2. **These three plants are used in research because...**

They are used as a model to understand all the plants, and that is why they are called "model organisms".

We do research like a scientist!

Mark with a cross which mutant plants you will work with:

- ☐ Mutant plants with bad light sight (Jaume's)
- ☐ Mutant plants without hair (Soraya's)

3. Draw in detail a mutant and a non-mutant plant, writing in the boxes below which is which.

Annalise the results!

4. What characteristic is different between a mutant and a non-mutant plant? Explain it.

Optional

If you work in the group with the plants with bad light sight, answer questions 5, 6 and 7.

5. Draw what you see in the new Petri dish.

6. Have you seen any differences between the plants in this Petri dish? How are they now?

7. This plants haven't seen the light. Seeing how they grew makes you rethink which ones were the mutants in the first Petri dish?

Revise your answers for questions 3 and 4.

To sum up...

8. **What types of mutants have we seen?**

1...

2...

9. **After listening to the scientists and observing the mutant plants, what do you think a mutant plant is? Select the most suitable choice:**

- A plant from another planet.
- A plant that has a disease or a malformation.
- A plant that once eaten can cause a disease because it isn't organic.
- A plant in which some information in its recipe has changed, and that makes it different someway.
- A plant that has been injected to make her more beautiful or bigger.

What is the use of all this?

10. **Now that we have understood what a mutation is, what do you think is the use of studying the plant hairs or how they sense the light?**

Notes

The workshop "Mutant Plants" has been designed jointly by the Centre for Research in Agricultural Genomics CSIC-IRTA-UAB-UB (CRAG) and the Centre for Scientific Research and Mathematics (CRECIM) in Universitat Autònoma de Barcelona, and has counted with the collaboration of the primary school Joan Maragall from Sant Cugat del Vallès.

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Workshop design: Zoila Babot, Margalida Martí, Jaume Martínez-García, Soraya Pelaz, Irma Roig-Villanova and Paula Suárez-López (CRAG), Anna Garrido-Espeja (CRECIM)

Didactic material design: Anna Garrido-Espeja and Èlia Tena (CRECIM), Zoila Babot and Margalida Martí (CRAG)

7. EXPECTED ANSWERS TO THE NOTEBOOK QUESTIONS

- **Question 1: Which plants have you seen on the table?**
  - Plant 1: Tomato plant
  - Plant 2: Rice plant
  - Plant 3: Arabidopsis plant

- **Question 2: These three plants are used in research because…**

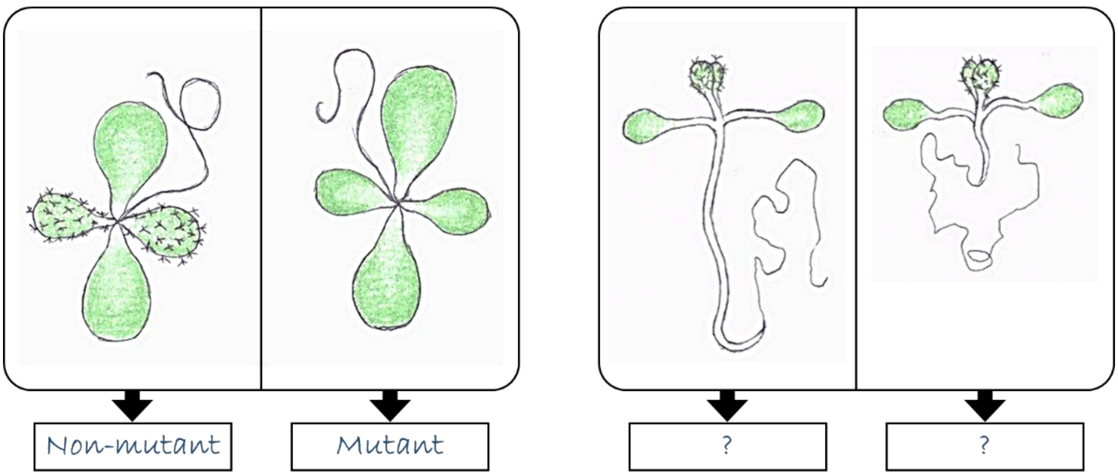
  There are multiple answers to this question, some of the good ones are: They are easy to grow in a small space, the scientists know them in detail, they have a short life cycle, they are easy to manipulate, the scientists know their "Instruction book".

  Some information for the instructors:
  - *Rice and Arabidopsis are the most used model species.*
  - *Rice is diploid, whereas wheat or other cereals are polypoid (thus, rice is easier to manipulate and to study its genetics).*
  - *Rice is a basic food in many countries.*
  - *The tomato plant is also diploid and offers a fleshy fruit, which other model species do not offer*

- **Question 3: Draw in detail a mutant and a non-mutant plant, writing in the boxes below which is which.**

  The students working with the trichomes mutants should draw the leaves and the hairs in detail. In this question, the students working with light mutants won't probably know which plants are mutant, but they should draw a smaller and a taller plant.

  Hair mutants (Soraya) — Light mutants (Jaume)

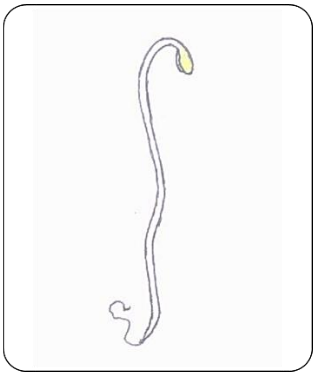


- **Question 4: What characteristic is different between a mutant and a non-mutant plant? Explain it.**

  Mutant without hair: Non-mutant plants have thin hairs almost transparent in the central leaves. The mutant plants have none or few hairs.

  Light mutants: Mutant plants are longer and non-mutant plants are smaller.

- **(OPTIONAL) Question 5: Draw what you see in the new Petri dish**

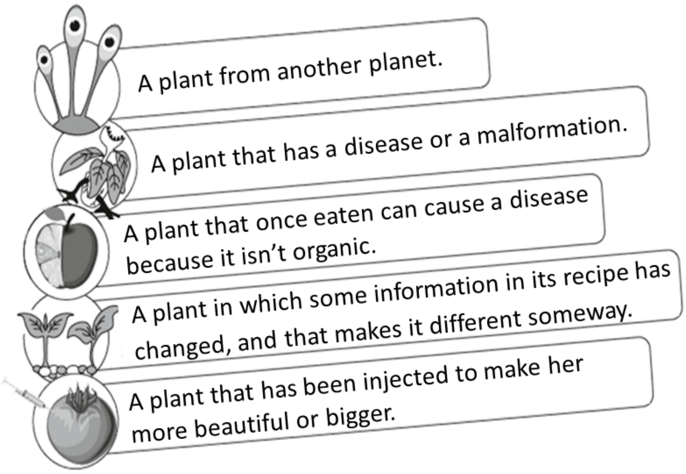


- **(OPTIONAL) Question 6: Have you seen any differences between the plants in this Petri dish? How are they now?**
  No, all the plants seem equal. All are white and long.

- **(OPTIONAL) Question 7: These Petri dishes haven't seen the light. Seeing how they grew makes you rethink which one were the mutants in the first place?**
  Yes, now I think that the mutants that have bad light sight are the longest.

- **Question 8: What types of mutants have we seen?**
  1. Mutants with bad light sight.
  2. Mutants without hair.

- **Question 9. After listening to the scientists and observing the mutant plants, what do you think a mutant plant is? Select the most suitable choice:**



- **Question 10. Now that we have understood what a mutation is, what do you think is the use of studying the plant hairs or how do they sense the light?**
  In this question there are many possible answers, some of them being:
  - To make hairier plants that produce more useful compounds (medicines, etc.)
  - To make plants that can adapt to different light conditions. E.g.: House grass that grows slower and smaller.
  - To know at what distance we should sow the seeds in a field.
  - There are many applications still to discover.

8. MATERIAL

To carry out this workshop, the centre should have the means to grow *in vitro* plants and have access to adult plants. Here is a detailed list of the needed material that could change depending on the centre's approach to the workshop:

- Grown model plants: *Arabidopsis thaliana*, tomato plant and rice plant. Preferably adult plants with fruits.
- Video of the researchers (Jaume and Soraya) asking for the students' help, with subtitles (you can find it as the complementary material *Researchers_need_your_help.mkv*). If have trouble playing the video or viewing the subtitles, please try again using VLC Media Player (you can download it for free at https://www.videolan.org/vlc/).
- Binocular lenses (one for each "research group")
- Clear Agar Petri dishes (minimum one for each "research group")
- Petri dishes with mixed hairless mutants and non-mutant plants (minimum one for each "research group" working with hairless mutants), detailed in *OBTENTION AND PREPARATION OF PLANT MATERIAL*
- Petri dishes grown in the light with mixed bad light sight mutants and non-mutant plants (minimum one for each "research group" working with bad light sight mutants), detailed in *OBTENTION AND PREPARATION OF PLANT MATERIAL*
- Petri dishes grown in the dark with mixed bad light sight mutants and non-mutant plants (minimum one for each "research group" working with bad light sight mutants), detailed in *OBTENTION AND PREPARATION OF PLANT MATERIAL*
- Workshop notebooks (one per Student): to assemble the notebook, print the *Notebook_english.pdf* document double-sided, fold it in half and staple it in the spine. You can also print and add the cover (*Notebook_cover.pdf*) before stapling the notebook. You can find both files in the complementary material folder.
- Disposable lab coats (one per Student)
- Pencils, rubbers, colours, permanent markers...
- PowerPoint presentation (you can find it as the complementary material *PowerPointPresentation_english.ppt* and *PowerPointPresentation_english.pdf*)
- Magnified picture of *Arabidopsis* leaves; detail of the trichomes or hairs (you can find the picture as the complementary material *Arabidopsis_trichomes.jpg*)
- Drawing illustrating a plant emerging from the soil (you can find it as the complementary material *Growing_plant.png*)

9. OBTENTION AND PREPARATION OF PLANT MATERIAL

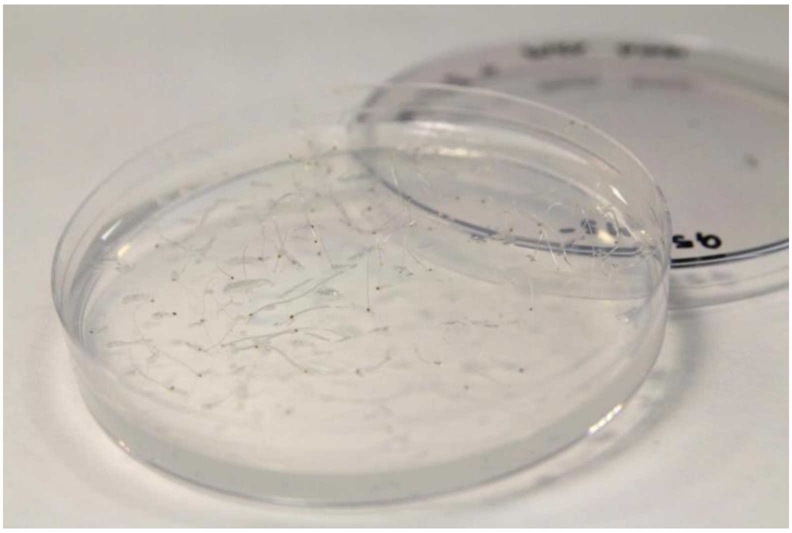
The *agl2*-1 allele (hairless mutants) is a mutant obtained by fast neutrons in Ler background. The *phyB-9* allele (bad light sight mutants) is a mutant in the phytochrome B photoreceptor obtained by EMS mutagenesis in the Columbia (Col-0) background. Both mutants can be requested to the Nottingham Arabidopsis Stock Centre (NASC http://arabidopsis.info/StockInfo?NASC_id=65; phyB-9 NASC ID is N6217; Col NASC ID is N1092) or The Arabidopsis Information Resource (TAIR https://www.arabidopsis.org/servlets/TairObject?type=germplasm&id=1005003825).

PETRI DISHES WITH MIXED HAIRLESS MUTANTS AND NON-MUTANT PLANTS

Seeds of Ler and the *agl2-1* mutant are plated at a density of about 24 seeds per plate (18 Ler and 6 *agl2-1*) and evenly distributed. After sowing, plates are stratified at 4°C for 7 days to break their dormancy. After that, plates are transferred to a room at 22-24°C with 16 hours of light for 10 days. Then, seedlings are ready for the observation by the students.

PETRI DISHES WITH MIXED BAD LIGHT SIGHT MUTANTS AND NON-MUTANT PLANTS

Seeds of Col-0 and the *phyB*-9 mutant are plated at a density of about 60 seeds per plate (45 Col-O and 15 *phyB-9*) and evenly distributed. Each plate contains both genotypes (Col-0 and *phyB*-9 mutants) and two replicas are plated to be grown under dark and light conditions, respectively. After sowing, plates are stratified at 4°C for 7 days. After that, one replica is transferred to a room at 22-24°C in complete darkness (dark-grown seedlings) and the second replica is transferred to a room at 22-24°C in continuous white light (light-grown seedlings). Seven days later, the seedlings are ready for the observation by the students.



10. CONTACT INFORMATION

For further information or if you have any questions, please do not hesitate to contact the Communication & Outreach Area at communication@cragenomica.es