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Background: Partnership for Research and Education in Plants

The Partnership for Research and Education in Plants (PREP), brings together

- Tucson-area secondary science teachers
- their students
- research scientists
- outreach personnel

to collaborate in sharing knowledge and research about plant molecular genetics and general plant biology and provide students with opportunities to collect, analyze, draw conclusions about, and share real data.

Our rationale for integrating scientific research experiences, where students collect 'real data', into traditional secondary science classes is to provide students with a holistic learning experience required for success in higher education, in the high-skilled workplace of today and tomorrow, and in general life skills including voting and healthcare use. The PREP program will support teachers and students as they design and conduct experiments in wild-type and mutant Arabidopsis thaliana to examine functions of different genes during plant growth and development. Students will share their findings with their peers, their community, and research scientists in plant biology and genomics at a year-end conference and on a PREP program website.

As part of the PREP program, students will be adding their findings to a large bank of experimental data that scientists are collecting as part of the Plant Genome Research Program, adding import to their work. The field of genomics is in the process of transforming agricultural and biomedical sciences. Conducting their own experiments to study mutant plants identified or generated as part of a genomics project will give students the opportunity to understand and examine this approach, so that they may better understand the molecular basis of heredity and critically evaluate the issues that are arising as a result of this new field. Finally, students who conduct their own 'real' experiments not only have the potential to advance their own understanding of the nature of science, but are also, with appropriate guidance, providing a wealth of reliable, accurate data that can used for further study of biology. Through the PREP program, students will improve their understanding of plant biology, of the burgeoning field of genomics, and of the nature of science, laying the foundation to become more scientifically and technologically literate citizens.
**Background: NSF Plant Genome Research Program**

The Plant Genome Research Program (PGRP) was initiated by the National Science Foundation in 1998. It is part of a national plant genome research initiative established by the Office of Science and Technology Policy. The long-term goal of this program is to understand the structure, organization, and function of plant genomes important to agriculture, the environment, energy and health. For more information about PGRP, please visit this website: http://www.nsf.gov/bio/dbi/dbi_pgr.htm

**Functional Genomics of Plant Protein Phosphorylation**

Proteins perform almost every function in an organism’s body. Proteins can be enzymes that catalyze chemical reactions, can send and receive information throughout an organism’s body, and can themselves serve as signals of events inside and outside a cell. Every living thing is, in essence, a big pile of proteins. Proteins are coded for by DNA, which also carries information about when and where different proteins should be made. For example, brain proteins are made in the brain, liver proteins are made in the liver, and cholesterol-handling proteins are made when you eat cholesterol. But it takes a lot of energy to make and destroy proteins so they function when you need them. Thus, many proteins can be turned ‘on’ and ‘off’ through a process called **phosphorylation**. Being able to turn proteins on and off means that cells don’t have to make a protein from scratch each time it’s needed.

Enzymes called **kinases** add phosphate groups (PO$_3^-$) to proteins, turning the proteins on or off depending on the type of proteins they are. Enzymes called **phosphatases** remove phosphate groups from proteins, reversing the action of kinases. Amazingly, 5% of the genes in plants code for proteins directly involved in phosphorylation or dephosphorylation, evidence of how important this process is in cells. The goal of the **Functional Genomics of Plant Protein Phosphorylation** project is to use genetics and bioinformatics (the study of biological information, like DNA sequences of genes) to investigate the process of protein phosphorylation in plants.

This project, in particular, examines phosphorylation in the plant *Arabidopsis thaliana*. As a component of this project, every gene in *Arabidopsis* that codes for a protein involved in phosphorylation will be ‘knocked out’. When a gene is knocked out, it no longer functions so the protein it codes for is not made. After knocking out a gene in *Arabidopsis*, scientists then examine the plant for changes in its phenotype, including its growth, development, appearance, and function. Students will grow and examine plants, each with a single gene knocked out, to determine if there are any changes in their phenotypes. Scientists can then follow up on what students find to determine how phosphorylation is important in the growth, development, appearance, and function of plants.
Arabidopsis Thaliana

Why study Arabidopsis?

Arabidopsis is a small flowering plant that is widely used as a model organism in plant biology. It belongs to the mustard family, which includes vegetables like cabbage and radishes. The characteristics that make Arabidopsis ideal for research are:

- small size: at most 5 cm in diameter, 30 cm in height, many can be grown in a small area
- sturdiness: grows well even in sparse, gravely soil
- fast growth: 6-8 week generation time, many can be grown in a short time
- self-pollinating: plants can be propagated easily
- crossing: matings between males and females of different strains can be done easily
- uniformity in a population: plants from the same parent look the same, generation after generation
- large number of progeny: a single plant produces thousands of seeds
- small number of genes: Arabidopsis has only 5 chromosomes and 25,500 genes, the genes themselves are also small, making them easy to examine
- simple genetic engineering: it’s easy to add or disrupt genes in Arabidopsis
- genome: the entire genome has been sequenced so we know what all of the genes are, even if we don’t know what every gene does

Why study Arabidopsis in the classroom?

The characteristics that make Arabidopsis attractive for research, also make it attractive for study in the classroom: small size - each group of students can conduct their own investigation; sturdiness - the plants are easy to grow with minimal maintenance; fast growth - students can study the whole life cycle in 8 weeks; and simple Mendelian and molecular genetics because they are easy to cross, yield many seeds, have a small genome that is completely sequenced, and can be genetically engineered, even in a high school classroom.

For more information about Arabidopsis, please visit the website and check out the other resources listed in Appendix E of this handbook.
Arabidopsis Research Project

Thanks to you and your students for agreeing to participate in the Partnership for Research and Education in Plants program. Here is a narrative overview of the project, including how to get started.

Big Idea
Students, working in pairs or small groups, will plant and grow wild-type (normal) and mutant (missing a single gene) Arabidopsis. Although scientists know what gene is missing in the mutant plants, they don’t know what that gene does normally. The students’ job is to design experiments to figure out what the gene does normally. Here is a pot of wild-type plants between two types of mutants, on the left is a plant that makes extra flowers and on the right is a plant that makes no flowers.

Scientists have already looked at the mutants your students will be studying and haven’t observed any obvious visible changes like those in the photo. But the mutants’ abilities to grow, develop, and thrive under different environmental conditions (e.g. high salinity, drought, low nitrogen, etc.) have not been examined. By designing creative and original experiments, students may be able to figure out what the missing genes do normally.
Example
For example, students who live in the desert might be interested in examining the plants' responses to drought conditions. The students will plant wild-type and mutant seeds in two separate pots to grow under normal watering conditions (the controls) and wild-type and mutant seeds, again in two separate pots, to grow in drought conditions. Thus, this student group will have 4 pots: 1 mutant and 1 wild type with water, and 1 mutant and 1 wild type without water (or with a lot less water). The students may choose to examine the plants' heights, leaf sizes, and flower number. A list of phenotypes students can study is included later in this handbook. Once or twice a week, students pick 10 plants in each pot to measure for height and leaf size. Once flowers appear, students count the number of flowers on 10 plants in each pot. Their data are now collected and the students can think about how to present their data to their classmates. Ideas for presentation and assessment are included later in this handbook.

Getting Your Students Started
For participating in the project, you and your students will receive seeds: wild type, or normal, seeds and mutant seeds, which will be missing a single gene. If you have more than one class participating in the research project, each class can study its own mutant or all of the classes can study the same mutant. We can also provide pots, soil, trays for pots, and consumable materials. You need to provide shelving and lighting for growing the plants. We will also do our best to provide any other materials you or your students need to conduct their experiments. Please contact Erin Dolan, Outreach Coordinator at the Fralin Biotechnology Center at Virginia Tech, to request additional materials <BIOoutreach@vt.edu> 540/231-2692.