

Background in Using This Project

The development of this project is based on calls for reform of undergraduate science education. As described in the introduction, one of the demands of the reform is to use data developed in research laboratories for science education. It is assumed that hands-on use of data generated from research enhances students learning and makes learning more relevant to science issues.

The research data in this project are generously provided by Dr. Kevin O'Connell, a scientist in Dr. John White's laboratory at the University of Wisconsin-Madison, Department of Molecular Biology. Dr. White's laboratory is interested in microscopy and developmental biology of *C. elegans*. The research data I have presented are primarily multimedia data on *C. elegans*, such as images and movies. By using primary research data in this project, I have defined certain topics concerning the use of *C. elegans*' data in education. For instance, a section entitled "The Use of Model Organisms in Instruction," details the advantages for using model organisms in teaching. I set up here a web site implementing the resources from Dr. O'Connell as an example on the use of research data in education.

In this project, I intend to build a model for disseminating research data to educators so that other researchers could easily adapt my model for making their research data available for educational purposes. Below I will briefly describe the format (a web format) I used and the pedagogical principles I followed to disseminate the available *C. elegans* research data. The interface of the web site in terms of its content and its arrangement will be provided to help people understand what can be found where. Also, examples of how this web site can be used in instruction will be explored. While possible

uses are discussed, it won't be difficult for one to imagine how he/she can use this resource in other classroom settings.

Inquiry-based science learning has become a prominent mode of teaching since the late 1950s (Chiappetta, 1997). As stated, NSF believes that students should learn science by the process of inquiry (National Science Foundation (NSF), 1996). Inquiry-based learning is defined as

... a pedagogical method that allows students to discover or construct information for themselves instead of an instructor simply telling them that information. --- the inquiry method of instruction allows your students to practice critical thinking and to discover for themselves the principle or major concept that the lab or activity is presenting. --- so that students have the opportunity to remain actively engaged in different aspects of science as a process (Uno, 1997).

By working with inquiry-based curricula, students learn biology via observation, questioning, forming hypotheses, doing data analysis, and generating conclusions. In this project, I developed a web-based, inquiry-based environment for introductory biology, using the model organism, *C. elegans*.

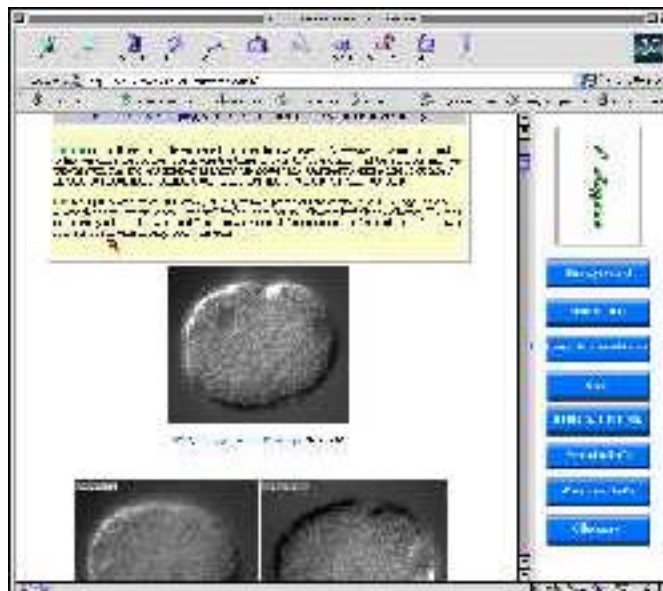
Based on the *C. elegans* research data and advantages of its use, I chose a web format to present this project. The primary research data are 4D movies (3D plus time). They are quicktime movies recording the embryogenesis of wild type and mutant *C. elegans*. Using a web format, movies can be accessed from around the world in a playable status. Other reasons for choosing a web format include learning computer skills, such as how to transfer data from a browser to other programs, navigating around the web site, and, not confining learning concepts to a certain order. Below I will demonstrate how this project is organized in terms of the content and the arrangement.

The Web Site Interface of This Project

First of all, the whole web site project can be accessed via two web addresses according to the audience. Accessing via "<http://www.loci.wisc.edu/outreach/>", the "home page", leads you to the whole project including all the sections I defined, such as the "Introduction" and "This Project". This web address is mainly for instructors.

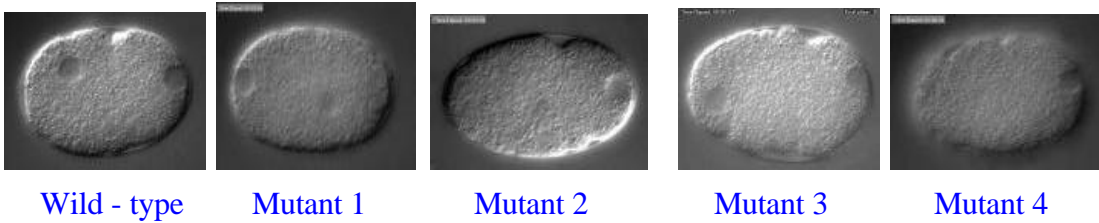
"<http://www.loci.wisc.edu/outreach/html/>", the "main page", will be the entry point for students.

In the home page, seven titles are listed. Each of them represents a topic in this project. For example, the "Overview" page leads users to the overall purpose of the project, the "Introduction" page links to a rationale for using research data in education, and "This Project" contains all the research data and the ways to disseminate research data in education.

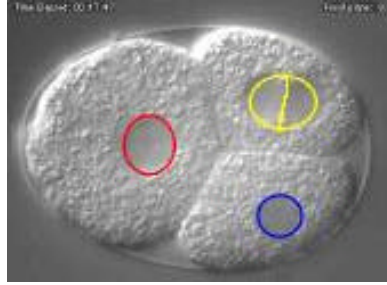


Frame set

Movies in main page



When clicking on "The Project", a frame-set shows the categories in the right frame and the research data (movies) in the left side. The research data shown in the left frame contains the embryogenesis of one wild-type (normal) embryo, and four mutant embryos. As can be seen, there are two different mutant phenotypes. Mutant 1 and mutant 2 possess the same phenotype that results from the same kind of mutation (type I), although the genotypes differ. For this type of mutation, there is no spindle formation during embryogenesis with the result that there is 1-celled embryo with multinucleate, which eventually dies. Mutant 3 and Mutant 4 express the same phenotype resulting from a second type of mutation (type II). This type of mutation results in excessive pole and spindle formation during embryogenesis. Usually, during embryogenesis, one cell division produces two cells. For this type of mutation, during cell division, a cell produces multiple-poles/spindle, which means it will divide into more than two cells. As a result, embryogenesis will be arrested in 10 to 20 multinucleate-cells embryo. For example, after first mitosis, mutant three produced a 3-celled embryo with one of the cells possessing two nuclei - a multinucleate-celled embryo.



A multinucleate-celled embryo
(the cell in the upper right corner
possesses two nuclei.)



A one-celled embryo with
multi-nucleate

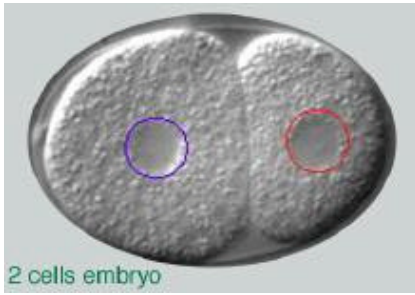
The right frame consists of eight categories, including "Background", "Movie Info", "Growth Conditions", "Size", "Time and Cell No.", "Protein Info", "Genome Info" and "Glossary". I will briefly describe each category in terms of what can be found in each of them.

Background

The aim of this page is to provide essential background about *C. elegans* itself, such as where it lives and, what can be observed in the movies on the main page. Detail annotation ("Annotation" page) of the movies can be accessed at the end of this page. The main purpose to provide annotation page of all movies is to help students understand what is occurring in embryogenesis. For example, while observing the movies students might have trouble in understanding what is happening during embryogenesis, such as mitosis, nuclear meeting. This page provides essential information for students to know there are spindle and poles in cell mitosis.

On the "Annotation" page, all five embryos are annotated. Clicking on the name of an embryo reveals a set of that embryo's annotation that is represented by links. Clicking on any link will show a short movie from the previous stage in the annotation table to the

stage you are interested in, again with annotation. For example, imagine you are in the



Annotation: a 2-celled embryo

WT embryo annotation page, and you are interested in "4-celled embryo" annotation. By clicking on "4-celled embryo", you will see a short, annotated movie playing from the "2-celled embryo", which is the previous stage, to the "4-celled embryo". In the very

right side of every embryo's annotation table, a "show all annotations" link leads you to all the annotations for that worm. While the advantage for using "show all annotations" is that one can see all annotations at once, the disadvantage is that it takes longer to download.

Movie Info

This page contains the basic information for all the movies in the main page. Information on the embryos' ancestors is provided, as well as movie profiles and descriptions of how these movies were made. The ancestors of Mutant 1 to Mutant 4 were mutated in the gene called *zyg-1*, resulting in a conditional-lethal phenotype. This phenotype is a temperature sensitive mutant, which means it will develop similar to the wild type under normal temperatures (18-22°C). However, when the temperature changes in the larva stage, the development of the offspring (e.g., Mutant 1) will be arrested, resulting in death. In addition there is information on how the embryo movies were collected and how the movies were processed. Also, a picture regarding various depths of focal planes and the changes in time lapses in recording those focal planes are shown.

Growth Conditions

This page is used to introduce the laboratory environment, including culture media and culture temperatures, that were used to grow the embryos. It also includes the growth conditions for those embryos shown on the main page. As shown, the environment for all the embryos is the same. However, only wild-type embryos will develop into adult worms, due to mutation in the *zyg-1* gene that inhibits embryo development. This page is for students to rule out environmental effect on the mutants' development, as all the embryos grow in the same environment.

Size

During embryogenesis, an embryo divides but does not grow. From the movies on the main page, this phenomenon is vividly represented. This page is for students to experiment with the concept of embryogenesis and they can use tools to measure cell growth. Tools, NIH image and Scion for Mac and PC, respectively, are available at the end of this page. Those tools can be downloaded for free to the users' desktop computers. Along with the process of embryogenesis, students can get images from the embryo of interest at different developmental stages and measure the size of the embryo. When they are done with the measurements, data can be transferred to any data analysis programs, such as MS Excel, to plot a graph and draw conclusions.

Time & Cell No.

Information on the relationship between an embryo's developmental time and its cell numbers is provided on this page. As the movies are 4D movies (3D plus time), its great

advantage is that students can experience the relationship between embryogenesis and developmental time. Students can see how much time it might take for an embryo to divide into different cell stages, such as the two-celled embryo or four-celled embryo. For example, in the wild-type embryo provided, it took about 23 minutes to form a two-celled embryo.

Protein Info

Protein information of the mutants and wild type is provided on this page. According to Dr. O'Connell, the defect of these mutants is in a specific kinase. The predicted length of each protein sequences is provided. As these are unpublished data, I can only use cartoons to represent how each of the protein sequences are alike. As you can see, Mutant 1 and 2 are both one amino acid different from the wild type protein sequence. For Mutant 3 and 4, because their defect is a nonsense mutation, transcription from DNA to mRNA stops early. Thus, translation from mRNA to the protein is truncated, as well. Therefore, the resulting protein has a shorter sequence.

Genome Info

On this page, you will see genotypes of the wild type and mutant embryos, the predicted DNA length, the number of codons according to the predicted DNA length, and the mutation type for all the mutants. Again, since the DNA sequences for those mutants are unpublished, cartoons are used to illustrate how the DNA sequence might look and where the mutation might happen. In the DNA sequence table, by placing the mouse over the mutant sequences, the location of the point mutation will be revealed. These mutants

all result from point mutations, thus, their nucleotide sequences are the same as the wild type, except for one nucleotide. Mutant 1 and 2 result from missense mutations, meaning that one of the nucleotides is substituted by another nucleotide, resulting in a different amino acid encoded into the protein. This type of mutation might produce a different three dimensional protein structure that will function differently. Mutant 3 and 4 are the result of nonsense mutations, which means that the mutation in one of the nucleotides forms a stop codon, causing transcription to stop early, producing a shorter mRNA. This shorter mRNA may produce a shorter protein sequence, and, may affect protein function. Within the function of the protein, its affect depends on where the stop codon occurs in the sequence, and where the active sites are located on the protein.

Glossary

You can find definitions for terminology used in the web site, such as hermaphrodite, zyg, etc.

Possible Ways to Use This Web Site

Here, I will provide some possible ways to use the web site - to suggest to users to how they might use the site, and further, to stimulate them to think how they can use it in various classroom settings.

For this project, my intention is to take the first step in building a problem-solving environment. The web site can be used for demonstration (show movies or other information to students), used to produce a question set for students to work on, or used

as an inquiry-based learning material that students can use to pose and solve their own problems.

Used as Demo

Images and movies can be downloaded from this project web site to a desktop computer and can be played in a classroom. For example, if a instructor would like to demonstrate that "during embryogenesis, an embryo divides but does not grow," then the wild-type embryo movie can be downloaded and played for students. Furthermore, tools, like NIH image, can be downloaded for free from the web. With NIH image and the wild-type movie, data can be collected. Instructors can work with students to gather data, analyze it and come to conclusions on the phenomenon, the "embryo divides but does not grow."

Another example of the use of this web site is to show how the genotype, protein sequence and phenotype tie together. For instance, by showing the movies on the main page, students will notice something is wrong with the mutant embryos. Then the protein information can be shown for students to know that the defect is in one of the embryo's kinases, and this is only one amino acid different from the wild type protein sequence. Subsequently, one can show the genotypes of those embryos. Students will know, on the gene level, that there is only one nucleotide difference in each of the mutants, compared to wild-type, that produces the lethal mutation. The truth is quite shocking - one point mutation can lead to death.

Used to Create Question Sets

By using this web site, question sets can be produced according to an instructor's needs. Some information might be given with the question set for students to work on. For example, the annotation on all the movies can be found in the "Background" page and the NIH image can be downloaded from the web and can be used to measure cell size. Questions like, "Is it that the genotype instructs phenotype or the phenotype results in genotype?" Students will be able to navigate this web site and find evidence to support their hypotheses. They can look at the movies and identify the differences between wild type and mutant embryos. They can then investigate the parental information on the "Movie Info" page, the embryos' growth conditions and environment, and, also, check the protein information and genome information for all the embryos. By gathering all the data available, students will understand that it is the genotype (e.g., possesses mutated *zyg-1* gene or not) which is inherited from a parent that results in an embryo's death rather than the parent's phenotype, as the parents resemble wild type, or environment. They can further learn that it is the genotype that instructs an embryo's development instead of the phenotype.

Used as an Inquiry-Based Learning Environment

This project is meant to provide a problem-solving environment for students to learn biology from an inquiry-based vantage. On the main page, five movies are provided with one wild type and two mutant types, each with two genotypes. While looking at the movies, various questions can be posed. For example by looking at the wild type embryo movies, some interesting questions can be asked, such as "How do cell numbers increase

during embryogenesis?", "Does the embryo's cell numbers increase irregularly or by uniform doubling?", "Is the time interval between cell division the same (e.g., from 2 to 4 cells and 4 to 8 cells)?" Alternatively, using the other movies, additional questions can be posed, such as "What's wrong with all four mutants?", "For mutants with the same phenotype, do they have the same genotype?", "What might have caused the mutation? Is that because of pollution or any other reasons?", "What are the mutants' parents' phenotypes? Are their parents similar to these mutant embryos?" and "Is this phenomenon inherited or adapted?"

Students can then gather resources or information to support and clarify their hypotheses. For example, if they would like to know whether mutants with the same phenotype are defective in the same place or not (i.e., Mutant 1 and 2), they will be able to find the evidence from the protein and genome info pages and realize that the same phenotype might not necessarily be produced by the same defect at the protein or genome level.

In sum, provided is a brief description on what can be found in this project web site and ways this web site can be used. It is my intention to build a model on using up-to-date research data to educate students to work and play with. Hopefully, using this model, other researchers can apply their research data to help students understand biology.

References:

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