**Scientific vs. Artistic Uses of the Green Fluorescent Protein**

**Abstract: If you could have a dollar for every experiment that is using GFP to study other genes and organisms, you would be rich! GFP can be expressed in almost every organism tested to date and is being used to study gene regulation in bacteria, yeast, invertebrates, plants, mammals, non-human primates, and humans. GFP is being used in biomedical research to aide in our understanding of complex systems involved in genetics, cell biology, cancer, the aging process, and much more. Recently, GFP has been used to create a green fluorescent rabbit as an art form titled "transgenic art."**

Introduction:

Scientists love using the simplest systems when designing experiments and theories. GFP serves as an elegant yet simple addition to their repertoire of tools for gene regulation and interactions. GFP is an optimal reporter gene because it is small, requires only UV light to be observed, is very stable, and can be observed in experimental systems as well as in living organisms. GFP has been expressed in organisms that range from bacteria to human cells (see table below). GFP, to date, has not been tested in humans. But it has been placed in rabbits, mice, and monkeys with various results. GFP has been mainly used for scientific research purposes, but as you will read below it has also been used to create "transgenic art."

The creation of Alba, the fluorescent bunny:

In February 2000, the first transgenic rabbit that contained the GFP gene was born in France. This albino rabbit, named Alba, lacks skin pigment and under ordinary conditions would be completely white with pink eyes. But with the addition of GFP to her genome, she now glows green when exposed to UV light. Under normal conditions she remains white. This was a collaborative effort with scientists at Joey-en-Josas, France and an artist who lives in Chicago, Eduardo Kac. He calls this creation – transgenic art. He proposes, "[This] is a new art form based on the use of genetic engineering to transfer natural or synthetic genes to an organism, to create unique living beings. This must be done with great care, with acknowledgement of the complex issues thus raised and, above all, with a commitment to respect, nurture, and love the life thus created." Would you agree that this is a continuum of selective breeding practices breeders have used on livestock and pets for the past few centuries? Or is this something new, adding specific genes to create designer pets?

ANDi, the GFP containing monkey

Another transgenic mammal with GFP inserted into its genome is the rhesus monkey ANDi (a name derived from "inserted DNA" in reverse). Scientists at Oregon Health Sciences University used GFP as a model system. Although the gene was inserted into 244 eggs, only one of these eggs resulted in the live birth of a rhesus monkey that contained the GFP sequences. But ANDi does not turn green when exposed to UV light and appears to be perfectly healthy. The scientists are using this technique to learn more about creating transgenic monkeys. The hope is that transgenic monkeys will serve as a powerful research tool to investigate many human diseases such as cancer, Parkinson's, and diabetes. What are your thoughts about learning about human diseases through experiments on primates? If this could result in finding cures for cancer and other diseases that benefit the human population, would the technique be justified?

Other research studies using GFP as a reporter

Below is a table that lists just a fraction of all the uses of GFP in various organisms. After reading this, what are some of your thoughts and questions?

**Table: Summary of the uses of GFP as a reporter gene**

| **Organisms** | **reports on:** |
|---|---|
| Bacteria | spore formation, cell division, bacterial-host interaction, bioremediation (the use of biological agents to remove toxic contaminants from soil and water), bacterial ecology (following genetically engineered micro organisms as they move in the environment), effect of antibiotics and pathogens. |
| C elegans (worm), insects | developmental biology, neurobiology, and cell biology. Allows researchers to tag cells and follow their development, and to study protein trafficking and localization in living cells. |
| Plants | visualize events in structures within the cells, used for breeding, and field trials, producing cloned products for therapeutic uses. |
| Vertebrates (fish, frog, mammals) | "watching everything from the protein actin moving along a muscle fiber to nerves growing" from Science News Oct. 1997. |
| Rabbit | fluorescent green bunny for artistic purposes. |
| Rhesus monkey | contains the GFP gene in cells tested-but the monkey does NOT glow green when exposed to UV light. Is GFP being expressed? |
| Inner ear hair cell in mice | to examine degeneration of this cell to explore what may be responsible for hearing impairment. |
| Mice | to study tumor growth and progression. Model system for testing cancer therapies. |
| Bone marrow stem cells | to tag specific bone marrow cells, sort and select these cells prior to bone marrow transplantation. This could result in decreasing the variability and enriching for specific cells. Overall, this would enhance cancer therapies. |

References:

Alba, the GFP-bunny

- http://www.ekac.org/gfpbunny.html
  The artist, Kac, wrote the very long article about the GFP transgenic bunny, Alba.
- Fusing art and life *Science* 289: 1679???

ANDi, the GFP monkey

- Brave New Monkey. Begley (2001). *Newsweek* January 22, 2001
- Infant monkey carries jellyfish gene *Science* 291:226
- Primate Genetic Engineering *Science* January 12; 291:205
- http://www.accessexcellence.org/WN/SU/monkey011201.html
  Monkeying with Genomics. Article on the GFP transgenic rhesus monkey. Note some "glowing" errors in paragraph two.

GFP transgenic mice

- Jellyfish light up mice *Science* 1997 July 4; 277:41
- http://www.sciencemag.org/cgi/gca?gca=277%2F5322%2F41c&sendit.x=144&sendit.y=8

GFP and colored silk

- http://www.sciencedaily.com/releases/1999/03/990315081219.htm

**Glossary for Scientific and Artistic Uses of GFP**

**bioluminescence**
A complex chemical reaction that occurs within a living organism, in which the end product of energy is released in the form of light instead of heat. Some organisms that have this ability are glowworms, fireflies, jellyfish, fungi, and some deep-sea fish.

**biotechnology**
The use of living entities to make products.

**cancer**
A type of disease caused by cells that divide and grow uncontrollably, invading and disrupting other tissues and spreading to other areas of the body (metastasis).

**chemiluminescence**
A general term for the production of light when the excitation energy has come from a chemical reaction. Bioluminescence is a type of chemiluminescence that occurs in a living organism.

**cloning**
The process of asexually producing a group of cells (clones), all genetically identical, from a single ancestor. In recombinant DNA technology, the use of DNA manipulation procedures to produce multiple copies of a single gene or segment of DNA is referred to as cloning DNA.

**DNA**
The material inside the nucleus of the cells that carries genetic information. The scientific name for DNA is deoxyribonucleic acid.

**ethical issues**
Questions concerning what is moral or right.

**fluorescence**
A phenomenon shown by certain substances when they are hit by ultraviolet radiation. The substance absorbs high frequency wavelengths and emits it at a lower frequency light. This emission stops as soon as the high frequency radiation is removed. For example, GFP absorbs the higher frequency blue light emitted by aequorin, undergoes a chemical reaction, and emits the lower wavelength green light.

**gene cloning (DNA cloning)**
A lab technique which uses DNA manipulation procedures to produce a recombinant DNA molecule and then to make multiple copies of it by inserting it into the genome of a host microorganism which is then grown in culture.

**gene expression**
The process by which a gene's coded information is converted into the structures present and operating in the cell. Expressed genes include those that are transcribed into mRNA and then translated into protein and those that are transcribed into RNA but not translated into protein (e.g., transfer and ribosomal RNAs).

**gene regulation**
The process by which genes are turned on and off. This process can occur by a variety of mechanisms.

**genetics**
The study of the patterns of inheritance of specific traits.

**genetic engineering (gene manipulation, genetic manipulation)**
The manipulation of an organism's genetic endowment by introducing or eliminating specific genes through modern molecular biology techniques. A broad definition of genetic engineering also includes selective breeding and other means of artificial selection. See recombinant DNA technologies.

**green fluorescent protein (GFP)**
A protein found in jellyfish that fluoresces, or emits a green visible light when excited by UV light with a wavelength of 395 nanometers. It can function as a biological marker when co-expressed with other proteins. The structure of the protein is cylindrical with the glowing component, an amino acid complex called a *fluorophore*, in the middle of it.

**in situ**
Refers to performing experiments or tests with intact tissues.

**in vitro**
*In vitro* means, literally, "in glass"; a biologic or biochemical process occuring outside a living organism.

**in vivo**
*In vivo* means, literally, "in life"; a biologic or biochemical process occuring within a living organism.

**ultraviolet radiation (UV)**
Electromagnetic radiation produced by the sun and or produced when an electrical current passes through ionized gas between two electrodes. It consists of wavelengths between 200 and 400 nanometers. Exposure to excessive amounts of UV radiation damages DNA and can cause health problems such as skin cancer and cataracts in the eyes.

**recombinant DNA**
Recombinant DNA is a fragment of DNA incorporated artificially into the DNA molecule of a suitable vector so that it can express itself many times. This way a large quantity of the DNA in question can be obtained. The DNA is usually one that contains genes of interest, such as interferon, insulin, or an oncogene. The DNA may also be intended to fix mutated genes causing diseases, such as hemophilia or sickle cell anemia. The vector could be plasmids, bacteriophages, and cosmids (packaged plasmid DNA into a phage particle).

**recombinant DNA technologies**
Procedures used to join together DNA segments in a cell-free system (an environment outside a cell or organism). Under appropriate conditions, a recombinant DNA molecule can enter a cell and replicate there, either autonomously or after it has become integrated into a cellular chromosome.

**reporter gene**
A gene that is used to locate or identify another gene**.** It is often used to examine the factors that regulate the gene of interest, in effect, it “reports” on the gene that is being examined.

**transgenic**
This term describes an organism that has had genes from another organism put into its genome through recombinant DNA techniques.

**transgenic animal**
Genetically engineered animal or offspring of genetically engineered animals. The transgenic animal usually contains material from at lease one unrelated organism, such as from a virus, plant, or other animal.

**transgenic plant**
Genetically engineered plant or offspring of genetically engineered plants. The transgenic plant usually contains material from at least one unrelated organisms, such as from a virus, animal, or other plant.