

PROPOSAL

Howard Hughes Medical Institute  
Office of Grants and Special Programs  
*1992 Precollege Science Education  
Initiative for Science Museums*  
6701 Rockledge Drive  
Bethesda, MD 20817

The Children's Museum of Utah  
840 North 300 West  
Salt Lake City, Utah 84103

*NIGHT-LIGHT: Science in the Dark*

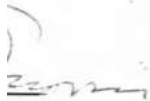
5 Years

\$350,000

Investigator: Mr. Richard R. Morris  
Executive Director  
The Children's Museum of Utah  
(801) 328-3383  
FAX (801) 328-3384

Center for Integrated Science Education (CISE)  
University of Utah  
2480 MEB  
Salt Lake City, Utah 84112

Principal Investigator: J.D. Andrade, Professor of Bioengineering  
2480 MEB  
University of Utah  
Salt Lake City, Utah 84112  
(801) 581-4379  
FAX (801) 581-8692



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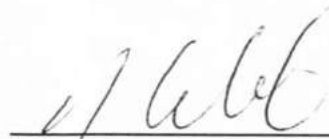
  
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J. Andrade  
University of Utah

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*NIGHT-LIGHT: Science in the Dark*

Executive Summary

We propose to develop, test, exhibit, and disseminate NIGHT WALK, an integrated science "discovery" system based on bioluminescence -- light generated by living systems [1-7].\*

Nearly everyone who discovers and observes bioluminescence is impressed and motivated to see and learn more. In these times where people have their senses constantly stimulated to near exhaustion, bioluminescence is a relatively unknown, unexperienced phenomenon which can readily compete for a visitor's attention and interest.

Bioluminescence is a phenomenon which is largely unknown to students and teachers and almost totally excluded from all science curricula and textbooks, from kindergarten to undergraduate college [5].

The project will develop integrated and interactive science exhibits which will be used for public education activities in an informal and interactive setting.

The basic idea is to have the participants *discover* something completely new -- and thus stimulate them to ask questions and formulate hypotheses.

Many of their questions and hypotheses are then addressed and tested in other exhibits.

Depending on age and background, participants will discover their own answers and be led into various areas and aspects of science. The exhibits serve as resources to *aid* their discoveries and education.

Our long range aim is simply to put together a fully integrated science discovery system based on bioluminescence suitable for science museums.

We propose a 5 year collaborative interdisciplinary project to research and produce interactive discovery exhibits using bioluminescence. This is a collaborative effort between The Children's Museum of Utah, the University of Utah's Center for Integrated Science Education,

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\* References are located on page 21.

and Protein Solutions, Inc., a local company specializing in materials for science education (Figure 1).

The materials will aid in the observation, discovery, and learning of basic concepts in various science fields. The visitors will develop new and expanded understandings of science concepts in a completely new domain -- bioluminescence. The concepts and understanding derived from bioluminescence are general and applicable to the full range of scientific and technical subjects (Figure 2).

We will develop and produce 8 different interactive bioluminescent exhibits (Figure 3), combine them to produce a comprehensive discovery exhibit, and prepare and provide supplementary discovery materials and kits. An assessment plan is included -- as well as a comprehensive plan for publication and dissemination.

We request a total budget of \$330,000, over 5 years, allocated to the following activities:

Bioluminescence Research	27%
Production of Organisms	18%
Exhibit Design	15%
Exhibit Construction	18%
Maintenance & Operation	12%
Assessment & Evaluation	6%
Dissemination	4%

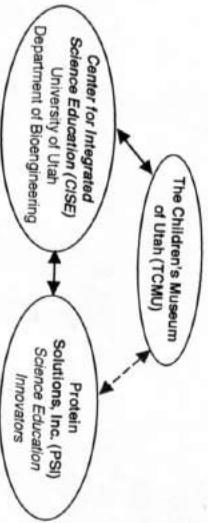


Figure 1: The three key participants in this project.

Narrative

*Overview:*

We propose to develop, test, exhibit, and disseminate NIGHT WALK, an integrated science "discovery" system based on bioluminescence -- light generated by living systems.

Our long range aim is simply to put together a fully integrated science discovery system based on bioluminescence.

We propose a 5 year collaborative interdisciplinary project to research and produce interactive discovery exhibits using bioluminescence. The is a collaborative effort between The Children's Museum of Utah, the University of Utah's Center for Integrated Science Education, and Protein Solutions, Inc., a local company specializing in materials for science education (Figure 1).

We will develop and produce 8 different interactive bioluminescent exhibits, combine them to produce a comprehensive discovery exhibit, and prepare and provide supplementary discovery materials and kits.

This project involves 7 tasks over its 5 year duration:

- Bioluminescence Research
- Production of Organisms
- Exhibit Design
- Exhibit Construction
- Maintenance & Operation
- Assessment & Evaluation
- Dissemination

*Institution Profile: The Children's Museum of Utah*

The Children's Museum of Utah is a relatively new, dynamic children's museum with highly dedicated and motivated professional and volunteer staff. It is located on an outstanding site immediately North of downtown Salt Lake City in the foothills of the Wasatch Mountains with ample parking and visitor access. The site includes an old hot springs and a magnificent building ideal for the development of interactive science exhibits.

In 1978 a group of dedicated parents and educators founded The Children's Museum of Utah (TCMU). They designed the Museum to be "hands-on," allowing visitors to experiment with the exhibits and explore new concepts. Beginning that year, Museum organizers secured a location, raised money, and eventually opened TCMU's doors in 1983 with eight exhibits. TCMU currently has 32 exhibits, two traveling exhibits, and one outreach program.

TCMU is in a unique situation. As the only "hands-on" museum in Utah, it serves an entire region. In 1991, TCMU hosted over 19,000 school children from all parts of Utah as well as parts of Idaho, Wyoming and Nevada. Therefore, TCMU provides its services to children of different backgrounds and situations. The Museum has special programs for at-risk students. For example, during the 1990-1991 school year, TCMU welcomed an inner city, at-risk preschool to hold daily class in the Museum. TCMU offers students an educational opportunity different than in regular classrooms -- hands-on experience.

TCMU's background in educational programs is strong. A recent example is the 1990 JASON Project -- a successful program to involve children directly in science with exploration. It involved collaboration with schools and youth organizations, with local corporate and foundation support. TCMU has also collaborated with the University Hospital and Primary Children's Medical Center (PCMC) on scientific programs. The University Hospital helped TCMU to establish an exhibit about the original artificial heart. They donated equipment and expertise to the project. PCMC is currently developing an exhibit on heart mechanics/functions and preventive medicine.

The Museum is working closely with the University of Utah's new Center for Integrated Science Education (CISE), a participant and subcontractor in this proposal, to develop totally new and unique interactive science experiences.

*Need:*

There is a growing awareness and interest in Utah in integrated discovery and experiment-based science education activities. Our museum, the University of Utah's Center for Integrated Science Education (CISE), the Natural History Museum of Utah, and Utah State University's Department of Elementary Education, have all become involved recently in the development and enhancement of such activities. The Davis, Salt Lake, and Jordan School districts are presenting a range of inservice programs for elementary and high school teachers along these lines.

We have already presented inservice courses titled, "Light from Life: Science in the Dark," to elementary and high school teachers in the region, with an exceptionally strong, positive, and enthusiastic response. The teachers and their students are interested in obtaining more information and experience with bioluminescence. The teachers realize that bioluminescence is an exceptionally strong tool for motivating students in science, and for the teaching of science as an integrated field of inquiry. They are requesting, indeed they are demanding, materials, exhibits, and additional experiences. Hence, this proposal.

Utah's school spending per student is fifth in the United States. Therefore, outside-of-class activities are important for the development of Utah's children -- especially in the sciences. To provide each Utah school with the necessary items to involve students in well-designed science projects is very difficult. The Children's Museum of Utah offers a central location, well-known for its educational emphasis, where interactive science exhibits, such as this bioluminescence project, would reach the maximum number of children.

Furthermore, this project will be an excellent outreach program for those schools that may not have the opportunity to visit the museum because of either distance or funding problems.

TCMU's audience includes children from both rural and urban areas. A majority of on-site Museum visitors come from Salt Lake City and surrounding areas. Nevertheless, because of the large rural population surrounding Salt Lake City, an estimated 25% of Museum visitors reside in rural areas. TCMU's off-site audiences include more distant school districts, some coming hundreds of miles to visit. In addition to daily school groups and non-group visitors, TCMU housed an at-risk preschool for the entire 1990-1991 school year.

*Strategy:*

Museum organizers feel a need to strengthen the Museum's science exhibits and activities for two reasons:

1) as the Museum develops its science facilities, more schools, children's organizations, and individual families will come to the Museum;

2) children's participation in captivating, exciting science exhibits in the Museum will encourage them to explore science in the classroom and at home.

The bioluminescence project is part of a 5 year plan to develop TCMU's science facilities. Along with this project, TCMU is focusing on the following projects:

- *Speleology*: TCMU and the U.S. Bureau of Mines are developing plans for a "cave exhibit," including stalagmites, stalagites, cave animals, etc. The project will be completely "hands-on."
- *Human Physiology*: TCMU is collaborating with Primary Children's Medical Center on a "hands-on" heart exhibit to explain and demonstrate how the heart functions.
- *Astronomy*: TCMU has plans for a space simulator exhibit, in collaboration with ASTC, NASA, and Morton Thieckel Corp.
- *Zoology*: Currently, TCMU has a small animal collection. The new exhibit would include a petting zoo and displays on animal families.

- *Technology*: TCMU has invited KSL-TV, U.S. West Telecommunications and Evans, and Sutherland Computer Corp. to develop hands-on exhibits focusing on the technology of their respective companies.

The Museum has aggressive exhibit development activities in collaboration with the Center for Integrated Science Education. The plan is for the two institutions, in partnership with local industry, to produce and disseminate materials and exhibits to other museums and institutions nationally and even internationally. We expect that these activities will eventually provide a modest income to help sustain and develop this museum.

*Proposed Activities:*

We have available a set of technologies which make it possible to demonstrate and experiment with bioluminescence in a highly interactive inquiry-based mode. We are also developing additional technologies and methods using bioluminescence.

The basic plan for the exhibit is given in Figure 3. After some preliminary orientation, including a short video, the visitors are directed into a dark room, similar to what is already used in museums for various kinds of light shows and for fluorescent mineral (black light) exhibits. Visitors first experience a small fountain, or LEFT-POND, in which a suspension of microscopic bioluminescent organisms is allowed to drop into the pool. With each drop, a brilliant blue bioluminescence is emitted from the point of contact; the light moves radially outward with the nipples. The column of drops is not luminescent. Bioluminescence in these organisms is mechanically stimulated, generally by pressure and force changes in the water. This is a dramatic observation and immediately results in a wide range of questions. They are not answered at this time. The objective is to let the visitors formulate their own questions and their own hypotheses as to what is happening, and to become fully, dark adapted to make the remaining stages of the exhibit even more impressive.

They are then directed to a flat panel on a wall or table and instructed to write their name by simple pressing and running their fingers over the panel, analogous to what one does with a Magic

Slate® or a touch sensitive computer screen. The panel contains a viscous suspension of the same bioluminescent microorganisms. As they touch, the suspension lights up, and their names (or other patterns they trace) are illuminated in the beautiful blue light. The light does not last; it is transient and only emitted *during* the mechanical stimulation, so in that sense it is quite different from Magic Slate® or Glow Slate® children's toys, but that actually adds to the aura and the mystery.

By now they have probably concluded that the blue light has something to do with water and with living organisms

They then move to Station C in Figure 3, where again they are exposed to a suspension of these organisms, but now they are asked to talk to them. By now, we have partially surmised that the stimulation of bioluminescence is mechanical and related to pressure and force changes. Now they stimulate it by sound; they do not physically contact the container. The container, of course, is designed with a flexible diaphragm, analogous to that in a microphone, which will concentrate and focus the air pressure changes due to the sound. After experiencing sound-induced bioluminescence, they will then be encouraged to tap the container. This should enable them to begin to discover the connections between sound, forces, pressure, and direct mechanical stimulation. Now it's time to move into the biology side and find out what is responsible for the light.

In Station D they observe the same suspension in a low power microscope, using a video camera output on a screen. There they will observe that the organisms are moon-shaped. They may even be able to observe the individual organisms bioluminescing depending on the resources available, the quality of the camera, etc. We are now well into biology. They should see some of the organisms in the process of fission, and hopefully will ask some questions regarding cell division, cell reproduction, the shape of the organism, the nature of the nucleus, and why the cell bioluminesces.

One of the real advantages of bioluminescence is that it is an unknown phenomenon. It is not usually found in textbooks [5]. No one has flunked it, no one has developed science anxieties

towards it. Therefore, students are exceptionally receptive to it; they are incredibly curious and highly motivated. It is an ideal vehicle by which to teach science in an integrated fashion (Figure 2).

In working through exhibits A-D, they will already have been introduced to some areas of physics, the principles of optics and mechanics. By the time they get to D they are starting to move into biology. By the time they are finished with D there will also be some brief introduction to chemistry, in terms of the chemical processes and nutrients required for bioluminescence.

Moving to Exhibit E we expect to have large, flat panels, analogous to Art Farms, but rather containing bioluminescent worms, both marine worms and terrestrial earthworms. They, too, give off a blue bioluminescence when mechanically, chemically, and/or electrically stimulated. Visitors will see the worms leaving behind a trail of bioluminescent mucus or slime, and that leads to a whole new series of questions.

Station F deals with a dry powder from a small marine crustacean. We may even have them prepare the powder with a simple mortar and pestle grinding operation. They then touch their finger to a tiny bit of tap water and into the powder and, again, bright bioluminescence is the result. We are tentatively calling this 'NEIGH-PANTS™'. They will be encouraged to dab it on their fingers and on their hands. It is non-toxic, but fishy smelling, so they will be encouraged to wash it off, where they will observe bioluminescence as the water goes down the drain! At this point we will probably introduce the concept of chemiluminescence by using the common 'Life-Silk™' that is readily purchased in hardware and outdoor equipment stores.

Station G is a set of small marine aquaria, in which other bioluminescent organisms are located. This is more of an observation to illustrate the diversity of bioluminescence in biology - various types of bioluminescent jellyfish, shrimp, fish, and worms will be there and induced to bioluminesce.

Station H requires a considerable amount of research and development. We expect to have other resources available for this part of the project. The long range goal is to culture and grow firefly larvae and have the students actually walk into a room containing fireflies. This may not be

too dramatic to those of you from the East and Midwest, but fireflies are very uncommon in the western United States. Textbooks say they are not found west of the Rockies, although we know they are found in some regions in Utah. This is the trickiest part of the project because although firefly larva can be maintained in storage for several years, the fireflies themselves are very delicate and sensitive. However, in an appropriate environment we should be able to transform larva to fireflies indoors. In fact, there is a considerable Japanese experience with this activity.

At each of the exhibit stations we will integrate what they are observing with what went before. Finally, at the Exit, they will be directed towards a comprehensive display exhibit on bioluminescence and to the museum shop, where there will be pamphlets and booklets. There will also be a variety of science education kits on bioluminescence available for purchase.

We are also planning on developing a video, including several excellent public TV segments on bioluminescence, for both museum use and possibly for commercial sale.

*Schedule:*

The project would be accomplished over a 5 year period. In the first year we expect to take existing technology which has already been developed by the Center for Integrated Science Education (CISE) and develop it into an interactive exhibit format. For example, Stations A, D, and F in Figure 3 could be implemented within the first year. This would provide experience in transferring some of the technology and expertise from CISE to the Museum; we would begin to train museum personnel to grow and maintain the organisms. It would also give us considerable experience with exhibit design, implementation, and maintenance and operation. To our knowledge, there has never been such an interactive exhibit, so clearly there will be a lot to learn.

Research, development, and organism production will continue within CISE for the first 2-3 years of the project. Exhibit design, construction, maintenance, and operation at the Children's Museum will begin in year 1, and will progressively increase in effort until the full exhibit is in place, probably in year 4.

In year 1 CISE will do the research and development required to make Stations B and C practical. They will then concentrate their efforts in year 2 on Exhibits E and G, and in years 3 and 4 on Exhibit H. They will also be largely responsible for putting together all of the educational materials for the static exhibit, Station I.

As soon as we have the first exhibit up and running (Stations A,D, and F), towards the conclusion of year 1, we will begin the assessment and evaluation process (described later).

*Administration and Personnel:*

Research and development, organism production, and preliminary exhibit design will be conducted largely by the Center for Integrated Science Education at the University of Utah. Dr. Joe Andrade, Director of that Center and co-investigator on this project, has four years of experience in bioluminescence, has conducted a variety of teacher inservices and demonstrations relating to bioluminescence, and already has the technology and experience in hand for exhibits A,D, and F in Figure 3 [7].

The Center sponsored the Utah Bioluminescence Contest last Spring and is mapping the location of bioluminescent organisms in the State of Utah. Andrade has been in communication and has interacted with bioluminescence experts throughout the world.

Andrade and his staff will also be primarily responsible for the educational materials and kits which will become available.

Exhibit design and construction will be done primarily by the staff of the Children's Museum of Utah under the direction of Richard Morris. TCMU will work with Gillespie/Las Vegas on exhibit design, construction, consultation, fabrication, installation, and testing (letter of commitment included).

Children's Museum staff and personnel will be trained in CISE laboratories on the maintenance and operation of the cultures and of the exhibits. The group will then establish an appropriate laboratory at the Children's Museum for this purpose.



Antrade has support from the State of Utah's Centers of Excellence Program, from local industry, and from the National Science Foundation related to the use of bioluminescence for science education. All of these activities are directly relevant to this project. He is spending about 50% of his time on bioluminescence-related activities.

*Dissemination:*

There are three different audiences for dissemination activities:

- 1) local and regional;
- 2) national museum and science center community; and
- 3) professional scientists and educators.

For *local and regional audiences* we will work closely with existing public relations and communications vehicles, including major daily newspapers, local and regional magazines, and local freelance writers, to encourage stories and features in the mass media relating to the bioluminescence exhibits. For the lay public, TCMU disseminates results and information through its newsletter and via an outreach program to students and educators involving demonstrations and lectures.

We will work closely with the State Office of Education, Offices of Education in neighboring states, and with the school districts to inform them as to the availability of these experiences at the Children's Museum Utah.

A good example of an activity which recently generated statewide publicity and interest is the Utah Bioluminescence Contest, conducted by the Center for Integrated Science Education last spring. We are also working closely with the Utah Chapter of the National Science Teachers Association, and participating in their semi-annual meetings, as well as offering inservices and workshops for the local public education community.

For the *national science museums and science center community*, we will utilize the publications of the Association of Science and Technology Centers (ASTC), American Association of Museums, and their national conferences to inform and to receive input from the informal

science education community as to our bioluminescence-based activities. We anticipate organizing special sessions at a future meetings of the ASTC and the National Science Teachers Association (NSTA), specifically related to integrated science education and the use of bioluminescence for such activities. We plan to submit guest columns in other museum publications, organize a traveling lecture series offered by project officers, and produce a video on bioluminescence.

For *professional scientists and educators*, we will utilize our professional affiliations in the scientific and education communities to bring these activities to their attention and to seek their input, advice, and critique. Drs. Shoddart, Dole, and Gess-Newsome, in the University of Utah's Department of Educational Studies, are all involved with the Center for Integrated Science Education and are already participating in some of its bioluminescence education activities. They will represent the project at annual meetings of the American Education Research Association, the National Association of Research in Science Teaching, and the Utah Education Association.

Antrade and his co-workers participate regularly in meetings of the American Chemical Society, Division of Chemical Education, the NSTA, the American Physical Society, the American Association for the Advancement of Science, and the international symposium on bio- and chemiluminescence.

All of these avenues will be used to disseminate information about our activities and, even more importantly, to obtain advice, critique, and input.

*Evaluation and Assessment:*

We have assembled a group of scientific experts to function as advisors and critics to ensure that the materials we develop are as scientifically accurate as possible.

W. G. (Woody) Hastings, Professor of Biology, Harvard University, is internationally recognized for his work on bacteria and dinoflagellate bioluminescence[4]. He and his co-workers have worked out the basic chemistry of dinoflagellate bioluminescence. He has applied these systems for the study of biological circadian rhythms, and is published widely on the subject. His laboratory and work were recently featured in the Public Broadcasting System program, "The

Infinite Voyage" in the recently aired segment dealing with biological rhythms, "The Living Clock."

James Morin is Professor of Biology at UCLA in Los Angeles. Dr. Morin is an expert on the small bioluminescent crustaceans, *vargula*, formerly called *cypridina*. Professor Morin has discovered and categorized some 50 new species of these organisms in the Caribbean and the Gulf of Mexico, and has observed that one of the major functions of bioluminescence is for sexual mating displays. His recent, plenary lecture at the 6th International Conference on Bio and Chemiluminescence, "Shedding Light on Shedding Light", included dramatic videotapes of *vargula*'s underwater luminescent activities.

William McElroy is Professor Emeritus and Chancellor Emeritus of the University of California at San Diego (USCD). He is also a former Director of the National Science Foundation. He pioneered bioluminescent studies in the United States and worked out the biochemistry of firefly bioluminescence. His students and post docs have gone on to form and develop a significant portion of the bioluminescence field.

John Buck, National Institute of Health, Bethesda, Maryland, is well known for his work on fireflies. He has worked with fireflies since the mid 1930's.

James Lloyd, University of Florida, Gainesville, is responsible for the most complete and thorough study of firefly species in the United States.

J. Wampler is with the University of Georgia and is an expert on bioluminescent worms. Over the past two years, J. Andrade has personally met and talked with each of these individuals except Lloyd and Buck. Andrade has talked with Lloyd extensively by phone and has corresponded with Buck. Meetings are planned in the near future.

Our education/curriculum consultants include Lawrence Lowery, Lawrence Hall of Science, Berkeley, and Dale Baker (Arizona State University).

Dr. Dale Baker is Chair of the Department of Curriculum and Instruction at Arizona State University. She is an expert on student attitudes towards science learning, gender differences in science achievement, and the relationship between instruction and student performance in science.

In 1989, she was the recipient of the "Outstanding Research Award for Practical Application in Science" from the National Association of Research in Science Teaching (NARST) and in 1988 received the NARST award for the best publication in science education.

Dr. Lawrence Lowery, Professor of Science Education in the Department of Mathematics, Science and Technology in the Graduate School of Education, University of California, Berkeley, is Director of the Educational Research and Applications Teacher Credential Program and a Senior Researcher at the Lawrence Hall of Science. Dr. Lowery is an expert in the development of children's scientific concepts and the design of science curriculum and instructional methods. He is principle investigator of Full Option Science System (FOSS), EQUALS in Technology, Science, Education for Rural California (SIRC) and Family Math. He is Co-PI on the Bay Area Math Project. He has received many awards including "Science Educator of the Year" in 1989 from the Association of Educators of Teachers of Science (AETS) and the "National Exemplary Project, Science Instruction for Rural California" in 1987 from the U.S. Department of Education.

The set of experts on bioluminescence will be asked to review and critique all of the materials and exhibits to minimize any scientific inaccuracies or misinterpretations. Several will be individually invited to campus to give seminars and lectures at the University of Utah on their bioluminescence work and to observe and to assess the activities and developments in this project. We expect them to be active partners throughout the entire project.

The recognized and accomplished science educators will provide criticism and advice regarding the implementation and application of bioluminescence to the student and teacher populations. They will also participate in critical assessment of the exhibits and hands-on activities.

Dr. T. Stodart, Asst. Professor of Educational Studies at the University of Utah, will work with us to assess visitor pre-conceptions about bioluminescence and their conceptions and understanding after experiencing Night-Light. This will be done in collaboration with elementary teachers and their classes.

Evaluation and assessment activities will also include visitor, teacher and general public surveys. The Advisory Board will provide input on an annual basis. The evaluation and assessment activities will be used to modify, improve, and enhance the activities in the grant.

*Future Plans:*

TCMU and CISE are committed to the use of bioluminescence for science education. The older adults who have experienced it are just as awed and motivated as are the kids. We expect no problem in developing local private funding with which to continue to operate, maintain, and enhance Night-Light after the conclusion of this H. Hughes Medical Institute grant.

In addition, we will work closely with Protein Solutions, Inc., and with others to insure wide spread dissemination of the materials, kits, and interactive exhibits.

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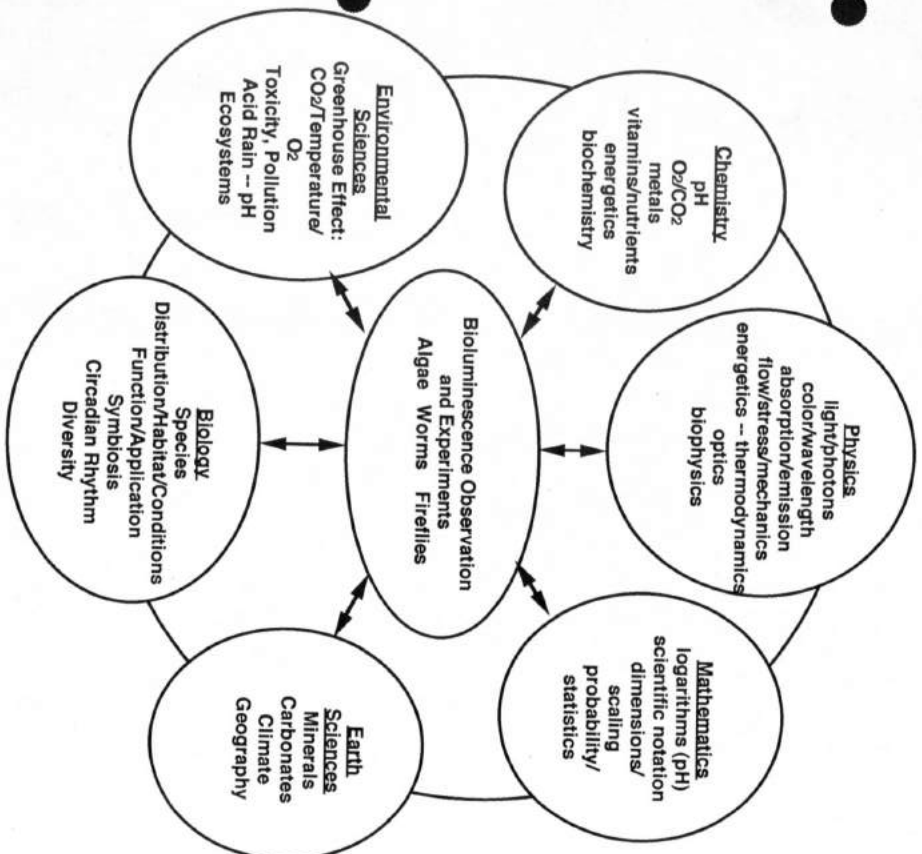


Figure 2: Bioluminescent organisms and their observation are shown as the center of an integrated science "wheel". Each of the classical specialties or disciplines are indicated with selected subject examples. These subjects and topics can all be directly observed and experimentally studied via bioluminescence.

**NIGHT-LIGHT™  
Science in the Dark!**

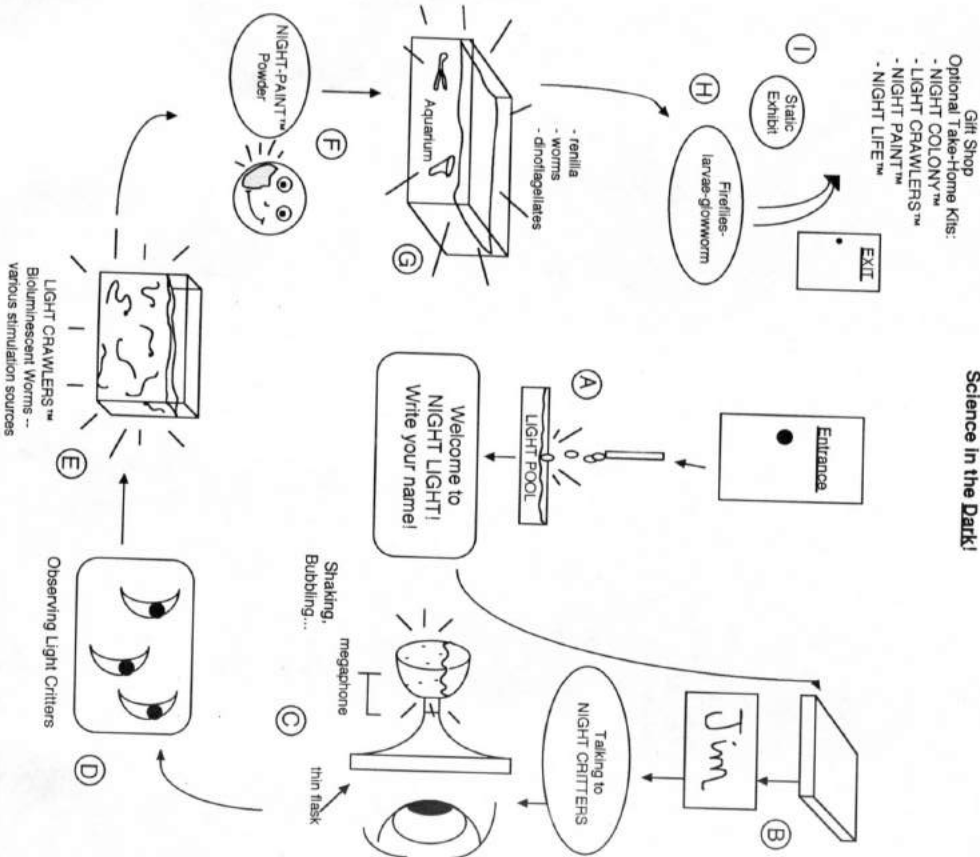


Figure 3: Bioluminescence-based activity exhibits.

References:

1. National Geographic Magazine has had many articles and photos of Bioluminescence: P.A.Zahl, "Nature's Night Lights," July, 1971, p.45. P.A.Zahl, "Fishing in the Whitpool," Nov, 1973, p.579. D.L. Teimann, "Nature's Toy Train, The Railroad Worm," July, 1970, p.58. P.A. Zahl, "Fireflies," July, 1962, p.48.
2. Several major encyclopedias include articles on bioluminescence: Encyclopaedia Britannica McGraw Hill Encyclopaedia of Science and Technology Popular science articles include: K.H. Neilson and C. Amussen, "Marine Bioluminescence: About to See the Light," *Oceanus* 28(3)(1985)13. P. Huyghe, "Wheels of Light, Sea of Fire," *Oceanus*, Dec, 1987, p.21. M. Root, "Glow-in-the-dark Biotechnology," *Biological Science* 38(11)(1988)745. A.K. Campbell, "Lying Light," *Trends in Biological Sci.* 11(1986)104. A.P. Neary and C.S.J. Walpole, "Bioluminescence-Chemical Light," *Science Progress* 70(1986)145. P.J. Herring, "How to Survive in the Dark: Bioluminescence in the Deep Sea," in M.S. Laverack, ed., *Physiologic Adaptation of Marine Animals*, Soc. of Experimental Biology of Great Britain, 39(1985)323-351.
4. J.W. Hastings, "Biological Diversity, Chemical Mechanisms, and the Evolutionary Origins of Bioluminescent Systems," *J. Molecular Evolution* 19(1983)309.
5. Although bioluminescence is largely unknown in the K-12 and college curricula, there is an extensive scientific literature: E.N. Harvey, *Bioluminescence*, Academic Press, 1952. A.K. Campbell, *Chemiluminescence*, VCH Publ, 1988.

F.H. Johnson and Y. Haneeda, *Bioluminescence in Progress*, Princeton Univ. Press, 1966

P.J. Herring, *Bioluminescence in Action*, Academic Press, 1978

P.J. Herring, A.K. Campbell, M. Whitfield, and L. Maddock, *Light and Life in the Sea*, Cambridge University Press, 1990.

Much of the current scientific information is being published in the *Journal of Bioluminescence and Chemiluminescence*, John Wiley and Sons

6. There is a limited discussion of bioluminescence in science and nature books for children, the most complete is

A. and U. Silverstein, *Nature's Living Light*, Little, Brown, & Co., 1988.

7. Our interest in bioluminescence began in 1985 when J. Andrade became interested in the subject and began doing some simple "discovery" experiments. Work began in earnest in the Fall of 1987. Protein Solution, Inc. (PSI) was established in early 1988 with the goal of developing bioluminescence for the children's education and toy markets. PSI has been funding bioluminescence work in Andrade's lab for nearly 3 years (about \$60,000 total to date). It was already clear in 1987 that bioluminescence was a real attention getter and motivator of children and adults. Andrade's wife, Barbara, is a first grade teacher.

Together they developed several demonstrations and experiments. The phenomena were presented to Dr. T. Stoddart and R. Stofflett in the Department of Educational Studies. Science curriculum specialists in the State Office of Education, several local school districts, and local educators and students were all excited (Table 2). It was decided that there was sufficient interest and commitment among all involved to develop bioluminescence as a discovery tool for integrated science education.

Protein Solutions, Inc. (PSI)  
Science Education Innovators

October 7, 1991

Mr. Richard Morris  
The Children's Museum of Utah  
840 North 300 West  
Salt Lake City, Utah 84108

Dear Richard:

Protein Solutions, Inc. is delighted to work with you in developing a series of interactive exhibits using bioluminescence.

Our NEAT-LIFE product will be launched in mid-November, 1991 and first marketed in the Salt Lake area. We expect regional and West Coast distribution in early 1992, with national distribution in Fall, 1992. Given the enthusiastic response from teachers and students in the Davis School District, we expect it to be a popular and successful science educational product.

We are eager to share this technology with you and to develop and enhance it for interactive exhibits. After successfully implementing such exhibits in TCMU, we look forward to working with you to sell and distribute such exhibits nationally.

PSI has a Technology Transfer and royalty agreement with the University of Utah and is a major corporate participant in the University's Center for Integrated Science Education. We are pleased to work with you in developing a suitable agreement between TCMU, the University of Utah, and Protein Solutions, Inc.

We expect Federal Small Business Innovation Research (SBIR) grants shortly to perform the research needed for several additional products. This technology will be directly applicable to your proposed exhibits C, E, and G in your Figure 2 in the Hughes proposal.

We are pleased to provide you and your co-workers at CISE with organisms, media, supplied, etc. on a cost only basis for your work on bioluminescence-based science exhibits.

We look forward to continuing to work with you.

Sincerely,

J.D. Andrade, Ph.D.  
President, PSI

Mailing Address:  
6009 Highland Drive  
Salt Lake City, Utah 84121  
(801) 277-1259 (evenings)

Lab & Delivery Address:  
390 Wakarusa Way, Room 63  
University of Utah Research Park  
Salt Lake City, Utah 84108

Giltspur/Las Vegas  
Division of Giltspur, Inc.

Suite B 4545 Cameron Street  
Las Vegas, NV 89103-6502  
USA

Telephone: (702) 368-7730  
Fax: (702) 368-7800

THE CHILDREN'S MUSEUM OF UTAH



October 2, 1991

Children's Museum of Utah  
840 N. 300 W.  
Salt Lake City, Utah 84103

Attn: Mr. Richard Morris

Dear Mr. Morris:

Giltspur/Las Vegas, a nationally recognized museum developer and fabricator, is pleased to provide this letter of commitment to the Utah Children's Museum.

Giltspur/Las Vegas will provide our full range of services for the successful completion of the Bioluminescence Project. These services include consultation, research and development, design and engineering, fabrication and testing, installation, and all resources associated with them.

Our team of museum experts will collaborate with the Utah Children's Museum and any other consultants necessary to insure an exhibit of the finest quality and highest educational value.

Again, Giltspur/Las Vegas would like to assure you of our commitment and dedication to this valuable project.

Sincerely,

*Bryan B. Kenny*

Bryan B. Kenny  
Account Executive

BBK/NKT:dmr

*M. Katherine Tipton*

M. Katherine Tipton  
Director Museum Development

Atlanta / Boston / Buffalo / Chicago / Cincinnati / Dallas / Las Vegas / Los Angeles / New Orleans  
New York / Orlando / Phoenix / Pittsburgh / Rochester / San Francisco / Tampa / Toronto / Washington, DC

A-23



7 October 1991

Refer to: 91-267

Mr. Richard Morris  
The Children's Museum of Utah  
840 North 300 West  
Salt Lake City, Utah 84103

Dear Mr. Morris:

We are pleased to endorse the collaboration and interaction between the Children's Museum of Utah and our newly formed Center for Integrated Science Education (CISE).

The University of Utah is eager to participate in activities which can aid the science awareness and education of the general public. We are impressed and pleased with The Children's Museum of Utah's programs for educating children, as well as their parents and teachers.

The budget which CISE has prepared for its part of your Night-Light proposal to the Howard Hughes Medical Institute includes direct costs only. The waiver of the usual indirect costs reflects our conviction of the importance and quality of your programs and activities.

Keep us posted on this exciting project!

*Ronald J. Pugmire*  
Ronald J. Pugmire  
Acting Vice President for Research

cc: J.D. Andrade, CISE

Vice President  
for Research  
210 Park Building  
Salt Lake City, Utah 84112  
(801) 581-7236

*Richard Morris Hughes  
CHILD MUSEUM UTAH*

**FOR PROCESSING OF PROPOSALS TO OFFICE OF SPONSORED PROJECTS**

**SECTION I (To be completed by the Principal Investigator or Originating Department/Office) (SEE REVERSE SIDE).**

PROJECT:  New  Renewal  
 Research Non-Fed  Continuation  
 Research Non-Fed  Reversed  
 Grant  Public Serv Non-Fed  Supplemental  
 Other Agreement  Other (Check one)

Deadline Date: \_\_\_\_\_ (Check one)  
 Postmark  Account no. to be charged  
 Due at Agency  Special Courier

Name of AGENCY where Proposal is to be submitted:  
 The Children's Museum of Utah  
 840 North 300 West  
 Salt Lake City, Utah 84103  
 Phone No. (801) 328-3383

City \_\_\_\_\_ State \_\_\_\_\_ Zip Code \_\_\_\_\_

Attention: Person to whom addressed:  
 R. Morris

**TITLE AND NARRATIVE DESCRIPTION (Indicate how project will aid academic program of University)**  
**NIGHT-LIGHTS: Science in the Dark.**

This is a multidisciplinary activity and a collaborative effort with the Children's Museum of Utah. The program will support much needed activities in the enhancement of science education in the community. Faculty, staff, and student support are budgeted. A company in which the University has an equity holding, Protein Solutions, Inc. (PSI), is also directly involved.

Principal Investigator:  Will  Will not be on extended leave of absence during the project. J. Andrade is Pres. of PSI.  
 Has  Has not potential conflict of interest with private company or investment group.  
 Health and/or Safety reviews required? (See reverse side)  Yes  No Committee/Board Approval This grant is covered by the indirect cost waiver request? (See reverse side)  Yes  No Waiver Approved: VP for research or designee Technology Transfer

**AGENCY FUNDS (fill in dollars and amounts)**

DATES	Irregular Period From 6/92 to 5/97	UNIVERSITY FUNDS	<input type="checkbox"/> Institutional Cost Sharing Agreement
Direct Costs	\$45,000	Indirect Costs	\$180,000
Indirect Costs	\$45,000	Other type matching or contribution	
Total Costs	\$45,000	Cost Sharing shown for proposal review only	

If other than institutional cost-sharing attach cost-sharing data sheet

**DEPARTMENT AND COLLEGE APPROVALS**

We certify that staff, space equipment, computer time, etc. are available and/or budgeted by us. If not, attach statement of additional requirements. Principal Investigator will submit the final technical report as required.

DEPARTMENT CHAIRPERSON: R. Norman  
 DEPARTMENT CHAIRPERSON: J.D. Andrade  
 DEPARTMENT CHAIRPERSON: J.D. Andrade  
 DEPARTMENT CHAIRPERSON: D. Pershing

**SECTION II (To be completed by the Office of Sponsored Projects) DTP, Technology Transfer, Tom Major**

**ADDITIONAL REQUIREMENTS BY THE UNIVERSITY**

**PROPOSAL OR APPLICATION REVIEW AND ROUTING**

Reviewed by Sponsored Projects \_\_\_\_\_

**SECTION III (To be completed when final contract or agreement is processed)**

Date contract received \_\_\_\_\_ Contract period of Performance 19\_\_ to 19\_\_ Contract Number \_\_\_\_\_ Amount \_\_\_\_\_

I have reviewed this contract and recommend that it be accepted. To the best of my knowledge the requirements and terms set forth therein can be fulfilled in the time and under the conditions specified. I am aware of the Utah State laws governing the employment of relatives on such contracts.

Date \_\_\_\_\_ Signature of Principal Investigator/Director \_\_\_\_\_

**CONTRACT OR FINAL REVIEW AND ROUTING**

Contact reviewed by Sponsored Projects \_\_\_\_\_

Contact or Grant No. \_\_\_\_\_

University Account No. \_\_\_\_\_

Revised 8-85-88 (Return to the Office of Sponsored Projects, 309 Park Building, for final processing)

**PROPOSAL**

To: Howard Hughes Medical Institute  
 Office of Grants and Special Programs  
 1992 Precollege Science Education Initiative for Science Museums  
 6701 Rockledge Drive  
 Bethesda, MD 20817

From: The Children's Museum of Utah  
 840 North 300 West  
 Salt Lake City, Utah 84103

Title: NIGHT-LIGHTS: Science in the Dark  
 Duration: 5 Years

Amount: \$350,000

Principal Investigator: Mr. Richard R. Morris  
 Executive Director  
 The Children's Museum of Utah  
 (801) 328-3383  
 FAX (801) 328-3384

Subcontract: Center for Integrated Science Education (CISE)  
 University of Utah  
 2480 MEB  
 Salt Lake City, Utah 84112

Subcontract PI: J.D. Andrade, Professor of Biomechanical Engineering  
 2480 MEB  
 University of Utah  
 Salt Lake City, Utah 84112  
 (801) 381-4579  
 FAX (801) 381-8692

R. Morris  
 The Children's Museum of Utah

J. Andrade  
 University of Utah



*NIGHT-LIGHT: Science in the Dark*

Executive Summary

We propose to develop, test, exhibit, and disseminate NIGHT WALK, an integrated science "discovery" system based on bioluminescence -- light generated by living systems [1-7].

Nearly everyone who discovers and observes bioluminescence is impressed and motivated to see and learn more. In these times where people have their senses constantly stimulated to near exhaustion, bioluminescence is a relatively unknown, unexperienced phenomenon which can readily compete for a visitor's attention and interest.

Bioluminescence is a phenomenon which is largely unknown to students and teachers and almost totally excluded from all science curricula and textbooks, from kindergarten to undergraduate college [5].

The project will develop integrated and interactive science exhibits which will be used for public education activities in an informal and interactive setting.

The basic idea is to have the participants *discover* something completely new -- and thus stimulate them to ask questions and formulate hypotheses.

Many of their questions and hypotheses are then addressed and tested in other exhibits.

Depending on age and background, participants will discover their own answers and be led into various areas and aspects of science. The exhibits serve as resources to *aid* their discoveries and education.

Our long range aim is simply to put together a fully integrated science discovery system based on bioluminescence suitable for science museums.

We propose a 5 year collaborative interdisciplinary project to research and produce interactive discovery exhibits using bioluminescence. This is a collaborative effort between The Children's Museum of Utah, the University of Utah's Center for Integrated Science Education,

\* references are located on page - 20.

and Protein Solutions, Inc., a local company specializing in materials for science education (Figure 1).

The materials will aid in the observation, discovery, and learning of basic concepts in various science fields. The visitors will develop new and expanded understandings of science concepts in a completely new domain -- bioluminescence. The concepts and understanding derived from bioluminescence are general and applicable to the full range of scientific and technical subjects (Figure 2).

We will develop and produce 8 different interactive bioluminescent exhibits (Figure 3), combine them to produce a comprehensive discovery exhibit, and prepare and provide supplementary discovery materials and kits. An assessment plan is included -- as well as a comprehensive plan for publication and dissemination.

We request a total budget of \$350,000, over 5 years, allocated to the following activities:

Bioluminescence Research	27%
Production of Organisms	18%
Exhibit Design	15%
Exhibit Construction	18%
Maintenance & Operation	12%
Assessment & Evaluation	6%
Dissemination	4%

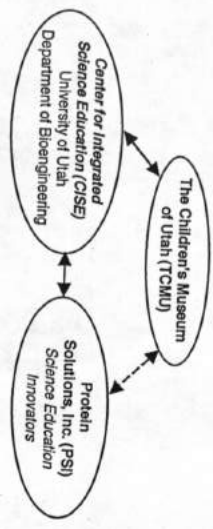


Figure 1: The three key participants in this project.



*The Center for  
Integrated Science Education (CISE)*

October 7, 1991

Mr. Richard Morris  
The Children's Museum of Utah  
840 North 300 West  
Salt Lake City, Utah 84108

Dear Richard:

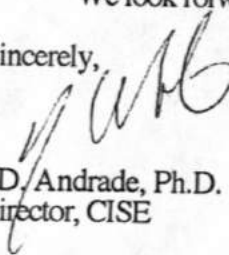
Thank you for the opportunity to participate in your NIGHT-LIGHT proposal to the Hughes Medical Foundation.

I have reviewed the final proposal and am in full agreement with the objectives, tasks, and budget.

The University of Utah has waived indirect costs on this project.

We look forward to continuing to work with you and your staff.

Sincerely,



J.D. Andrade, Ph.D.  
Director, CISE

**Department of Bioengineering**  
2480 Merrill Engineering Building  
Salt Lake City, Utah 84112  
(801) 581-8528  
FAX: 801-581-8692