If a Starfish Can Grow a New Arm, Why Can't I?

A Permanent TE Exhibit with Systemically Integrated Formal and Informal Classroom Connections

Phase I and Phase II NCRR SEPA Project

Presented by: Joan F. Schanck, MPA
Director of Education & Workforce Development
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The project is supported by Grant Number R25 RR023286 from the National Center for Research Resource, a component of the National Institutes of Health.

National Center for Research Resources
NATIONAL INSTITUTES OF HEALTH

PTEI – Background

- Organized in 1993 as informal network of scientists, engineers, community leaders, business persons, et al. to promote commercially-promising TE research in local universities, as well as inter-institutional collaborations.
- 501(c)(3) tax-exempt status awarded by IRS in 1997.
- MISSION: Improve the health of individuals by establishing SW PA as an internationally recognized center of excellence in research, education, and successful translation of TE-related medical therapies.

PTEI – Partners

- Allegheny-Singer Research Institute
- Carnegie Mellon University
- Duquesne University
- US Army Medical Research and Material Command/ISR
- Georgia Institute of Technology
- University of Pittsburgh and UPMC
- Wake Forest Institute for Regenerative Medicine
- University of Washington
- University of California, Santa Barbara
- California Institute of Technology
- Tufts University
- Stanford University
- Windber Research Institute
- Organogenesis, Inc.
- Tissue Genesis, Inc.
- Tissue Engineering and Regenerative Medicine Int'l Society
- Shanghai Second Medical University

PTEI –
The Starfish Collaborative

PTEI
ADVANCING REGENERATIVE MEDICINE

The PTEI and CSC

Introduce TE concepts in a hands-on, interactive way; broaden visitors' interest across disciplines; further understanding of the impact this new technology has on their own health and well-being… with special references to regional strengths driving the field and future regional impact.

Develop exhibit focused on "If a Starfish can grow a new arm, why can't I?"

To explore innate abilities of various life forms in the process of self-regeneration, limited ability in humans, and role of TE toward facilitating regeneration within humans. Foci to further understanding of basic biology, chemistry, and engineering principles of TE.

PTEI –
Really Connecting to the Classroom

ASSET , Inc. (Achieving Student Success through Excellence in Teaching): K-8 science education reform organization. Provides curricula material and PD to PA K-8 schools.

**SW PA LASER site (Leadership and Assistance for Science Education Reform)*

University of Pittsburgh Learning Research and Development Center (LRDC): Research on teaching and learning to contribute to educational reform inside and outside the classroom.

SEPA *Starfish* Project: Goals

PTEI
ADVANCING REGENERATIVE MEDICINE

1. **Broad Aim:** Excite and meaningfully engage students/public to wonders of science, field of TE and stem cell research.

2. Recognizing that 6th-8th grade science curricula textual approach leaves out the "how and why" of science, **primarily targets middle school** (6^{th} – 8^{th}) students and teachers.

3. PTEI, ASSET, CSC and LRDC to collaboratively develop **TE Exhibit** and accompanying **standards- and inquiry-based curricula** and **teacher PD.**

4. **Learning Research & Reform:** How students interact with and learn from informal educational experiences with connections to formal learning critical areas of interest. LRDC as lead.

5. **Traveling Exhibit:** Buffalo Museum of Science; University of Alabama at Birmingham, Discovery Science Center, Pacific Science Center, and the Exploreum.

Overview: *Starfish* Components

PTEI
ADVANCING REGENERATIVE MEDICINE

- **Exhibit Component**
- Form of exhibit (3 Kiosks)
  - Natural World
  - Science of TE
  - Clinical Applications and Future Questions
- PTEI TE focus/content
- Kiosks and activities vetted by middle-school teacher focus groups by both CSC and ASSET

Starfish Formal Educational *REVERBERATIONS*

PTEI
ADVANCING REGENERATIVE MEDICINE

ASSET Life-science teaching modules for connections and enhancements and teacher PD.

- **Diversity of Life (FOSS)**
- **Organisms Macro to Micro (STC/MS)**
- **Human Body Systems (STC/MS)**
- **My Body and Me (SEPUP)**
- **Micro Life (SEPUP)**
- **Our Genes Ourselves (SEPUP)**

FOSS – Full Option Science System
STC/MS – Science and Technology Concepts/Middle School
SEPUP – Science Education for Public Understanding Program

LRDC led, Detailed project effectiveness assessments conducted throughout.

Additional Resources and Linkages: Electronic, Web, etc.

Traveling Exhibit Component

Exhibition Details

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

Mission:

Serve as *introduction* to TE to:

- General Public
- Middle School Students & Teachers in target ASSET districts
- School Students at large

Complemented with:

- Pre & Post-visit Classroom Activities/Curricula
- Teacher Professional Development
- Web-available Enhancements/Interactives
- Middle School Summer Camps

Exhibit Design & Operational Criteria

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

- Exhibit flow can be linearly structured, but must also accommodate entry from any point.
- Each interactive should engage a visitor for at least 15 seconds and no more than 60 seconds.
- Interactives can relate to each other, but should not be dependent on information from one applied to the next.
- Must occupy an entire class (25 students).
- Must occupy an entire family (ages 5 - 85).
- Content at 6th-Grade reading level.

Exhibit Design & Operational Criteria

CARNEGIE SCIENCE CENTER
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Entry Structure and Pathways:

Visitors enter the exhibition via an arch or other concept that serves as a location marker for the entry to the exhibition, as well as a theme-setting piece, representative of skin or bone tissue, etc.

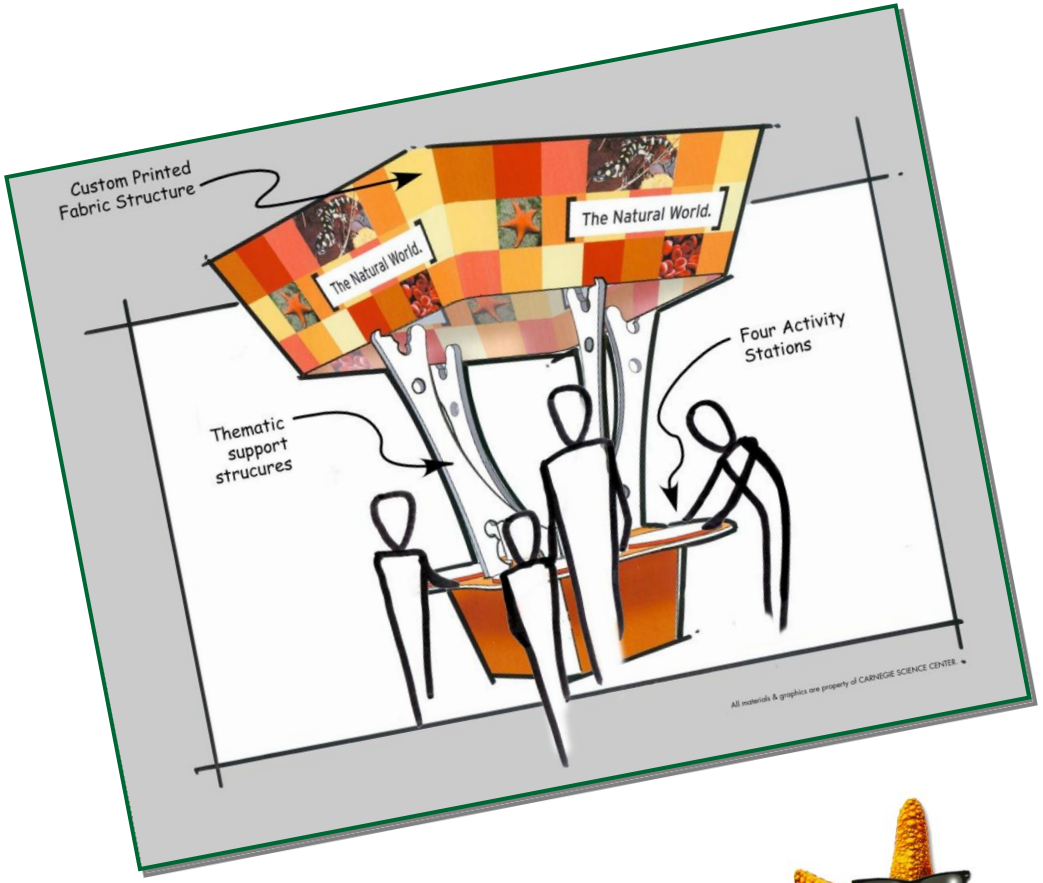
The exhibition is divided into three sections, each with their own theme and content level.

Kiosk I: The Natural World

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

Basic introduction to cells and tissues.

Interactives focused on elementary level, and hands-on/mechanical rather than electronic.



Kiosk I: The Natural World

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Basic introduction to cells and tissues.

Interactives focused on elementary level, and hands-on/mechanical rather than electronic.

Content Goals (abridged)

- All living things are composed of one or more cells.
- There are differences - and similarities - between plant and human cells.
- Cells Individual cells are too small to be seen by the human eye.
- Some organisms are unicellular (e.g. bacteria) and others are multicellular (humans).
- Cells are constantly working, changing, sending and responding to chemical cues, even correcting their mistakes when possible.

Kiosk II: The Science of TE

CARNEGIE SCIENCE CENTER
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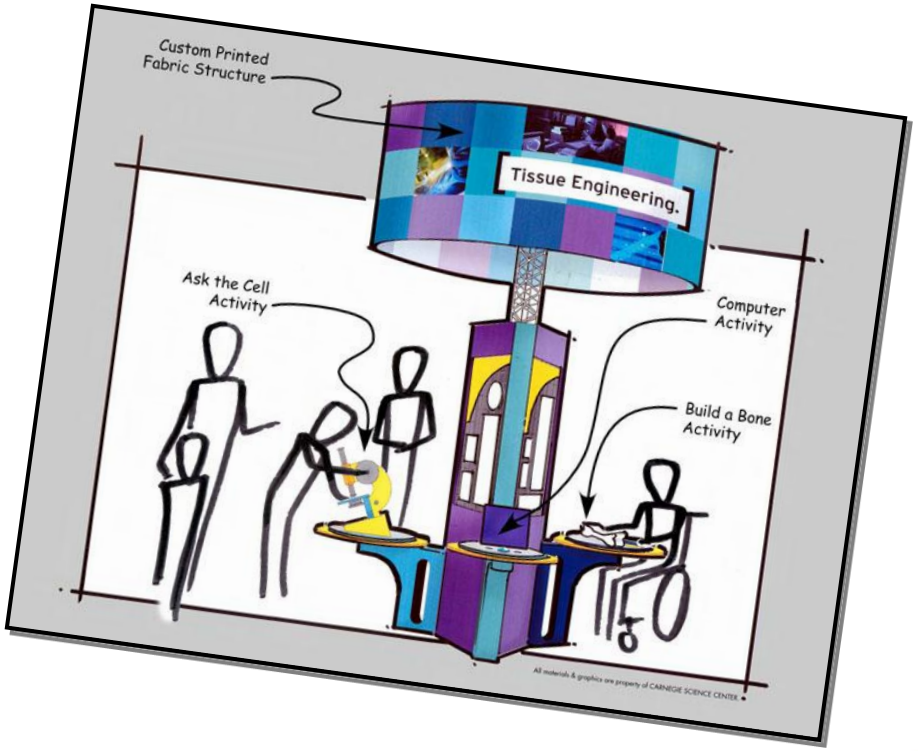
Higher-level content which begins to specifically address TE basics.



Kiosk II: The Science of TE

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Higher-level content which begins to specifically address TE basics.

Content Goals (abridged)

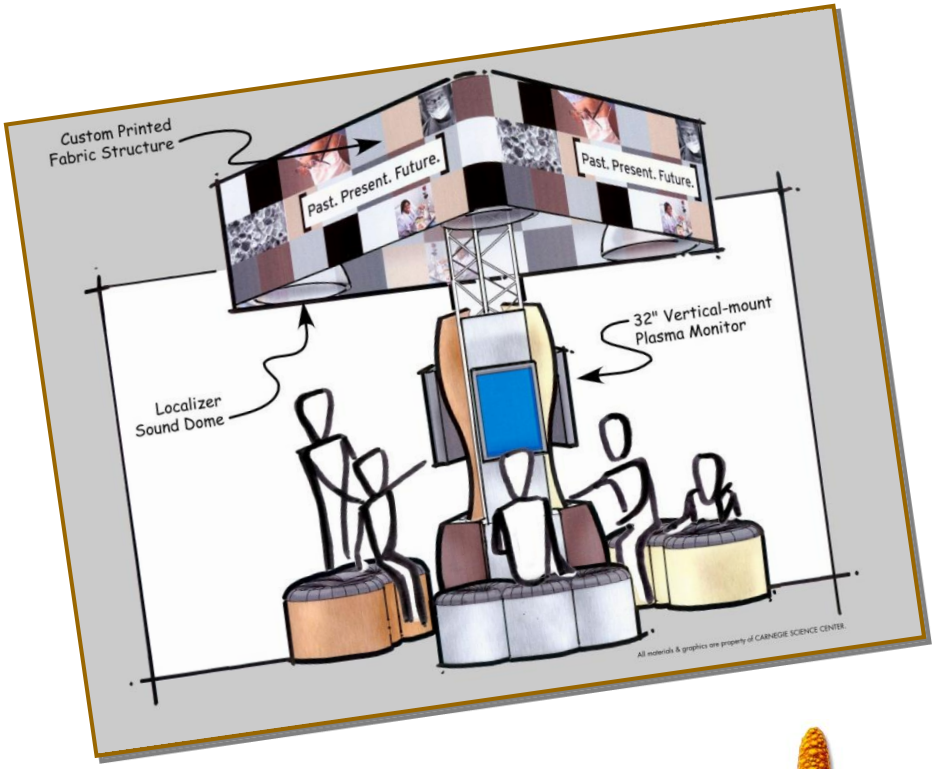
- Stem cells are unspecialized cells that have the remarkable potential to develop into many different, specialized cell types in the body.
- The two broad categories of stem cells are mature (adult) and early (embryonic).
- Adult stem cells are primarily multipotent - can yield all of the cell types associated with the tissues from which they originate. The mature stem cell is an (unspecialized) cell that is found in a (specialized) tissue, renews itself for a lifetime.
- It is expected that stem cells could be used to create an unlimited supply of cells, tissues, or even organs that could be transplanted to restore function lost to illness, disease and injury.

Kiosk III: Clinical Applications & Future Questions

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

Heralds success to date and explores where TE is headed.

Highest-level content, delivered via series of video and computer interactives.



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Content Goals (abridged)

- Real-life case studies where tissue engineering already has helped a person. Examples may include an engineered thumb bone for a man who lost his thumb in an accident, or a burn victim helped with skin “sprayed” onto them, artificial bladder, integration of TE technologies with organ transplantation.
- The most common questions, as well as the promises this field holds.
- Ethical issues surrounding tissue engineering. Responses are saved and tabulated so visitors can see an on-going summary of votes and opinions.

CURRENT STATUS

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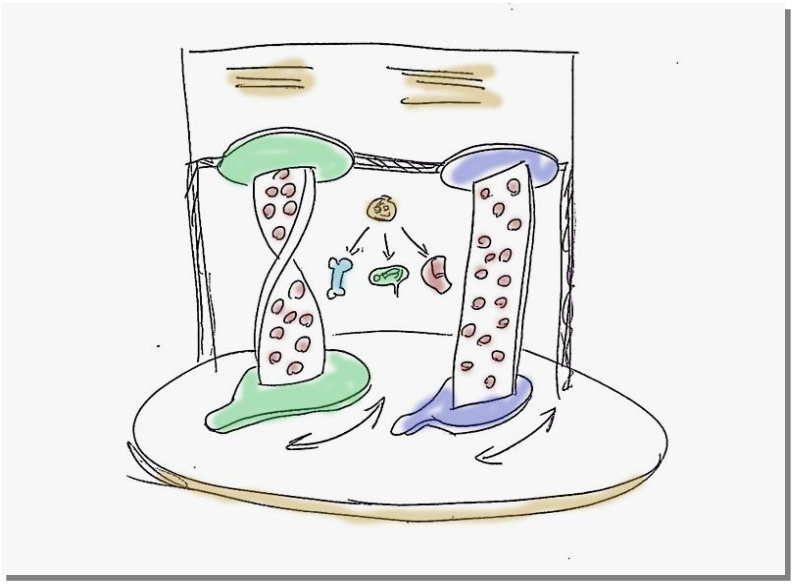
- All interactives from kiosks I & II developed, prototyped and into the Design Phase.



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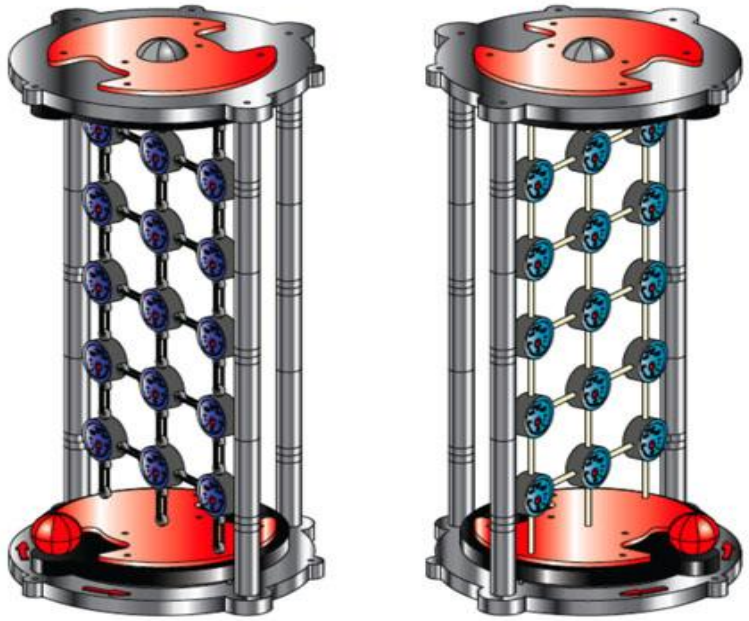

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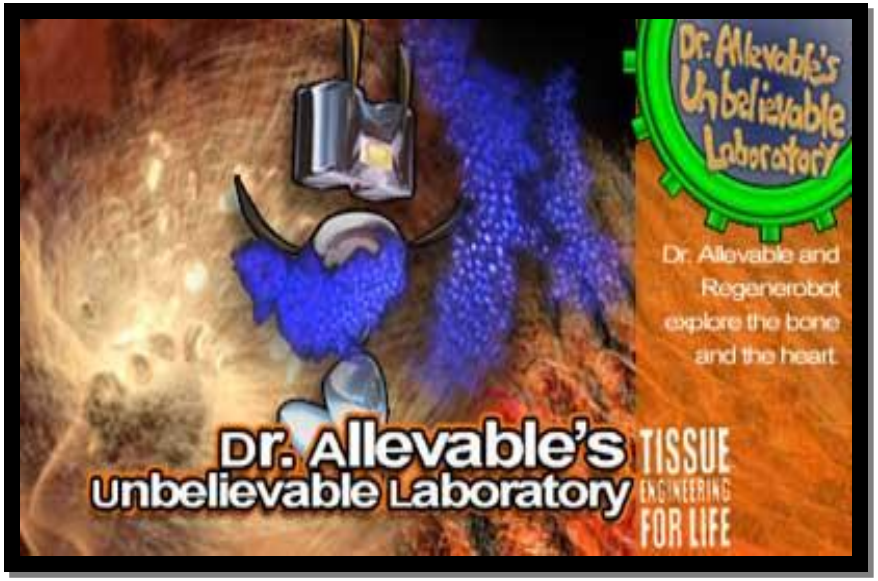

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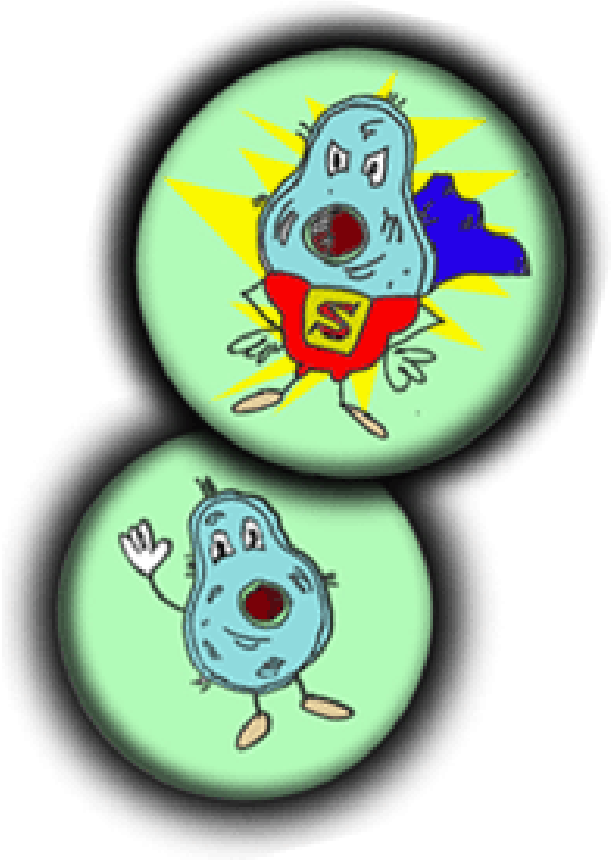

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- Text Panels for Kiosks I & II drafted and into graphic design.

Ani-Motion

What to Do:

Bend down and look through the slots in these drums, while you spin them at a moderate speed. You'll see some cell regeneration in action!

What's the Big Idea?

These zoetropes show actual tissue regeneration, but much faster than in real life. One shows a salamander regenerating a missing arm (over a 32 day period); the other shows an X-ray of a broken human bone healing.

A major goal scientists are seeking is to understand and reproduce the wound healing process. Wound healing – and scarring – is the production or overproduction of cells at the injury point with formation of the *blastema*, a collection of cells.

Tissue engineers aim to demonstrate they can successfully take the first step, and grow a blastema that can form a new body part.

Seamore Says:

In addition to well-know examples like the seastar (also known as a starfish) being able to regrow a lost arm, or a lizard being able to replace a missing tail, there are other examples in the animal kingdom:

- Butterflies are able, during metamorphosis, to change their cell structures into new tissues and organs.
- The marine animal Hydra can regenerate cells to produce offspring, a form of cloning.

Humans have some limited ability to regenerate body parts. New cells heal cuts to the skin and broken bones; children under six can grow back lost fingertips; and the human liver can regenerate all during a person's lifetime.

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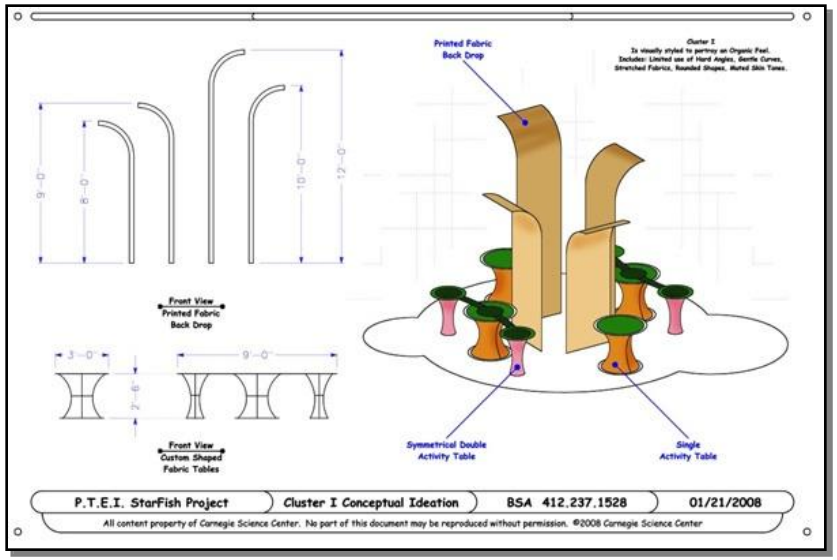
- RFPs sent out for Kiosk III multi-media production and interactive programming.
- Text Panels for Kiosks I & II drafted and into graphic design.
- All Kiosk superstructure designed, sourced and priced.



NEXT STEPS - 2008

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- Fabrication of interactives for Kiosks I & II.
- Completed work with Science Advisory for content of Kiosk III.
- Hiring of production company for Kiosk III multi-media.
- Fabrication of superstructure for all kiosks.
- Completion of visual design approach for graphics.
- Evaluation with public and school groups of content for Kiosk III.
- Production of interactives for Kiosk III.

NEXT STEPS - Kiosk III

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Real Stories Real People:

7 Semi-finalists needed; 5 to be filmed.

- Limb and Digit Reconstruction (Lee)
- Military Combat Injuries (AFIRM)
- Burns (Gerlach)
- Infant Skin Disease (Tolar and Balzar)
- Urinary Incontinence (Huard and Chancellor)
- Leukemia and Cancer Stem Cells (Lagasse)
- Cardio Stem Cell Therapies (Patel, Atala)
- Stroke Victims
- Craniofacial Reconstruction (Sfeir)
- Bladder TE (Atala)

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Ask the Scientist:

7 Semi-finalists needed; 5 to be filmed.

- Can TERM work for animals, too?
- What are the most promising TERM procedures today?
- How is TERM helping our soldiers and veterans?
- How do animals help in research?
- What career paths could I take to work in TERM?
- Does TERM research in the US lag due to policy and research restrictions?
- What's next in TERM labs, clinical trials and future therapeutic applications?
- Are adult stem cells as good as or different from embryonic stem cells?
- What are the two sides to the stem cell debate?
- What organs can be grown or engineered today?
- Should parents save/bank their child's umbilical cord blood for future TE applications?
- Can you clone me?
- Can we clone meat for food?
- Are all stem cells beneficial?
- Where would I get more info on TERM?

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- Are all stem cells beneficial?
- Where would I get more info on TERM?

Speak Out!:

- Is it OK to use embryos for research that would have been discarded anyway?
- Is it ethical to use TE research/techniques for purely cosmetic reasons?
- Is it ethical to pay women for their eggs to be used for TERM purposes?
- If available and proven to be effective and safe, should an athlete be able to utilize stem cell technology to enhance their athletic performance?
- Do you think that only reprogrammed umbilical or placental cells should be used for research, in place of embryonic stem cells?
- Should health care plans cover TERM treatments?
- Should parents have a second child specifically in hopes of creating a donor for another child's organ/disease needs?

ANTICIPATED USES & TIE-INS

CARNEGIE SCIENCE CENTER
One of the four Carnegie Museums of Pittsburgh

- **Long-Term Installation at Carnegie Science Center (5-7 years).**
  - CSC annual attendance = 610,000 visitors per year; potential 400,000+ users.
  - Used as resource for:
    - Summer Camps
    - Youth Programs
    - Workshops
- **Traveling version reaches 4-6 Science Centers over 3 years.**
  - Potential for 600,000+ additional users
  - Most sites have similar range of in-depth programming

Classroom Connections and Curricula Mapping

ASSET Life-science teaching modules for connections and enhancements and teacher PD.

- Diversity of Life (FOSS)
- Organisms Macro to Micro (STC/MS)
- Human Body Systems (STC/MS)
- My Body and Me (SEPUP)
- Micro Life (SEPUP)
- Our Genes Ourselves (SEPUP)

Diversity of Life (FOSS) *LESSON MAPPING*

Students observe and maintain protists, plants, and animals in the classroom and study their characteristic features. The study progresses from macroscopic to microscopic observation to discover the fundamental unit of life, the cell. Concepts: cell, tissue, organism, structure, function, behavior, adaptation, system, interaction.

Lesson/ Investigation	Description of Lesson/ Investigation	Connection to Kiosk/Interactive Learning Goals	PA Standards	NSES	Suggestions for TE connections
Investigation 1 – What is Life?	Students explore characteristics common to all living things and develop operational definition of life; beginning of structure/ function	Kiosk I Interactive 1	3.1.7A 3.1.7C 3.2.7B 3.3.7A 3.3.7B	A C	*Background knowledge needed to understand needs of living things
Investigation 2 – Introduction to the Microscope	Students are introduced to the microscope and observe living organisms	Kiosk I Interactive 2	3.1.7A 3.1.7D 3.2.7B 3.3.7A 3.3.7B	A C	Background knowledge needed for observing cells at microscopic level.

STARFISH EXHIBIT AND ASSET CURRICULA LINKS to NATIONAL SCIENCE EDUCATION CONTENT STANDARDS AND PENNSYLVANIA SCIENCE AND TECHNOLGOY STANDARDS

NSES Science Content Standards (Levels 5-8)	**ASSET Module** Diversity of Life (FOSS) - Microscopic Life - The Cell	**ASSET Module** Science and Life Issues (Lab-Aids) - Body Works - Micro-Life - Our Genes, Our Selves - Using Tools and Ideas	**ASSET Module** Human Body Systems (STC) - Digestive System - Respiratory and Circulatory Systems - Musculoskeletal Systems	**ASSET Module** Organisms Macro to Micro (STC) - The Beginning Earthworm - Regeneration - Exploring Cells - Continuing the Cycle	**STARFISH EXHIBIT** Kiosk I The Natural World - The Cell - Structures in Nature Built from Cells - Animals that Regenerate	**STARFISH EXHIBIT** Kiosk II The Science of TE - Stem Cells 101 - How does it All Grow and Work Together? - Structures in Bioengineering	**STARFISH EXHIBIT** Kiosk III Clinical Applications and Future Questions - Real Stories/Real People - Ask the Scientist - The Future and Bioethical Considerations
A. Science as Inquiry	**X**	**X**	**X**	**X**	**X**	**X**	X
C. Life Science	**X**	**X**	**X**	**X**	**X**	**X**	X
E. Science and Technology		**X**				**X**	X
F. Science in Personal & Social Perspectives		**X**	**X**	**X**		**X**	X
PA SciTech Standards (Levels 5-8)							
3.1.7. Unifying Themes	**X**	**X**	**X**	**X**	**X**	**X**	X
3.2.8. Inquiry and Design	**X**	**X**	**X**	**X**	**X**	**X**	X
3.3.7. Biological Sciences	**X**	**X**	**X**	**X**	**X**	**X**	X
3.6.7. Technology Education	**X**		**X**				
3.7.7 Technological Devices	**X**		**X**	**X**		**X**	
3.8.7. Science, Technology and Human Endeavors	**X**	**X**	**X**	**X**		**X**	X

Evaluation

PTEI
ADVANCING REGENERATIVE MEDICINE

- How students interact with and learn from informal educational experiences and connections to formal learning critical area of interest.

- Ongoing, formative and summative evaluations assess effectiveness of all project aspects, especially the process of integration of educational programming traversing formal and informal educational landscapes

Evaluation

PTEI
ADVANCING REGENERATIVE MEDICINE

- Focuses on the CIPP (*context, input, process, product*) evaluation model. Supports relationship between development and evaluation

- How? Links front-end, formative, remedial, and summative evaluation results to project evolution.

- Utilizes a quasi-experimental design study *(process and product stages of evaluation model).*

Evaluation CIPP (context, input, process, product)

- ***Context*** *evaluation assesses project needs. Context* evaluation focuses on the two major project goals: 1) development of **exhibit kiosks** and 2) related **instructional materials and PD**. Includes review of Kiosks and activities, exhibit text panels, exhibit user manual, and curricula enhancements to ASSET instructional materials.

- ***Input*** *evaluation assesses strategies and work plans*. Evaluation of *input* assesses responsiveness of program's proposed strategies and designs to objectives. Includes review of teacher guides and training materials, front-end evaluation of exhibit mock-ups, and pilot of prototype instructional materials and exhibit kiosk activities with multiple groups.

- ***Process*** *evaluations monitor and assess program activities.* Evaluation of *process* identifies match between design and implementation. Evaluators will observe student interactions with the exhibit, conduct pre- and post-visit assessment, focus group interviews with a sample of targeted and other middle school students, and interview teachers.

- ***Product*** *evaluation assesses impact on target audience and effectiveness (quality and significance) of outcomes.* A holistic examination of the completed exhibit and student and teacher instructional materials, correlating and synthesizing context, input, and process information.

Project Goals/Activities	Evaluation Focus	Evaluation Instruments	Year(s)
Goal 1: Plan for and develop Starfish Exhibit and educator manual	Mock-up evaluation and feedback	Mock-up surveys	1 and 2
Goal 2: ASSET curriculum mapping and development of middle school enhancement lessons	Review PD and lesson designs against needs	Observational data	1 and 2
Goal 3. Design PD plan for educators	Observe pilot PD	Pilot PD observation protocol	2
Goal 4: Conduct PD workshops for middle school teachers	PD observations and feedback	PD observation protocol	2, 3, 4, and 5
Goal 5: Incorporate lessons in middle school science instruction	Classroom observations and feedback	Classroom observation protocol. Pilot pre- and post- visit student assessments	2, 3, 4, and 5
Goal 6: Assess student/visitor interest and understanding of TE concepts	Exhibit impact students and visitors	Observational data and student assessments	3, 4 and 5
Goal 7: Replicate exhibit at additional sites	Evaluate exhibit effect at other sites	Visitor survey	3, 4 and 5

Current Status

Project Activity	Assessment Activity
Development of Cluster III exhibit activities (Aug 08 – Oct 08/Nov 08)	Review for compatibility with instructional objectives
Groups to view mock-up of Cluster III (Nov 08 – Dec 08)	Studies of clarity and understandability of text panels in conveying ideas
Pilot testing of Cluster III activities with several groups (Dec 08 – Jan 09)	Studies of interactions with exhibit by different groups and provision of feedback
Development of full exhibit and beginning development of website materials (Jan 09/Feb 09 – Mar 09)	Provision of feedback about instructional materials
Pilot testing of full exhibit with several groups (Mar 09)	Video studies of interactions with exhibit: documentation of differences between groups having pre-visit instruction versus those without

STARFISH Project Evaluation -

University of Pittsburgh Learning Research and Development Center

Year 1 – Evaluation Activities

- Attended monthly project Leadership and Scientific Advisory Team meetings. Purpose is to determine and ensure that target audience and general science center visitor needs are addressed.
- Attended focus group meetings with middle school teachers using ASSET modules relevant to the exhibit to determine professional development and instructional needs.
- Reviewed PD design document against needs and provided feedback.
- Tested the SuperCell movie, a component of the exhibit, with classroom teachers and students and provided feedback.
- Administered surveys during mock-up of Kiosks I & II to assess the extent to which the exhibit conveys main ideas and the clarity and understandability of exhibit text panels. Provided feedback to exhibit designers.
- Examined the PD design document and relevant instructional modules and science standards to plan for pre and post student assessments (on-going).

SuperCell Movie

- Feedback from six classroom teachers after viewing the SuperCell movie prototype. Forty-eight students from two classes (48 students) viewed the movie and responded to a questionnaire.

- Although a majority of students had heard about stem cells from TV or research-related news stories, only a handful knew any valid information. After viewing the movie, most students appeared to have picked up the main ideas about stem cells.

- Five of the six teachers had positive comments about the movie and appreciated that it brings out the difference between stem cells and other cells, without using a lot of scientific jargon.

> *I loved it! It was very attention-getting for kids and would help them get the main idea of stem cells. The sound effects and the color jazz it up to keep kids watching. I plan to use it in my class.*

Kiosk I & II Prototypes

- Thirty people including project team members, teachers, high school students, elementary school students, college undergraduate, general science center visitors, one local university outreach educator, viewed the mock-up over four afternoons.

- All thirty provided feedback on the exhibits including specific comments on each of the seven exhibits and associated text panels. In general, they indicated that the exhibit activities were informative, understandable, and fun. Suggestions for improvement were provided to the project team who have updated the exhibits based on the comments and are now in the production stage.

Year 2 – Evaluation Activities

- Observe pilot PD training and interview participants to determine impact and how participants plan to integrate new concepts in their biology instruction.
- Classroom observations to examine impact of PD on topics addressed.
- Develop PD and classroom observation protocols and student assessment for classroom use based on PD design document.
- Attend planning meetings and review development of materials for Kiosk III exhibit materials.
- Administer mock-up surveys for Kiosk III and provide feedback for exhibit designers.
- Pilot-test full exhibit and text panels with several groups and provide feedback for refinement.
- Develop prototype pre- and post-visit student assessments. Pilot test with focus group classrooms.
- Develop visitor observation logs to evaluate exhibit activities and text panels.

ASSET Update of Activities

- Refining development of PD structure; pilot of PD in October 2008
  - Structured by Learning Cycle; teachers will construct their knowledge of TE through inquiry and experience with materials
  - Background of the content and exhibit learning goals
  - Exploration of investigations from ASSET offered curricula and Enhancement Activities provided by PTEI
  - Modeling of connections
  - Teacher reflection: formulate and share a plan on connecting TE into their classrooms
- ASSET Middle School Resource Teachers identified to facilitate PD
- PD provided for their professional development of TE:
  - Focus groups on curricula development
  - General training sessions held at PTEI and labs
  - Review of exhibit mock-up at CSC

ASSET Update of Activities

- Classroom connections and curricula mapping identified, in an inclusive teacher-friendly document:
  - Life Science ASSET Modules identified, including:
    - Description of Investigation
    - Connections to the Learning Goals of the Exhibit Kiosks and Interactives
    - Specific Connections to TE Content
  - Alignment to National and State Standards
- Currently improving curricula mapping items in collaboration with PTEI content specialists

Next Steps:

PTEI
ADVANCING REGENERATIVE MEDICINE

Resources for Sharing and Dissemination Strategies:

- **Web-based *Educators Manual*** on CSC's website and project website. The guide will contain an overview and map of the exhibit, a detailed description and explanation of each component, and instructions for related classroom activities.

- ***Professional Development*** using the targeted Educators Manual and TE enhancements to ASSET modules. Emphasizes correlating TE science content with state and national standards and clear guidance for integrating TE as a topic into life- and physical-science classes and other academic areas. ASSET and CSC will hold workshops several times per year. PTEI, AIU3, etc. will provide special content-deepening PD.

- **Traveling exhibit component:**
  - Discovery Science Center, Santa Ana, CA (Joseph Adams)
  - Buffalo Museum of Science (Carroll Simon)
  - Gulf Coast Exploreum Science Center, Birmingham, AL (Ilka Porter)
  - Pacific Science Center, Seattle, WA (Mark Latz)
  - University of Alabama at Birmingham
  - W5, Belfast (Sally Montgomery)

Next Steps:

PTEI
ADVANCING REGENERATIVE MEDICINE

- ***Association of Science & Technology Centers****:* CSC and PTEI will host workshop as part of the Association of Science & Technology Centers (ASTC) RAP Session project. Will cover the unique partnership, plans and research materials that went into our production. Materials relating to the NCRR-funded portion of the project will be made available to other science centers nationally at no cost (Oct 18-21, 2008, Philadelphia)

- ***Electronic Distribution of Educational Materials*** through project website.

Next Steps:

PTEI
ADVANCING REGENERATIVE MEDICINE

- ***SEPA Collaboration*** for video gaming component and related educational curricula resources with J. Pollock, Duquesne University, The *TISSUE ENGINEERING SHOW* (DVD) was produced with funding from the "Tissue Engineering Show and Educational Partnership" (NCRR SEPA R25 RR15619)

- ***Presentations and Workshops*** at NSTA, NABT, Tissue Engineering and Regenerative Medicine International Society annual meetings

- ***SEPA/CTSI Mobile Lab Collaboration:*** PTEI is partnering with the University of Pittsburgh CTSI and SEPA programs to implement a pre-college mobile laboratory program to serve the region's educational and workforce development needs. Modules will relate to TE and stem cell research.