2/07/17

Strategic Plan

Center for Cellular Construction
PI: Wallace Marshall

Vision

Harness the untapped potential of cells as living factories and building blocks for better and more sustainable products, materials, and devices to benefit humankind.

Mission

Launch a new approach to understanding and designing cells. We will revolutionize industry through novel cell-based approaches to produce chemicals and materials for medical, civil, and consumer applications. We will educate and train a diverse research and manufacturing workforce. We will engage and inspire the public to embrace the promise of engineering cells and the materials and factories of tomorrow.

RESEARCH: OPTIMAL OUTCOMES

1. Instrumentation and reagents that allow "structure" to be a standardized and easily measured property of cell.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
We have 10 genetically encoded fluorophore markers that can be used across species to perform standardized measurements of cell structure Standardized set of vectors for expression across species (as possible) Year 1 Contact: Mark Chan & Jennifer Fung	1) Identify candidate organelle markers from literature and existing collections, and test them in yeast cells. 2) Compile vectors required to express markers in yeast, mammalian cells, and industrially relevant microbes
Install high content imaging platform Train and set-up management system 6 months Standard algorithms for detection of 10 key cell structures 2 Years Zev Gartner, Annette Chan & Jennifer Fung	1) Install high content imaging platform (searchable installation with GE) 2) Set-up site training with Robert Moody 3) Assign imaging liaison - SFSU – Annette Chan - UCSF – Jennifer Fung
Searchable database for reagents will be available with center-wide access through the LabBook system. Year 1 Simone Bianco & Laura Burrus	1) Generate temporary database - Model Google Docs after Addgene 2) Request lists of - Validated antibodies - Markers for cell structures

RESEARCH OPTIMAL OUTCOME 2:

Validated engineering and computational tools for tailoring cells and cellular assemblies to custom specifications.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Have database of models and dependencies based on data extracted from relevant literature. Year 1 Contact: Simone Bianco	1) Identify literature sources and relevant databases (6 months) 2) Decide and implement a standard format for ontology (3 months) 3) Literature mining and database population (12 months)
Engine for model compilation and statistical ranking focused by automated experimental design for validation. Year 2	1) Build model-agnostic simulation engine 2) Implement model validation tool based on statistically robust indicators (e.g. ranking) Year 2 Contact: Shawn Douglas 1) Build parameter identification and model reduction engine 2) Implement automated experimental design engine based on model reduction engine Year 3 Contact: Hana El-Samad

RESEARCH OPTIMAL OUTCOME 2 (continued):

Validated engineering and computational tools for tailoring cells and cellular assemblies to custom specifications.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Benchmarking the approach using industrially relevant microbe(s). Year 3 Contact: Wallace Marshall	1) Pick organisms and organelle for which Project 1 has a reliable probe and for which mutant collection exists 2) Run modeling validation pipeline to generate predictions for organism and relevant organelles 3) Check prediction against mutant library
Engine that collates center collected data from IBM LabBook and incorporates it into growing databases while checking against existing models. Year 3 Contact: Simone Bianco	1) Integrate database with LabBook search capabilities 2) Implement consistency test engine to integrate with LabBook for automatic validation of existing models against data. 3) Identify external tester for pipeline. Outsource pipeline for independent evaluation
Second generation engine which implements “function” instead of “structure”. Year 5 Contact: Wallace Marshall	1) Identify function and structures for testing 2) Adapt existing pipeline
User friendly inputs : outputs that provide access to cellular design for a wide user base. Year 5 Contact: Shawn Douglass	1) Track usage of computational engines and pipelines, to identify common shared computational tasks that could benefit from automation. 2) Construct graphical user interfaces to simplify and facilitate common computational tasks in cell engineering.

RESEARCH OPTIMAL OUTCOME 3:

It is possible to direct the self-organization of multicellular structures that have properties or capabilities that single cells do not.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Constrain boundary conditions - Having the technological infrastructure to do it - Knowing what the limits of how far the system can be perturbed or constrained before it can't put itself back together again (NOTE OF EXPLANATION: for all structures we are building, they rely on self-organization; there need to be constraints. In the context of the lab, we introduce different types of constraints.) Year 1-2 Contact: Zev Gartner	Implement methods to fabricate physical chambers to attach self-organizing tissues in defined patterns and shapes.
Have established conditions for growing and modulating the shapes of epithelial and mesenchymal tissues Shape topography Connecting topology Year 3-5 Contact: Zev Gartner and Wendell Lim	1) Select three different chassis cells 2) Identify what's sufficient/required to form epithelium from non-epithelial cells 3) Establish method to quantify transport and conductivity
We have engineering control over cell number in a multicellular structure. • Structural • Communication between cells Year 5+ Contact: Zev Gartner and Wendell Lim	1) Identify molecular components that allow cells to communicate without interference from endogenous communication pathways 2) Design molecular regulatory pathways to produce controllable cell number

RESEARCH OPTIMAL OUTCOME 4:

Engineering of cellular structure becomes a widely accepted standard approach for enabling academic and industrial processes and applications.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Correlate organelle structure to change in internal cellular chemical environment. Year 1 Contact: Mark Chan	1) Measure vacuole and other organelle size in conjunction with the effect on pH, redox potential, and other chemical environments that could affect biochemical output 2) Collaborate with Project 1 (markers) and Project 2 (analysis)
Tune organelle structure to achieve desired cell environment. Year 2 Contact: Mark Chan and Sindy Tang	1) Screen mutants and take conclusions for P5-Y2 to predictably alter vacuole percentage in yeast cells
Correlate organelle cell environment to chemical yield. Year 3 Contact: Mark Chan and Sindy Tang	1) Measure yield of methyl halide synthesis in identified yeast mutants or conditions
Improve (2 fold?) a chemical reaction's yield by tuning organelle structure in addition to metabolic pathways. Year 4 Contact: Mark Chan and Sindy Tang	1) Optimize run yields through a combination of organelle and metabolic engineering

RESEARCH OPTIMAL OUTCOME 4 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Establish a standardized assay and prototype a platform technology to accelerate design-build-test cycle by interrogating 1000's cells structures and outputs. Years 1-5	1) Develop a yeast incubator compatible with chemical testing. Specifically, the device will allow the immobilization of yeast to provide access to introduced chemical moiety as well as having the ability to read off cellular changes. Year 4 Contact: Sindy Tang and Jennifer Fung 2) Design, implement, and iterate a microfluidic device to: A. Test and measure methyl halide production using fluorescent reporter bacteria and validate with GC/MS measurements B. Select device materials compatible with reagents/chemicals to be used C. Design geometry, work flow compatible with high throughput screening (NOTE: Also addresses **Optimal Outcome 5**) Contact: Sindy Tang and Mark Chan

RESEARCH OPTIMAL OUTCOME 5:

Analysis of cellular structure becomes an accepted method for monitoring internal, natural and industrial environments.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Correlate 10,000 common industrial chemicals with changes in cell/organelle structure. Year 2 Contact: Jennifer Fung	1) High throughput yeast screen using Project 1 installation of the Incell system to screen chemicals for effects on organelle to cell structure. 2) Implement image classification software. 3) We will feed this information to Project 2.
Establish dynamic range / close response of a cell / organelle to identified chemicals. Year 3	1) Use Incell and software developed by Project 2 to determine close response to identified chemicals to select best chemicals to monitor Year 3 Contact: Jennifer Fung 5) Inject positive from yeast screen into Drosophila embryos with fluorophores; dose response with organelle structural changes Year 3 Contact: Blake Riggs 6) Test positives from yeast screens in chicken embryos, a human embryo animal model organism, in assessment of toxicity and cellular embryo growth/organogenesis developmental defects. Year 3 Contact: Wilfred Denetclaw SFSU

RESEARCH OPTIMAL OUTCOME 5 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Prototype device that monitors chemical levels using cell sensors. Year 4-5 Contact: Ray Esquerra	1) Design a yeast specific system to incorporate the CooA chemically-regulated transcription factor system 2) Test implementation 3) Refine and optimize Year 3 4) Use CooA regulatory system as basis to modify sensing domain using molecular modeling and other proteins to design new sensing systems (**NOTE: also key action for first milestone)** Years 4-5
Implement web/software infrastructure to integrate organelle classification and analysis with predictive models of morphological modification being developed as part of Outcome 2 Year 5 Contact: Simone Bianco	Cooperate with the CellCAD software development effort to adapt predictive models of organelle morphology with image classification framework

RESEARCH OPTIMAL OUTCOME 6:

Create fundamental understanding of the multiscale relationships between molecular pathways, cell structure, and cell function.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Data linking cell structure to molecular pathways is compiled and accessible Year 1 Contact: Jennifer Fung	1) Implement an image database that links metadata about experiments and pathways
The center has used its data and models to formulate new hypotheses about cellular dynamics and function Year 5	1) Data analytics is used to extract potential new hypotheses and connections from the total set of collected image data. Contact: Simone Bianco 2) Mechanistic hypotheses generated during the construction of models for CellCAD are identified, collected, and disseminated to the cell biology community Contact: Wallace Marshall

EDUCATION: OPTIMAL OUTCOMES

1. Educators have mapped the knowledge and skills used in the discipline cellular engineering and have developed a framework to guide teaching of cell biology through the lens of cellular engineering using an interdisciplinary, problem-based approach.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Refined conceptual framework exists for cellular engineering education Year 5 Contact: Rebecca Smith	1) Conversations with Center members regarding the knowledge, skills, and habits of mind of Cellular Engineers to inform development of the framework. Year 1. 2) Annual revision of Framework to refine and update as discipline (and our understanding of how to best train Cellular Engineers) develops. Refinement process includes sharing framework within the Center to solicit feedback from a wide variety of Center members. 3) Paper published in CBE-Life Science Education describing cellular engineering-based educational approaches by year 5.
A network of science educators interested in learning to teach cell biology using an engineering-based approach to cell biology has been established. Network will represent the diversity of schools, educators, and students in the region. 18 months. Contact: Rebecca Smith	1) Identify target districts, schools, teachers to include within the network. Reach out to colleagues in informal science education who work with teachers from around the region. 2) Send letter of introduction about center and opportunities to teachers within the network.

EDUCATION OPTIMAL OUTCOME 2:

High school students and undergraduates are aware of, and excited about, the potential of building things and solving problems with cells, and are prepared for opportunities in this field.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
10-15 high school students per year have taken part in the summer bootcamp program Years 1 forward Contact: Rebecca Smith	Two-week summer bootcamp offered annually to high school students and teachers.
85% of high school students trained through program pursue STEM majors in college Timeframe: ongoing through year 10. Contact: Rebecca Smith	Ongoing tracking of high school participants through various means including: SFUSD Linkedin interface, National Student Clearinghouse, and surveys of program alumni
80% of undergraduate students trained in center labs go on to further STEM training Year 1-5 Contact: Wallace Marshall	1) Leverage existing summer programs to recruit students to CCC labs by having CCC faculty take part in summer student selection and by giving recruiting presentations for the summer programs to URM undergraduate student groups at target partner institutions each year 2) Center leadership make hosting undergraduates an expectation of Center Members. 2) Mentorship training offered each spring to all faculty/mentors for undergraduates, training will be led by SEP and SFSU. Center leadership will require all mentors participate in the training. CONTACT: Carmen Domingo

EDUCATION OPTIMAL OUTCOME 3:

The general public is aware of, and excited about, the potential of building things and solving problems with cells.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Exploratorium has developed 8 new exhibits and demonstrations for their new collection, *Cells to Self* Year 5 Contact: Jennifer Frazier	1) Identify new concepts, skills, and research areas in Cell engineering 6 months 2) Create 4 exhibits and/or demonstrations for the "Cells to Self" exhibit opening December 2017 Year 1 3) Create two more exhibits or demos for Cells to Self Phase Two, employing two interns (Center Trainees) Year 2 4) Create final four exhibits/demonstrations, building on lessons learned from the first four projects and considering concepts or skills that remain to be addressed Year 4 5) Secure ongoing funding for future dissemination of exhibits Year 3
Five CCC faculty have presented public lectures/demonstrations at the Exploratorium Year 5 Contact: Jennifer Frazier	1) Develop database of faculty research and its potential relevance to the public Year 1 2) Arrange for at least 1-2 CCC faculty per year to present at existing Exploratorium programs (After Dark, Pairings, etc), of which 30% of faculty are from underrepresented groups. Ongoing: years 1-5

EDUCATION OPTIMAL OUTCOME 3 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
CCC members present hands-on demonstrations of cell engineering at 20 different Maker Faire and Science Festival events in at least five different states to engage 5,000 members of the public Cumulative over five years. CONTACT: Rebecca Smith	1) Modify existing Maker Faire demonstrations already being presented by Center members to emphasize engineering concepts, and present at two local maker faire events 6 months. Wallace Marshall 2) Develop two new demonstrations based on research and ideas related to cell engineering. Year 2. Rebecca Smith 3) Identify center members who are interested in participating, and taking into account diversity inclusion criteria, and train them in how to present demonstrations by pairing them up with experienced Maker Faire presenters in Center labs. Ongoing. Rebecca Smith 4) Create sign-up mechanism for matching center members to upcoming Maker Faire and Science Festival events Year 1. Rebecca Smith 5) Map out list of future Maker Faire and Science Festival events that target geographic, socioeconomic, and racial diversity, including at least one out of state event per year and one rural even per year, and submit applications to each Maker Faire organization to present our exhibits at their event. Annual. Rebecca Smith

EDUCATION OPTIMAL OUTCOME 3 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Hackathons engage 200 STEM professionals to solve technology-related problems relevant to the center Years 2-5 Contact: Rebecca Smith	1) Develop relationships with and sponsor 1 Hackathon in an existing Hackathon series. Year 2. Host three additional Hackathons in years 3-5. Rebecca Smith 2) Develop criteria for problems to be presented, based on consultation with experience Hackathon organizers and participants. 3) Identify Center Members to lead the Hackathons in each year
Novel Foldoscope educational modules based on cellular structure and function, developed by the Center, are used by at least 10,000 users in 100 countries to explore cell biology. Year 5 Contact: Manu Prakash	1) Develop 1-2 new foldoscope activity modules Year 1 2) Engage foldoscope superusers to test prototype modules, allowing iterative improvement. Year 2 3) Launch activity modules for the global foldoscope user community Year 3

EDUCATION OPTIMAL OUTCOME 4:

Graduate students and postdocs are prepared to solve complex interdisciplinary problems in cellular engineering, understand the ethical considerations of the field, and can communicate the importance of this work clearly to diverse audiences.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Three-week graduate minicourse using LEGO Mindstorms to explore robotics as an analogy for understanding cellular decision making has been piloted and assessed. 6 months. Contact: Jennifer Fung	1) Develop and organize cellular robotics minicourse 6 months. Jennifer Fung 2) Determine mechanisms for students from any center campus to participate in graduate courses at any other center campus Year 1. Wallace Marshall and Diana Chu
Two inter-disciplinary graduate level courses have been developed and assessed. Year 3 Contact: Hana El-Samad and Manu Prakash	1) Pilot one new course per year using the minicourse framework. Years 2-5 2) Determine most successful course approaches, combine/expand them to create two core cellular engineering graduate courses. Use this information to inform and refine the Framework for Cellular Engineering Education Year 5

EDUCATION OPTIMAL OUTCOME 4 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Twenty-five center graduate students and postdocs have gained experience in teaching and industrial workplace settings in order to expand their view of science career paths, to prepare them for future careers, and to build connections between center institutions as well as outside partners. Year 5	1) Determine selection criteria for participation in Exploratorium internship program taking into account diversity goals. Contact: Jennifer Frazier 2) Write up description and schedule for internship projects. Contact: Jennifer Frazier 3) Work with Exploratorium staff to set up infrastructure for CCC student interns. Contact: Jennifer Frazier 4) At least 2 IBM internships per year are arranged for students from Center labs in support of the centers Integrative Research project. Years 2-5 Contact: Simone Bianco 5) Center postdocs will be given the opportunity to teach courses at SFSU. Contact: Diana Chu 6) Center trainees have opportunity to intern at SEP to co-develop and teach summer bootcamp, support development of Maker Faire and Science Festival Activities (N=1/year). Contact: Rebecca Smith 7) Leverage center industry collaborations and contacts to arrange 1-2 internships in companies outside the center per year for center students. Contact: Charly Craik 8) Interns from the center report back on their experiences during the annual retreat.

EDUCATION OPTIMAL OUTCOME 5:

All center members are prepared to act as ambassadors for the field by clearly communicating the importance of their work in a wide variety of settings, to help building awareness of the importance of cellular engineering and its potential to solve complex problems.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
All center members (faculty, students, and postdocs) are able to present a two-minute "elevator pitch" about the work of the center, and have the skills to vary their "pitch" to appropriately engage different audiences. Year 2 Contact: Wendell Lim	1) Packaged materials exist for elevator pitches that center members can use as the basis for their own practice. 2) Center members are formally trained in presenting their elevator pitches in special workshops. 3) Center students and postdocs compete for the best elevator pitch at the annual retreat, with prizes given to encourage excellence.
Center faculty have communicated to broad audiences about center activities on at least 5 different occasions and venues per year for lifetime of grant Year 5 Contact: Rebecca Smith	1) Identify and publicize opportunities to present to broad audience throughout the center. 2) Develop a sign-up system for public presentations and train members who might want to present to the public but who have not had prior experience in how to do so, including one on one mentoring and practice talks.
Center participants are trained in how to engage policy makers at local, state, and national levels in understanding the impact of science; how science works; the value of openness, diversity, and logic in crafting effective policy; and the potential for engineering cells in solving real world problems. Year 3 Contact: Hana El-Samad	1) Work with professional societies to identify opportunities and best practices for interacting with policy makers 2) Policy discussion workshop at annual retreat

BROADENING PARTICIPATION: OPTIMAL OUTCOMES

1. The Center for Cellular Construction is a model for creating a diverse STEM workforce that is emulated by other institutions

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
All center participants have been trained in best practices for mentoring diverse populations and apply this training to all center activities Year 1. Blake Riggs & Carmen Domingo	Diversity mentoring events are held at all annual retreats, during which faculty who have participated in NRMN and other formal training can educate other center members, from students to faculty, in data-informed best practices.
Broadening participation goals are woven into all center activities including research, education, and knowledge transfer Year 1. Frank Bayliss	Implement a procedure for tracking and reporting diversity of participation, and steps taken to broaden participation, linked to all individual center activities, which will allow for identification of activity areas that might require additional work in this area.
Partner institutions begin to emulate CCC approaches for collaboration between minority serving institutions and research-intensive institutions. Year 3. Wallace Marshall & Frank Bayliss	Establish an expanded network with select partner institutions that increases minority recruitment into our center while, at the same time, sharing knowledge with the partner institutions about ways to promote cooperation between institutions in broadening participation.

BROADENING PARTICIPATION OPTIMAL OUTCOME 2:

Advancement and retention of students, postdocs, and faculty towards STEM careers has been realized at all levels of participation, from K-12 to faculty.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
K-12 and informal science outreach activities of the Center have led to an increase in the number of URM students entering STEM degree programs Year 5 Rebecca Smith	1) Longitudinal tracking of high school student education and career outcomes following participation in summer bootcamp program. 2) Assess impact of Exploratorium and Maker Faire exposure on interest of URM student attendees in pursuing further education in STEM areas.
80% of undergraduate URM students who participated in Center summer research will be admitted into STEM graduate programs Year 4 Hana El-Samad	1) Provide mentoring to all faculty and student/postdoc mentors in summer research labs on best practices for mentoring diverse students prior to the start of each summer session. 2) Track outcomes for summer undergraduate students and assess their experience during the summer research experience. 3) Center faculty will actively recruit URM undergraduate students to participate in center-affiliated summer research programs by visiting minority serving institutions and undergraduate student research conferences to spread the word about the Center as a major research effort that welcomes diversity.
90% of masters students in the Center ultimately join the STEM workforce, and of those who pursue doctoral-level training, 90% will complete their training successfully. Year 5 Frank Bayliss	1) Masters students will be fully integrated into center research, education, and knowledge transfer activities and treated as equal partners, preparing them to compete successfully at the next level. 2) Masters students will be given the same opportunity to participate in internship programs with center partner companies that are being made available to the Ph.D. students

BROADENING PARTICIPATION OPTIMAL OUTCOME 2 (continued):

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
The number of Ph.D. students entering graduate programs with which the Center faculty are affiliated has increased by 20% Year 3	1) Center faculty will volunteer to join admissions committees for graduate programs at their respective institutions, where they can encourage the careful consideration of URM candidates. Contact: Wallace Marshall 2) Center faculty will join diversity committees if such exist. If diversity committees do not exist for a given program, center faculty will volunteer to form such a committee. Contact: Wallace Marshall 3) Center faculty will actively recruit undergraduate students into the respective graduate programs by visiting undergraduate serving institutions and attending SACNAS/ABRCMS conferences Contact: Frank Bayliss 4) Interview URM students who were accepted into graduate programs affiliated with center faculty but who chose not to join the program, in order to identify possible factors that are lowering the student acceptance rate. Contact: Frank Bayliss 5) Identify barriers that prevent URM students from persisting through the Ph.D., at each participating institution, so that these can be reduced or eliminated. Contact: Frank Bayliss

BROADENING PARTICIPATION OPTIMAL OUTCOME 3:

Postdoctoral training has become a key element in promoting diversity and broadening participation.

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
The number of postdoctoral fellows from underrepresented groups in Center labs increases by 10% relative to non-center labs Year 4 Contact: Wallace Marshall	1) URM postdoc applicants to any center lab will be invited to interview with multiple center labs to increase likelihood of being accepted into a center lab. 2) Postdocs are recruited from diverse pools of students
All center postdocs, regardless of their own minority status, are trained in broadening participation issues Year 2 Contact: Wallace Marshall	Postdocs will participate in mentorship training.

BROADENING PARTICIPATION OPTIMAL OUTCOME 4:

Infrastructure and partnerships between SFSU and other CCC institutions increase opportunities for diverse faculty to succeed in their research

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
50% increase in presentations, publications, and grant awards by SFSU faculty after joining the Center Year 3	1) Establish at least one research collaboration between each SFSU CCC faculty and at least one other CCC faculty member. Year 1 Frank Bayliss 2) Establish core facility access at all CCC institutions for SFSU faculty members. 6 months Wallace Marshall 3) Center faculty from research intensive institutions work to get SFSU faculty invitations to present their work at national meetings Ongoing Frank Bayliss & Wallace Marshall

KNOWLEDGE TRANSFER: OPTIMAL OUTCOMES

1. The Center is known as a place that is generating ideas in cellular engineering that can be translated into products

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
At least five op-ed articles will be published by the Center to define cellular engineering according to our center mission. Year 2 Hana El-Samad	Write op-ed articles designed for electrical and chemical engineering audiences, and submit to IEEE Spectrum and Chemical & Engineering News, then write variations on these articles to target other engineering audiences
Center Website is the top Google search result for “cellular engineering” and conveys center goals, ideas, and results to a broad range of stakeholders, potential collaborators, and the general public. Year 2 Diana Chu, Charly Craik, Debra Singer, Simone Bianco	1) Construct a well-designed professional website 2) Content is updated on a monthly basis and aggressively promoted through SEO techniques 3) Design a compelling center logo that conveys our identity 4) Create a “Cellular Engineering” Wikipedia page 5) Develop a social media presence for the Center
Center has established active collaborations with least three companies to explore possibilities of applying cellular engineering approaches in actual industrial processes. Year 4 Charly Craik	1) Assemble a center “slide deck” that any center member can use to introduce the center concept and activities 2) Establish dialogues with 3-5 companies per year working on biotechnology, fermentation processes, and materials production to explore potential collaborations or licensing agreements.

KNOWLEDGE TRANSFER OPTIMAL OUTCOME 2:

We have created a broad community of researchers who are informed about how to take research and transform ideas into products

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Center web page serves as a repository for knowledge transfer information Year 2 Contact: Zev Gartner & Simone Bianco	1) Identify institutional liaisons to gather specific institutional information regarding knowledge transfer and training 2) Identify "master inventors" at each institution to serve as mentors
Each year a diverse group of center students, postdocs, and faculty will receive raining in entrepreneurship and startups Year 2 and thereafter Contact: Charly Craik	1) Fund entrepreneurship educational programs in cooperation with QB3 2) Develop mechanism to select students and postdocs who will participate in training programs

KNOWLEDGE TRANSFER OPTIMAL OUTCOME 3:

We have generated companies, IP, and tangible products that grow the economy and create jobs around cellular engineering

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
The Center has launched four startup companies and supported them long enough to have a strong chance of securing VC investment. Year 5 Charly Craik	1) Set up procedure by which startup funds can be requested by center members who have completed one or more entrepreneurship training activities such as Startup 101 or Lean Launch Pad. 2) Develop mechanism for selecting center member ideas to be supported by seed funding 3) Leverage center funds to identify opportunities for further startup support through alternative RFAs, VC, existing companies, and private foundations 4) Launch one startup per year, starting in year 2, and provide mentorship for the founders during this period.
The center has generated intellectual property in the form of 5 patents. Year 5 Charly Craik	1) Develop procedures for selecting proposals for center discoveries with sufficient potential value to justify pursuing IP protection 2) File 2-5 provisional disclosures per year 3) With input from industrial partners and advisory committees, as well as through consultation with industry experts, select at least one disclosure per year to file a patent application 4) Develop approaches for disseminating information about center patents and discoveries to potential industrial partners, with the view towards establishing licensing agreements

KNOWLEDGE TRANSFER OPTIMAL OUTCOME 4:

Cellular engineers trained in the center carry center concepts and approaches into the industrial workforce

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
10 center trainees have entered the industrial workforce at the level of research scientist or above End of Year 5 Charly Craik, Frank Bayliss, & Rebecca Smith	1) Center students and postdocs will take part in the internship activities being organized within the Education component of the center 2) After internships are completed, the Center will maintain contact with host companies to explore possible collaborations, giving students a way to stay connected.

ETHICS: OPTIMAL OUTCOMES

1. We have produced an academic and industrial cell engineering workforce that is aware of the ethical implications of engineering cells and trained in how to think about risk

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
100% of center participants have been trained in responsible conduct of research at their home institutions Year 1 and each year thereafter Contact: Frank Bayliss & Ray Esquerra	1) Implement a system for tracking progress of training across center institutions.
All graduate students and postdoctoral trainers in Center labs have been trained in ethical questions related to Cellular Construction End of Year 2 Contact: Wendell Lim and Manu Prakash	1) Develop polished materials to initiate students and faculty to the ethical implications of the discipline 2) Re-enact the Asilomar conference, but focused on questions surrounding cell engineering and synthetic biology. Every two years 3) Ethics discussion at each annual retreat
High school students and teachers are introduced to 1) the field of ethics broadly and 2) the role of ethics in the practice of science Year 1 (and ongoing) Contact: Rebecca Smith	1) Leverage existing materials in use in SEP programs to teach ethics in the context of science to high school students & translate these materials to a cellular engineering context. 2) Design an Asilomar-style conference simulation focused on cellular engineering questions, appropriate for high school students, which will be integrated into the 2-week summer bootcamp for high school students and teachers.

ETHICS OPTIMAL OUTCOME 2:

Center exploits state of the art technology to monitor and contain potential spread of industrially relevant cellular systems

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Bar-coding of strains is implemented for all strain construction by the center Year 2 Contact: Wendell Lim.	A bar code scheme is developed along with a database to store information on strains as they are generated
Best practices for biosafety are established for center activities Year 1 Contact: Wallace Marshall	1) Consult with ethics advisory panel and institutional safety officers to determine potential laboratory hazards entailed by center engineering activities 2) Harness existing standard operating procedures and training to mitigate the specific types of risk that arise during center work.
Genetic containment strategies are implemented for key industrially relevant microbes Year 3 Contact: Wallace Marshall	Research existing options for containment, such as engineered dependency and kill switches, and invest research resources if these prove inadequate

ETHICS OPTIMAL OUTCOME 3:

Stakeholders and general public are engaged in and aware of the center's commitment to ethics and safety

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Center web site has a section discussing ethical implications to demonstrate our engagement with this issue. Year 1 Contact: Jennifer Frazier	1) Discuss with ethics panel to determine what aspects of center activity might generate ethical concerns among the public and stakeholders 2) Develop web site content that sets forth the center's approach to mitigating risk, while discussing the balance between risk and reward
Ethical considerations are addressed whenever the center engages with broader audiences Year 2 Contact: Jennifer Frazier	1) Speakers from the center presenting talks to the general public include a section in the talk addressing ethical concerns 2) Center publications aimed at the public and the larger engineering community address ethical issues

LEADERSHIP AND MANAGEMENT: OPTIMAL OUTCOMES

1: The center is an integrated community that lowers barriers for collaboration and creates new connections between participants at all levels

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Mechanisms exist to foster and support collaboration and interaction among center members Year 1 Contact: Wallace Marshall & Zev Gartner	1) Establish a quarterly all-hands meetings at which two members will discuss their activities, with location rotating among all participating institutions 2) Establish an annual center-wide retreat that will focus on overall progress and team integration activities 3) Establish monthly group meetings for each of the main research project groups, as well as for education, broadening participation, and knowledge transfer 4) Implement a center-wide electronic notebook and discussion forum based on IBM LabBook technology
All center members understand the benefits and responsibilities of center membership Year 1 Contact: Zev Gartner	1) Develop mechanism for onboarding of new center members (students and postdocs) which involves specific discussion of benefits and responsibility. 2) Director addresses benefits and responsibilities at the annual retreat each year 3) Benefits and responsibilities are specifically stated in the center's internal web site 4) Implement an annual survey of perceived responsibility and benefits.
Center has developed a cohort of 10-20 collaborators outside the center involved with research, education. knowledge transfer, or broadening participation activities Year 5 Contact: Wallace Marshall & Zev Gartner	1) Implement a Center Affiliate program to identify potential collaborators and involve them in center meetings and seminars. 2) Implement a seed grant program to provide small packets of funding for non-members to perform research or educational activities related to the mission of the center

LEADERSHIP AND MANAGEMENT OPTIMAL OUTCOME 2:

Center decision-making is transparent and ensures that all voices are heard

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Center members are aware of the process by which decision are reached, the status of center goals and progress, and any potential problems or hurdles the center is facing Year 1 Contact: Wallace Marshall & Zev Gartner	1) Implement an internal web site where members can go to read the center's strategic plan and updates from the leadership team 2) Reports from the leadership team at all regular meetings to keep members updated. 3) Develop and administer an annual survey to monitor perceived transparency
All center members have the opportunity to provide input into the activities of the center Year 2 Contact: Zev Gartner	1) Conduct a center-wide brainstorming session at each annual retreat 2) Solicit input through the center's internal website
100% of individual center faculty meet with center directors at least annually Year 2 Contact: Wallace Marshall & Zev Gartner	Schedule personal meetings between director, co-director, and each center faculty member at all participating institutions

LEADERSHIP AND MANAGEMENT OPTIMAL OUTCOME 3:

Center leadership tracks progress in all goal areas and shifts resources as necessary to maintain progress

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
Progress in research, education, broadening participation, and knowledge transfer is tracked by the Center Manager Year 1 Contact: Debra Singer	1) Quarterly requests for status updates will be sent to all center PIs 2) Annual re-evaluation of center progress will be performed in conjunction with preparation of the center annual report
Underperforming members are given the opportunity and whatever support they may need to become more actively engaged Year 2 Contact: Wallace Marshall, Zev Gartner, & Wendell Lim	1) Underperforming members as identified in the annual review of progress will meet with center leadership team in order to determine whether the problem is lack of interest or because of external pressures 2) In the case of lack of interest, members will have the choice to become more engaged, or to withdraw from the center 3) In the case of low productivity due to external pressures, center leadership team will provide mentorship and explore ways to support the member

SUCCESSION PLANNING: OPTIMAL OUTCOMES:

The Center is able to continue its mission even if members of the leadership team leave the center

TARGETS/ MILESTONES	ACTIVITIES / ACTIONS
A formal plan is in place to handle succession in the event that the current director is no longer able to act in that role Year 1 Wallace Marshall, Zev Gartner, & Wendell Lim	1) The leadership team will review the existing succession plan that was developed during the first site visit
All leadership team members have designated successors who are kept updated to the corresponding component of center activity Year 1 Wallace Marshall, Zev Gartner, & Wendell Lim	1) The co-directors will assign a designated successor for each leadership team member, and update this individual on the nature of the responsibility involved. 2) Each leadership team member will meet with their designated successor at the time that the annual report is prepared, in order to update them on progress and challenges that might have taken place.
A mechanism is in place to replace any center members who withdraw from the center Year 1 Wallace Marshall, Zev Gartner, & Wendell Lim	1) If any center members withdraw from the center, the leadership team will evaluate possible replacements from among the cohort of Center Affiliates

CENTER EXTERNAL ADVISORY COMMITTEE:

We have constituted the EAC for our center. The committee will be composed of the following individuals, all of whom have agreed to participate:

Jennifer Lippincott-Schwartz (HHMI, Janelia Farm Campus)

Radhika Nagpal (Dept. of Computer Science, Harvard University)

Neda Bagheri (Dept. of Chemical and Biological Engineering, Northwestern University)

Wenying Shou (Fred Hutchinson Cancer Research Center)

Erin Dolan (Dept. of Biochemistry and Molecular Biology, University of Georgia)

Carlos Gutierrez (Dept. Chemistry and Biochemistry, CSU Los Angeles)

Brian von Herzen (CEO, Rapid Prototypes)

Kinkead Reiling (Co-founder, Amyris)

Dan Widmaier (CEO, Bolt Threads)

We have composed our EAC to include representation from a range of disciplines including Cell Biology, Computer Science, Chemical Engineering, Electrical Engineering, Synthetic Biology, Biology Education, and Industrial Biotechnology. Our External Advisory Committee will meet each year after the annual retreat. Prior to this meeting, EAC members will attend the retreat. EAC members will also receive written status updates when projects make major progress or changes, or if any problems arise that may require external advice.