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PI/PD Name: Wallace Marshall

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
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Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

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PI/PD Name: Zev J Gartner

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Wendell Lim

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☒ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
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Disability Status: (Select one or more)
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- ☐ Mobility/Orthopedic Impairment
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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 15-1

NSF 14-600 **06/16/15**

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

IIA - SCI & TECH CTRS (INTEG PTRS)

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1548297

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/12/2015	1	01060000 IIA	1297	094878337	06/12/2015 5:36pm

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

946036493

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

University of California-San Francisco

AWARDEE ORGANIZATION CODE (IF KNOWN)

0013193000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

University of California-San Francisco
1855 Folsom St Ste 425
SAN FRANCISCO, CA. 941430812

NAME OF PRIMARY PLACE OF PERF

University of California-San Francisco

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE

University of California-San Francisco
600 16th Street
San Francisco ,CA ,941432200 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Center for cellular construction**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **24,000,000**	**60** months	**06/01/16**	**1522186**

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ FUNDING MECHANISM **Facility/Center**

☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)

☒ COLLABORATIVE STATUS
A collaborative proposal from one organization (GPG II.D.4.a)

PI/PD DEPARTMENT
Biochemistry & Biophysics

PI/PD FAX NUMBER
415-502-5315

PI/PD POSTAL ADDRESS
600 16th Street
Genentech Hall
San Francisco, CA 941432200
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Wallace Marshall**	**PhD**	**1997**	**415-514-4304**	**wmarshall@biochem.ucsf.edu**
CO-PI/PD **Zev J Gartner**	**DPhil**	**2004**	**415-514-9962**	**zev.gartner@ucsf.edu**
CO-PI/PD **Wendell Lim**	**PhD**	**1991**	**415-502-8080**	**lim@cmp.ucsf.edu**
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide,Part I: the Grant Proposal Guide (GPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of AAG Chapter IV.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Michelle Stevens**	**Electronic Signature**	**Jun 12 2015 5:33PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
415-476-9730	**Michelle.Stevens@ucsf.edu**	**415-476-5367**

PROJECT SUMMARY

Overview:

See Supplementary Documents section for the Project Summary

Intellectual Merit :

See Supplementary Documents section for the Project Summary

Broader Impacts :

See Supplementary Documents section for the Project Summary

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

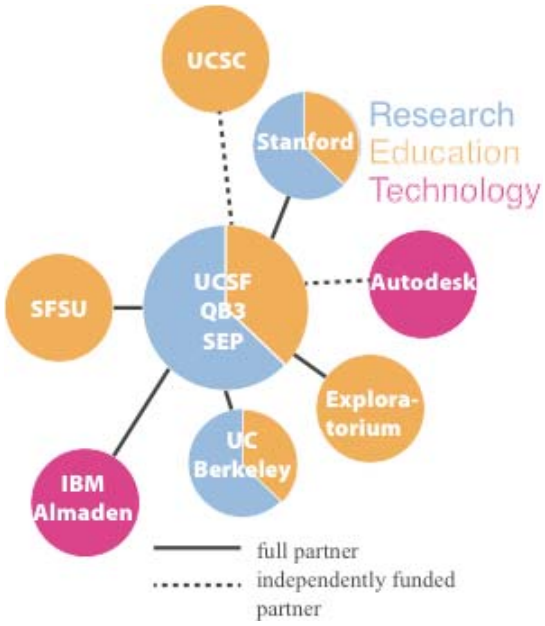
(4.a) Rationale for Center Approach

The overall goal of our center – to convert cell biology into an engineering discipline – is inherently an integrative activity requiring participation of individuals from a wide range of backgrounds and having diverse scientific perspectives. UCSF has a world-class group of cell biologists but virtually no engineers, while IBM is justifiably famous for its strength in computer engineering but is not a center of biological experimentation. San Francisco State University brings a strong presence in undergraduate and masters level education to the table, in both biology and engineering. UC Berkeley and Stanford add world-class research and undergraduate training in bioengineering and other basic engineering disciplines. Preexisting relationships with industrial design pioneers Autodesk (with Center member Shawn Douglas and with the Exploratorium) provide a seasoned perspective in integrating cellular models and tools into an efficient design platform. In tackling our goal of creating awareness of cell-based engineering among the public, the Exploratorium brings a unique opportunity to reach a large number of people that neither traditional universities such as UCSF or SFSU, nor an industrial partner like IBM, can provide.

Within the research group, there is no single faculty member with the necessary expertise to define organelle morphological regulatory pathways, learn how to reprogram them with synthetic methods, develop software to predict and specify cell organization, or to tackle the interdisciplinary application-based research programs that we propose. Each of the sub-projects of the Research Objectives are by themselves inherently interdisciplinary. None of the Research Objectives could be accomplished by a single lab. In all aspects of our proposed work, therefore, a Center Approach is absolutely critical.

Creating a new type of engineering requires an intimate combination of research, education, and knowledge transfer, making the STC the ideal form of organization. Moreover, because all of the research, education, broadening participation, and knowledge transfer activities are based around a common unifying goal of turning cell biology into an engineering discipline, a Center organization is a natural way to bring these activities together.

We believe that the potential legacy of our Center would be nothing less than to spawn an entirely new branch of engineering. This will have a national and global impact, particularly if we can rapidly disseminate our approach into an industrial setting.



4.b Research Objectives

The goal of the Center for Cellular Construction is to turn cell biology into an engineering discipline. By learning how cells build themselves, we will develop the tools and concepts necessary to re-engineer the structure of the cell and to build novel structures inside living cells. By learning how groups of cells use these subcellular structures to self-organize and work together, we will learn how to use cells as building blocks to assemble novel devices and materials composed of multiple cells. The result of these efforts will be an understanding of how biological systems self-organize at the subcellular and multicellular length scales to accomplish the diverse tasks necessary to sustain life and thrive in specialized niches.

To achieve this vision, we must confront major conceptual and technological challenges. Unlike molecular biology, that can be understood in terms of chemistry, or physiology, that can be understood in terms of the principles of biomechanics and homeostasis, cell biology operates at a meso-scale of organization. At the meso-scale, direct determination of structure is non-trivial and both macroscopic intuitions as well as assumptions about solution-phase chemistry can easily lead us astray. Indeed, the unique physics of biology at the spatial scale of the cell poses deep conceptual challenges for basic science, but also represents a tremendous opportunity for innovation and development of new technologies because if we can learn to control biological structure at these subcellular size scales, we can use cells themselves as a new engineering medium to build new devices and applications (Lim et al., 2012). It is these challenges and opportunities that the Center for Cellular Construction is designed to tackle.

We will stretch our research program across the multiple spatial scales at which cells operate: organelle level, whole-cell level, and cell-collective level. Organelle scale research will focus on individual organelles with a focus on integrating models of regulatory pathways into models of organelle dynamics. Whole cell level studies will focus on cell shape and polarization and the link between cell mechanics and structure. Cell collective level studies will focus on the assembly properties of small but precisely defined 3D aggregates of cells to span the cell to tissue levels. In addition to work at these three levels, there will be a sustained collaborative effort between academic labs and industry (spearheaded by our collaborators at IBM) to build multi-scale design and modeling tools that will allow us to span the molecular pathway to tissue organization levels.

In pursuit of our major goal of making cell biology an engineering discipline, we have defined four specific Sub-Goals: (i) create **awareness and broaden participation** in cell-based engineering as a new field by recruiting and informing individuals from academic, industrial, and public sectors; (ii) **educate** a next generation workforce that can operate at this new interface between engineering and biology; (iii) assemble **the scientific tools and knowledge** necessary to implement a full design-build-test cycle using living cells as the construction medium; and (iv) drive innovation in cellular construction by **real-world applications.** Research projects will primarily advance sub-goals (iii) and (iv) but will impact sub-goal (ii) by providing state-of-the-art graduate training in quantitative and multidisciplinary science and sub-goal (i) through knowledge sharing and a focus on training of underprivileged and minority students.

Project 1: Cellular Machine Shop and Core

Summary: We will assemble a set of core resources and instruments for the center community including high throughput and quantitative imaging systems, gene synthesis, and next generation sequencing. We will use these core resources to assemble modules for cellular engineering in other Center projects including adhesion systems, polarity systems, trafficking systems, timers, sensors, and kill-switches.

Relevance to Center Vision: The scientific vision of this project is to create a core of high throughput and modular tools for cell engineering that will enable the "build" step of the engineering "design, build, test" cycle (Center sub-goal 3). These tools will represent enabling technologies that feed directly into

the other projects of the center, but will also have broader impacts in the cell engineering and synthetic biology communities.

Background: Although advanced concepts of design and theory play an important role in any engineering discipline, ultimately engineering is about building things, and this requires the right set of tools. One of the main lessons learned from synthetic biology research to date is that it is not always possible to force a biological system to behave exactly as one intends. Thus any attempt at rational design must take into account the variability and robustness of biology. Thus the main "fab" approach for engineering cells will have to involve high-throughput approaches to rapidly test a range of different related parameter sets.

Implementation: We thus propose to combine high-throughput screening and visualization methods with automated gene synthesis and nanoscale chemical tools to develop a chemical and genetic toolkit that will allow us to sculpt and shape organelles, cells, and tissues, according the specification of a designer. Specific synthetic biology tools that will be generated are: adhesion systems (see also project 3); polarity systems; trafficking systems; timers, sensors and decision making systems; and kill-switches to eliminate cells if the need arises. These efforts build directly on the existing expertise of center investigators in optogenetics (Lim, Thomson, Weiner), synthetic polarity (Lim, Fletcher, Gartner), trafficking systems (Marshall, Chan), mechanical systems (Dumont, Tang), and decision making systems (El Samad, Lim). In all cases, collections of related constructs will be synthesized via automated total gene synthesis using the services of Twist Bioscience (Mission Bay, San Francisco) according to design principles developed in CellCad (project 2). These will then be transformed into cells and the resulting effects on structure and behavior assessed using high-throughput automated imaging platforms coupled with automated liquid handling robotics systems. A primary challenge in this approach is codifying the experimental protocols in a platform-agnostic manner that will allow our approaches to be reproduced as automated systems evolve over time. Our informal partner Autodesk will play a key role solving this challenge. We plan to adopt the Wet Lab Accelerator system under development by the Bio/Nano/ Programmable Matter group at Autodesk (www.wetlabaccelerator.com). This system provides maximum cross-platform portability by generating vendor specific control programs at run time. We will use this framework to tie together our experimental approaches and tools.

Developing these tools will yield unprecedented insights into the molecular pathways regulating the size and morphology of organelles and tissues, as well as enabling fundamental investigations into the functional consequences of organelle geometry, for example the influence of surface to volume ratio on metabolic pathways in which some steps are membrane associated and others internal to the organelle lumen. Such studies might shed new light onto the basic question of why different organelles have reproducibly different morphologies. It will also provide insight into how geometries of organelles and membrane domains affect their function. Finally, it will provide the tools to program multicellular organization of mammalian cells and microbes in a semi-rational manner.

In the course of carrying out the research goals of this project, many tools and platform technologies will be developed which will be applicable to all other projects of the center. We therefore envision the Cellular Machine shop as not only a research project in its own right, but also as a distributed technology core that will provide access to its tools and instrumentation to all Center members in support of their own synthetic cell biology projects. In addition, the Cellular Machine Shop will provide an access point for existing technology cores available at all Center partner institutions.

Project Lead: Wendell Lim (Synthetic biology, particularly engineering yeast and T-cells).
Other project members: Wallace Marshall (tuning organelle size), Jennifer Fung (imaging, image analysis), Sophie Dumont (engineering mechanosensors), Orion Weiner (engineering optogenetic elements), Shawn Douglas (engineering DNA-based origami, software development), Zev Gartner (engineering adhesion systems), Mark Chan (engineering organelle size), Blake Riggs (cell division), Dan Fletcher (engineering vesicles *in vitro*)

Project 2. CellCAD

Summary: This project aims to create integrated and multiscale modeling and Computer Aided Design (CAD) tools that will allow us to implement a computational "design" platform for engineering cellular and multicellular structure. Two exemplary scientific goals are discussed. First, we will use models of organelle size control to develop design tools to predict molecular changes capable of yielding cells with a desired internal structure. Second, we will use coarse-grained tissue-scale models to design methods for designing multi-cellular structures.

Relevance to Center Vision: The scientific vision of this project is to create computational tools for specifying the organization and integration of subcellular, cellular, and tissue-scale structures as the "design" component of the engineering "design, build, test" cycle (Center Sub-goal 3).

Background: Cell and tissues are organized at multiple spatial scales. The complexity of cellular pathways means that changing one aspect of the cell may have rippling effects on other aspects, which can only be fully represented with detailed mathematical models. These principles apply equally well at the tissue level and across the cell-to-tissue length scales. By analogy with electrical circuit design, we will develop a set of tools to simulate the dynamics of cellular and multicellular structures (analogous to simulation of circuits with SPICE or similar programs), specify desired cellular structures using a formal language (analogous to VHDL), predict the appropriate molecular changes that one would need to make in order to achieve a desired structure (analogous to a tool path in CNC machining), and visualize the expected outcome along with analysis of failure modes. This is an extremely long term goal but one which we feel should start to be addressed from the beginning of the project because it provides part of the motivation for Project 1 and part of the approach for Project 4.

Subproject 2a: Initially this work will use hypothetical models for organelle size control systems but as information accumulates from the work of Project 1, this will be immediately used to generate more realistic models. The Douglass lab, through a long standing collaboration with Autodesk, has an established track record of building CAD software for nanoscale design. The Marshall lab has an established track record of developing predictive models for organelle size control system including for vacuoles, flagella, and mitochondria (Ludington 2012; Rafelski 2013; Chan 2014). Size control models will be based on our established framework of treating organelles as steady state systems whose size is set by the balance of assembly and disassembly, converting information about known trafficking pathways that regulate organelles into systems of differential equations, which we will represent and archive in searchable form using SMBL. We will employ two distinct methods to convert predictive models into designed perturbations. The first is enumerative search of parameter space – we will use guided searching to obtain sets of parameters within a given organelle model to achieve the desired state. The second is model inversion. We will analyze each model as a dynamical system using analytical and numerical methods. Such dynamical system analysis of large models is a particular strength of the Bianco group. Parameter sensitivity analysis will be used to determine functional relationships between relevant parameters, and to assess which pathways of organelle dynamics play the largest role in determining size and which parts of the pathway need to be changed in order to bring about a desired organelle state. These pathway changes will then be fed into automated systems to design synthetic constructs that could regulate size by increasing or decreasing the activity of specific genes within organelle biosynthetic, trafficking, or regulatory pathways. These in turn will be further developed and tested in Project 1 for the ability to actually reprogram cell structure as intended. This process will repeat in a design-build-test cycle to improve the efficacy of the algorithms and downstream implementation. We thus plan to convert predictive models into design tools that (a) optimize size of each organelle and (b) design synthetic biology systems to achieve those sizes

Because biology is inherently noisy compared to other engineering media, and given the inherent robustness of biological assembly, which provides a number of alternative paths to produce functionally

equivalent results, our CAD program will never be able to provide a single unique solution that is guaranteed to produce cells with the desired structure and behavior. Rather, we envision the software as providing a set of candidate solutions constraining a potentially broad solution space, which will then serve as a starting point for systematic optimization via combinatoric strategies and high throughput imaging methods in the Cellular Machine Shop. We have been in contact with Florencio Mazzoldi, who directs software development at the Autodesk Bio/Nano/Programmable Matter group. Our plans for using predictive models and simulations as the basis for design tools at the cellular scale match current interests of the Bio/Nano/Programmable Matter group in developing design tools for biological systems, and we will continue to collaborate with the Autodesk group as we proceed with the project.

Subproject 2b: In addition to engineering cell compartments and cell shapes, we will simultaneously work to integrate these models with models of multicellular organization. We will use a combination of coarse-grained stochastic and mechanical models to simulate tissue self-organization from populations of cells with specific physical properties. These efforts will build directly on existing models developed by center investigators (Thomson, Gartner, Dumont) and will facilitate complex applications such as those described in projects 3 and 4 (Cerchiari 2015).

Project Lead: Shawn Douglas (building CAD software tools for molecular assembly).
Other project members: Simone Bianco (mathematical modeling and computational system integration); Matt Thomson (numerical methods); Wallace Marshall (predictive modeling of organelle size control systems); Manu Prakash (biological and physical self-organization)

Project 3. Cellular Legos

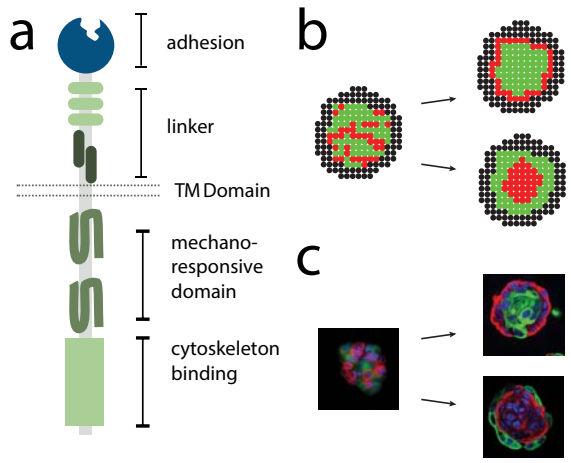
Summary: This project aims to create the tools necessary to program multiple specialized cell types or organisms into multicellular structures capable of executing more complex functions. As exemplary projects, we will design and evaluate mechanosensitive membrane spanning adhesion molecules (assembled in the Cellular Machine Shop) that will provide a synthetic and mechanically responsive adhesion system for mammalian cells. Analogous systems will be useful as cross-kingdom adhesion systems. This project will also benefit from the CAD tools refined in the course of Project 2 to program living matter into structurally defined and functional consortia.

Relevance to Center Vision: The scientific vision of this project is to create experimental tools for building multicellular and multiorganismal structures at the tissue-scale and beyond – the "build" component of the engineering "design, build, test" cycle.

Background: Cell and synthetic biologists have traditionally focused on the functions and behaviors of individual cells. In multicellular organisms and in complex ecosystems, however, cells specialize to optimally perform certain simple tasks. To perform more complex tasks, they must work together in groups. Therefore, cells have evolved mechanisms to mechanically integrate with each other and their environment in order to coordinate their behaviors and work together as a collective. In addition to having physical linkages, cells must also be organized into specific three-dimensional structures that allow for the ordered exchange of metabolites, information, or mechanics so as to perform complex tasks in a synchronized and orderly fashion.

In order to program the multicellular organization of mammalian and microbial consortia, we must be able to engineer mechanosensitive adhesion molecules onto a non-adhesive cellular chassis. We will therefore design and evaluate synthetic adhesion systems for programming multicellular interactions. These synthetic adhesion systems will be used to assimilate specialized cell-types into structured communities, combine cell-types from different organisms and kingdoms into novel structures, or seamlessly integrate cells with inorganic structures providing functional living-machine interfaces. From a basic science perspective, these synthetic adhesion systems will allow the testing of "sufficiency" for multiscale models of tissue self-organization developed in CellCad (project 2).

Subproject 3a: A modular mammalian cell adhesion system in a non-interacting cellular chassis. We will first explore a modular adhesion system using a mammalian cellular chassis. The system will have several key components: adhesive domains, membrane spanning domains, and mechanoresponsive cytoplasmic effector domain. Emerging evidence suggests that adhesion domains linked to force generating domains are sufficient to drive organization of adhesion molecules into membrane microdomains (James 2012). We will take two parallel approaches. First, beginning with E-cadherin, we will swap out component domains and replace them with synthetic domains. Second, we will construct an adhesion system from the bottom-up, using only synthetic components isolated from other biological systems. In either case, the goal is to develop an adhesion system that links with the cytoskeletal force generating system and is orthogonal to other adhesion molecules in the proteome. This project will build on the core expertise of Center investigators including Zev Gartner (tissue self-organization and programmed cellular assembly), Dan Fletcher (adhesive membrane microdomains), Manu Prakash (principles of self-organization), Sophie Dumont (cell mechanics), among others.



Domain structure (a) of a synthetic adhesion system. (b) Stochastic model of tissue self-organization makes (c) predictions about multicellular organization.

A*dhesive domains* will derived from any two interacting proteins or materials. Numerous options are available for adhesion to inorganic materials (e.g. bone or metal), polymeric extracellular matrices, or other cells (Villarreal 1989). Such options include covalent systems (e.g. SpyCatcher), non-covalent heterotypic (e.g. scFv-ligand pairs such as the MycTag), non-covalent homotypic adhesion systems (e.g. coiled-coils suchs as GCN4) (Hilpert 2001, Zakeri 2012). These can be further engineered as "catch-bond" adhesion molecules (i.e. stronger binding with increased mechanical load), for example by synthesizing symmetric coiled coils that can adhere in cis or trans. Adhesion can also be made small-molecule dependent using the Rapamycin-FRB-FKBP system.

Membrane spanning domains will be derived from alpha-helical transmembrane domains from cadherins or orthogonal components and non-interacting type-I transmembrane domains such as that from CD86. Oligomerizing transmembrane domains are also available, as well as domains that are cleavable by cell surface proteases such as gamma-secretase and ADAM-17 (Gordon 2015).

Cytoplasmic effector domains will be rendered mechanically responsive by (i) linkage to the cytoskeleton to generate a force and (ii) by also including a variety of well-characterized mechanoresponsive protein domains between the membrane and the cytoskeletal linkage. Adhesion systems must be mechanically responsive to function as structural proteins in mammalian systems (Maitre 2012). Linkage to the actin cytoskeleton will occur through the β-catenin binding domain of E-cadherin (Huber 2001). Linkage to the intermediate filament cytoskeleton, to serve a more long-term structural role, would occur by substituting for the analogous regions on demosomal cadherins that bind plakoglobin. Basal adhesion machinery will substitute the Talin binding domains of integrin beta chains (Calderwood 1999). Mechanoresponsive proteins will include the Notch Regulator Region (NRR), Titin, and the silk flagelliform protein (Grashoff 2010, Gordon 2015). These domains unfold upon specific levels of mechanical loading to reveal internal domains for protein binding and recruitment to the membrane.

The synthetic adhesion system will be evaluated in a non-interacting cellular chassis such as Jurkat cells – a human lymphocyte cell line. We will use the high-throughput imaging systems implemented in the Cellular Machine Shop (project 1) to assay for the formation of microscale adhesive domains at cell-cell

and cell-surface interfaces; the recruitment of actin and β-catenin to adhesive domains; and the recruitment of desired proteins to mechanoresponsive domains. Completion of this project will provide a new and modular means of mechanically integrating any mammalian cell with any other cell or material with broad impacts in cyborg systems, mechanical or electronic implants, medical devices, and basic science. A suite of these systems with programmed adhesive and mechanical responses will allow us to engineer unique multicellular structures using our existing models of tissue self-organization (Cerchiari 2015). These will also provide powerful means of testing "sufficiency" to validate multiscale predictive models for tissue self-organization developed CellCad (project 2).

Subproject 3b: A multi-organism adhesion system. Unlike mammalian cells, most bacterial and fungal adhesion systems are not linked directly with the actinomyosin cytoskeleton to couple force generation with cell adhesion and self-organization. Therefore, we will explore a completely different strategy to program multiorganismal self-organization – we propose to develop genetically encoded and cross-species extracellular matrix (ECM) adhesive interactions. While a variety of microbes produce ECM, ECM engineering has not been explored as a means of engineering physical interactions among unrelated microbial species. We will therefore repurpose cell surface proteins to allow controlled adhesion between prokaryotic and eukaryotic microbial cells that normally exist as free-living organisms. By focusing on unicellular and genetically tractable microbes with proven industrial applicability, we will put ourselves in a strong position to enable Self-Assembling Hybrid Living Bioreactors (project 4) and to spin off our research results into tangible real world products. However, we anticipate that principles of self-organization unraveled in these studies will be applicable to other multiorganismal microbial systems as well.

We will first explore algal systems (Volvox or Chlamydomonas) and bacterial system (B. subtilis) that are genetically tractable and possess the rudimentary machinery necessary to self-organize (Volvox spheroid formation; B. subtilis biofilm formation). We will take advantage of the Volvox ECM secretion system or Chlamydomonas peripheral cell-wall binding proteins as scaffolds for modification. Key protein components (for example Volvox protein SSG185) will be engineered with modular adhesion domains such as those described in subproject 3a (Ertl 1989). In parallel, we will take advantage of the B. subtilis biofilm formation program. B. subtilis is a non-pathogenic gram-positive bacterium that naturally forms biofilms at the air-water interface, but can also be engineered to form biofilms at liquid-solid interfaces. It's ECM comprises a combination of exopolysaccharide and proteins that are together largely impervious to organic solvents and aqueous media (Vlamakis 2013). To program interactions between B. subtilis and Volvox, we will engineer B. subtilis to express an ECM-protein fusion incorporating domains that bind the Chlamydomonas cell wall or Volvox ECM. Similarly, Volvox and Chlamydomonas will be engineered to express surface protein that interacts with domains engineered into the B. subtilis ECM system. We will measure the kinetics of association of these engineered strains as a function of cell concentration and fluid sheer. These parameters will be used to build predictive models for self-organization in CellCad (project 2). We will also explore synthetic polarity circuits engineered as part of the Cellular Machine Shop (project 1) that could be used to form polarized adhesive domains.

Project Lead: Zev Gartner (Engineering multicellular assemblies).
Other project members: Matt Thomson (Potts models); Sophie Dumont (mechanical sensing and modeling); Sindy Tang (mechanical engineering); Manu Prakash (fluid mechanics); Dan Fletcher (mechanics of adhesion molecule segregation and organization); Laura Burrus (developmental biology); Orion Weiner (imaging, cell polarity, development);

Project 4. The Living Bioreactor

Summary: We will harness our ability to specify the organization of intracellular and multi-cellular structures to implement an entirely new approach to metabolic engineering for production of biofuel and other high value compounds, first by tuning organelle size to improve yield, and second by creating

multi-layered self-assembling/self-healing multi-kingdom cell aggregates capable of withstanding harsh conditions, resisting contamination, and facilitating harvesting of the desired products.

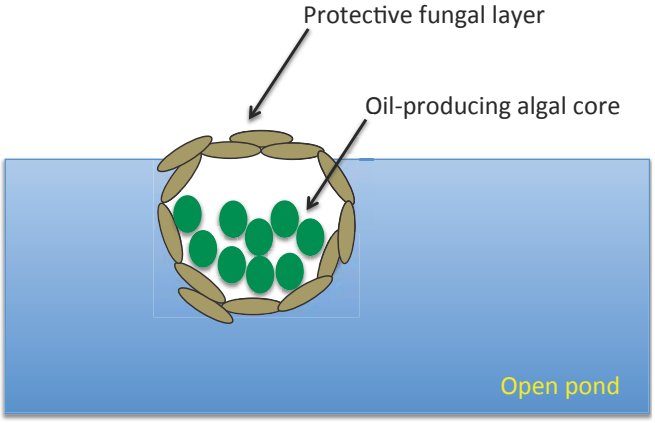
Relevance to Center Vision: The scientific vision of this project is to solve a multiscale engineering problem with real world and practical implications. How could we deploy synthetic biology for the synthesis of specialty and commodity chemicals that would not require a complex underlying infrastructure? We envision deployable and living bioreactors which use cross-species cooperation, barrier functions, and basic immune principles to self-organize and self-heal given minimal underlying infrastructure (e.g. ponds or canals). Solving this multiscale engineering problem requires the seamless integration of the "design, build, test" paradigm with a concrete and well motivated goal. We will use collaborative integration tools being developed at IBM to integrate CellCad with design goals for self-organization and metabolic engineering.

Background: Current efforts at metabolic engineering, for example with the goal of making cells store or secrete lipid for biofuel production, are focused exclusively on the enzymatic pathways of metabolism. Such an approach ignores the fact that metabolic pathways are encapsulated within organelles whose size and surface to volume ratios will strongly affect the functional throughput of the enclosed pathways. Moreover, many of the challenges faced in biofuel production on a large scale have nothing to do with enzymatic reactions, but rather concern process engineering concerns such as contamination and harvesting. By learning how to engineer cells at intracellular and multi-cellular scales, we propose novel strategies to deal with the limitations of current metabolic engineering and process engineering approaches.

Subproject 4a: Engineering organelles as intracellular reaction vessels. We hypothesize that gaining control over organelle size and trafficking (see Project 1) in industrial strains of fungi and algae could lead to vastly improved production of economically important metabolic products including, but by no means limited to, biodiesel, jet fuel, methyl halides (Bayer et al., 2009), etc. By using the tools developed in projects 1 and 2, applied to plant, algal, and fungal cells, we will manipulate organelle size and shape and determine how much such re-engineering can improve output of valuable products. We will use standardized assays to probe photosynthetic efficiency, biomass growth rate, and lipid synthesis (based on TAG assays and LC/MS) under growth and stationary conditions. Standard assays for bioproducts will be conducted using core facilities at UCSF, and microfluidic scale assays will be implemented by the Tang group. We will thereby test our hypothesis that modulation of an organelle size control system can affect industrially relevant production of metabolic products (triglyceride/biodiesel). If we succeed in this initial milestone, we will then explore the effects of modulating other organelles and other products, particularly focusing on the effect of yeast vacuole size reprogramming on methyl halide production. Methyl halides are an industrially valuable class of compounds that serve as precursors for many other products, but their biosynthesis is thought to involve generation of toxic intermediates that are sequestered in the vacuole. We predict that larger vacuoles might increase production. <u>This general strategy has the potential to launch a whole new area of biotechnology, and will serve as a powerful proof of concept for the general idea of cellular engineering</u>.

Subproject 4b: Self-assembling hybrid living bioreactors. For this sub-project, we will take a multi-scale engineering approach that spans from metabolic processes to the organelle level to the multicellular level, in order to allow simple harvest and robust function in open ponds. Current biotechnology is based almost universally on single-species systems, for example a yeast or fungal culture grown in a closed bio-reactor that provides optimal conditions for growth including sterility, temperature control, and nutrients. But closed bioreactors cease to be practical for the extremely large-scale cultures currently envisioned for algal biofuel production. In order for algal biodiesel production to be economically feasible, it is likely necessary to turn to large open-pond or raceway systems (Fishman 2008). But in such open systems, the fuel-producing alga is at the mercy of its environment, and subject to contamination by other organisms. In Project 3 (Cellular Legos), we propose to develop flexible methods for fabricating controllable self-organizing multi-cellular structures that combine different types of species into single living devices. In

this sub-project, we propose to harness this capability to develop living, multi-cellular equivalents of bioreactors, in which one organism would self organize into a protective layer, designed to act as a self-healing, growing barrier to protect the actual fuel-producing alga inside, much like an artificial lichen. By tuning the buoyancy of the multi-cellular complex, for example by producing gas that would then be trapped in secreted ECM, it should be possible to cause these bioreactor layers to float on the surface of a pond during the growth phase and then, in response to defined chemical signals, switch to a lower buoyancy so that the entire system would settle to the bottom, obviating the need to enrich the fuel-containing cells by centrifugation. Additional features that we will build into the protective layer cells would be secretion of targeted antimicrobial products to prevent harmful organisms from taking over the pond, tuned exchange of fluids and gases with the environment to provide optimal growth conditions to the interior fuel-producing cells, secretion of moisture for cooling, futile metabolic cycles for heating, and generation of colorimetric signals that would provide rapid visual assessment of conditions within the pond. Using engineered cell-cell communication systems, we will connect the fuel-generating cells to the surface layer cells, so that when the fuel cells accumulate sufficient lipid, they would signal the surface layer cells to generate a signal that could be observed remotely (such as color patches for visual detection via flying drones, or chemical secretions for detection through appropriate sensors). For non-photosynthetic systems, we propose to combine cells that can break down a feed stock with cells that can produce a desired product (see for example Bayer 2009) in defined complexes to increase efficiency.



Schematic of a self-assembling hybrid living bioreactor.

This long-term, highly integrative aim will not only combine methods from Projects 1, 2, 3 and Subproject 4a, it will require us to integrate concepts from developmental biology and ecology. We will be able to use this project as a way to train engineering students in these areas to further expand their biological concept base.

Project Lead: Sindy Tang (encapsulation of metabolically engineered cells).
Other project members: Wallace Marshall (Chlamydomonas algal molecular biology and biofuel); Mark Chan (yeast vacuole engineering); Laura Burrus (developmental biology); Wendell Lim (synthetic biology); Hana El-Samad (metabolic modeling); Zev Gartner (engineering cell layers)

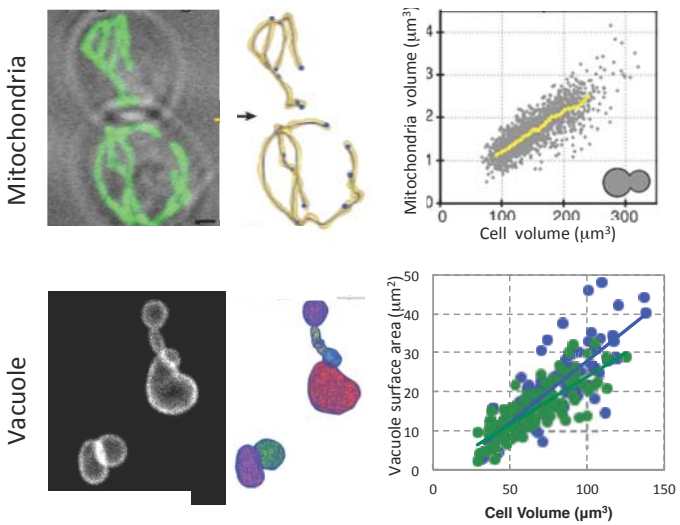
Project 5. Cell-State Inference Engine

Summary: The scientific vision of this project is to create a software platform for converting images of cells into estimates of cell environment and signaling state.

Relevance to Center Vision: Methods devised in this project will facilitate the "test" step in the engineering "design, build, test" cycle (Center Sub-goal 3), and will be driven by the goal of using cells as living sensors of environmental conditions for real-world application (Center Sub-goal 4).

Background: Cell biologists studying organelle morphology have often noticed that organelle organization changes in response to cellular metabolic state. To the extent that this phenomenon has been addressed, the focus of research has always been on understanding the role of these changes in the normal physiological regulation of the cell. We propose to address this phenomenon in an entirely different way, by exploiting the responsiveness of cellular organization to provide a non-destructive way to probe the inputs that a cell is experiencing.

Subproject 5a: Cellular Sentinels.
Cells are covered with sensory molecules to detect their environment with exquisite sensitivity and precision. In many cases, changes in a cell's environment lead to rapid changes in internal organization, for example alteration in oxygen levels and sugar in the surrounding media can cause dramatic changes in mitochondrial network morphology. We propose to harness this strong connection between external inputs and internal structure to implement non-destructive testing approaches based on image analysis, that will allow us to use cells as sensory platforms to detect environmental changes. Use of overall cell morphological state as a reporter, rather than specific molecular biosensors such as have already been developed for various compounds, are numerous. Most importantly, cells are able to integrate a wide range of inputs, so that by monitoring cellular morphological state, we can detect alterations in many biochemical signaling pathways in parallel, thus providing sensitivity to broad classes of toxins or environmental stimuli.



Quantitative metric of organelle geometry for Cellular Sentinels and a Cellular Facebook.

We have developed automated image analysis software to quantify cellular organelles in three dimensions (as shown in the figure below), and these methods provide a numerical representation of cell morphological state. Using the predictive models from Project 2 that allow us to predict cellular structure from molecular state, we will attempt to develop inverse predictor tools to estimate molecular state from cellular structure, based on our image analysis tools. In parallel to this modeling-focused approach, we will also conduct an empirical data-driven approach in which cells will be exposed to a wide range of chemical signals, using chemical diversity libraries, as well as by using collections of deletion mutants (for yeast) and RNAi constructs (for mammalian cells) that will modify many different intracellular pathways. For each perturbation, cellular organization will be quantified using microscopy and image analysis, and the final data set analyzed to determine what is the minimal basis set of cell structures that can cover the total observed variation over all possible inputs. This "periodic table" of cell states will provide an instant way to determine what environmental signals a cell has been exposed to, in a completely non-destructive way such that the same cells can be used for multiple tests. Each living cell would thus serve as a living sentinel, poised to detect and report on environmental changes of any kind, even those that cannot be anticipated.

One advantage of using cell structure and morphology as a read-out is that it can be performed even in cell types that are not amenable to the normal range of molecular manipulations, such as industrial fungal strains or novel cell types that may be investigated for their inherent robustness and viability under extreme conditions. But in engineerable strains, the range of sensory modalities can be expanded by building in mechanosensory and chemosensory systems with visual read-outs to augment the inherent state-sensing made available by organelle analysis.

Applications of cells as sensory platforms would be numerous. In an industrial setting, cells can instantly report on conditions in bioreactors during complex process development. In environmental or defense applications, cells will be able to sense and respond to toxins, including novel agents that cannot be detected by existing molecular assays but which can still be detected by cells via their effects on cell signaling or metabolism. In food biology, the concept of "sentinel" cells maybe used as a "canary in a

coal mine", by monitoring changes in cell morphology to detect unexpected, never before seen toxins and other contaminants (e.g. melamine in milk). Since alterations in cell morphology are common in pathology, the same computational tools developed for this project will have potential application in developing new medical software for cytopathology.

Subproject 5b: Cellular Facebook. The steady pace of advances in biomedical instrumentation and imaging technology development has created a new problem of how to extract useful information from the wealth of imaging data that can be collected. One very simple but important goal is classification – given an image of a cell, we would like to know exactly what type of cell it is, what state it is in, and what function other than its basic ones it is performing. Through the model-inverse and big-data approaches of Subproject 5a, we will have compiled a periodic table of cell states that serve as reference data against which any actual cell image can be checked. In this way, different cell images can be grouped based on similar identity. Orthogonal information, such as genetic data or cellular "meta-data" (chemical bio-products, environmental conditions, response to targeted stimuli, etc.) can then provide additional mechanistic understanding of the relationship between structure and function in different settings. This subproject will therefore create a novel enabling technology that would drive further innovation in fields other than the ones initially envisioned for this project, from biophysical and biomedical devices to more general industry solutions.

Project Lead: Wallace Marshall (organelle image analysis);
Other project members: Jennifer Fung (live-cell and super-resolution microscopy); Simone Bianco (inference algorithms from big data, linking cell data to genomics); Matt Thomson (information theory); Hana El-Samad (network inference algorithms).

Timelines

PROJECT	YEAR 1 *2016-17*	YEAR 2 *2017-18*	YEAR 3 *2018-19*	YEAR 4 *2019-20*	YEAR 5 *2020-21*
Project 1: Cellular Machine Shop					
- Purchase core equipment	▲				
- Build synthetic modules	▲	▲	▲	▲	▲
Project 2: CellCad					
- Organelles	▲	▲	▲	▲	▲
- Tissues	▲	▲	▲	▲	▲
Project 3: Cell Legos					
- Mammalian	▲	▲	▲	▲	▲
- Microbial	▲	▲	▲	▲	▲
- Modeling Synthetic Adh. Systems			▲	▲	▲
Project 4: Living Bioreactors					
- Organelle	▲	▲	▲	▲	▲
- Self-assembling Hybrid			▲	▲	▲
Project 5: Cell State Inference Engine					
- Cellular Sentinels	▲	▲	▲	▲	▲
- Cellular Facebook	▲	▲	▲	▲	▲
Startups from center research activities		▲	▲	▲	▲

4.c. Education and Human Resources Development Objectives

4.c.1 Overview of Education and Human Resources Development Plan

As the primary goal of The Center for Cellular Construction is to develop cell biology as an engineering discipline, building awareness of, interest in, and training the scientists and engineers of the future to work at this novel interface are core components of the work of the Center. To these ends, we have developed a coherent pathway, one that actively engages students from high school through graduate school, as well as postdoctoral fellows, secondary teachers, STEM professionals, and public audiences, in high quality learning experiences that immerse them in cellular engineering. Notably, these program components are synergistic, as integrated into the training of graduate students and postdoctoral fellows are opportunities for them to support programs for secondary students, STEM professionals, and public audiences, thereby developing their knowledge of research-based pedagogy and strengthening their mentoring and communication skills.

High School: While more and more cutting edge science is being done at the interfaces between disciplines, secondary science teaching is largely silo-ed. As a result, students remain unaware of the exciting opportunities emerging at these interfaces. CCC will partner with the UCSF Science & Health Education Partnership (SEP) to develop innovative instructional modules and lead immersive, authentic summer science experiences for high school students and their teachers. Instructional modules will be designed to help high school biology teachers enact the Next Generation Science Standard's vision of three-dimensional pedagogy (Science & Engineering Practices, Cross-Cutting Concepts, and Disciplinary Core Ideas) (NGSS Lead States 2013). By framing cell biology as a problem-based discipline and highlighting the potential of cellular engineering to address global challenges including those related to food and fuel production, and improving human health, students will experience science as a process of discovery and realize that they can use their scientific knowledge to solve pressing world problems. This stands in stark contrast to many students' view that science is a litany of facts to be memorized, in fields where everything interesting has already been discovered.

Each year CCC will develop two instructional modules – each approximately 10-class sessions in length (15 hours). Modules will be piloted in two-week intensive summer Boot Camp experiences that will jointly enroll high school students and their teachers. This model of engaging teachers and students together as learners is both deliberate and innovative. In this setting, teachers will see diverse students from a variety of schools and backgrounds grappling with difficult content, working together on design teams to solve complex problems, and engaging deeply in scientific thinking. This experience will help teachers to recognize how creative and capable students are when science learning is presented in novel and engaging ways. Moreover, as few high school biology teachers have themselves had experiences either learning or teaching engineering, or in teaching in this interdisciplinary manner, the workshops will serve as high quality professional development for participating teachers (Loucks-Horsley 1998).

Student recruitment will focus on schools with significant populations of low-income and under-represented minority students as well as those who have the potential to be the first in their families to attend college. SEP will draw on its extensive network of teachers to identify talented students from our target populations to participate in the Boot Camps, and compensate participating students (and teachers) as compensation greatly increases the number of low-income students who can participate as their families are dependent on their earnings for the summer. Teachers from San Francisco Unified School District and across the Bay Area will be recruited using existing SEP networks.

UCSF Research Internships*:* Much as there is little focus on engineering in high school biology classes, at the undergraduate level, there similarly little opportunity for students to learn how to integrate the intuition of multiple disciplines with physical and engineering approaches to tackle biological problems. Biomedical engineering programs have typically focused on medical problems and, critically for this work, have not focused on the cell as the key level of organization or as a chassis for engineering and construction. Likewise, biotechnology programs focus on molecular biology as a tool, but have been limited to engineering genomes to manipulate gene expression rather than engineering cells to program

novel behaviors and structures. There is thus a need to provide focused training at the specific interface of engineering with Cell Biology.

Research internships are an ideal entrée for undergraduates to begin to build knowledge and skills at this interface as they provide students with direct, hands-on experience in this type of research. CCC will sponsor 10-20 undergraduate research internships per year from local institutions (San Francisco State, City College of San Francisco, and UC Santa Cruz). These students will work at the interface of cell biology and engineering, both on a year round and summer-only basis depending on the needs of the students, with the intention that they would be able to participate for two summers in a row in order to build the strong research foundation that correlates strongly with future success in graduate school (Thiry 2015; Weiner 2014). In addition to these local students, the CCC will recruit 10 additional students from across the nation through UCSF's Summer Research Training Program (SRTP) to work in Center labs.

Mentoring undergraduates will provide important training for Center graduate students and postdoctoral fellows. Recognizing the critical nature the mentor-mentee relationship plays in supporting the success of students and particularly those from URM backgrounds, all UCSF-based day-to-day mentors of undergraduate research students will be required to participate in SEP's Mentoring Workshops. These workshops, inspired by *Entering Mentoring* (Handelsman 2005) build mentors' repertoire of teaching and mentoring strategies and help mentors learn to be culturally aware in their interactions with their students.

The CCC is committed to increasing diversity in the sciences. Our undergraduate recruitment efforts will focus on under-privileged (low-income, first generation in college) or under represented minority (URM) students. Details of our efforts to broaden participation are described in the Broadening Participation Objectives, and will be organized by Diversity Coordinator Frank Bayliss of SFSU. It is important to note here that two factors known to be important in helping undergraduates, particularly those from URM backgrounds, persist in STEM majors are having a mentor in the field and a positive experience in scientific research (George et al 2001; LPFI 2005) – two areas that our plan will emphasize.

Corporate Research Internships*:* IBM has a well-developed internship program in which students (graduate and undergraduate) can work in ARC research labs for periods of 3-6 months. STC funds will support these internships and if appropriate, extend their duration. In years 3-5 of the CCC, we will construct combined academia-industry internships in which a student will work on a collaborative project between IBM and one or more of the other participating STC labs. We believe this will present a truly unique research opportunity for students that would be extremely difficult to obtain through conventional internship or research experience programs.

Innovative Course Experiences to Prepare the Next Generation of Cellular Engineers*:* In addition to training graduate students directly in Center labs, we will develop a Total Immersion Lab Experience program in which center PIs organize three-week long intensive lab experiences for undergraduate, graduate, and postdoctoral trainees. These courses are modeled on the MBL (Marine Biological Laboratory) educational program at Woods Hole and will involve project-based training in small groups. Importantly, Professor Marshall has six years of experience teaching and organizing MBL practical courses. The course will begin with a 1-week "boot camp" phase consisting of hands on training and didactic lectures. Two boot camps will be run concurrently: biology boot camp to train engineering students in basic biological and molecular techniques, such as cell culture, microscopy, and gene cloning, and engineering boot camp to train biology students in computational and physical methods commonly used in engineering such as computer programming, image analysis, Fourier transforms, and basic control systems theory. Following the initial boot camp, center PIs will design small projects to address interesting questions in a short time period, but specifically designed to require a combination of technologies and disciplines. Research projects will be conducted during the second two weeks of the program. Examples of research projects include developing new image analysis methods to probe size mechanisms for organelles that have not previously been studied, or testing the effect of changing the size of an organelle on the ability of a cell to store a toxic metabolic intermediate.

At UCSF, we will develop a new set of graduate courses using a minicourse format, in which small groups of students meet with 2-3 faculty every day for two weeks to discuss current literature and open questions on a focused topic. This format provides an easy way to introduce new material into existing graduate programs. Courses will be open to students from all Center institutions, including advanced undergraduates, and the grant will set aside funds to help with travel and housing for students coming to the courses from longer distances or out of state. These intensive focused minicourses will inform the development of learning experiences that can be included in the core curriculum to help biology, chemistry and physics students apply their understanding across length scales.

Science Festivals & Maker Faires*:* The Science Festival and Maker Faire movements are both expanding across the United States and world. There are now 55 Science Festivals and nearly 90 Maker Faires in communities across the United States. Science Festivals and Maker Faires are complementary. Festivals draw representation from a broad cross-section of STEM fields and significant numbers of STEM professionals as exhibitors at their Expo events, in which a public space is turned into a science museum for a day. Festivals showcase interactive exhibits organized by local universities, non-profits, museums, and corporations. At the Bay Area Science Festival's annual Discovery Day event, more than 30,000 people attend and interact with the scientists and engineers leading nearly 200 exhibits. Maker Faires also draw broad representation and include professionals from the technology sector, hobbyists, and STEM enthusiasts pushing the boundaries between disciplines as exhibitors. Each year, the CCC will develop exhibits to present at both Science Festivals and Maker Faires in the Bay Area and across the nation. Distant events will be chosen with particular attention to Festivals (such as the Philadelphia Science Festival) and Maker Faires (Maker Faire Detroit) serving minority communities.

The design of CCC exhibits is seen as a training opportunity for the Center graduate students and postdoctoral fellows involved. Exhibits in both settings must be robust and capable of engaging participants with a wide range of background knowledge. Through exhibits, event attendees engage with phenomena and talk with the exhibit host (a representative of the CCC) about their work and its implications. Thus, the Center scientists staffing the exhibit learn to communicate the significance of their work clearly to diverse audiences. SEP staff, as founders of the Bay Area Science Festival, have extensive expertise helping groups to develop exhibits and training scientists to communicate clearly with attendees.

Hackathons*:* Hackathons are intensive events focused on the rapid development of new technologies. Hackathons typically use an open meeting structure in which participants suggest problems or product ideas to the assembled audience and attendees team up to work on these project suggestions based on their interests and skills. The numerous hackathons in the San Francisco Bay Area provide an unparalleled opportunity to present technological challenges to a motivated and skilled group of software developers, engineers, and product designers. Each year the CCC will host two hackathon events. Participation in these events serves multiple purposes. Most importantly, the presentation of CCC projects at these events builds awareness of the interesting challenges being pursued in cellular engineering within a population with the skills to help us address these challenges. Hackathons are generative, and the ideas and nascent tools created at the events will help us to move the work of the center forward.

Science Museum Exhibits & Public Demonstrations*:* A partnership with the Exploratorium will provide unique opportunities to engage museum visitors with key topics in cellular engineering while simultaneously creating innovative opportunities for graduate students to learn how to effectively communicate the work of the Center. In this component of the work, experienced exhibit developers at the Exploratorium will mentor and partner with CCC graduate student interns to develop both an exhibition on cellular engineering and interactive demonstrations for the museum floor. The exhibition will consist of eight exhibits focused on key concepts and emerging research in cellular engineering, such as self-assembly or the origins of multicellularity. This small exhibition will complement and extend the Exploratorium's new exhibit on cell biology, *Cells to Self,* a large exhibition that will open in 2018. In addition, eight interactive demonstrations will be developed by the graduate student interns and piloted on the museum floor for addition to the rotation of menu of demonstrations given by museum staff each day.

4c.2 Key Organizations and Individuals

SEP (K-12): The Science & Health Education Partnership (SEP) has a 28-year history of supporting high quality science teaching and learning experiences in San Francisco. SEP facilitates partnerships between UCSF scientists and San Francisco Unified School District (SFUSD) K-12 teachers to support authentic science learning experiences in the classroom; provides professional development to deepen both teachers' scientific content learning and their understanding of how to integrate the practices of science into their teaching; leads a Presidential Award-winning summer biomedical research internship program for URM high school students that includes mentoring training for the participating researchers; and founded the Bay Area Science Festival. In its fourth year, the Science Festival is the region's largest free educational event and attracts over 70,000 attendees annually. SEP has an extensive and ongoing track record of successfully implementing funding initiatives from the NIH, NSF, HHMI, Gordon & Betty Moore Foundation, and others. SEP staff have backgrounds in scientific research and K-12 education and extensive experience developing, implementing and evaluating innovative science education programs. SEP's portion of the CCC work will be led by Co-Director Rebecca Smith, PhD.

Underprivileged and Underrepresented Minority Undergraduate (SFSU): SFSU has a diverse student body and a well-established track record of increasing diversity in science and research. These efforts are described in the Broadening Participation Objectives.

Graduate (UCSF, SFSU, UCB, Stanford): All participating academic institutions have strong graduate programs, with the focus of UCSF on Ph.D., SFSU on master's, and UCB and Stanford on both levels of graduate training.

Post-doctoral (UCSF): UCSF has a long tradition of providing postdoctoral mentoring and training. Details of the postdoctoral training within the Center are given in the Postdoc Mentoring Plan. Center postdocs will also be able to take advantage of UCSF resources for postdocs including Speed Mentoring events and the MIND program, which seeks to expose postdocs to alternative career paths.

Industry (IBM): Through their established internship program, IBM will provide students with research experiences in an industrial setting as described above.

Entrepreneurial (QB3/UCSF): Education in entrepreneurship is a unique feature of our proposal and will be accomplished through the "summer startup" program as described in the Knowledge Transfer Objectives. This aspect of the educational mission will be directed by Entrepreneurship Coordinator Charly Craik, and will harness existing resources at UCSF, particularly QB3 and the Idea to IPO course.

Public (Exploratorium): The Exploratorium is San Francisco's internationally renowned museum of science, art, and human perception. More than a million visitors explore hundreds of interactive exhibits annually. Partnering with scientists is central to the Exploratorium's exhibit and program development: they have partnered with researchers from over a hundred agencies and universities, including UCSF, Stanford, Harvard, MIT, NASA and NOAA through grants from NSF, NOAA, NASA, and NIH. This collaborative development has included large-scale projects to adapt research grade microscopes and petascale datasets into exhibits and programs for the public. The Exploratorium facilities were designed to support life sciences exhibit development, with research-grade microscopes, a cell culture facility, a greenhouse, and saltwater table. The Exploratorium also has a large a machine shop for building exhibits. Work at the Exploratorium will be led by the Exploratorium Site Director, Staff Scientist Jennifer Frazier.

4c.3 Integration of Research and Education

Because the nature of this Center is building a new discipline, research and education are inextricably linked. Education programs are designed to connect students at all levels to current problems/questions in cellular engineering while helping them to develop the laboratory and engineering skills needed to tackle those questions. CCC Boot Camps, minicourses, and public engagement events are specifically designed to be dynamic, introducing new biological questions and problems to be solved with each implementation cycle. This allows research discoveries to be rapidly integrated into the Center's education programs.

4c.4 Development, Evaluation, and Revision of Education and Human Resource Goals

Evaluation for Education and Human Resource activities will include both ongoing formative assessment to guide and refine program development and a final summative evaluation in order to provide complete description of the project's outcomes and the programmatic structures that contributed to those outcomes. Rebecca Smith has extensive experience guiding the evaluation of education initiatives in her role as Co-Director of SEP. She will work with the CCC Leadership Team and the leads of each of the Education and Human Resource components to ensure that program development is guided by SMART (specific, measurable, achievable, relevant, and time-bound) goals and desired outcomes of the work. Logic models will guide the evaluation of the Education and Human Resource components of this project. Note that evaluation will assess both quality of program implementation as well as outcomes from the work.

Evaluation will use a mixed methods approach. Educational and career outcomes for Center supported high school students, undergraduates and graduate students will also be studied. Exhibits at the Exploratorium will be evaluated by the Exploratorium's internal evaluation team using their established measures and results will be shared with Center leadership. Evaluation of Maker Faire and Science Festival exhibits will leverage the work being done by the NSF-funded EvalFest (#DRL-1423050 – Co-PI Nielsen is Co-Director of SEP) to develop evaluation tools that assess Science Festival exhibits.

Results from the formative evaluation will be shared with all project leadership and will be used to iteratively refine the EHR program components. In addition, evaluation results will inform the refinement of the programmatic goals so that they remain relevant and continue to promote the overall objectives of the CCC – training the next generation of cellular engineers and building awareness of this emerging field. Results of the summative evaluation will be shared broadly, both within the project and among the project's partners as well as in papers and through conference presentations.

4c.4 Timeline of Education and Human Resource Development Efforts

PROJECT MILESTONES	YEAR 1 *2016-17*	SUMMER	YEAR 2 *2017-18*	SUMMER	YEAR 3 *2018-19*	SUMMER	YEAR 4 *2019-20*	SUMMER	YEAR 5 *2020-21*	SUMMER
Leadership Team Planning	▲		▲		▲		▲		▲	
Develop High School Instructional Modules	▲		▲		▲		▲		▲	
Pilot Instructional Modules in Summer High School Boot Camp		▲		▲		▲		▲		▲
Disseminate Instructional Modules			▲		▲		▲		▲	▲
Undergraduate Research Internships @UCSF	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Research Internships at IBM ARC	▲		▲		▲		▲		▲	
Total Lab Immersion for Graduate Students	▲		▲		▲		▲		▲	
Mini-Course Development & Implementation	▲		▲		▲		▲		▲	
Exploratorium Internships	▲		▲		▲		▲		▲	
Science Festivals/Maker Faire Exhibits	▲		▲		▲		▲		▲	
Hackathons			▲		▲		▲		▲	
Formative Evaluation - Data Collection - Results Review - Leadership & Program Leads	▲	▲	▲ ▲	▲	▲ ▲	▲	▲ ▲	▲	 ▲	
Summative evaluation							▲	▲	▲	▲

4.d Broadening Participation Objectives of the Center

4.d.1 Overview of broadening participation objectives

Our plans to broaden participation will leverage three existing pipelines for minority and underprivileged scientific education already in place at our partner organizations, but will direct students from these pipelines in entirely new directions towards our focus on cell engineering. The first pipeline at the undergraduate level is the high diversity of student enrollment at SFSU. The second pipeline, also at the undergraduate level, is UCSF's SRTP. The third pipeline is through minority student research training at the high school level with SEP. Additional opportunities for broadening participation will come through our displays and exhibits at Science Festivals, Maker Faires and the Exploratorium. Drawing on these partners, we will ensure diverse participation in the research, education, and knowledge transfer activities of the center. Diversity efforts will be lead by Professor Frank Bayliss (SFSU), a pioneer in identifying and mentoring underprivileged and underrepresented minorities in graduate science and engineering education.

4.d.2 How progress will be measured

The External Advisory Committee (EAC) will conduct annual reviews of Center Diversity at all levels, including faculty, staff, postdocs, graduate students, undergraduate students, teachers, and high school students. This diversity progress measurement will also include examination of success rates in terms of admission, graduation, selection for travel funding, and selection for seed funding the summer startup program (see Knowledge Transfer Objectives) to ensure there is no hidden bias and that diversity is being promoted in all aspects of the center's activities. The EAC will itself have a diverse composition, and among the members of the EAC, one will be appointed whose specific focus will be oversight of efforts by the Center to broaden participation and increase diversity.

4.d.3 Diversity of current students of participating faculty and of Center members

The faculty at SFSU is highly diverse. The 781 tenured/tenure - track faculty in Fall 2013 were 49% female, 34% ethnic minorities, and 13% URM (4.2% African American, 7.7% Hispanic, 1.4% Native American). These figures exceed the national average of 10% URM faculty at 4 - year public institutions (nationally: 5.3% African American, 4.3% Hispanic, 0.5% Native American). The SFSU Center Faculty included in this partnership also represents this diversity: 4 of 8 faculty members are URM (Wilfred Denetclaw: Native American; Carmen Domingo: Latina/Hispanic; Ray Esquerra: Latino/Hispanic; Blake Riggs: African American). These researchers have strong backgrounds in Cell Biology and funded research projects that address fundamental questions in development and cell function (see Biographical Sketches). The presence of diverse faculty role models helps to ensure a welcoming climate for URM students while also changing perceptions about the face of contemporary scientific research.

SFSU has a strong history of preparing diverse students for graduate education in the sciences. With 29,541 students enrolled in Fall 2012, SFSU is the 97th largest public institution in the US (http://www.stateuniversity.com/rank/tot_enroll_rank/5#97). Of students reporting their ethnicity in Fall 2013, 8,308 (32.5%) were under - represented minorities (URM includes African American, Hispanic, Native American, Pacific Islander/Hawaiian), 1,624 students (6.3%) reported being "two or more races", and 36% of freshmen are the first in their family to attend college. Biology is the second largest major at SFSU with 1,028 (33% URM, 5% two or more races) undergraduates and 183 (26% URM, 5% two or more races) master's students. Engineering is the third largest major, with 957 (28% URM, 5% two or more races) undergraduates and 96 master's student (10% URM, 2% two or more races). Thus there is substantial opportunity to engage the large and diverse student population at SFSU in the proposed activities that focus on engineering and biology.

UCSF recognizes that it needs to do better to increase diversity and strengthen inclusion in all areas and levels of the campus community. While UCSF's student populations is relatively diverse - 20% of UCSF's students are underrepresented minorities and nearly 25% of students are first generation students, the majority of the students of color are in UCSF's professional degree programs. Further, this representation drops at each level of advancement, with fewer than 10% of UCSF's faculty from underrepresented minority backgrounds. UCSF has been increasing the resources dedicated to nurturing diversity on campus and the work of the CCC is closely aligned to this important goal both for the University and the scientific enterprise as a whole.

4.d.4 Describe plan for increasing diversity

The Center Diversity Coordinator will work with all Center members to increase diversity of participation in all center activities, including research, education, outreach, and knowledge transfer. Our Diversity Coordinator, Professor Frank Bayliss, SFSU, has extensive experience in increasing diversity as the Program Coordinator for the SFSU NIH-MARC, RISE, and Bridges programs.

Recruitment of undergraduate students for research training experiences within the center will be carried out with a direct focus on increasing diversity. At UCSF, one of the main routes for recruiting undergraduate students is the Science Research Training Partnership (SRTP). SRTP is a long running program that administers student application, evaluation, pairing with mentors, oversees safety training, and provides workshops in important topics like scientific careers, written and verbal communication of science, GRE preparation, and graduate school application procedures. A major focus of the SRTP program is increasing diversity among the student group, last year the SRTP student group were 37% minorities, and 55% women. Center faculty including Marshall, Gartner, Lim, Fung, El-Samad and Dumont have a proven track record of training SRTP students, many of whom have gone onto graduate study at top institutions across the country. Center member Fung has also established a many-year track record of training undergraduate summer students from under-represented groups through the UCSF/Kaiser Undergraduate Research Internship (URI) program, which not only provides summer research experiences to URM students but also provides ongoing mentorship and career advice in the subsequent years. Moreover, Center faculty including Marshall, Fung, Gartner, and El-Samad travel to neighboring institutions on behalf of this program to meet with minority student research programs to spread the word and encourage students to apply. We will continue these activities, with a special emphasis on meeting with undergraduate engineering student groups and increasing engineering participation in the SRTP and URI programs.

A further aspect of broadening participation is to provide opportunities to involve members of the public, outside of the standard academic community, in research projects of the Center, through the Exploratorium and our Hackathon, Science Festival, and Makerspace activities. By reaching out to the local DIY and Makerspace communities, we engage a broad sector of the public from all walks of life, including older retirees who are turning to science as a hobby. This will allow the center to promote diversity and awareness not just in terms of ethnicity but also in terms of age and educational background.

4.d.5 Role of partner institutions

Education of students from backgrounds underrepresented in biomedical/behavioral research and from the under - served communities is at the forefront of SFSU's educational mission. In 2012, SFSU ranked 16th of 3,600 institutions nationally in awarding baccalaureate degrees to minority students and 34th to minority students in biological/biomedical - related disciplines (http://diversepodium.com/top100/). Tracking data from SFSU URM student - training programs as of March 2014 indicate that a total of 131 URM students from SFSU have gone on to earn their PhD degrees in the biomedical sciences. Forty more students are on track to complete their PhDs in the next 3 years for an average rate of 12 -15 PhDs awarded to our URM students per year. Currently, approximately 15 NIH funded trainees per year enter PhD programs after graduating from SFSU. However, highly qualified students at SFSU far outnumber the available funded training positions. Therefore, there is much more potential to engage

diverse undergraduate and Masters students in the research training infrastructure at SFSU and the proposed activities to propel students into STEM careers. The Center grant would provide funding to expand the scope of these already successful activities at SFSU and to extend the scope into the engineering sciences.

Professor Frank Bayliss, the Center Diversity Coordinator, in cooperation with other researchers at SFSU will identify students with the most potential to be recruited into Center programs. Rather than identifying students merely by URM status, existing programs at SFSU have a track record of identifying students having experienced true hardship, but also having unusual passion and drive for engineering and basic science. These organizations will, in turn, partner with a more extensive list of institutions to open a pipeline of students to the STC.

4.d.6 Role for students and faculty of minority-serving institutions

Recruitment of undergraduate students into the Center via the SRTP program (see above) will in part draw on the long standing relation between UCSF and the MARC program at UC Santa Cruz (UCSC). UCSC has a substantial minority student body, mostly Latino, and a highly active MARC program. Many of the faculty members from UCSF who will make up the center make annual visits to meet with the UCSC MARC group. We will continue to work with UCSC MARC coordinator Yulianna Ortega to increase our interactions with their program and especially to expand the involvement of engineering URM students.

Recruitment of high school students and teachers will focus on the San Francisco Unified School District (SFUSD) and the neighboring Oakland Unified School District (OUSD), both of which are large urban school districts with high minority enrollment. Enrollment in SFUSD is currently 56,000 students, 23% Latino, 10% African American, with 27% of students from non-English speaking households and 60% of students from low-income families. Enrollment in OUSD is 36,180 students, 38% Latino, 31% African American, with 32% of students from non-English speaking households and 69% of students from low-income families. The UCSF SEP program, directed by Center Education Coordinater Rebecca Smith, is spearheading our educational activities. SEP has a long and successful history of working with SFUSD to provide summer research experiences to talented minority high school students. Many of the Center faculty have hosted these SEP students in past years, and we will continue to expand this activity to include students from OUSD. These students will participate in the Student-Teacher bootcamp program (see Educational objectives) as well as participate directly in research of Center labs.

(4.e) Knowledge Transfer Objectives of the Center

IBM Accelerated Discovery Lab (IBM Almaden Research Center)
IBM ARC, a major partner in the Center for Cellular Construction, is a world leader in knowledge transfer between academia and industry, and has a well established program to facilitate such transfer via its Accelerated Discovery Lab (http://www.research.ibm.com/client-programs/accelerated-discovery-lab/). The Accelerated Discovery Lab provides a complete environment for data analytics facilitating the discovery process and enabling experts in various domains to focus on their investigations. Working alongside researchers with expertise in all aspects of data and analytics, partners can access public and licensed data sets, generous storage facilities, a rich software stack, and a library of analytics, models and analytics tools and frameworks. The combined expertise and cyber-infrastructure of the Accelerated Discovery Lab will provide a direct pathway to knowledge dissemination. The lab maintains extensive networks of contacts across industries and will thus be able to guide the Center in identifying fruitful directions for reaching out to academic and industrial entities most likely to be interested in the knowledge that we are generating. Knowledge transfer interactions with the ADL will be coordinated jointly by the Knowledge Transfer Coordinator and by the IBM Site Director of our Center.

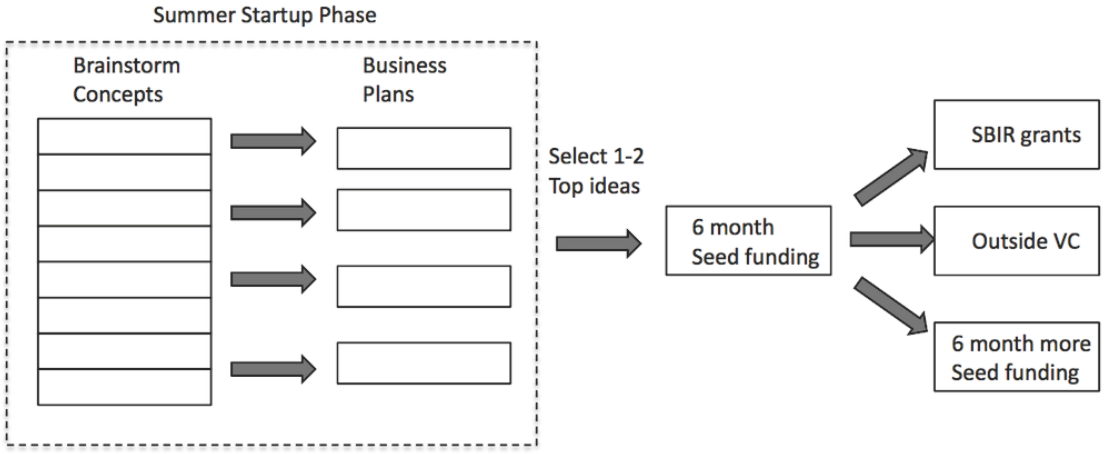
Center Website
The center will maintain an updated website listing all member labs and institutions, including up to date news and links to published data. All software generated through Project 2 (CellCAD) will be linked on the website as well as through GitHub. We will also provide links and materials for all educational activities and modules. Finally, Center news including new discoveries, events, meetings, startup companies and key milestones will be provided through the website. We have budgeted for a web designer to build and maintain the site.

Exploratorium Special Events for Industry Leaders
Knowledge dissemination requires that possible recipients of the knowledge become aware that the knowledge is being discovered. We will leverage the resources and convening power of the Exploratorium to conduct annual Special Events for Industry Leaders, inviting local business and thought leaders from the software, electronics, biotech, venture capital, and green technology sectors to evening events featuring presentations and hands-on experiences with cells and cell-based engineering. These events will spread the word of the Center's activities, opening up leads for subsequent direct knowledge transfer activities, which would then be handled by the IBM Accelerated Discovery Lab.

Industrial Internships for Students and Postdocs in the CCC
IBM ARC has a well-established internship program for students at many different levels of education. We will take advantage of this program, by arranging for students in Center research labs to work on collaborative projects with the IBM research group led by Dr. Bianco, taking advantage of the existing infrastructure for internship organization and support. This will provide an excellent opportunity for our students to learn about research in an industrial setting. We will further expand the internship program by enrolling our students as interns in other local companies of interest. One such company is Autodesk – an organization with a vibrant internship program and with whom the center has pre-existing and strong relationships. Internships will be made available to students from all participating institutions in the Center. A key goal of the internship program is knowledge transfer: students will bring their own experience of Center research with them to an industrial context, thus spreading the knowledge in new directions at a grass-roots level.

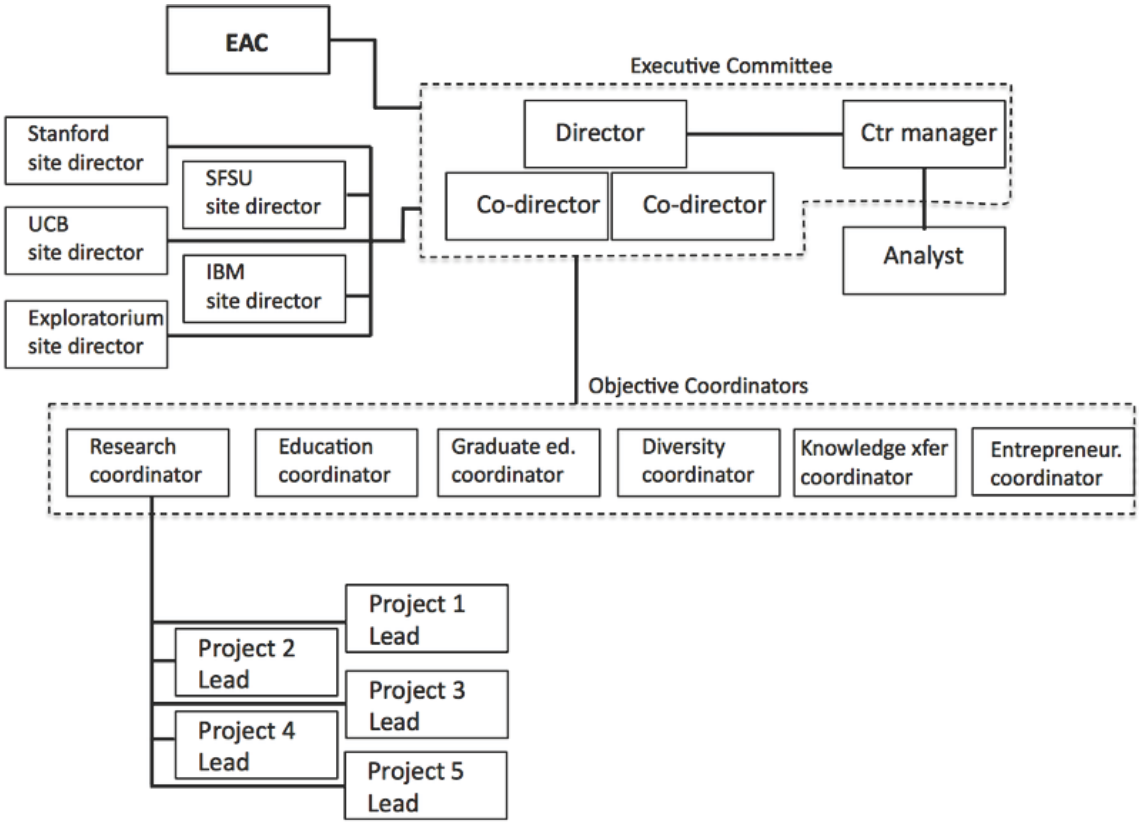
Startup Company Incubator/Seeding program

In order to directly move discoveries and inventions from the Center into the real world, we have budgeted funds to support 2-3 startup companies per year, based on Center research. Students or postdocs with an interest in entrepreneurship will begin by participating in an intensive "summer startup" program where they will be given basic training in startup management, business plan development, and intellectual property. They will apply for the Center budgeted seed money based on a basic business plan and three-month milestones. The best projects will be awarded seed money to explore their venture in the nearby QB3@953 incubator space. Companies located in this incubator space become part of the QB3 entrepreneurship mentoring network and will be able to have access to shared equipment, networking activities, and direct mentoring from seasoned entrepreneurs. Ventures that achieve their milestones will have the opportunity to win seed money and space for an additional year, so as to build sufficient results to secure funding from SBIRs, Angel Investors, or Venture Capitalists. Funds for this program are budgeted in six month increments, allowing flexibility in switching course based on performance and progress assessments. By forming these small startups and then encouraging them to secure independent venture capital funding, we believe we can generate a rapid pathway to real world industrial application of Center ideas. This program will draw on the high enthusiasm of many graduate and undergraduate students, as well as postdocs, for pursuing entrepreneurial careers, and will thus not only provide a knowledge transfer goal by taking Center research concepts directly into the commercial space, but will also provide an unusual training and workforce development opportunity. The Startup program will be directed by Professor Charly Craik (UCSF), who has been designated the Center Entrepreneurship Coordinator. The "Idea to IPO" course at UCSF, which was founded by Dr. Craik, will serve as the basis for our "summer startup" phase of the program. The startup program will be open to students and postdocs from center labs at all participating academic institutions. Selection of ideas for seed funding, and decisions about continued seed funding, will be made by a committee that Dr. Craik will assemble composed of industry and VC experts who currently participate in the Idea to IPO program, with oversight from the Executive Committee.



(4.f) Management Plan

4.f.1 Overall center structure. The Center for Cell Construction will be an interconnected network of participants at UCSF, UC Berkeley, San Francisco State University, Stanford University, IBM Almaden Research Center, and the Exploratorium. We will also leverage existing relationships between center faculty and software engineers at Autodesk – a leader in the development of computer aided design (CAD) software. We have constructed a highly interdisciplinary team combining experts in cell biology, tissue engineering, biophysics, mathematics, bioengineering, and industrial design, including both research and education experts, into a synergistic network. We have also set up pipelines to integrate undergraduates at Bay Area teaching-focused institutions into the research of the center. Industrial internship programs will create multi-level interactions between Center labs and industry, but will also represent a key way in which non-academic educational programs can be intimately linked with the work of the center. All aspects of this work rely critically on interactions between the multiple member institutions of the center, both academic and private.



4.f.2. Organizational Structure. The major decision-making bodies in the center will be two internal committees and one external committee. An External Advisory Committee (EAC) will be formed from a diverse group of scientists, educators, and entrepreneurs that will be tasked with annually evaluating the Center's progress towards its four sub goals. Internally, the Executive Committee, encompassing the center director, two co-directors, and managing staff (e.g. Center Manager), will be tasked with communicating with the EAC and NSF, organizing key center activities, coordinating with Center participants to advance Center goals, and revising Center strategies towards achieving those goals as necessary. Also internally, the Managing Committee will consist of the Executive Committee plus the Objective Coordinators responsible for education, knowledge transfer, entrepreneurship, and research. The Managing Committee will meet quarterly, with minutes recorded and distributed by the Center Manager. The Executive Committee will additionally meet monthly to discuss progress, evaluate research projects, and define future directions. Within 90 days of Award, we will convene a retreat of

Center key personnel to plan priorities for the year and introduce the managing personnel. Thereafter, regular meetings by the Executive and Managing Committees will be complemented by monthly Scientific Meetings and Annual Center Retreats.

4.f.3 Management Team. We have assembled a leadership team comprising a combination of senior and mid-career faculty and seasoned educators:

Executive Committee: Director: Wallace Marshall, UCSF; Co-directors Wendell Lim, UCSF, Zev Gartner, UCSF

Objective Coordinators: Zev Gartner, UCSF (Research Coordinator), Rebecca Smith, SEP/UCSF (Education Coordinator), Hana El-Samad, UCSF (Graduate Education Coordinator), Frank Bayliss, SFSU (Diversity Coordinator), Charly Craik, UCSF (Entrepreneurship and Knowledge Transfer Coordinator)

Site Directors: Mark Chan (SFSU); Daniel Fletcher (UC Berkeley); Sindy Tang (Stanford); Simone Bianco (IBM); Jennifer Frazier (Exploratorium)

4.f.4. Managerial experience of leadership team Faculty with strong managerial experience occupy key positions at all levels of the center:

Wallace Marshall (Director) has organized two successful collaborative grants involving six PIs across five departments at UCSF to investigate the cell biology of cancer. He is currently lead PI of a four-PI NSF research grant as well as an NSF grant to build a community to pursue quantitative cell biology nationwide by organizing a series of workshops and student exchanges. He has organized or co-organized five international conferences and as Program Committee Chair of the ASCB 2014 meeting, he led three program sub-committees with over 20 members world-wide, to plan the 2014 annual meeting.

Wendell Lim, (co-director), is currently lead PI on an NIH systems and synthetic biology center, Director for UCSF Center for Systems and Synthetic Biology, and Director of UCSF/UCB/ NIH Nanomedicine Development Center.

Frank Bayliss (SFSU site director) has >20 years experience in creating successful mentoring and training programs that serve as national models for the training of under-represented groups. He helped establish a College-wide office – the Student Enrichment Opportunities (SEO) office – and was able to compete for funding from the NIH, NSF, USDA, USDEd and DOD to support financially needy, first-generation college, women, and under-represented minority students.

Rebecca Smith (Education Coordinator) is director of the Science and Health Education Partnership at UCSF, where she has been leading a team of educators and organizing their activities including large grant proposals and special activities.

Charles Craik (Knowledge Transfer and Entrepreneurship Coordinator) is founder and Director of the UCSF Chemistry & Chemical Biology graduate program, co-founder of the Idea to IPO course at UCSF, SAB Chair for several biotechnology companies, and co-PI for the Bay Area NSF Innovation Corps grant (iCorps), a collaboration between UCSF, UC Berkeley and Stanford Univ. building educational programs to accelerate the commercialization of science and technology entrepreneurship.

4.f.5. Leadership Mentoring. A key innovative feature of our management plan is to build capacity in scientific leadership and management at UCSF and in the Bay Area by mentoring young investigators in managerial roles at several levels of the center managerial hierarchy, with Dr. Lim providing top-level mentoring in leadership practices to the other members of the Executive Committee. In addition, Mark Chan will receive leadership mentoring from Frank Bayliss at SFSU, and Shawn Douglas will be mentored by Charly Craik in the context of the CellCad research project to coordinate with IBM and leverage his existing relationships with Autodesk.

4.f.6 Key partnering institutions integration plan The contribution of each Key Partnering Institution will be ensured by the corresponding Institution Site Director, who will have oversight of the research, education, outreach, and knowledge transfer activities of the groups at each Institution.

4.f.7 Research Management. Building the scientific and modeling tools to implement a "design, build, test" cycle to engineer cells is a major focus of our center. Oversight of center research activities will fall under the responsibility of the Executive Committee, and specifically under the responsibility of Research Coordinator, Zev Gartner. Individual Research projects will be supervised by individual Center Investigators, who will meet monthly with Project Directors to discuss progress and coordinate future directions. Project directors will also submit progress reports annually to Dr. Gartner and the Executive Committee who will evaluate progress and impact. Project funding and directions will be evaluated annually, with continued funding contingent on progress and potential impact.

4.f.8 Education and Outreach Management. Dr. Rebecca Smith, Director of the UCSF Science and Health Education Partnership, will serve as Education Coordinator for the Center and will oversee the execution of our education and Human Resources plan as described in section 4.c. She will interface with the Exploratorium Site Director to integrate Exploratorium activities with the overall education plan. The strong existing relationship between the Exploratorium and Autodesk will provide further opportunities to share knowledge and educational opportunities between the public, educational communities, and industry. Hana El-Samad as Graduate Education Coordinator to coordinate graduate student training across Center institutions and labs. She will build upon a number of innovative teaching strategies she has developed for quantitative biology instruction at UCSF, but applied to cell engineering.

4.f.9 Diversity Management. Frank Bayliss, Diversity Coordinator, will coordinate efforts to broaden the diversity of participation at all levels and phases of the center, as outlined in section 4.d.

4.f.10 Entrepreneurship and Knowledge Transfer Management. Charly Craik, in his capacity as Center Knowledge Transfer Coordinator and Entrepreneurship Coordinator, will oversee the knowledge transfer activities of the center, under the overall supervision of the Executive Committee, and in cooperation with IBM's Accelerated Discovery Lab and QB3, as detailed in section 4.e.

4.f.11 Conferences and Workshops. Students (graduate and undergraduate) as well as postdocs in the center will be encouraged to disseminate their results by presenting their work at national meetings, for which purpose we will set aside substantial travel funds. Travel funding decisions will be made jointly by the Research Coordinator and the Education Coordinators.

4.f.12 Ethics and conflict resolution. The Executive Committee will oversee ethics training and policies as outlined in the Ethics Plan (section 11). The Site Directors will ensure that uniform ethics policies are followed at all participating institutions. If any scientific or personal conflicts develop within the center, the executive committee will meet with the involved parties and attempt to resolve the dispute. In the unlikely event that they fail to resolve the dispute, the disagreement shall be referred to the EAC. In the event of a conflict within the executive committee, an arbitration committee will be formed consisting of one impartial senior leader from each co-director's research unit and a fourth impartial senior leader mutually agreed upon by all three co-directors. No members of the arbitration committee will be directly involved in the research grant or disagreement.

4.f.13 External Advisory Committee. We will coordinate with the NSF to select an external advisory committee with combined experience in managing diversity, education, basic research, and academic-industry partnerships. The advisory committee will aid the Center in identifying opportunities and improving outcomes on all of its subgoals.

4.f.14 Changes Management. If key leadership positions become vacant, a center-co-director will stand in while a general search is coordinated by the members of the Managing Committee and the External Advisory Committee. If a PI moves to a new institution, attempts will be made to transfer the relevant portion of the grant to the new institution. Otherwise, a new PI will be recruited as a replacement.

References

Bayer TS, Widmaier DM, Temme K, Mirsky EA, Santi DV, Voigt CA. 2009. Synthesis of methyl halides from biomass using engineered microbes. *J. Am. Chem. Soc.* 131, 6508-15.

Bennett, J., & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *International Journal of Science Education*, *31*(14), 1975–1998.

Calderwood, D. A., Zent, R., Grant, R., Rees, D. J., Hynes, R. O., & Ginsberg, M. H. The Talin head domain binds to integrin beta subunit cytoplasmic tails and regulates integrin activation. *The Journal of Biological Chemistry*, 274(40), (1999) 28071–28074. http://doi.org/10.1074/jbc.274.40.28071

Cerchiari, A. E., Garbe, J. C., Jee, N. Y., Todhunter, M. E., Broaders, K. E., Peehl, D. M., Desai, T. A., LaBarge, M. A., Thomson, M., and Gartner, Z. J. "A Strategy for Tissue Self-Organization That Is Robust to Cellular Heterogeneity and Plasticity." *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 7 (2015): 2287–2292. doi:10.1073/pnas.1410776112,

Chan YH, Marshall WF. 2014. Organelle size scaling of the budding yeast vacuole is tuned by membrane trafficking rates. *Biophys. J.* 106, 1986-96.

Ertl, H., Mengele, R., Wenzl, S., Engel, J., & Sumper, M. The extracellular matrix of *Volvox carteri:* molecular structure of the cellular compartment. *The Journal of Cell Biology*, 109(6), (1989) 3493–3501. http://doi.org/10.1083/jcb.109.6.3493

Fishman D, Majumdar R, Morello J, Pate R, Yang J., eds. 2008. *National Algal Biofuels Technology Roadmap*. U.S. Department of Energy. 140 pp.

George, Y. S., D. S. Neale, V. Van Horne, and S. Malcolm, *In Pursuit of a Diverse Science, Technology, Engineering, and Mathematics Workforce*; American Association for the Advancement of Science, 2001.

Gordon, W. R., Zimmerman, B., He, L., Miles, L. J., Huang, J., Tiyanont, K., *et al.* Mechanical Allostery: Evidence for a Force Requirement in the Proteolytic Activation of Notch. *Developmental Cell.* (2015) http://doi.org/10.1016/j.devcel.2015.05.004

Grashoff, C., Hoffman, B. D., Brenner, M. D., Zhou, R., Parsons, M., Yang, M. T., McLean, M. A., Sligar, S. G., Chen, C. S., Ha, T., and Schwartz, M. A. "Measuring Mechanical Tension Across Vinculin Reveals Regulation of Focal Adhesion Dynamics" *Nature* 466, no. 7303 (2010): 263–266. doi:10.1038/nature09198

Handelsman J., Pfund C., Miller Lauffer S., Maidl Pribbenow C. (2005). *Entering Mentoring: A Seminar to Train a New Generation of Scientists. Madison*, WI: University of Wisconsin Press; 2005.

Hilpert, K., Hansen, G., Wessner, H., Küttner, G., Welfle, K., Seifert, M., and Höhne, W. "Anti-C-Myc Antibody 9E10: Epitope Key Positions and Variability Characterized Using Peptide Spot Synthesis on Cellulose." *Protein engineering* 14, no. 10 (2001): 803–806.

Huber, A. H., & Weis, W. I. The Structure of the β-Catenin/E-Cadherin Complex and the Molecular Basis of Diverse Ligand Recognition by β-Catenin. *Cell*, 105(3), (2001). 391–402. http://doi.org/10.1016/S0092-8674(01)00330-0

James, J. R., & Vale, R. D. Biophysical mechanism of T-cell receptor triggering in a reconstituted system. *Nature*, 487(7405), (2012) 64–69. http://doi.org/10.1038/nature11220

Kirschner M, Gerhart J, Mitchison T. 2000. Molecular "vitalism". *Cell* 100, 79-88.

Level Playing Field Institute (LPFI), Increasing the Representation of Women and People of Color in Science, Technology, Engineering and Math: Scan and Synopsis of Approaches and Opportunities, 2005.

Lim WA, Alvania R, Marshall WF. 2012. Cell Biology 2.0 *Trends Cell Biol*. 22, 611-2.

Loucks-Horsley, S., P. W. Hewson, N. Love, K. E. Stiles, *Designing Professional Development for Teachers of Science and Mathematics*; Corwin Press, Inc. / The National Institute for Science Education, 2003.

Ludington, W.B., Shi, L.Z., Zhu, Q., Berns, M.W., and Marshall, W.F. 2012. Organelle size equalization by a constitutive process. *Curr. Biol*. 22, 2173-9.

Maître, J.-L., Maître, J.-L., Berthoumieux, H., Berthoumieux, H., Krens, S. F. G., Krens, S. F. G., Salbreux, G., Salbreux, G., Jülicher, F., Jülicher, F., Paluch, E., Paluch, E., Heisenberg, C.-P., and Heisenberg, C.-P. "Adhesion Functions in Cell Sorting by Mechanically Coupling the Cortices of Adhering Cells." *Science* (New York, NY*)* 338, no. 6104 (2012): 253–256. doi:10.1126/science.1225399.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington DC: The National Academies Press.

Rafelski, S.M., Viana, M.P., Zhang, Y., Chan, Y.M., Thorn, KS, Yam P., Fung, J.C., Li, H., da F. Costa, L, and Marshall, W.F. 2012. Mitochondrial network size scaling in budding yeast. *Science*. 338, 822-4.

Rafelski SM, Marshall WF. 2008. Building the cell: design principles of cellular architecture. *Nat. Rev. Mol. Cell Biol.* 9, 593-602.

Sorge, C. (2007). What Happens? Relationship of Age and Gender with Science Attitudes from Elementary to Middle School. *Science Educator*, *16*(2), 33–37.

Thiry, H., Laursen, SL, & Hunter, A-B. 2011. What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *Journal of Higher Education 82*(4)*,* 357-388.

Villarreal, X.C., Mann, K.G. and Long, G. L. Structure of Human Osteonectin Based Upon Analysis of cDNA and Genomic Sequences. *Biochemistry*, 28(15), (1989) 6483–6491. http://doi.org/10.1021/bi00441a049

Vlamakis, H., Chai, Y., Beauregard, P., Losick, R., & Kolter, R. Sticking together: building a biofilm the Bacillus subtilis way. *Nature Reviews Microbiology*, 11(3), (2013). 157–168. http://doi.org/10.1038/nrmicro2960

Weiner OD. How should we be selecting our graduate students? *Molecular Biology of the Cell,* 25:429-30 (2014).

Zakeri, B., Fierer, J. O., Celik, E., Chittock, E. C., Schwarz-Linek, U., Moy, V. T., & Howarth, M. Peptide tag forming a rapid covalent bond to a protein, through engineering a bacterial adhesin. *Proceedings of the National Academy of Sciences of the United States of America*, 109(12), (2012). E690–E697. http://doi.org/10.1073/pnas.1115485109

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(a) Professional Preparation

State University of New York at Stony Brook	Biochemistry	B.S. 1991
State University of New York at Stony Brook	Electrical Engineering	B.E. 1991
University of California, San Francisco	Biochemistry	Ph.D. 1997
Postdoctoral: Yale University	Cell Biology	1997 - 2003

(b) Appointments

2013 - present Professor, UCSF Dept. Biochemistry & Biophysics
2009 - 2013 Associate Professor, UCSF Dept. Biochemistry & Biophysics
2003 - 2009 Assistant Professor in Residence, UCSF Dept. Biochemistry & Biophysics

(c) Publications

(i) **Five publications most closely related to proposed project**

Engel, B.D., Ludington, W.B, and Marshall, W.F. 2009. Intraflagellar Transport Particle Size Scales Inversely with Flagellar Length: Revisiting the Balance-Point Length Control Model. ***J. Cell Biol***. 187, 81-9.

Ludington, W.B., Shi, L.Z., Zhu, Q., Berns, M.W., and Marshall, W.F. 2012. Organelle size equalization by a constitutive process. ***Curr. Biol***. 22, 2173-9.

Rafelski, S.M., Viana, M.P., Chan, Y.M., Thorn, KS., Yam, P., Fung, J.C., Li, H., da F. Costa, L, and Marshall, W.F. 2012. Mitochondrial network size scaling in budding yeast is achieved in the bud at the expense of the mother. ***Science***. 338, 822-4.

Ludington, W.B., Wemmer, K.A, Lechtreck, K.F., Witman, G.B, and Marshall, W.F. 2013. Avalanche-like behavior in ciliary length control. ***Proc. Natl. Acad. Sci. U.S.****A*. 110, 3925-30.

Chan, Y.H., Marshall, W.F. 2014. Organelle size scaling of the budding yeast vacuole is tuned by membrane trafficking rates. ***Biophys. J.*** 106, 1986-96.

(ii) Five other significant publications

Azimzadeh, J., Wong, M.L., Downhour, D.M., Sanchez Alvarado, A., and Marshall, W.F. 2012. The centrosome was lost in the evolution of planarians. ***Science***. 335, 461-3.

Tang, N., Marshall, W.F., McMahon, M., Metzger, R.J., and Martin, G.R. 2011. Control of mitotic spindle angle by the RAS-regulated ERK1/2 pathway determines lung tube shape. ***Science***. 333, 342-5.

Marshall, W.F. 2007. Stability and robustness of an organelle number control system: modeling and measuring homeostatic regulation of centriole abundance. ***Biophys. J.*** 93,1818-33.

Feldman, J.L, Geimer, S., and Marshall, W.F. 2007. The mother centriole plays an instructive role in defining cell geometry. ***PLoS Biology***. 5,e149.

Marshall, W.F., Qin, H., Rodrigo Brenni, M., and Rosenbaum, J.L. 2005. Flagellar length control system: testing a simple model based on intraflagellar transport and turnover. ***Mol. Biol. Cell*** 16,270-278.

(d) Synergistic Activities

- Interdisciplinary teaching in quantitative cell biology: Physiology Course, Marine Biological Lab, Woods Hole MA: Instructor 2009-2013, Co-Director 2014 - present. UCSF: Developed graduate level minicourse on "cellular cognition" exploring the computational capacity of living cells using hands-on project based learning in 2012, 2014.
- Meeting Organization: Organized series of pre-meeting sessions entitled *"Building the Cell*" on the topic of cellular morphogenesis, held at the American Society for Cell Biology meetings in 2001, 2002, 2003, 2006, 2007, 2008, 2009, 2010, 2011, 2012, and 2013. Co-organizer of the Cold Spring Harbor *Computational Cell Biology* conferences in 2011 and 2013. Co-organizer, EMBO Conference on Centrosomes and Spindle Pole Bodies, Lisbon Portugal, 2014. Program Committee Chair, American Society for Cell Biology 2014 Annual Meeting
- Public outreach: Presented hands-on demonstration of an Arduino-controlled device for testing learning in single cells at the Mendocino County Mini Maker Faire (May 2013), the East Bay Mini Maker Faire in Oakland, CA (October 2013), Maker Faire Bay Area in San Mateo, CA (May 2014), and Benicia Mini Maker Faire (March 2015).
- Grant review activity: Member NSF Cytoskeleton peer review panel (2010 and 2011) and MCB panel (2008, 2009). Member, NIH NCSD Study Section, 2012 - present.
- Developing new books: Editor, *Methods in Enzymology* volume on Cilia and Flagella 2013. Editor, ebook series on *Quantitative Cell Biology* (Morgan and Claypool Life Sciences: http://www.morganclaypool.com/page/qcb). Co-author, 8th edition of *Cell and Molecular Biology, concepts and experiments* by G. Karp, Wiley Inc.

(e) Collaborators and Affiliations

Collaborators and co-editors: David Agard (UCSF), Renata Basto (Institute Curie, Paris), Luciano da Fontoura Costa (University of Sao Paolo), Stefan Geimer (Bayreuth University), Ritsu Kamiya (University of Tokyo), Karl Lechtreck (University of Georgia), Xiangyi Lu (Wayne State University), Katherine Osteryoung (Michigan State), Gregory Pazour (UMASS Worcester), Jennifer Ross (UMASS Amherst), Hongmin Qin (Texas A&M), Alejandro Sanchez Alvarado (Stowers Institute), Sindy Tang (Stanford University), George Witman (UMASS Worcester), John Yates (Scripps Research Institute).

Graduate and postdoctoral advisors: John Sedat (UCSF), Joel Rosenbaum (Yale).

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Professional Preparation

1999	UC Berkeley, Chemistry BS
2004	Harvard University, Chemical Biology PhD
2005-2008	UC Berkeley, Chemical Biology

Appointments

1998-1999	Undergraduate Researcher, Laboratory of Professor Y. K. Shin
1998-2000	Graduate Student Researcher, Laboratory of Professor D. R. Liu
1999 2004	Full Time Research Consultant, Ensemble Pharmaceuticals (formerly Ensemble Discovery)
2000 2005-2008	Postdoctoral Researcher, Laboratory of Professor C. R. Bertozzi
2001 2008-now	Assistant Professor, Dept. of Pharmaceutical Chemistry, University of California, San Francisco

5 Publications Most Closely Related to This Project

Gartner, Z. J.; Bertozzi, C. R. "Programmed assembly of 3-dimensional microtissues with defined cellular connectivity." *Proc. Natl. Acad. Sci. USA*. **106**, 4606-4610 (2009).

Hsiao, H.C.; Shum, B.J.; Onoe, H; Douglas, E.S.; **Gartner, Z.J**.; Mathies, R.A.; Bertozzi, C.R.; Francis, M.B. "Direct cell surface modification with DNA for the capture of primary cells and the investigation of myotube formation on defined patterns" *Langmuir* **25,** 6985 (2009).

Selden, N; Todhunter, M; Jee, N; Liu J; Broaders, K; **Gartner, Z. J.** "Chemically programmed cell adhesion with membrane anchored nucleic acids." *J. Am. Chem. Soc*. (2012).

Onoe, H.; Hsiao, S. C.; Douglas, E. S.; **Gartner, Z. J**.; Bertozzi, C. R.; Francis, M. B.; Mathies, R. A. "Cellular Microfabrication: Observing Intercellular Interactions Using Lithographically-Defined DNA Capture Sequences." *Langmuir* **28**, 8120 (2012).

Liu, J.; Farlow, J. T.; Paulson, A. K.; Labarge, M.; **Gartner, Z.J.** "Programmed cell-to-cell variability in Ras activity triggers emergent behaviors during mammary epithelial morphogenesis." *Cell Reports* (2012).

5 Other Publications

Gartner, Z. J. and Liu, D. R. "The Generality of DNA-Templated Synthesis as a Basis for Evolving Non-Natural Small Molecules." *J. Am. Chem. Soc*. **123**, 6961-6963 (2001).

Gartner, Z. J.; Kanan, M. W.; Liu, D. R. "Multistep Small-Molecule Synthesis Programmed by DNA Templates." *J. Am. Chem. Soc*. **124**, 10304 (2002).

Buskirk, A. R.; Ong, Y.; **Gartner, Z. J**.; Liu, D. R. "Directed Evolution of Ligand Dependence: Small Molecule-Activated Protein Splicing." *Proc. Natl. Acad. Sci. USA* **101** , 10505-10510 (2004).

Gartner, Z. J.; Tse, B. N.;Grubina, R.; Doyon, J. B.; Snyder, T. M.; Liu, D. R. "DNA-Templated Organic Synthesis and Selection of a Library of Macrocycles" *Science* **305**, 1601-1605 (2004).

Farlow J, Seo D, Broaders KE, Taylor M, **Gartner ZJ****, Jun YW**. "Exclusive formation of monovalent quantum dot probes by steric exclusion." *Nature Methods* **10**, 1203-1205 (2013). *****co-corresponding authors***

Synergistic Activities

Innovations in graduate education: Innovations in graduate education have come in three areas. In 2008 I wrote a series of lectures for Chemistry and Chemical Biology students on the general topic of "building chemical intuition on the nanoscale." Specific topics include scaling of diffusion, transport/flow/locomotion at different length scales, non-covalent interactions at the nano and mesoscale, and interactions of nanoscale materials with radiation. In 2010 I initiated a scientific writing course organized around the NSF Graduate Research Fellowship as the key writing exercise. The course introduces funding mechanisms, the structure of a research proposal, writing techniques, pitfalls, and editing. In the Spring of 2013 I am leading a mini course with Dr. Matt Thomson on the topic of multicellular systems biology. We will critically read papers and build mathematical models to understand organizing principles of distributed control in biology. I have also initiated a seminar series featuring UCSF and external speakers on the general topic of control and regulation of multicellular systems.

Development and refinement of research tools: As a graduate student, I initiated and led a project developing DNA-Templated Synthesis as a tool to evolve drug-like small molecules. I continued this work as a full time consultant at Ensemble Discoveries (currently Ensemble Therapeutics). Ensemble accelerated my work and is currently partnered with several large pharmaceutical companies and has a first in class IL-17 antagonist in preclinical trials. The structure of this molecule is based on the general macrocyclic scaffold I chose as a graduate student and promoted as a consultant. As a postdoctoral fellow with Carolyn Bertozzi and currently as an Assistant Professor, I've pioneered the used of nucleic acids as chemical adhesion molecules to control the structure of tissues. Our unpublished results indicate that this strategy is general, and can control the structure of tissues for 3D culture at a 10 μm resolution and across distances greater than 1 cm.

Broadening participation by groups of under represented minorities: I have actively participated in preparing, recruiting, and mentoring underrepresented student groups in basic science research. At the recruitment level, I have sought opportunities to present scientific talks and meet with students at California State Universities that have a history as feeder schools for students of underrepresented groups. Examples include University of the Pacific, Cal State Los Angeles, Cal State San Francisco, UC Irvine, and San Jose State. I have attended SACNAS scientific meetings to follow up with students and to also recruit more broadly from other national universities. Finally, I have mentored three undergraduate students as part of the UCSF Summer Research Training Program (SRTP). Two of these students are members of underrepresented groups and both plan to perform graduate studies.

Service to the Scientific Community: Ad hoc reviewer for Current Biology, JACS, PNAS, Nature Methods, Development, Developmental Biology, Development, among others. I have served repeatedly as a peer reviewer for the Department of Defense, the NSF, and several European funding agencies. I have served as an ad hoc integration panel member for the Department of Defense Breast Cancer Research Program. I have also served on the organizing committee for the 2013 International Conference of Biomolecular Engineering and the 2015 ACS meeting in Denver.

Collaborators & Other Affiliations

Collaborators and Co-Editors

Mark Labarge (Lawrence Berkeley National Lab); Matthew Francis (UC Berkeley); David Rabuka (Redwood Biosciences); Richard Mathies (UC Berkeley)

Graduate Advisors and Postdoctoral Sponsors.

David Liu (Harvard University); Carolyn Bertozzi (UC Berkeley)

Thesis Advisor and Postgraduate-Scholar Sponsor.

Graduate Students: Jennifer Liu (current), Michael Todhunter (current), Justin Farlow (current), Noel Jee (current), Samantha Liang (current), Alec Cerchiari (current, joint student), Amanda Paulson (current), Katherine Southard (current, joint student). **Total = 8** *Postdoctoral Fellows*: Melanie Bocanegra (Assistant Dean for Graduate Education and Director of Biosciences, Stanford), Kyle Broaders (current). **Total = 2**

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Professional Preparation

1986	Harvard University, Chemistry, AB
1991	Mass. Institute of Technology, Biochemistry & Biophysics, PhD
1992-1996	Yale University, Biophysics & Biochemistry

Appointments

2015-present	Chair, Department Cellular & Molecular Pharmacology, University of California, San Francisco.
2010- present	Director, UCSF Center for Systems & Synthetic Biology
2008- present	Investigator, Howard Hughes Medical Institute.
2006- present	Director, UCSF/UCB NIH Nanomedicine Development Center.
2006- present	Deputy Director, NSF Synthetic Biology Engineering Research Center.
2006- present	Member, Board of Scientific Counselors, National Cancer Institute.
2003- present	Professor, Department Cellular & Molecular Pharmacology (primary appointment); Department of Biochemistry & Biophysics; Department of Pharmaceutical Chemistry; University of California, San Francisco.
2000- 2003	Associate Professor, Department Cellular & Molecular Pharmacology; Department of Biochemistry & Biophysics; Department of Pharmaceutical Chemistry; University of California, San Francisco.
1996- 2003	Assistant Professor, Department Cellular & Molecular Pharmacology; Department of Biochemistry & Biophysics; Department of Pharmaceutical Chemistry; University of California, San Francisco.

Five publications closely related to the proposed research

1. Zalatan JG, Lee ME, Almeida R, Gilbert L, Whitehead EH, La Russa M, Tsai JC, Weissman JS, Dueber JE, Qi LS, **Lim WA**. Engineering Complex Synthetic Transcriptional Programs with CRISPR RNA Scaffolds. Cell. 2015 Jan 15;160(1-2):339-50. PMCID: PMC4297522.
2. Park JS, Rhau B, Hermann A, McNally KA, Zhou C, Gong D, Weiner OD, Conklin BR, Onuffer J, **Lim WA**. Synthetic control of mammalian-cell motility by engineering chemotaxis to an orthogonal bioinert chemical signal. Proc Natl Acad Sci U S A. 2014 Apr 22;111(16):5896-901. PMCID: PMC4000811.
3. Toettcher JE, Weiner OD, **Lim WA**. Using optogenetics to interrogate the dynamic control of signal transmission by the Ras/Erk module. Cell. 2013 Dec 5;155(6):1422-34. PMCID: PMC3925772.
4. Qi LS, Larson MH, Gilbert LA, Doudna JA, Weissman JS, Arkin AP, **Lim WA**. Repurposing CRISPR as an RNA-guided platform for sequence-specific control of gene expression. Cell. 2013 Feb 28;152(5):1173-83. PMCID: PMC3664290.
5. Chau AH, Walter JM, Gerardin J, Tang C, **Lim WA**. Designing synthetic regulatory networks capable of self-organizing cell polarization. Cell. 2012 Oct 12;151(2):320-32. PMCID: PMC3498761.

Five other significant publications

1. Youk H**, Lim WA**. Secreting and sensing the same molecule allows cells to achieve versatile social behaviors. Science. 2014 Feb 7;343(6171):1242782. PMCID: PMC4145839.
2. Fischbach MA, Bluestone JA, **Lim WA**. Cell-based therapeutics: the next pillar of medicine. Sci Transl Med. 2013 Apr 3;5(179):179ps7. PMCID: PMC3772767.
3. **Lim WA**, Lee CM, Tang C. Design principles of regulatory networks: searching for the molecular algorithms of the cell. Mol Cell. 2013 Jan 24;49(2):202-12. PMCID: PMC3664230.
4. Coyle SM, Flores J, **Lim WA**. Exploitation of latent allostery enables the evolution of new modes of MAP kinase regulation. Cell. 2013 Aug 15;154(4):875-87. PMCID: PMC3787944.
5. Peisajovich SG, Garbarino JE, Wei P, **Lim WA.** Rapid diversification of cell signaling phenotypes by modular domain recombination. Science. 2010 Apr 16;328(5976):368-72. PMCID: PMC2975375.

Synergistic Activities

2007-present Advisor, UCSF iGEM Team
2005-present Deputy Director, SynBERC
2004-present Director UCSF/UCB NIH Nanomedicine Center (Cell Propulsion Lab)
2010-present Director, UCSF Center for Systems & Synthetic Biology

Collaborators & Other Affiliations

Collaborators and Co-Editors

UCSF: Dyche Mullins, Chris Voigt, Tanja Kortemme, Chao Tang, Hana El-Samad, Art Weiss, Orion Weiner, Bruce Conklin. UC Berkeley: Dan Fletcher. NYU: Dafna Bar-Sagi. U. Conn.: Bruce Mayer.

Graduate and Postdoctoral Advisors

Graduate Advisor: Professor Robert T. Sauer, Massachusetts Institute of Technology
Post Graduate Advisor: Professor Frederic M. Richards, Yale University

Thesis Advisor and Postgraduate-Scholar Sponsor

Graduate Students: Caleb Bashor (Postdoc, James J. Collins Lab Boston University); Angela Hoi-Yee Chau (Director, Bourn Idea Lab at Castilleja School); Scott Coyle (current); Jaline Gerardin (Research Scientist, Institute for Disease Modeling Intellectual Ventures Labs); Matt Good (Assistant Professor, Yale University); Jason Park (MSTP, UCSF); Thomas Stevens (Research Associate, Refactored Materials; Jasper Williams (current); Reid Williams (Bioscience resident, IDEO). **Total = 9**

Postdoctoral Fellows: Ricardo Almeida (current), Pedro Beltrao (Group Leader, EMBL-EBI, UK), Maria Borovinskaya (past), Lukasz Bugaj (current), Leon Chan (Postdoc, Weis Lab, UC Berkeley), Illes Farkas (Senior Research Associate, Hungarian Academy of Sciences), Russell Gordley (current), Oliver Hoeller (Postdoc, Weiner Lab, UCSF), Andrew Horowitz (Scientist, LS9), Isabel Kolinko (current), Anselm Levskaya (Postdoc, Deisseroth Lab, Stanford), Lingfeng Liu (past), Amir Mitchell (current), Leonardo Morsut (current), Geoffrey O'Donoghue (current), Sergio Peisajovich (Staff Scientist Illumina, Inc.), Elias Puchner (Assistant Professor, University of Minnesota), Kole Roybal (current), Levi Rupp (current), Satoshi Toda (current), Jared Toettcher (Assistant Professor, Princeton University), Jessica Walter (Scientist, Amyris), Ping Wei (Assistant Professor, Center for Quantitative Biology, Peking University, China), Wilson Wong (Assistant Professor, Boston University), Chia-Yung Wu (current), Xin Xiong (current), Hyun Youk (Assistant Professor, Bio-nanoscience, Delft University of Technology, The Netherlands), Jesse Zalatan (Assistant Professor of Chemistry, University of Washington).
Total = 28

Biographical Sketch
Frank Bayliss, Professor of Biology,
San Francisco State University

(a) **Professional Preparation:**

Long Beach State University	Long Beach, CA	Zoology	B.S. 1965
University of California, Davis	Davis, CA	Microbiology	PhD 1971
Clemson University	Clemson, SC	Genetics	PD 1981-2

(b) **Appointments:**

San Francisco State University	1975 to present	Professor of Biology
Edinboro State University	1971 to 1975	Associate Professor of Biology
University of California, Davis	1969 to 1971	Instructor in Bacteriology

(c) **Publications:**

Peterfreund, A.R., K. Rath, S. Xenos, Nancy Carnal and F. Bayliss "Supplemental Instruction in Biology I: Enhancing the Performance and Retention of Underrepresented Minority Students". CBE-Life Sciences Education Vol. 6, 203-216, Fall 2007.

Peterfreund, A. R., Rath, K. A., Xenos, S. P., & Bayliss, F. (2008). The impact of supplemental instruction on students in STEM courses: San Francisco State University. Journal of College Student Retention.

Frank Bayliss, Alan Peterfreund and Ken Rath "Partnering for Success: Creating & Maintaining STEM Student Enrichment Programs at San Francisco State University in *Broadening Participation in Undergraduate Research* Council of Undergraduate Research, Chap 18, Mary Boyd &Jodi L. Wesemann, eds, 5/2009

Rath, K.A., Alan Peterfreund, Frank Bayliss, Elizabeth Runquist, and Ursula Simonis. Impact of Supplemental Instruction in Entry-Level Chemistry Courses at a Midsized Public University. Journal of Chemical Education Article ASAP, December 7, 2011. DOI: 10.1021/ed100337a

Bayliss, F.T. and R.T. Vinopal. "Selection of ribosomal mutations by antibiotic supression in yeast". Science 174:1339-41, 1971

Bayliss, F.T. and J.L. Ingraham. "Mutation in Saccharomyces cerevisiae conferring streptomycin and cold sensitivity by affecting ribosome formation and function. J. Bact. 118:319-328, 1974.

Kline, E.L. and F.T. Bayliss. "The effect of ilvA Mu phage insertion on ilv gene expression in Escherichia coli K-12". BBRC 63(4):1048-1055, 1975.

Smith*, J., F. Bayliss, and M. Ward. Sequence of the cloned *pyr4* gene of Trichoderma reesei and its use as a homologous selectable marker for transformation. Current Genetics 19:27, 1991

(d) **Synergistic Activities:**

As an active research/teacher in a minority serving institution, it became clear to me in the early 1990's that as an institution we needed to provide opportunities to science majors to 1) conduct research while pursuing undergraduate study and 2) to relieve graduate students conducting master's level study from prolonged time to graduation brought about by the need to work to afford college. Thus, I embarked on an effort to obtain grant funding to support undergraduates as well as master's students to conduct year-round research with adequate income to "buy out" their time from outside jobs. In the process, it

became obvious, we would also need to build research infrastructure at our institution. Indeed, the efforts we undertook have transformed the San Francisco State University (SFSU) College of Science & Engineering^. Once we were awarded funding to train students, I became a mentor on a large scale. We established a College-wide office called the Student Enrichment Opportunities (SEO) office to manage the grants and to lead the effort. We were able to compete for funding from the NIH, NSF, USDA, USDEd and DOD to support financially needy, first-generation college, women, and under-represented minority students in proportions similar to our enrollments. In each grant, mentoring was at the core of every program.

Most students have little or no idea what to expect in college let alone the demands of majoring in STEM disciplines. It is therefore imperative that a strong mentoring program be established for each student to "lead them through" the maze. It is through mentoring, often by several faculty and senior peers, which these students begin to consider graduate education and an academic or professional science career. Without personal encouragement students would typically get a job at the BS level. As students leave SFSU for graduate programs across the U.S., we help them identify new mentors known to us at the doctoral institution they choose to attend. With continued mentoring as students progress we make an effort to instill the importance for students, themselves, to seek mentors at each new level. Of course, we also continue to mentor prior students at a distance as their careers progress.

Successful mentoring at SFSU requires students have time to take advantage of research opportunities, which can be provided by significant direct scholarship funding to replace work income. Structured programmatic components such as technical workshops/training, GRE prep, honors courses, and reading primary literature, are also essential to student preparation for graduate school.

Once successful programs and adequate infrastructure are established, it is essential to institutionalize them, especially with the uneven availability of funding. This is however, very difficult to accomplish and as is the current case in California, it would not be possible to continue these programs as constituted without funding from extra-mural sources. We have highly successful programs that serve, as national models for the training of under-represented groups. All are heavily dependent on mentoring future scientists; our challenge is to maintain and grow them.

(e) **Collaborators and Other Affiliations:**

Gutierrez, Carlos, Professor of Chemistry, CSU Los Angeles
Peterfreund, Alan, Partner, SageFox Associates Amherst, MA
Rath, Ken, Partner, SageFox Associates Amherst, MA
Runquist, Beth, Instructor in Chemistry, San Francisco State University
Simonis, Uschi, Professor of Chemistry, San Francisco State University

Graduate Advisors and Postdoctoral Sponsors:

John Ingraham, Professor of Microbiology UC Davis (thesis adviser), Emeritus.
Ellis Kline, Professor of Microbiology Clemson University, (PD adviser) Emeritus.

Thesis Advisor and Postgraduate Scholar Sponsor:

Michelle Allegria	MS Microbiology	PhD UC Davis - Scientist at Roche Scientific
Soveasna Khoun	MS Physiology	High School teacher in San Francisco
Emil Palacios	MS Cell & Molecular	PhD UCSF - Scientist II at Celera Scientific
Raimi Quinton	MS Physiology	PhD U Maryland – Community College professor
LeRoy Robinson	MS C&MB	PhD Candidate at NYU
Jacinto Villanueva	MS C&MB	PhD UC Davis – COO Spring Scientific
Kyoko Owhaki	Postdoctoral Fellow	Faculty in Japan

Biographical Sketch – Simone Bianco
IBM Almaden Research Center

A. Professional Preparation

Undergraduate:	Universita' di Pisa,	B.S.	Physics and Astrophysics	2004
Graduate:	Universita' di Pisa	M.S.	Physics	2004
	University of North Texas	Ph.D.	Physics	2007
Postdoctoral:	William and Mary		Applied Science	2010
	UCSF		Bioengineering and Therapeutic Sciences	2014

B. Appointments

April 2014-present Research Staff Member, Dept of Industrial and Applied Genomics, IBM Almaden Research Center

C. Ten Most Relevant Publications
Five publications closely related to the proposed project

1. Z. Li, **S. Bianco**, and C. Tang, "Generic properties of random gene regulatory networks", *Quantitative Biology,* 1(4), 253-260 (2014).

2. A. Stern, **S. Bianco**, M. T. Yeh, C. Wright, K. Butcher, C. Tang, R. Nielsen, and R. Andino, "Costs and benefits of mutational robustness", *Cell Reports*, 8(4), 1026-1036 (2014).

3. I. B. Schwartz, E. Forgoston, **S. Bianco**, and L. B. Shaw, "Converging towards the optimal path to extinction", with *J. Royal Soc. Interface* 8:65, 1699-1707 (2011).

4. E. Forgoston, **S. Bianco**, L. B. Shaw, and I. B. Schwartz, "Maximal sensitive dependence and the optimal path to disease extinction", *Bull. Math. Biol.,* 73:3, 495-514 (2011).

5. **S. Bianco**, L. B. Shaw, and I. B. Schwartz, "Epidemics with Multistrain Interactions: The Interplay Between Cross Immunity and Antibody-Dependent Enhancement", *Chaos,* **19**, 043123 (2009).

Five other significant publications

1. **S. Bianco** and L. B. Shaw, "Asymmetry in the presence of migration stabilizes multistrain disease outbreaks", *Bull. Math. Biol.,* 73:1 248-260 (2011).

2. **S. Bianco**, E. Geneston, P. Grigolini, and M. Ignaccolo, "Renewal aging as emerging property of phase synchronization", *Physica A,* **387**, pag. 1387-1392 (2008).

3. **S. Bianco**, M. Ignaccolo, M.S. Rider, M. Ross, P. Winsor, and P. Grigolini, "Brain, music and non-Poisson renewal processes", *Phys. Rev. E,* **75**, 061911 (2007).

4. **S. Bianco**, P. Grigolini, and P. Paradisi, "Fluorescence intermittency in blinking quantum dots: renewal or slow modulation?", *J. Chem. Phys,* **123**, 174704 (2005).

5. O. Akin, **S. Bianco**, P. Grigolini, and P. Paradisi, "Renewal aging in non-homogenous Poisson processes with periodic rate modulation", *Int. J. of Bifurcations and Chaos*, **18**, pag. 2681 (2008).

D. Synergistic Activities (up to five examples)

- Meeting organizer: Co-organizer of the 2014 IBM Almaden Institute themed “Sequence the City”
- Co-organizer of the IBM 2015 Distinguished Speakers Series
- Committee member: 2015 AAAI-W3PHI Conference on World Wide Web and Public Health Intelligence
- 2009 HHMI Biomathematics Program Fellowship: Teaching scholarship as undergraduate instructor at the College of Willliam and Mary
- Undergraduate activity: While at the College of William and Mary, I have been involved in training Dr Andrea Gregory during her BS.

E. Collaborators and Other Affiliations

E. 1 Collaborators and Co-Editors

Chao Tang (PKU), Raul Andino (UCSF), Adi Stern (Tel Aviv University), Rasmus Nielsen (UCB), James H. Kaufman (IBM Research), Ira B. Schwartz (US Naval Research Lab), Leah B. Shaw (William and Mary), Paolo Grigolini (University of North Texas), Roberto Reno' (Universita' di Siena)

E. 2 Graduate and Postdoctoral Advisors

Prof. Paolo Grigolini, University of North Texas (Graduate Advisor)
Prof. Leah B. Shaw, William and Mary (Postdoctoral Advisor)
Prof. Chao Tang, UCSF (Postdoctoral Advisor)

E. 3 Post Graduate Sponsor

Thesis Advisor and Postgraduate-Scholar Sponsor.

Thesis advisor for: Mr Chang Chang (PKU, joint with Chao Tang)

Graduate intern mentoring: Mr Garrett Nieddu (IBM Intern, PhD program at Montclair State University)

E. 4 Total Number of Graduate Students Advised

• 2

E. 5 Total Number of Postdoctoral Scholars Sponsored

• 0

BIOGRAPHICAL SKETCH

Burrus, Laura W.

Professional Preparation

1982-1986	College of William & Mary, Williamsburg, CA	Chemistry	1986, BS
1986-1991	University of Wisconsin, Madison, WI	Biochemistry	1991, PhD
1991-1996	Harvard University, Cambridge, MA	Dev Biol	1996, Postdoc

Appointments

2006-	Professor, Department of Biology, San Francisco State University
2003-2004	Visiting Professor, Department of Anatomy, UCSF
2001-2005	Associate Professor, San Francisco State University
1997-2001	Assistant Professor, Department of Biology, San Francisco State University

Publications Most Closely Related to Proposal (out of 25 total)

*master's level student, **undergraduate student, [F]Female student, [U]URM student

1. Miranda, M.** [FU], Galli, L.M., Enriquez, M.** [U], Szabo, L.A.* [F], Gao, X., Hannoush, R.N., and Burrus, L.W. (2014) Identification of the WNT1 residues required for palmitoylation by Porcupine. *FEBS Letters.* 2014 Nov 20 [Epub ahead of print].
2. Galli, L.M., Szabo, L.A.* [F], Li, L.* [F], Htaik, Y.M.**, Onguka, O.* [U], Burrus, L.W. (2014) Concentration-dependent effects of WNTLESS on WNT1/3A signaling. *Developmental Dynamics* 243(9):1095-105.
3. Galli, L.M., Munji, R.N.** [U], Chapman, S.C., Easton, A.** [F], Li, L.* [F], Onguka, O.* [U], Ramahi, J.S.** [U], Suriben, R.** [FU], Szabo, L.A.* [F], Teng, C.** [F], Tran, B.** [F], Hannoush, R.N., Burrus, L.W. (2014) Frizzled10 mediates WNT1 and WNT3A signaling in the dorsal spinal cord of the developing chick embryo. *Developmental Dynamics* 243(6):833-43.
4. Galli L.M. and Burrus L.W. (2011) Differential palmit(e)oylation of Wnt1 on C93 and S224 residues has overlapping and distinct consequences. *PLoS One* 6(10): e26636.
5. Galli, L.M., Barnes, T.L., Secrest, S.S. * [F], Kadowaki, T., and Burrus, L.W. (2007) Porcupine-mediated lipid-modification regulates the activity and distribution of Wnt proteins in the chick neural tube. *Development* 134(18): 3339-48.

Other Publications

1. Galli, L.M., Barnes, T.L., Cheng, T. *[F], Acosta, L.*[FU], Anglade, A.*[U], Willert, K, Nusse, R., and Burrus, L.W. (2006) Differential inhibition of Wnt-3a by Sfrp-1, Sfrp-2 and Sfrp-3. *Developmental Dynamics* 235(3): 681-90.
2. Chesnutt, C., Burrus, L.W., Brown, A.M.C., Niswander, L. (2004) Coordinate regulation of neural tube patterning and proliferation by TGFb and Wnt activity. *Developmental Biology* 274(2):334-47.
3. Galli, L.M., Willert, K., Nusse, R., Yablonka-Reuveni, Z., Nohno, T., Denetclaw, W., and Burrus, L.W. (2004) A Proliferative Role for Wnt-3a in Chick Somites. *Developmental Biology* 269(2):489-504.
4. Jin, E.-J., Erickson, C.A., Takada, S. and Burrus, L.W. (2001) Wnt and BMP signaling govern lineage segregation of melanocytes in the avian embryo. *Developmental Biology* 233: 22-37.
5. Burrus, L.W. and McMahon, A.P. (1995) Biochemical analysis of murine Wnt proteins reveals both shared and distinct properties. *Exp. Cell Res.* 220: 363-373.

Synergistic Activities

1. I am a mentor for MARC, RISE, and BRIDGES fellows as well as "Choose Development" fellows.
2. Member, Advisory Boards: I am on the advisory committee for the Minority Biomedical Research Support – Support of Continuous Research Excellence (MBRS-SCORE) program at SFSU. MBRS-SCORE is a large source of funding for Cell and Molecular Biologists and Biochemists on the SFSU campus. One of the roles of the advisory committee is to set selection criteria to determine which PIs can apply for funding, and then to select those PIs via an internal review system. Committee members also serve as advocates for funded PIs and work to insure that the institutional goals of the grants are being met (ie: hiring and retention of URM faculty).

   I am also a member of the Faculty Consensus Group for the CSU Program for Education and Research in Biotechnology. The mission of CSUPERB is to mobilize CSU students and faculty to promote the development of a professional biotechnology workforce.
3. Chair, SFSU Biology Department Strategic Planning Committee: One of the most important roles of this committee is to generate and implement plans to attract and retain diverse students and faculty.
4. Student Outreach: I am an active participant in several student outreach programs, including the CCSF Bridges student-training program, the SFSU NSF-REU summer program, the Expanding Your Horizons program (for middle school girls), and the Children's Hospital Oakland Research Institute Summer Research Program.
5. Undergraduate Education Advocate: I partner with the Science Education Partnership and Assessment Lab to collect data pertaining to the efficacy of active learning in classrooms and the importance of "Instructor Talk". I also organize a gathering for faculty from Primarily Undergraduate Institutions at the Annual Society for Developmental Biology Meeting.

Collaborators and Other Affiliations

1. Research mentor to under-represented minority undergraduate and master's level students: In 18 years, I have mentored 27 under-represented minority students (Lisa Acosta, Eric Alonzo, Adolph Anglade, Raymund Bueno, Ricardo Collaco, Lisa Dorsey, Michael Enriquez, Anthony Eritano, Eugenel Espiritu, Gabriel Fraley, Jorge Franco, Eva Grebe, David Hernandez, Joni Jones, Robert Monroy, Ouma Onguka, Yurixsa Martinez, Matilde Miranda, Roeben Munji, Gina Pay, Chris Pineda, Joe Ramahi, Lluvia Rodriguez, Luis Sanchez, Rowena Suriben, Baouyen Tran, Michelle Wallace). Of these students, 4 have already received their PhDs (from UCSF, UC-Davis, and Memorial Sloan Kettering/Cornell) while 7 are currently in PhD programs at Albert Einstein, Baylor, Johns Hopkins, NYU, UC-Davis, UCLA and UT-Southwestern.

Biographical Sketch – Yee-Hung Mark Chan
San Francisco State University

A. Professional Preparation

Undergraduate:	Harvard University	B.A.	Chemistry	2001
Graduate:	Stanford University	Ph.D.	Chemistry	1997
Postdoctoral:	UC San Francisco		Biochemistry & Biophysics	2003

B. Appointments

2015- Assistant Professor, Dept of Biology, San Francisco State University

C. Publications

Five publications closely related to the proposal

1. **Chan Y-HM**, Marshall WF. "Organelle Size Scaling of the Budding Yeast Vacuole Is Tuned by Membrane Trafficking Rates." *Biophysical Journal* (2014) 106: 1986-1996.
2. Rafelski SM, Viana MP, Zhang Y, **Chan Y-HM,** Thorn KS, Yam P, Fung JC, Li H, Costa LdF, Marshall WF. "Mitochondrial Network Size Scaling in Budding Yeast is Achieved in the Bud at the Expense of the Mother." *Science* (2012) 338: 822-824.
3. **Chan Y-HM,** Marshall WF. "How cells know the size of their organelles." *Science* (2012) 337:1186-1189.
4. **Chan Y-HM,** Marshall WF. "Threshold-free method for three-dimensional segmentation of organelles." *Proc. SPIE* (2012) 8225: 822529.
5. **Chan, Y-HM,** Marshall WF. "Scaling properties of cell and organelle size." *Organogenesis* (2010) 6:88-96.

Five other significant publications

6. Arigovindan M, Fung J, Elnatan D, Mennella V, **Chan, Y-HM,** Pollard M, Branlund E, Sedat JW, Agard DA. "High-resolution restoration of 3D structures from extreme low exposure widefield fluorescence images." *Proc Natl Acad Sci USA* (2013) 110: 17344-17349.
7. Chung M, Lowe R, **Chan Y-HM,** Ganesan PV, Boxer SG. "DNA-tethered membranes formed by giant vesicle rupture." *J. Struct. Biol*. (2009) 168:190-199.
8. **Chan Y-HM,** van Lengerich B, Boxer SG. "Effects of linker sequences on vesicle fusion mediated by lipid-anchored DNA oligonucleotides." *Proc. Natl. Acad. Sci. USA* (2009) 106, 979-984.
9. **Chan Y-HM,** van Lengerich B, Boxer SG. "Lipid-anchored DNA mediates vesicle fusion as observed by lipid and content mixing." *Biointerphases* (2008) 3, FA17-FA21.
10. **Chan Y-HM,** Lenz P, Boxer SG. "Kinetics of DNA-mediated docking reactions between vesicles tethered to supported lipid bilayers." *Proc. Natl. Acad. Sci. USA* (2007) 104, 18913-18918.

D. Synergistic Activities

- Undergraduate Mentorship – I have been an active mentor to 4 high school and undergraduate students during my postdoctoral and graduate training, 2 of which belong to underrepresented minority groups. At SFSU, a major goal of my research program will be to train undergraduate scientists and guide them as they develop their careers as academic and industrial scientists.
- Meeting Organization – In 2011, I organized the Bay Area Yeast and Other Fungi Symposium which brought together researchers throughout the Bay Area to present and discuss their latest results.

E. Collaborators and Other Affiliations

E. 1 Collaborators and Co-Editors

Mara Duncan (U Michigan), Lois Weisman (U Michigan)

E. 2 Graduate and Postdoctoral Advisors

Prof. Wallace Marshall, UCSF
Prof. Steven Boxer, Stanford University

BIOGRAPHICAL SKETCH

Annette Chan, Director, Cell and Molecular Imaging Center

Professional Preparation

Univ. of California, Berkeley	Berkeley, CA	B.A.	1990	Zoology
Univ. of California, Berkeley	Berkeley, CA	Ph.D.	1997	Plant Biology

Appointments

2005-present	Director/Manager, Cell and Molecular Imaging Center (CMIC), San Francisco State University, San Francisco, CA
1998-2005	Research Specialist for Dr. Barbara J. Meyer, University of California, Berkeley
1991	Laboratory Assistant for Dr. Steven E. Ruzin, NSF Center of Plant Developmental Biology, University of California, Berkeley, CA
1990-1991	Laboratory Assistant for Dr. Zinmay Renee Sung, University of California, Berkeley, CA
1988	Laboratory Assistant for Dr. Zinmay Renee Sung, University of California, Berkeley, CA
1986	Laboratory Technician for Dr. Robert Schwartz, Children's Hospital, Oakland, CA

Publications Related to Proposal

Tsai CJ, Mets DG, Albrecht MR, Nix P, Chan A, and Meyer BJ Meiotic crossover number and distribution are regulated by a dosage compensation protein that resembles a condensin subunit. **2008** *Genes & Development*, 22(2): 194-211.

Chan RC, Chan A, Jeon M, Wu TF, Pasqualone D, Rougvie AE, and Meyer BJ Chromosome cohesion is regulated by a clock gene paralogue TIM-1. **2003** *Nature*, 423(6943):1002-1009.

Chan A and Cande WZ Maize meiocytes in culture. **2000** *Plant Cell, Tissue and Organ Culture*, 60(3): 187-195.

Chan A and Cande WZ Maize meiotic spindles assemble around chromatin and do not require paired chromosomes. **1998** *Journal of Cell Science*, 111(23): 3507-3515.

Yu H Hiatt EN, Chan A, Sweeney M, and Dawe RK Neocentromere-mediated chromosome movement in maize. **1997** *The Journal of Cell Biology*, 139(4): 831-840.

Synergistic Activities

Experience Managing Research Facilities

Director/Manager (Research Technician III), Cell and Molecular Imaging Center (CMIC)
San Francisco State University, July 2005 to present
Manage the Cell and Molecular Imaging Center (CMIC), a state-of-the-art research facility at San Francisco State University, with a Zeiss LSM 710 Confocal Microscope, a Nikon C1 Confocal Microscope, a Zeiss Cell Observer Spinning Disk Confocal Microscope, a 3i Marianas Deconvolution System, a BD FACSCalibur flow cytometer, an InCyt Standard IM, a Nikon Eclipse 80i Upright Microscope, a Nikon TE2000-S Inverted Microscope, an Olympus SZX12 stereozoom microscope, and a LI-COR Odyssey CLx Infrared Imaging System; support faculty research; train students and researchers; and maintain a recharge system.

Research Specialist
Howard Hughes Medical Institute, University of California, Berkeley, January 1998 to July 2005
Managed the laboratory's microscopes (including dissecting scopes, an injection scope, GFP stereomicroscopes, epifluorescence microscopes, confocal microscopes, and a spinning disk confocal microscope), taught microscopy and immunostaining procedures, trained and supervised people on the use of microscopes, maintained and serviced microscopes, wrote justifications for new equipment, evaluated and purchased new equipment.

Laboratory Assistant, NSF Center of Plant Developmental Biology (Biological Imaging Facility)
University of California, Berkeley, January 1991 to August 1991
Managed the NSF Center of Plant Developmental Biology (now called the Biological Imaging Facility), determined the gene expression patterns of an embryogenesis gene in plant ovules.

Contributions to the Science of Learning
Guest Lecturer for the Following Courses:
Biology 351 - Experimental Cell and Molecular Biology; Biology 391 - Microscopy and Photomicrography; Biology 402 - General Microbiology Laboratory; Biology 436 - Immunology Laboratory; Biology 443 - Microbial Physiology Laboratory; Biology 526 - Plant Physiology Laboratory; Biology 570 - Biology of Fishes; Biology 614 - Vertebrate Histology; Biology 784 - Cell Culture and Stem Cell Techniques; Biology 864 - Recent Developments in Microbiology; Biology 865 - Current SFSU Physiology Research; Biology 881 - Current Research Topics in Biology; Chemistry 800 - Methods in Proteomics; Chemistry 851 - Biochemical Spectroscopy

NIH Bridges to the Baccalaureate Directed Research Program, City College of San Francisco/Skyline College/San Francisco State University
Molecular and Cytogenetics Laboratory, CSU Stanislaus and San Francisco State University
NSF Summer Research Experience for Undergraduates
Under-Represented Minorities Student Enrichment Opportunities

Departmental Committees
Research Infrastructure Committee, Department of Biology, San Francisco State University, October 2006 to present

Collaborations and Other Affiliations

Collaborators and Co-Editors
Dr. Laura Burrus, Department of Biology, San Francisco State University
Dr. Lily Chen, Department of Biology, San Francisco State University
Dr. Diana Chu, Department of Biology, San Francisco State University
Dr. Carmen Domingo, Department of Biology, San Francisco State University
Dr. Megumi Fuse, Department of Biology, San Francisco State University
Dr. Bruce Macher, Department of Chemistry and Biochemistry, San Francisco State University
Dr. Blake Riggs, Department of Biology, San Francisco State University

Graduate Advisors and Mentors

Graduate: W. Zacheus Cande, Department of Molecular and Cell Biology, University of California, Berkeley, CA

Thesis Advisors and Research Sponsor
Sibing Wei, MS in Biology: Biomedical Laboratory Science, Aug. 2007, supervisor: Diana Smith-Beckerman
Cerise (Jei-Ying) Chen, MS in Biology: Marine Biology, Dec. 2011, supervisor: Gary Williams
Arrezo Moghaddasi, MS in Biology: Cell & Molecular Biology, Aug. 2012, supervisor: Lily Chen
Steven Ho, MS in Chemistry: Biochemistry, January 2014, supervisor: Marc Anderson
Julia Taylor, MS in Biology: Ecology, Evolution, & Conservation, April 2014, supervisor: Karen Crow-Sanchez

Biographical Sketch
Diana S. Chu, Associate Professor

A. Professional Preparation

Univ. of California, Berkeley	B.S.	1991	Biochemistry
Univ. of California, Los Angeles	Ph.D.	1997	Molecular Biology
Univ. of California, Berkeley	Post-Doc	1998-2003	Developmental Biology

B. Appointments

Research Positions

2010-present Associate Professor, Department of Biology, San Francisco State University
Research: Nuclear organization during spermatogenesis in *C. elegans*.
2004-2010 Assistant Professor, Department of Biology, San Francisco State University
1998-2004 Postdoctoral Fellow, University of California, Berkeley.
Research: Sex Determination and Dosage Compensation in *C. elegans*.

C. Publications

(* SFSU student, (URM) under-represented minority, ^ woman author)

Samson M*[URM], Jow MM^, Wong CL, Fitzpatrick C*, Aslanian A, Saucedo I*[URM], Estrada R*[URM], Yates JR, Chu DS^ The specification and global reprogramming of histone epigenetic marks during gamete formation and early embryo development in *C. elegans*
PLoS Genet. 2014 Oct 9;10(10):e1004588. doi: 10.1371/journal.pgen.1004588.

Chu DS^ and Shakes DC^ Spermatogenesis *Germ Cell Development in C. elegans* Springer Adv Exp Med Biol. 2013;757:171-203.

Tzur YB, Egydio de Carvalho C, Nadarajan S, Van Bostelen I, Gu Y, Chu DS, Cheeseman IM, Colaiácovo MP. LAB-1 targets PP1 and restricts Aurora B kinase upon entrance into meiosis to promote sister chromatid cohesion.
PLoS Biol. 2012;10(8):e1001378. doi: 10.1371/journal.pbio.1001378. Epub 2012 Aug 21.

Wu JC^, Go AC^*[URM], Samson M*[URM], Cintra T^*[URM], Mirsoian S^*[URM], Wu TF^, Jow MM^, Routman EJ, Chu DS Sperm Development and Motility are Regulated by PP1 Phosphatases in *Caenorhabditis elegans.* GENETICS **2012** Jan;190(1):143-57. Epub 2011 Oct 31. PMID: 22042574

Wu TF^, Nera B^*[URM], Chu DS^, and Shakes DC^ Elucidating gene regulatory mechanisms for sperm function through the integration of classical and systems approaches in *C. elegans*. *Systems Biology in Reproductive Medicine* **2010** Jun;56(3):222-35.

Han T, Manorhan AP, Harkins TT, Bouffard P, Fitzpatrick C*, Chu DS^, Theirry-Mieg D, Thierry-Mieg J, Kim JK Germline-generated 26G endo-siRNAs regulate spermatogenic and zygotic gene expression in *C. elegans. Proceedings of the National Academy of Sciences* **2009** Nov 3;106(44):18674-9. PMC2765456

Shakes DC^, Wu J^, Sadler PL^, LaPrade K^*, Moore LL, Noritake A^, Chu DS^ Spermatogenesis-specific features of the meiotic program in *Caenorhabditis elegans PLoS Genetics* **2009** Aug;5(8):e1000611. Epub 2009 Aug 21. PMC2720455

Wu TF^ and Chu DS^ Sperm chromatin: fertile grounds for proteomic discovery of clinical tools. *Mol Cell Proteomics* **2008** Oct 7 (10):1876-86. PMC2559940

Wu TF^, Chu DS^ Epigenetic processes implemented during spermatogenesis distinguish the paternal pronucleus in the embryo. **2008** *Reproductive BioMedicine Online*
http://www.rbmonline.com/Article/2937 [e-pub ahead of print on 9 October 2007]

Chu DS^, Liu H, Nix P^, Wu TF^, Ralston EJ, Yates JR, and Meyer BJ^ Sperm chromatin proteomics identifies evolutionarily conserved fertility factors. *Nature.* **2006** Sep 7, 443(7107):101-5.

Chu DS^, Dawes HE^, Lieb JD, Chan RC, Kuo AF, and Meyer BJ^ A molecular link between gene-specific and chromosome-wide transcriptional repression. *Genes and Development* **2002** Apr 1, 16(7): 796-805.

D. Synergistic Activities

Research mentor to minority undergraduate and graduate students: In 11 years I have mentored 28 Masters/Post-bac (17 URM) and 23 undergraduate (22 URM) students. URM students include (graduate school): Jason Randolph (UCSF Medical School/UCB MPH), Aiza Go (UC Davis PhD), Joseph Beyene (Harvard PhD), Susan Mirsoian (UCSF Pharmacy), Cristina Partida (Illinois College of Optometry), Mark Samson (Ross Medical School), Bernadette Nera (UC Davis PhD), Michael Tufaga (UCSF Medical), Thais Cintra (Ross Medical School), and Jennifer Gilbert (UW Madison PhD). I have obtained a minority supplements to my NSF and NIH grants to support 5 URM students.

Career development of minority students: I participate in programs to enhance URM participation in research including the NIH *Science Education Partnership Award: Spectrum: Building Pathways to Biomedical Research Careers for Girls and Women of Color*, the NSF REU program *Biological Research in Ecological and Evolutionary Developmental Biology*, and the CIRM *Bridges to Stem Cell Research Program, the NIH RISE, Bridges to the Baccalaureate, Bridges to the PhD, and MARC Programs.*

Course development: BIOL861: Epigenetics. I developed a graduate seminar course that encompasses cellular strategies for epigenetic regulation of gene expression.

BIOL357: Molecular Genetics. I incorporate alternative teaching strategies to this undergraduate majors core course, including group projects with oral presentations and writing assignments on primary research articles to promote written communication skills.

BIOL716: Skills for Scientific Proposal Writing. I developed a course where graduate students learn to write proposals on their own research, which will be submitted to funding agencies like the NSF to promote career development of multicultural students at SFSU.

Graduate Coordinator for the Biology program at SFSU.

Reviewer: *The National Science Foundation, PLoS Genetics, Molecular and Cellular Proteomics*, *Systems Biology in Reproductive Medicine, Stem Cells, Molecular Reproduction and Development, Journal of Proteomic Research*, and *genesis*

E. Collaborators & Other Affiliations

Collaborators and Co-Editors

John Yates III, Department of Cell Biology, Scripps Research Institute, La Jolla, CA
Geeta Narlikar, Biochemistry Department, University of California, San Francisco, CA
Monica Colaiacovo, Department of Genetics, Harvard University, Boston, MA
John K. Kim, Life Sciences Institute, University of Michigan, Ann Arbor, MI
Diane Shakes, Department of Biology, William and Mary College, Williamsburg, VA

Graduate Advisors & Postdoctoral Sponsors

Postdoctoral: Barbara J. Meyer, HHMI/UC Berkeley, Berkeley, CA
Graduate: Gregory S. Payne, Biological Chemistry Department, UCLA School of Medicine, Los Angeles, CA

Thesis Advisor & Research Sponsor (URM = under-represented minority; current status)

Postdoctoral fellows: Margaret Jow, Dana Byrd
Current students: Grad - Jennifer Gilbert[URM], Londen Johnson[URM], Israel Saucedo[URM], Lucy Pill[URM], Maryam Saadat, Luis Quintanilla[URM], Vanessa Cota[URM], Marco Monroy[URM]
Undergrad: Monet Jimenez[URM], Jordan Berry[URM], Daniel Zamora[URM], Chris Black

Charles S. Craik

(a) Professional Preparation

Allegheny College, Meadville, PA	Chemistry	B.Sc. 1972-1976
Columbia University, NY, NY	Chemistry	M.A. 1976-1978
Columbia University, NY, NY	Chemistry	Ph.D. 1978-1981
University of California, San Francisco	Biochem & Biophysics	Postdoc 1981-1985

(b) Appointments

2010-present	Director, Quantitative Biosciences Consortium of Graduate Programs
1999-present	Director, Chemistry and Chemical Biology Graduate Program
1998-present	Member of the UCSF Comprehensive Cancer Center
1997-present	Member of the UCSF AIDS Institute
1995-present	Prof, Depts. of Pharm. Chemistry, Pharmacology and Biochem. & Biophysics, UCSF
1994-present	Prof, Depts. of Pharm. Chemistry, and Biochem. & Biophysics, UCSF
1991-1994	Assoc. Prof, Depts. of Pharm. Chemistry and Biochem. & Biophysics, UCSF
1985-91	Asst. Prof, Depts. of Pharm. Chemistry and Biochem. & Biophysics, UCSF

(c) Products

Products Most Closely Related to the Proposed Project

1. Co-Founder and architect of the Idea to IPO course that is an experiential, team based entrepreneurship class that teaches the fundamentals of establishing business value from research discoveries. This intensive, 12-week course is in its 14th year and teaches faculty researchers, clinicians, residents, PhD, Masters and health science students how to move an idea from the lab/clinic/digital world to commercialization. Teams assemble during class and through an online marketplace. - See more at: http://ita.ucsf.edu/entrepreneurship-center/education/courses/idea-ipo

2. Founder and Chairman of the Scientific Advisory Board of Catalyst Biosciences, a clinical-stage company focused on the development of novel catalytic biopharmaceutical products based on engineered human proteases. The portfolio of clinical and preclinical development-stage products addresses areas of high unmet need in the orphan area of hemophilia and in complement-driven diseases such as dry age related macular degeneration, as well as kidney and myocardial ischemia reperfusion injury in the surgical settings of transplant, coronary artery bypass grafting, myocardial infarction, and stroke. See more at: http://www.catalystbiosciences.com/

3. Co-principal investigator for the Bay Area NSF Innovation Corps grant (iCorps) a collaboration between the University of California Berkeley, University of California San Francisco and Stanford University funded by the National Science Foundation that offers educational programs to accelerate the commercialization of science and fosters technology entrepreneurship nationally. See more at: http://bayicorps.com/

4. Chairman of the Scientific Advisory Board for CytomX Therapeutics, a biotechnology company developing the next generation of highly targeted antibody therapeutics. A particular emphasis of the company is to use proteolytic enzymes to activate masked versions of antibodies to have greater specificity and efficacy of antibody therapeutics. I have considerable experience in the area of proteolysis. See more at: http://www.cytomx.com/

5. Chairman of the Scientific Advisory Board for Protagonist Therapeutics, a biotechnology company developing oral peptide therapeutics. A particular emphasis of the company is to use bacteriophage display for developing the diversity of peptide scaffolds, an area of my expertise. See more at: http://www.protagonist-inc.com/

Other Significant Products

1. Founder and director of the UCSF Chemistry and Chemical Biology graduate program, a PhD granting program started in 1998 that provides training at the interface between Chemistry and Biology in a health science setting. See more at: http://ccb.ucsf.edu/

2. Principal Investigator for an NIH Chemical Biology Initiative training grant that provides partial support to the Chemistry and Chemical Biology Graduate Program. The training grant is in its 15th year.
3. Course director for the Chemical Biology course that teaches principles of protein engineering, biotechnology and chemical biology to first year graduate students in various graduate programs. See more at: http://coursecatalog.ucsf.edu/course/168
4. Lecturer for the annual National Amgen Scholars program that is supported by the Amgen Foundation to provide undergraduate students an exciting summer research experience at select institutions in the nation. See more at: http://www.amgenscholars.com/
5. Director of a research laboratory at UCSF to focused on defining the roles and the mechanisms of enzymes in complex biological processes and on developing technologies to facilitate these studies to aid in the rapid detection, monitoring and control of infectious disease and cancer. See more at: http://www.craiklab.ucsf.edu/ Five recent, relevant publications are listed below.

(d) Synergistic Activities (Publications related to health science research)

1. Tumor detection by imaging proteolytic activity. Darragh MR, Schneider EL, Lou J, Phojanakong PJ, Farady CJ, Marks JD, Hann BC, **Craik CS.** *Cancer Res*. 2010; 70(4):1505-12. PMC2823079.
2. Lee GM, Balouch E, Goetz DH, Lazic A, McKerrow JH, **Craik CS**. Mapping Inhibitor Binding Modes on an Active Cysteine Protease via NMR Spectroscopy. Biochemistry. 2012 Dec 18;51(50):10087-98. PMID: 23181936
3. Global identification of peptidase specificity by multiplex substrate profiling. O'Donoghue AJ, Eroy-Reveles AA, Knudsen GM, Ingram J, Zhou M, Statnekov JB, Greninger AL, Hostetter DR, Qu G, Maltby DA, Anderson MO, DeRisi JL, McKerrow JH, Burlingame AL, **Craik CS**. *Nature Methods*. 2012 Nov;9(11):1095-100. PMCID: PMC3707110.
4. Imaging a functional tumorigenic biomarker in the transformed epithelium. LeBeau AM, Lee M, Murphy ST, Hann BC, Warren RS, Delos Santos R, Kurhanewicz J, Hanash SM, Vanbrocklin HF, **Craik CS.** *Proc Natl Acad Sci U S A*. 2013 Jan 2;110(1):93-8. PMCID: PMC3538269.
5. Targeting uPAR with Antagonist Recombinant Human Antibodies in Aggressive Breast Cancer. LeBeau A, Duriseti S, Murphy S, Pepin F, Hann B, Gray J, VanBrocklin H and **Craik CS**, *Cancer Research*. 2013 Apr 1;73:2070-81 PMCID: PMC3618559.

(e) Collaborators & other Affiliations

Bode, W.	Martinsreid, Germany	Kisiel, W.	University of New Mexico
Bogyo, M.	Stanford	Majundar, A..	UC Berkeley
Bromme, D.	University of BC, Canada	Nelson, P.	University of Washington
Doetsch, V.	University of Frankfurt, Germany	Roush, W.	Scripps Institute, FL
Ellman, J.	UC Berkeley	Tuohy, M.	Natl. Univ. of Ireland

Graduate Advisors and Postdoctoral Sponsors.

Sherman Beychok, Columbia University; Charles Cantor, Columbia University; William Rutter, UCSF

Thesis Advisor and Postgraduate-Scholar Sponsor.

C. Farady	Novartis, Inc., Scientist	A. Barrios	Asst, Prof, Univ. of Utah
S. Mahrus	Scientist, Genentech, S.SF, CA	J. Sun	Scientist, Eli Lilly and Co, San Diego
D. Greenbaum	Asst. Prof., Johns Hopkins Univ.	C.I. Wang	Asst. Prof., Biopolis Singapore
D. Hostetter	Scientist, CytomX Pharmaceuticals, S.SF, CA	J. Bell	Asst. Prof., Virginia Commonwealth Univ.
A. Bhatt	Hem/Onc Fellow, Broad Institute, Harvard Univ.	E. Schneider	Scientist, ProLynx Inc, SF, CA
M. Darragh	Ocean Nanotech, Scientist, Springdale, AR	D. Goetz	WSG&R IP Counseling & Patents

Total Grad Students= 41 Total Postdocs= 60

Wilfred F. Denetclaw, Ph.D.
Biographical Sketch

Associate Professor, Biology
Department of Biology
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132
(415) 338-1784
denetclw@sfsu.edu

(a) Professional Preparation:

Fort Lewis College, Durango, CO	Department of Biology	B.S. 1983
University of California, Berkeley	Department of Zoology	Ph.D. 1991
University of California, Berkeley	Molecular Cell Biology (Post-graduate Research)	1992-1994
University of California, San Francisco	Department of Anatomy and Cardiovascular Research Institute (CVRI)	Postdoc 1994

(b) Appointments:

Since 2006	Associate Professor Biology, San Francisco State University
2000-2006	Assistant Professor Biology, San Francisco State University
1999-2000	Assistant Research Anatomist, Anatomy, UC San Francisco

(c) Products:

(i) Most Relevant to Proposal

1. **Denetclaw, W. F. Jr.**, Bi, G., Pham, D. V., and R. A. Steinhardt. (1993). Heterokaryon myotubes with normal mouse and Duchenne nuclei exhibit sarcolemmal dystrophin staining and efficient intracellular free calcium control. *Mol. Biol. Cell* 4(9):963-72.
2. **Denetclaw, W. F. Jr.**, Hopf, F. W., Cox, G. A., Chamberlain, J. S., and R. A. Steinhardt. (1994). Myotubes from transgenic *mdx* mice expressing full-length dystrophin show normal calcium regulation. *Mol. Biol. Cell* 5(10):1159-67.
3. **Denetclaw, W.F. Jr.**, Christ, B., and Ordahl, C.P. (1997). Location and growth of epaxial myotome precursor cells. *Development* 124:1601-10.
4. **Denetclaw, W.F. Jr.**, and Ordahl, C.P. (2000). The growth of the dermomyotome and formation of early myotome lineages in thoracolumbar somites of chicken embryos. *Development* 127:893-905.
5. **Denetclaw, W.F**., Berdougo, E., Venters, S.J., and Ordahl, C.P. (2001). Morphogenetic cell movements in the middle region of the dermomyotome dorsomedial lip associated with patterning and growth of the primary epaxial myotome. *Development* 128:1745-55.
6. Estrada, M., Burnett, M., Campbell, A.G., Campbell, P.B., **Denetclaw, W.F.**, Gutierrez, C.G., Hurtado, S., John, G.H., Matsui, J., McGee, R., Nettles, M.T., Okpodu, C.M., Robinson, T.J., Summers, M.F., Werner-Washburne, M., Zavala, M. (2013). Improving Underrepresented Minority Student Persistence in STEM. *Science (Submitted).*

(ii) Other Products

1. McCarter GC, **Denetclaw WF Jr,** Reddy P, Steinhardt RA. (1997). Lipofection of a cDNA plasmid containing the dystrophin gene lowers intracellular free calcium and calcium leak channel activity in *mdx* myotubes. *Gene Ther.* 4(5):483-7.
2. Ordahl, C.P., Berdougo, E., Venters, S.J., and **Denetclaw, W.F**. (2001). The dermomyotome dorsomedial lip drives growth and morphogenesis of both the primary myotome and dermomyotome epithelium. *Development* 128:1731-44.

3. Galli, L.M., Willert, K., Nusse, R., Yablonka-Reuveni, Z., Nohno, T., **Denetclaw, W**., and Burrus, L.W. (2004). A proliferative role for Wnt-3a in chick somites. *Dev. Biol.* 269:489-504.
4. Venters, S.J., Argent, R.E., Deegan, F.M., Perez-Baron, G., Wong, T.S., Tidyman, W.E., **Denetclaw, W.F. Jr**., Marcelle, C., Bronner-Fraser, M., and Ordahl, C.P. (2004). Precocious terminal differentiation of premigratory limb muscle precursor cells requires positive signalling. *Dev. Dyn.* 229:591-9.
5. Karpuj, M.V., Giles, K., Gelibter-Niv, S., Scott, M.R., Lingappa, V.R., Szoka, F.C., Peretz, D., **Denetclaw, W.F**., and Prusiner, S.B. (2007). Phosphorothioate oligonucleotides reduce PrPSc levels and prion infectivity in cultured cells. *Mol. Med.* 13:190-8.

(d) Synergistic Activities.

- Journal reviewer in Editorial Board for "Developmental Dynamics", 2005-2012.
- Active membership in professional scientific societies: American Society for Cell Biology (1992-Present); Society for Developmental Biology (2003-Present); Society for Advancement of Chicanos and Native Americans in Science (Life Member).
- Member in ASCB Minorities Affairs Committee (3 terms, completed in 2013); Member in SACNAS Council of Senior Advisors (COSA) 2012-2014; Past SACNAS Board Member (1996-98)
- Grant Review Panels: NIH F31 Pre-doctoral Fellowships, 2002; The Jeffress Trust Research in 2004; NSF Animal Development Review Panel, 2009; Ad Hoc Reviewer NSF.
- Mentoring Activities: Speaker, Institutional Research and Academic Career Development Awards (NIH-IRACDA) Conference in Kansas City, KS, 2006; Speaker, ASCB-MAC Junior Faculty and Postdoctoral Fellows Career Developmental Workshop held in Washington, DC, 2008, Chicago, IL, 2009, San Antonio, TX, 2012; Panel Speaker, "Insights to Success: Real-Life Adventures of SACNAS Scientists" 2011 SACNAS Annual Meeting; Co-chair, Cell Biology mini-symposia, SACNAS annual meetings 2009, 2010; SFSU faculty mentor in RISE, MARC, Bridges and REU student research programs; Faculty supervisor of the SFSU Cell and Molecular Imaging Facility
- URM Mentoring Awards: 2004 Crossing Borders Award, 4th Annual Border Learning Conference, El Paso, TX; 2009 SACNAS Presidential Service Award, Dallas, TX

(e) Collaborations and Other Affiliations

(i) Collaborators and Co-Editors

Carmen Domingo, Ph.D. Professor of Biology, San Francisco State University; Laura Burrus, Ph.D., Professor of Biology, San Francisco State University; Blake Riggs, Ph.D., Assistant Professor of Biology, San Francisco State University; Kwok-Siong Teh, Ph.D., Associate Professor of Engineering, San Francisco State University; Takashi Mikawa, Ph.D., Professor in Residence, UCSF School of Medicine; Walt Holleran, Pharm.D., Associate Adjunct Professor Dermatology, UCSF School of Medicine; Jon Fukuto, Ph.D., Department of Chemistry, Sonoma State University

(iii) Thesis Advisor and Research Sponsor

Former MS Students (Degree Awarded): Bryan Kuo (Ph.D. UC Davis); Gustavo Gomez (Ph.D. UC Los Angeles); Hanam Nguyen (Ph.D. Johns Hopkins); Emi Okada; Wendy Rosenthal; Matthew Carlos Smith; Seung Jong Lee; Farzad Ghamsari

Current Masters Thesis Advisor: Fernando Curiel (1st year masters student)

Current Undergraduates (>60 mentored): Noah Kipper; Anders Peterson; Alex Chong

Biographical Sketch
Carmen R. Domingo, Ph.D.

Professor and Associate Chair of Biology, San Francisco State University
1600 Holloway Ave, San Francisco, CA 94132
Phone: (415) 338-6995, cdomingo@sfsu.edu, http://biology.sfsu.edu/people/carmen-domingo

A. PROFESSIONAL PREPARATION

Univ. of California, Berkeley, Postdoctoral Fellow, comparative embryology, 1995-1997
Univ. of California, Berkeley, Ph.D. in Molecular and Cell Biology, 1989-1995
Univ. of California, Irvine, B.S. in Biological Sciences, 1983-1987

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

2008-Present	Professor, Department of Biology, San Francisco State University
2007-Present	Associate Chair, Department of Biology, San Francisco State University
2003-2008	Associate Professor, Department of Biology, San Francisco State University
1997-2003	Assistant Professor, Department of Biology, San Francisco State University Research: Early embryogenesis in Xenopus laevis
1995-1997	Postdoctoral Fellow, University of California, Berkeley. Research: Role of hormones in early amphibian embryogenesis.

C. PRODUCTS

#SFSU Undergraduate student; * SFSU Master's student; ~URM

i. Publications Most Closely Related to Proposal (max 5 papers)

~*Leal M.A., *Fickel SR, ~#Sabillo A, ~Ramirez J, *Martínez Vergara H, ~*Nave C, #Saw D, ~Domingo CR. 2013. The role of Sdf-1α signaling in *Xenopus laevis* somite morphogenesis. Dev Dyn. Nov 8. doi: 10.1002/dvdy.24092. PMID: 24357195

*Krneta-Stankic, V., ~# Sabillo, A. and ~Domingo, CR. 2010.The temporal and spatial patterning of axial myotome fibers in *Xenopus laevis. Dev Dyn* 239: 1162-1177. PMID:20235228

*Chu, FH., Afonin, B., Gustin, JK., #Bost A., #~Sanchez, M., and ~Domingo, CR. 2007. Embryonic cells depleted of β-catenin remain competent to differentiate into dorsal mesodermal derivatives. *Dev Dyn*, 236:3007-3019. PMID:17907203

Afonin, A., *Ho, M., Gustin, J.K., *~Meloty-Kapella, C., and ~Domingo, CR. 2006.Cell behaviors associated with somite segmentation and rotation in *Xenopus laevis*. *Dev Dyn,* 235:3268-3279. PMID:17048252

*Wunderlich, K., Gustin, J., and ~Domingo, CR**.** 2005. Muscle specification in the *Xenopus laevis*-gastrulation stage embryo. *Dev Dyn,* 233:1348-1358. PMID:15965978

ii. Other Significant Publications (max 5 papers)

*Dali, L.A., Gustin, J., *Perry, K. and ~Domingo, CR. 2002. Signals that instruct somite and myotome formation persist in the *Xenopus laevis* tailbud. *Cells Tissues Organs,* 172:1-12. PMID:12364823

Daggett, D. F., ~Domingo, CR, Currie, P.D., and Amacher, S.L. 2007. Control of morphogenetic cell movements in the early zebrafish myotome. *Dev Biol*, *309:169-179*. PMID:17689522

~Domingo, CR. and R. Keller. 2000. Cells throughout the gastrula remain competent to respond to mesoderm inducing signals present during gastrulation in *Xenopus laevis*. *Dev Biol,* 225:226-240. PMID:10964477

~Domingo, C**.** and Keller, R. 1995. Induction of notochord cell intercalation behavior and differentiation by progressive signals in the gastrula of *Xenopus laevis*. *Development,* 121:3311-3321. PMID:7588065.

Keller, R., Shih, J., and ~Domingo, C. 1992. The patterning and functioning of protrusive activity during convergence and extension of the *Xenopus* organizer. *Development Suppl. "Gastrulation"* (Stern, C. ed., 1992), 81-92. PMID:1299372

D. SYNERGISTIC ACTIVITIES

- ***Director of SFSU NSF REU program & Member of NSF-BIO REU Leadership Council***: Oversee all activities associated with this 10-week summer research program focused in ecological, evolution, and developmental biology at SFSU. To-date this program has trained 60 undergraduate students (URM = 35). As a member of the REU Leadership Council (2011-2015) I work with REU site directors to increase the success of BIO REU programs across the country.
- ***Director of the SFSU-CIRM Bridges to Stem Cell Research***: Oversee all activities associated with this master's program, which provides training to students in the area of stem cell biology in collaboration with UCSF, UCB, Stanford University, CHORI, and Buck Institute for Research on Aging. To-date 70 students (URM = 41) have been trained in this master's program.
- **Co-Leader of SF BUILD Student Training Core**: This is a new NIH funded program in collaboration with UCSF focused on training a diverse group of students interested in pursuing graduate studies in the field of biomedical research. I oversee the design and implementation of this new student training program.
- ***Associate Chair of Biology Department***: Responsible for implementing the department's course offerings as well as curricular innovations which support over 2400 undergraduate biology majors, 165 master-level students, and over 5000 undergraduate students associated with GE curriculum each semester. I also oversee the teaching responsibilities of approximately 40 faculty, 20 lecturers and 50 teaching assistants.
- ***Panelist:*** Currently serve as a member of the NIH TWD-D panel (2010-2015) which reviews NIH MBRS RISE, MARC, PREP, and IMSD (R25) as well as T36 and R13 proposals and the NIH NICHD panel (2015-2019) which reviews K99, R03, R13, and R15 proposals in the area of Developmental Biology. I have also served on panels for NSF (Div Integrative Organismal Systems, NSF Animal Developmental Biology).

E. COLLABORATIONS AND OTHER AFFILIATIONS

- **Thesis Advisor**: Dr. Ray Keller, Department of Biology, University of Virginia, VA
- **Post-doctoral Advisor**: Dr. Tyrone Hayes, Department of Integrative Biology, UC Berkeley, CA.

Shawn M. Douglas
Biographical Sketch

Department of Cellular and Molecular Pharmacology,
University of California, San Francisco
GH-S472C Box 2240

(a) Professional Preparation

Yale University	New Haven, CT	Computer Science	B.S.	2003
Harvard University	Boston, MA	Biophysics	Ph.D.	2009
Harvard University	Boston, MA	Bionanotechnology	Postdoc	2009–2012

(b) Appointments

2012–present	Assistant Professor, Cellular & Molecular Pharmacology, UCSF
2009–2012	Technology Fellow, Laboratory of G.M. Church, Wyss Institute, Harvard University
2004–2009	Graduate Student Researcher, Laboratory of W.M. Shih, Dana Farber Cancer Institute, Harvard University
2003–2004	Undergraduate Researcher, Laboratory of M.B. Gerstein, Yale University

(c) Products

(i) Closely Related

1. Douglas SM, Dietz H, Liedl T, Högberg B, Graf F, Shih WM. (2009). Self-assembly of DNA into nanoscale three-dimensional shapes. *Nature*, 459, 414-8. doi: 10.1038/nature08016.
2. Dietz H, Douglas SM, Shih WM. (2009). Folding DNA into twisted and curved nanoscale shapes. *Science*, 325, 725-30. doi: 10.1126/science.1174251
3. Douglas SM, Bachelet I, Church GM. (2012). A logic-gated nanorobot for targeted transport of molecular payloads. *Science*, 335, 831-4. doi: 10.1126/science.1214081
4. Douglas SM, Marblestone AH, Teerapittayanon S, Vazquez A, Church GM, Shih WM. (2009). Rapid prototyping of 3D DNA-origami shapes with caDNAno. *Nucleic Acids Research*, 37, 5001-6. doi: 10.1093/nar/gkp436
5. Dr. Douglas led development of CADNANO software for designing DNA origami structures and has made it publicly available for the development and progression of the field. In 2009, he launched http://cadnano.org/ to share the tool as open-source software. The site has had 30,000+ unique visitors and the software has been downloaded 8,000+ times.

(ii) Significant

1. Patent: WM Shih, SM Douglas, JJ Chou. WO/2007/127020. "Nucleic-acid-nanotube liquid crystals and use for NMR structure determination of detergent-solubilized membrane proteins".
2. Patent: SM Douglas, I Bachelet, GM Church. WO/2012/061719 "DNA origami devices".
3. Douglas SM, Chou JJ, Shih WM. (2007). DNA-nanotube-induced alignment of membrane proteins for NMR structure determination. *PNAS*, 104, 6644-8. doi: 10.1073/pnas.0700930104

(d) Synergistic Activities

1. Dr. Douglas collaborated with artist Jason Brown to create a whiteboard animation introduction to his research and posted it to YouTube. The animation is called "**What is Bionanotechnology?**" and is available at url http://youtu.be/ITtGJUGXFKc and has 50,000+ views 4 years following release. It introduces basic concepts and rationale for using the building blocks of life (DNA, proteins) to create nanotechnology applications, such as new scientific tools and next-generation therapeutics.

2. Dr. Douglas founded **BIOMOD**, a nanoscale design competition for undergraduate students. This competition was inspired by the International Genetically Engineered Machines (iGEM) competition at MIT. Students conceive and execute projects during the summer and then travel to Boston in November to present their work and win awards. During the first four years of the competition (2011–2014), over 800 undergraduate students, graduate students, and faculty mentors from 12 different countries have participated. Dr. Douglas manages the competition from UCSF. A description and recent highlights of the competition are available at http://biomod.net/.
3. Dr. Douglas collaborated with artist Jason Brown to create "**What is Biomod**?" a traditional frame-by-frame animation with cartoon "stick figure" characters. It is available at url http://youtu.be/dR31pBvMUV8 and has over 1350 views. The animation walks the viewer through a "virtual museum" tour of the Biomod competition to explain the contest requirements, including what deliverables each team is expected to produce, and the logistics of participating, such as fundraising and travel planning.
4. Dr. Douglas developed and co-taught a graduate-level course at UCSF called **Molecular Animation and Visualization** with Drs. Graham Johnson and Megan Riel-Mehan in Spring 2014. The course taught i) principles of effective visual communication, ii) tools for digital visualization, including 3D animation software, Photoshop, Illustrator, and compositing software, iii) esthetic best methods, including composition, modeling, texturing, lighting and effects, and iv) how to create a collection of professional-quality molecular visualizations by working through the entire production process, from script development and storyboarding to rendering and compositing.

(e) Collaborators & Other Affiliations

Collaborators (Total: 8)
Ido Bachelet, Bar-Ilan; James Chou, Harvard; Rhiju Das, Stanford; Hendrik Dietz, Technische Universität München; Björn Högberg, Karolinska Institutet; Tim Liedl, Ludwig-Maximilians-Universität München; Chenxiang Lin, Yale University; Hao Yan, Arizona State University

Graduate and Postdoctoral Advisors (Total: 2)
William Shih, Dana-Farber Cancer Institute, Harvard Medical School & Wyss Institute; George Church, Harvard Medical School & Wyss Institute

Postgraduate-Scholar Sponsor and Thesis Advisor (Total: 5)
Tural Aksel (current); Parsa Nafisi (current); Ngoc-Han Tran (current); Suraj Makhija (current); Brian O'Donovan (past)
Total Postgraduate scholars: 1
Total Graduate students: 3

Sophie Dumont
Biographical Sketch

University of California, San Francisco
513 Parnassus Ave, HSW-613, San Francisco, CA 94143-0512, USA
sophie.dumont@ucsf.edu ; http://dumontlab.ucsf.edu

a. Professional Preparation

Princeton University	Physics, *magna cum laude*	B.A., 1995-1999
University of Oxford, UK	Theoretical Physics	Candidate for D.Phil., 1999-2000
University of California, Berkeley	Biophysics	Ph.D., 2000-2005
Harvard University	Harvard Society of Fellows	Junior Fellow, 2006-2009
Harvard Medical School	Cell biophysics	Postdoctoral Fellow, 2006-2012

b. Appointments

7/2012-present Assistant Professor, Dept of Cell & Tissue Biology and Dept of Cellular & Molecular Pharmacology, University of California, San Francisco

c. Publications

(i) Five most closely related to proposal project

1) **Dumont S**, Prakash M. Emergent mechanics of biological structures. *Molecular Biology of the Cell* 25, 3461-3465 (2014).

2) Elting MW*, Hueschen CL*, Udy DB, **Dumont S**. Force on spindle microtubule minus-ends moves chromosomes. *Journal of Cell Biology* 206, 245-256 (2014).

3) Kuhn J, **Dumont S**. Imaging and physically probing kinetochores in live dividing cells. *Methods in Cell Biology* 123, 467-87 (2014).

4) **Dumont S**, Salmon ED, Mitchison TJ. Deformations within moving kinetochores reveal different sites of active and passive force generation. *Science* **337**, 355-358 (2012).

5) **Dumont S**, Mitchison TJ. Compression regulates spindle length by a mechanochemical switch at the poles. *Current Biology* **19***,* 1086-1095 (2009).

(ii) Five other significant publications

***equal contribution**

1) Wühr M, Chen Y, **Dumont S**, Groen AC, Needleman DJ, Salic A, Mitchison TJ. Evidence for an upper limit to mitotic spindle size. *Current Biology* **18**, 1-6 (2008).

2) Cheng W*, **Dumont S***, Tinoco I Jr, Bustamante C. NS3 helicase actively separates RNA strands and senses sequence barriers ahead of the opening fork. *PNAS* **104**, 13954-13959 (2007).

3) **Dumont S***, Cheng W*, Serebrov V, Beran RK, Tinoco I Jr, Pyle AM, Bustamante C. RNA unwinding mechanism of HCV NS3 helicase and its coordination by ATP. *Nature* **439**, 105-108 (2006).

4) Onoa B*, **Dumont S***, Liphardt J, Smith SB, Tinoco I Jr, Bustamante C. Identifying the kinetic barriers to mechanical unfolding of the T. thermophila ribozyme. *Science* **299**, 1892-1895 (2003).

5) Liphardt J, **Dumont S**, Smith SB, Tinoco I Jr, Bustamante C. Equilibrium information from nonequilibrium measurements in an experimental test of Jarzynski's equality. *Science* **296**, 1832-1835 (2002).

d. Synergistic Activities

• Women in academia/science:
- Seminar and discussion leader for sessions on applying for academic jobs (two-body problem, etc.) as a woman (Harvard Medical School 2011-2012, and American Society for Cell Biology 2011-on)
- Lunches, seminars and interviews with UCSF Women in Life Sciences group (2012-2014)

• Under-represented minorities in science: seminar and mentoring for UCSF Summer Research Training Program students (summer 2013-on)
• High school student outreach: introduction to Foldscope-based microscopy (Philadelphia high schools, Fall 2014)
• Science in developing countries, series of lectures to first year undergraduate science majors in a rural college in India (Bisalpur College, UP) to get them excited about the connection between physics, chemistry and biology (summer 2013)
• Grant review activity: ad hoc reviewer for European Research Council (ERC, 2014) and Medical Research Council (MRC, 2014)

e. Collaborators & Other Affiliations

(i) Collaborators and Co-Authors in the Past 48 Months

Zev Bryant, Department of Bioengineering, Stanford University
Timothy J. Mitchison, Department of Systems Biology, Harvard Medical School
Manu Prakash, Department of Bioengineering, Stanford University
Edward Salmon, Department of Biology, University of North Carolina, Chapel Hill
Ke Xu, Department of Chemistry, University of California, Berkeley

(ii) Graduate and Postdoctoral Advisors

Prof. Douglas Abraham, University of Oxford, Graduate Advisor
Prof. Carlos Bustamante, University of California, Berkeley, Graduate Advisor
Prof. Timothy Mitchison, Harvard Medical School, Postdoctoral Mentor

(iii) Thesis Advisor and Postgraduate-Scholar Sponsor

Three graduate students currently sponsored: Christina Hueschen (BMS), Jonathan Kuhn (Tetrad), Alexandra Long (Tetrad)
One postdoctoral scholar currently sponsored: Mary Elting

Hana El-Samad, Ph.D

Department of Biochemistry and Biophysics
University of California, San Francisco,
San Francisco, CA 94158
Hana.El-Samad@ucsf.edu

A. Professional Preparation

America University of Beirut, Lebanon	Electrical Engineering	BA	1998
Iowa State University, Ames	Electrical Engineering	MS	1999
University of California, Santa Barbara	Mechanical Engineering	PhD	2004

B. Appointments

07/13 – present	Associate Professor, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
05/08- 06/13	Assistant Professor, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
04/08- 11/05	Fellow, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)

C. Publications closely related to project

1. O. S. Venturelli, I.A. Zuleta, R.M. Murray and **H. El-Samad**, "Population Diversification in a Metabolic Program Promotes Anticipation of Environmental Shifts", *PloS Biology,* DOI:10.1371/journal.pbio.1002042 January 27, 2015.
2. I.A. Zuleta, A. Aranda-Diaz, H. Li and **H. El-Samad,** "Dynamic Characterization of Growth and Gene Expression Using High-Throughput Automated Flow Cytometry", *Nature Methods,* Volume 11, 443-448,2014 .
3. D. Pincus, A. Aranda-Diaz, I.A. Zuleta, P. Walter, and **H. El-Samad**, "A delayed Wave of Ras/PKA Signaling Augments the Unfolded Protein Response", *Proceedings of the National Academy of Sciences,* Volume 111, no. 4, pp. 14800-14805, 2014.
4. J. S-Ornstein, J. S. Weissman and **H. El-Samad,** "Cellular Noise Regulons Underlie Fluctuations in *Saccharomyces cerevisiae*", *Molecular Cell*, Volume 45, Issue 4, 483-493, 24 February 2012.
5. M-Argeitis, S. Summers, J. S-Ornstein, I. Zuleta, D. Pincus, **H. El-Samad*,** M. Khammash*, J. Lygeros*, "In silico Feedback for *in vivo* Regulation of a Gene Expression Circuit", *Nature Biotechnology*, Vol. 29, 1114-1116, 2011. ** co-corresponding authors listed in alphabetical order*

Other Publications

1. Q.A. Justman, Z. Server, J.E. Ferrell Jr., **H. El-Samad***, and K.M. Shokat*, "Tuning the Activation Threshold of a Kinase network by Nested Feedback Loops*, Science,* Vol. 324, No. 5926, 509-512, 2009. *Co-corresponding authors.
2. D. Pincus, M.W. Chevalier, T. Aragon, E. Van Anken, S. Vidal, **H. El-Samad*** and P. Walter*, "BiP Binding to the ER sensor Ire1 Buffers the Homeostatic Regulation of the Unfolded Protein Response", *PLoS Biol*. Vol. 8, No. 7, e1000415*,* 2010. *Co-corresponding authors
3. E. McCullagh, A. Seshan, **H. El-Samad*,** and H. Madhani*, "Coordinate Control of Gene Expression Noise and Interchromosomal Interactions in a MAP Kinase Pathway", *Nature Cell Biology,* 12(10):954-62, 2010. *Co-corresponding authors
4. M. Chevalier and **H. El-Samad,** "A Data-Integrated Method for Analyzing Stochastic Biochemical Networks with Applications to Synthetic Biology", *J. Chemical Physics,* 135,

214110, 2011.

5. M. Chevalier and **H. El-Samad**, "Toward a Minimal Stochastic Model for a Large Class of Diffusion-Reactions on Biological Membranes", *J. Chemical Physics,* 137, 084103, 2012.

Honors and Awards

1994-1998	Dean's Honor List
1999	Finalist: Best Master's Thesis Award in Electrical Engineering
2006	Best PhD dissertation award, Mechanical Engineering, University of California, Santa Barbara
2008	Grace Boyer Junior Faculty Endowed Chair in Biochemistry and Biophysics
2009	David and Lucille Packard Foundation Fellow
2011	Donald P. Eckman Award for "Novel applications of Control Theory in the analysis and synthesis of complex biological systems
2012	CSB^2 Prize in Systems Biology (Merrimack Pharmaceuticals and the Council for Systems Biology in Boston)
2013	Paul Allen Family Distinguished Investigator

D. Synergistic Activities

- Faculty mentor for the UCSF iGem team, 2007-2009
- Developer of the Systems Biology Curriculum at UCSF.
- Member of the diversity committee at UCSF.
- Member of the IEEE, Women in Engineering and Women in Control Association
- Referee and session organizer for IEEE Conference on Decision and Control, American Control Conference, International Conference on Systems Biology, Proceedings of the National Academy of Sciences, Biophysical Journal, Journal of Molecular Biology, Science, Nature, Cell.
- Member of editorial board of Cell Reports.

Collaborators & Other Affiliations

(a) Collaborators and Co-Editors

UCSF: Hiten Madhani, Peter Walter, Hao Li, Alexander Johnson, Wendell Lim, Jonathan Weissman

Other institutions: Richard Murray (Caltech)

Co-editors: Chris Voigt (MIT), Michael Elowitz(Caltech) and Jeff Hasty (UCSD).

(b) Graduate and Postdoctoral Advisors

Ph.D. advisor Mustafa Khammash ETH, Zurich

(c)Thesis Advisor and Postgraduate-Scholar Sponsor

Current and former graduate students (total 13):	Kieran Mace, Charles Biddle-Snead, Susan Chen, Patrick Harrigan, Graham Heimberg, Benjamin Heineike, Joanne Lipinski-Kruszka, Ophelia Venturelli, Richard Oberdorf, Jacob Stewart-Ornstein, David Pincus, Jordi Sylvester-Ryan, and Alain Bonny.
Current and former postdoctoral fellow (total 6):	Raj Bhatnagar, Michael Chevalier, Joao Fonseca, Ignacio Zuleta, David Camarillo, and Cihan Oguz.

BIOGRAPHICAL SKETCH

Dr. Raymond Manuel Esquerra
San Francisco State University
esquerra@sfsu.edu; 415-338-3444

Professional Preparation:

Stanford University, Stanford CA,	Physics	BS	1990
University of California, Santa Cruz, CA	Chemistry	PhD	1998
University of California, Santa Cruz, CA	Biophysics	Postdoc	1998-2000

Appointments:

Professor, San Francisco State University, 2011 – present
Visiting Research Scientist, University of California, Santa Cruz, 2009– present
Associate Professor, San Francisco State University, 2006 – 2011
Visiting Associate Professor, University of California, Santa Cruz, 2007
Assistant Professor, San Francisco State University, 2000- 2006

Publications:

1. Five Publications most Project Related

a. R.A. Goldbeck, R.M. Esquerra, D.S. Kliger, J.M. Holt, and G.K. Ackers. 2004. "The molecular code for hemoglobin allostery revealed by linking the thermodynamics and kinetics of quaternary structural change. 2. Cooperative free energies of (alphaFeCObetaFe)2 and (alphaFebetaFeCO)2 T-state tetramers." *Biochemistry* 43:12065-12080.
b. R.A. Goldbeck, S. Bharaskaran, C. Ortega, J.L. Mendoza, J.S. Olson, D.S Kliger, and R.M. Esquerra. 2006. "Kinetic Competition Between Ligand and Water Entry in Sperm Whale Myolgobin: Assessing the Speed and Extent of Heme Pocket Hydration after CO photolysis." *Proc Natl Acad Sci U. S. A*. 103:1254-9.
c. R.M Esquerra, R.A. Jensen, S. Bhaskaran, M.L. Pillsbury, J.L. Mendoza, B.W. Lintner, D.S. Kliger, and R.A. Goldbeck. 2008. "The Ph Dependence Of Heme Pocket Hydration And Ligand Rebinding Kinetics In Photodissociated Carbonmonoxymyoglobin". *J Biol Chem.* 283:14165-75.
d. R.A. Goldbeck, M.L. Pillsbury, R.A. Jensen, J.L. Mendoza, R.L. Nguyen, J.S. Olson, J. Soman, D.S. Kliger, and R.M. Esquerra. 2009, "Optical detection of disordered water within a protein cavity." *J Am Chem Soc*. 131:12265-72.
e. R.M. Esquerra, I. López-Peña, P.Tipgunlakant, I. Birukou, R.L. Nguyen, J. Soman, J.S. Olson, D.S. Kliger, and R.A. Goldbeck. 2010. "Kinetic Spectroscopy of Heme Hydration and Ligand Binding in Myoglobin and Isolated Hemoglobin Chains: An Optical Window into the Functional Dynamics of Water in the Heme Pocket." *Phys. Chem. Chem. Phys.* 12:10270-8.

2. Five Other Significant Publications

a. R.M. Esquerra, R.A. Goldbeck, S. Reany, A.M. Batchelder, J.W. Lewis, Y. Wen, and D.S. Kliger. 2000. Multiple geminate recombination in Hemoglobin. *Biophysical Journal*. (2000) 39: 7145-7192.
b. R.A. Goldbeck, R.M Esquerra, and D.S. Kliger. 2002. "Hydrogen bonding to Trp beta37 is the first step in a compound pathway for hemoglobin allostery". *J Am Chem Soc* 124:7646-7647.
c. Y. Wang, Y., A. Suzuki, M. Pastore, R.M. Esquerra, and N.C. Geber. 2005. "Expression Isolation, and Characterization of Cytochrome P450fas." *Proceedings of the 14th International Conference on Cytochromes P450: Biochemistry, Biophysics and Bioinformatics.* Medimond S.r.l., Bologna, Italy 14:145-150.
d. D.L. Mendez, R.A. Jensen, L.A. McElroy, J.M. Pena, and R.M. Esquerra. 2005. "The Effect of Nonenzymatic Glycation on the Unfolding of Human Serum Albumin." *Arch Biochem Biophys. 444:92-9.*
e. C.L. Leasure, H. Tong, X. Hou, A.S. Shelton, M.R. Minton, R.M. Esquerra, Z-H He. 2011. "A Novel Role of an Aspartate Aminotransferase in Vitamin B6 Homeostasis." *Molecular Plant. 1:1–12.*

Synergistic Activities

- **Student training and broadening the participation of groups underrepresented in STEM fields.** I am committed to student training in biomedical research at all levels and integrate my own research activities with training the next generation of ethnically diverse biomedical scientists. San Francisco State University is a highly diverse urban comprehensive university committed to excellence and to increasing diversity in STEM disciplines. I serve as co-Program Director for our NIH-funded minority access to research careers (MARC) program (20 MARC scholars) and serve on the advisory board for both our NIH Bridges and NIH RISE programs. I direct (SFSU-PI) the teaching component of the UCSF/SFSU STRIDE program (NIGMS-IRACDA postdoctoral training grant). I have also served on the Executive committee for the Beckman Scholars program. I am currently the chair of the NIH TWD-C study section which evaluates NIGMS funded student training programs. I have an active research laboratory with six graduate (5 URM) and twelve undergraduate (8 URM) students. Since 2008, 39 students I have trained have graduated and 26 of those are URM. Of those 39 graduating, thirty have entered PhD programs. Sixteen of those 26 URM students enrolled in PhD programs (e.g. Washington University St. Louis, UCSD, Harvard, UC Davis, UT Southwestern, Purdue, U. Oregon and NYU) and four more are applying to PhD programs this fall. Most of those entering PhD programs enter programs in biophysics.
- **Biophysics Education:** In addition to the student research training, I have helped developed a molecular biophysics (CHEM 443) course which combines computational and biophysical methods to describe the effect of site-directed mutagenesis on myoglobin. This course is offered yearly and serves 14 students per year. I have also reviewed physical chemistry text books, including texts by Raymond Chang and Robert Gennis.

Collaborators & Other Affiliations

Collaborators & Co-Editors (within 4 years): Professor Anton Guliaev (SFSU), Professor Nancy Gerber, (SFSU), Professor Zheng-Hui He (SFSU), Professor Olof Einarsdóttir (UCSC), Professor John Olson (Rice University). Professor David Kliger (UCSC).

Graduate Advisors & Postdoctoral Sponsors:

Graduate Advisor: David S. Kliger, University of California, Santa Cruz, CA

Postdoctoral Appointment: David S. Kliger, University of California, Santa Cruz, CA

Thesis Advisor & Research Sponsor, Former & current undergraduate and MS Students: George Imperial, Cheri Ortega, Tammy Tamayo, Tina Ngyuen, Darlene Pederson, Hal Paterson, Maia Carnevalli, Le-Xian Diec, Matt Pitts, Juan Mendoza, Shyam Bharaskaran, Kyle Chipman, Micheal Lau, Deanna Mendez, Erin Rohde, Stephanie Garcia, Jose Pena, Jimmy Hernandez, Laura McElroy, Arthur De Los Reyes, Alejandra Cavazos, Ezekiel Talbot-Melquist, Danny Tabari, Latevi Lawson, Marlisa Pillsbury, Khin Oo, Khinsandi Shine, Chantal Smith, Ayako Suzuki, Bess-Carolina Dolmo, Jessica Reyes, Russell Jensen, Richelle Raagas, AyeAung, Bjorn Fox, Maria Yabut, Nancy Hua, Yumi Wantabee, Ben Lintner, Elizabeth Juarez, Luiz Galdino, Kay Saw, Damon Robles, Ignacio Lopez, Yadiel Kinfu, Mike Minton, Christopher Bernt, April Ranney, Lea Marcias, Pooncharas Tipgunlant, Marcos Guimaraes, Emelia Padilla, Ben Rodriquez, Daniel Asarnow, Natalie Davis, Ai Sasho, Diego Baptisa, Tseboat Berkaki, Aaron Whitlach, Rodriquo Qunitero, Wes Salameh, Tsebaot Baraki, Bradley Schaller, Troy Lowe, Irina Volosko, Sylvia Wojdyla, Susie Calhoun, Apurwa Sharma, April Toledo, David Poole, Arieo Hasemi, Dagim Legasse, Marco Monroy, Andrea Coleman, Jessica Bow, Kevin Tran, Adriana Garcia, Pilar Malari, Min Seo, Lara Manimbao, Emily Zepada, Bushra Bibi, Jee-Young Kim, Richard Lauman, Issa Esaid.

DANIEL A. FLETCHER

Bioengineering & Biophysics, University of California, Berkeley

(a) Professional Preparation

Stanford University School of Medicine	Biochemistry & Physics	Postdoc	2001-02
Stanford University	Mechanical Engineering	Ph. D.	2001
Oxford University	Engineering Science	D. Phil.	1997
Princeton University	Mechanical Engineering	B.S.	1994

(b) Appointments

2011- Associate Chair, Department of Bioengineering, UC Berkeley
2010- Professor, Department of Bioengineering, UC Berkeley
2008- Deputy Director, Physical Biosciences Division, Lawrence Berkeley National Lab
2007–10 Associate Professor, Department of Bioengineering, UC Berkeley
2003- Faculty Scientist, Physical Biosciences Division, Lawrence Berkeley National Lab
2003- Member, Nanoscale Science & Engineering Graduate Group, UC Berkeley
2002- Faculty Affiliate, California Institute for Quantitative Biomedical Research
2002- Member, Bioengineering Graduate Group, UCSF/UC Berkeley
2002- Member, Biophysics Graduate Group, UC Berkeley
2002–07 Assistant Professor, Department of Bioengineering, UC Berkeley

(c) Publications

(i) List of 5 publications most closely related to the proposed project:

Vahey MD, Fletcher DA. The biology of boundary conditions: cellular reconstitution in one, two, and three dimensions. Curr Opin Cell Biol. 2014 Feb;26:60–68.

Good MC, Vahey MD, Skandarajah A, Fletcher DA, Heald R. Cytoplasmic volume modulates spindle size during embryogenesis. Science. 2013 Nov 15;342(6160):856–860.

Stachowiak JC, Schmid EM, Ryan CJ, Ann HS, Sasaki DY, Sherman MB, Geissler PL, Fletcher DA, Hayden CC. Membrane bending by protein-protein crowding. Nat Cell Biol. 2012 Sep;14(9):944–949.

Risca VI, Wang EB, Chaudhuri O, Chia JJ, Geissler PL, Fletcher DA. Actin filament curvature biases branching direction. Proc Natl Acad Sci USA. 2012 Feb 21;109(8):2913–2918.

Richmond DL, Schmid EM, Martens S, Stachowiak JC, Liska N, Fletcher DA. Forming giant vesicles with controlled membrane composition, asymmetry, and contents. Proc Natl Acad Sci USA. 2011 Jun 7;108(23):9431–9436.

(ii) List of 5 other significant publications:

Webster KD, Ng WP, Fletcher DA. Tensional homeostasis in single fibroblasts. Biophys J. 2014 Jul 1;107(1):146–155.

Brownfield DG, Venugopalan G, Lo A, Mori H, Tanner K, Fletcher DA, Bissell MJ. Patterned collagen fibers orient branching mammary epithelium through distinct signaling modules. Curr Biol. 2013 Apr 22;23(8):703–709.

Lam WA, Chaudhuri O, Crow A, Webster KD, Li T-D, Kita A, Huang J, Fletcher DA. Mechanics and contraction dynamics of single platelets and implications for clot stiffening. Nat Mater. 2011 Jan;10(1):61–66.

Chaudhuri O, Parekh SH, Lam WA, Fletcher DA. Combined atomic force microscopy and side- view optical imaging for mechanical studies of cells. Nat Methods. 2009 May;6(5):383–387.

Liu AP, Richmond DL, Maibaum L, Pronk S, Geissler PL, Fletcher DA. Membrane-induced bundling of actin filaments. Nat Phys. 2008 Aug 31;4:789–793.

(d) Synergistic Activities

(i) MBL Physiology Course Instructor: I serve as an Instructor in the summer Physiology Course at the Marine Biology Laboratory in Woods Hole, MA, which teaches graduate students and postdoctoral fellows quantitative methods in cell and molecular biology.

(ii) Practical Light Microscopy: I teach a new lecture and laboratory course on Optics and Microscopy that introduces the fundamentals of optics and image formation and describes the use of optical microscopy as a tool for investigation of cells and molecules.

(iii) CellScope: My laboratory developed CellScope, a compact, cell-phone based microscope for disease diagnosis in developing countries.

(iv) Microscopy for elementary education: My laboratory developed a set of iPad-based microscopes for an elementary education program at the California Academy of Sciences.

(v) White House Fellow: I served as a White House Fellow in the Office of Science and Technology Policy in the White House advising on biotechnology and biosecurity issues.

(e) Collaborators & Other Affiliations

(i) Collaborators & Co-Editors: A. P. Arkin (UC Berkeley), C. Bertozzi (UC Berkeley), M. J. Bissell (LBL), W. Z. Cande (UC Berkeley), S. C. Dawson (UC Davis), M. Francis (UC Berkeley), P. L. Geissler (UC Berkeley), R. Heald (UC Berkeley), Richard Mathies (UC Berkeley), S. Mitragotri (UC Santa Barbara), Dyche Mullins (UCSF), Thomas Nutman (NIH), J. A. Theriot (Stanford), Orion Weiner (UCSF)

(ii) Graduate Advisors: K. E. Goodson, G. S. Kino, and C. F. Quate (Stanford)

Postdoctoral Sponsors: J. A. Theriot and T. I. Smith (Stanford)

(iii) Thesis Advisor (18 total): Matthew Bakalar (UC Berkeley), Carmen Chan (UC Berkeley) Ovijit Chaudhuri (Stanford), Ailey Crow (Stanford), Keith Erickson (Georgia Gwinnett College), Wendy Hansen (University of Washington), Pamela Jreij (UC Berkeley), Allen Liu (University of Michigan), Win Pin Ng (L'oreal, Singapore), Sapun Parekh (Max Planck Institute), David Richmond (Max Planck Institute), Viviana Risca (Stanford), Mike Rosenbluth (Veracyte, Inc.), Arunan Skandarajah (UC Berkeley), Neil Switz (Evergreen State College), Asa Tapley (UC Berkeley/UCSF) Gautham Vanugopalan (US Department of State), Kevin Webster (McKinsey & Co.)

Postgraduate-Scholar Sponsor (20 total): Dr. Brian Belardi (UC Berkeley), Dr. Peter Bieling (UC Berkeley), Dr. Mike D'Ambrosio (UC Berkeley), Dr. Alba Diz-Muñoz (UC Berkeley and UCSF), Dr. Erik Douglas (CellScope, Inc.), Dr. Matthew Good (University of Pennsylvania), Dr. Andrew Harris (UC Berkeley), Dr. Wilbur Lam (Georgia Tech & Emory University), Dr. Tai-De Li (Georgia Institute of Technology), Dr. Lutz Maibaum (University of Washington), Dr. Lina Nilsson (UC Berkeley Blum Center), Dr. Sander Pronk (Stockholm University), Dr. Ben Ricca (UC Berkeley) Dr. Ross Rounsevell (Sanger Institute, UK), Dr. Eva Schmid (UC Berkeley), Dr. Joshua Shaevitz (Princeton University), Dr. Jeanne Stachowiak (UT Austin), Dr. Sungmin Son (UC Berkeley) Dr. Martijn van Duijn (Erasmus MC), Dr. Mike Vahey (UC Berkeley)

Jennifer Frazier
Project Director
Exploratorium

(a) Professional Preparation

University of California, Davis	Genetics and Ethics	B.S.	1994
University of California, San Francisco	Cell Biology	Ph.D.	1999

(b) Appointments

2010-present	Project Director and PI, Living Liquid and other Life Science exhibition projects
2007-2010	Project Director, Visualization Laboratory, Exploratorium, San Francisco, CA
2004-2007	Exhibit Developer, *Microscope Imaging Station*, Exploratorium, San Francisco, CA
2003	Lecturer, Division of Molecular & Cellular Biology, UCDavis
2001-2003	Genetics Exhibition Consultant, *Putting DNA to Work* at Koshland Museum of Science; *Genetics: Technology with a Twist* at Tech Museum
2000-2001	Vice President of Content Development, Science Interactive Learning, San Francisco, CA
1999-2000	Associate Producer, National Academy of Sciences, Washington, D.C.

(c) Publications

(i) **five publications most closely related to proposed project**

Ma, Kwan-Liu, Isaac Liao, Jennifer Frazier, Helwig Hauser, Helene-Nicole Kostis. 2012. Scientific Storytelling Using Visualization. *Computer Graphics and Applications IEEE* 32, no. 1 : 12-19.

Ma, J., Liao, I., Ma, K. L., & Frazier, J. (in press). Living Liquid: Design and Evaluation of an Exploratory Visualization Tool for Museum Visitors. *IEEE Transactions on Visualization and Computer Graphics*.

(ii) five other significant publications

Hawley, R. S., Frazier, J. A., and Rasooly, R. 1994. Separation Anxiety: the Etiology of Nondisjunction in Flies and People. *Human Molecular Genetics*. 3:1521-28.

Frazier, J. A., and Field, C. M. 1997. Actin Cytoskeleton: Are FH Proteins Local Organizers? *Current Biology*. 7: 414-17.

Frazier, J. A., Wong, M. L., Longtine, M. L., Pringle, J., Mann, M., Mitchison, T. J., and Field, C. M. 1998. Polymerization of Purified Yeast Septins: Evidence That Organized Filament Arrays May Not Be Required for Function. *Journal of Cell Biology*. 143: 737-49.

Frazier, J. A. 1999. In Brief: Novel Functions for Adhesion Molecules; PINCH Proteins at Adherens Junctions; Roles for Coronin in the Actin, and Possibly Microtuble, Cytoskeleton. *Journal of Cell Biology*. 1144: 1-2.

(d) Synergistic Activities

Principal Investigator:

- *Ocean Observatory: Engaging the Public with Ocean Tools and Data.* Gordon and Betty Moore Foundation, 11/2011 – 03/2014, $1,800,000 – Co-PI
- *Ocean Observatory: Engaging the Public in Tools and Data from Marine Research*. Gordon and Betty Moore Foundation, 4/2014 – 10/2015, $1,200,000
- *Living Liquid: Creating Interactive Visualization Tools to Explore Large Ocean Datasets*. NSF 1322828, 10/2013 – 10/2016, $1,600,000

- *Living Liquid: A Pathways Project Visualizing the Ocean's Microbes and Their Impact on Our Planet* NSF 1011084, 8/2010 – 7/2011, $216,640

Interdisciplinary teaching in cell biology: Upper Division Cell Biology Course, University of California at Davis: Lecturer 2003. Physiology Course, Marine Biological Lab, Woods Hole MA: Instructor 2009-2013, Co-Director 2014 - present. UCSF: Developed graduate level minicourse on "cellular cognition" exploring the computational capacity of living cells using hands-on project based learning in 2012, 2014.

Meeting Organization: On the Scientific Program Committee for the AAAS Annual Meeting from 2014 – 2016; Organized a workshop on visualizing nanoscale science in 2010.

Grant review activity: Member NSF AISL review panels in 2003, 2012, 2014, and 2015; Gordon and Betty Moore SPARK Competition Panelist in 2014.

(e) Collaborators and Affiliations

Collaborators and co-editors:
Kwan-Liu Ma (UCD), Isaac Liao (Stanford), Helwig Hauser (University of Bergen), Helene-Nicole Kostis (GESTAR), Joyce Ma (Exploratorium), Kristina Yu (Exploratorium), Mick Follows (MIT), Stephanie Dutkiewicz, (MIT), Barbara Block (Stanford), James Cloern (USGS).

Graduate and postdoctoral advisors: Timothy Mitchison, Ph.D.

Biographical Sketch
Fung, Jennifer Carol

Assistant Professor – Obstetrics, Gynecology and Reproductive Sciences
Adjunct Assistant Professor – Biochemistry and Biophysics
University of California, San Francisco
600 16th St., GH N412B
San Francisco, CA 94158
Tel. (415) 514-4309
Email: jennifer.fung@ucsf.edu

(a) Professional Preparation

University of California, Berkeley	B.A.	12/87	Biophysics
University of California, San Francisco	Ph.D.	12/96	Biophysics
Yale University, New Haven CT	Postdoc	4/97-8/03	Genetics

(b) Appointments

2013 -	Director, Computational Biology Core, Center for Reproductive Science UCSF
2009 –	Assistant Professor, Dept. of Obstetrics, Gynecology and Reproductive Sciences, Center of Reproductive Sciences, University of California, San Francisco
2003 – 2009	UCSF Fellow, Dept. of Biochemistry and Biophysics, University of California, San Francisco

(c) Publications

Five most relevant to this proposal

1. Fung JC, Marshall WF, Dernburg AF, Agard DA, Sedat JW. 1998. Homologous chromosome pairing in Drosophila melanogaster proceeds through multiple independent interactions. ***J. Cell Biol***. 141: 5-20.

2. Fung JC, Liu W, Deruijter WJ, Chen H, Abbey C, Sedat JW, Agard DA. 1996. Towards fully automated high resolution electron tomography. ***J. Struct. Biol***. 116: 181-189.

3. Rafelski, S.M., Viana, M.P., Chan, Y.M., Thorn, KS., Yam, P., Fung, J.C., Li, H., da F. Costa, L, and Marshall, W.F. 2012. Mitochondrial network size scaling in budding yeast is achieved in the bud at the expense of the mother. ***Science***. 338, 822-4.

4. Arigovindan M, Fung JC, Elnatan D, Mennella V, Chan YH, Pollard M, Branlund E, Sedat JW, Agard DA. 2013. High-resolution restoration of 3D structures from widefield images with extreme low signal-to-noise ratio. ***Proc. Natl. Acad. Sci. U.S.A.*** 110, 17344-9.

5. Oke A, Anderson CM, Yam P, Fung JC. 2014. Controlling meiotic recombinational repair – specifying the roles of ZMMs, Sgs1 and Mus81/Mms4 in crossover formation. ***PLoS Genetics***. 10: e1004690.

Other significant publications:

6. Fung JC, Rockmill B, Odell M, Roeder GS. 2004. Imposition of crossover interference through the nonrandom distribution of synapsis initiation complexes. ***Cell*** 166: 795-802.

7. Chen SC, Tsubouchi T, Rockmill B, Sandler J, Richards D, Vader G, Hochwagen A, Roeder GS, and Fung JC. 2008. Global Analysis of the Meiotic Crossover Landscape. ***Dev. Cell.*** 15: 401-415.

8. Anderson CM, Chen SY, Dimon MT, Oke A, DeRisi JL, Fung JC. 2011. ReCombine: a suite of programs for detection and analysis of meiotic recombination in whole-genome datasets. ***PLoS One*** 6, e25509.

9. Rockmill BM, Lefrancois P, Voelkel-Meiman Oke A, Roeder GS, Fung, J.C. 2013. High Throughput Sequencing Reveals Alterations in the Recombination Signatures with Diminishing Spo11 Activity. ***PLoS Genetics*** 9:e1003932.

10. Liu Y, Gaines W, Callender T, Oke A, Busygina V, Fung JC, Sung P, Hollingsworth NM. 2014. Down-regulation of Rad51 Activity During Meiosis in Yeast Prevents Competition with Dmc1 for Repair of Double-Strand Breaks ***PLoS Genetics*** 10:e1004005

(d) Synergistic Activities

- Development of computational statistics tools to analyze patterns of recombinational events genome-wide in large datasets.
- Curriculum development and teaching for the Biological Regulatory Mechanisms graduate course, and the Microscopy course at UCSF
- Mentor, Science Research Training Program at UCSF, 2009 - present
- Mentor, Women's Health Undergraduate Research Internship, which provides summer research experiences to female undergraduate students interested in women's health, with emphasis on first-time college attendees and minorities.
- Outreach presentations to regional institutions to recruit underrepresented undergraduate minorities for the Science Research Training Program summer undergraduate program at UCSF

(e) Collaborators and Other Affiliations

Collaborators and co-editors:
David Agard (UCSF), Elizabeth Blackburn (UCSF), Andreas Hochwagen (NYU, NY), Nancy Hollingsworth (Stony Brook University), Amy MacQueen (Wesleyan College, CT), Alain Nicolas (Pasteur Institute, Paris, France), Susan Rafelski (UC Irvine) Shirleen Roeder, John Sedat (UCSF), Peter Walter (UCSF)

Graduate and Postdoctoral Advisors: Thesis: John Sedat and David Agard, University of California, San Francisco. Postdoctoral Studies: G. Shirleen Roeder, Yale University, CT

Thesis advisor and postgraduate scholar sponsor: Carol Anderson (postdoctoral fellow), Stacy Chen (graduate student, currently Associate Dean, Dharma Realm Buddhist University). Total number supervised = 2.

Clive Hayzelden
Biographical Sketch

a. Professional Preparation

University of Sussex	Materials Science	B.Sc.,	1978
University of Sussex	Physical Metallurgy	D.Phil.,	1984
Oxford University	Postdoctoral Research Assistant		1981-1983
Oxford University	SERC Postdoctoral Fellow		1984-1985

b. Appointments

2011- Director, Electron Microscopy Facility, San Francisco State University
2007-2010 Manager, Carl Zeiss Center of Excellence in Electron Microscopy, UC Irvine
2001-2006 President, Hayzelden Research Group Inc.
1997-2001 Senior Manager, KLA-Tencor Corporation
1995-1997 Director, UltraTest International
1989-1995 Research Collaborator, IBM Corporation, T.J. Watson Research Centre
1989-1995 Research Associate, Materials Science, Harvard University
1985-1989 Assistant Professor, Materials Science, Harvard University

c. Publications

(i) Five most closely related to proposal project

New Program (April 2015). Collaboration with Jeffrey O. Bush using correlative microscopy (Confocal and FESEM) to study the basic mechanisms by which signaling between cells leads to facial deformities.

(ii) Most-Cited Journal Publications

1. Hayzelden, C., and Batstone, J.L., Silicide Formation and Silicide-Mediated Crystallization of Ni-Implanted a-Si Thin Films. J. Appl. Phys. 73 (12), 8279, (1993), [484]
2. Hayzelden C., Batstone J.L., and Cammarata R.C., In Situ TEM Studies of Silicide-Mediated Crystallization of Amorphous Silicon, Appl. Phys. Lett. 60 (2), 225, (1992), [196]
3. Cammarata R.C., Thompson C.V., Hayzelden C., and Tu K.N., Silicide Precipitation and Silicon Crystallization in Ni-Implanted a-Si Thin Films, J. Mat. Res., 5, 2133, (1990), [103]
4. Hayzelden C., Rayment J. J., and B. Cantor B., Rapid Solidification Microstructures in Austenitic Fe-Ni Alloys, Acta. Metall., 31, 379, (1983), [58]
5. Hayzelden C., and Cantor B., The Martensite Transformation in Fe-Ni-C Alloys, Acta Metall., 34 (2), 233, (1986), [34]

d. Synergistic Activities

1. Principal Conference Organizer: "Electron Microscopy of Semiconducting Materials and ULSI Devices", Eds., C. Hayzelden, C. Hetherington and F. Ross, Proc. Mat. Res. Soc. **532**, (1998)
2. Co-organizer (with J.L. Batstone) of American Physical Society Focused Session: Atomic Structure at Interfaces, and Session Chair: "Interfacial Reactions," March Meeting, Indianapolis, Indiana 1992
3. Minority High School Outreach: Annual Electron Microscopy Demonstrations to Sixty Oakland High Schools Students
4. Co-Teaching BIOL-741 (Electron Microscopy) at SFSU
5. Guest Lectures for BIOL-784 (Cell Cultures and Stem Cell Techniques)

e. Collaborators & Other Affiliations

(i)Collaborators

A.S. Ichimura, Department of Chemistry and Biochemistry, San Francisco State University
J.O. Bush, Cell and Tissue Biology, University of California at San Francisco, School of Dentistry

(ii) Graduate and Postdoctoral Advisors
Professor Brian Cantor CBE, Vice Chancellor Bradford University

(iii) Thesis Advisor and Postgraduate-Scholar Sponsor
R. Nikolic, Dynamic Growth of Anti-Plane Shear Cracks in Ideally Plastic Crystals, Ph.D. Harvard University, 1988
J. D. Beyeler, The Influence of Rock Properties on Bedrock and Sediment Erodibility in Rivers, M.Sc. San Francisco State University, 2012
M. Sanchez, A Study of the Crystal Structure of Oriented {001} Anatase Thin Films via Electron Backscattered Diffraction, M.Sc., Department of Chemistry and Biochemistry, San Francisco State University, 2014
D.G. Mars, M.Sc., Department of Chemistry and Biochemistry, San Francisco State University, (Expected Completion 2015)
B. Hill, M.Sc., Department of Chemistry and Biochemistry, San Francisco State University, (Expected Completion 2015)
B.W. Aldridge, M.Sc., Department of Chemistry and Biochemistry, San Francisco State University, (Expected Completion 2015)
M.S. Martinez, M.Sc., Department of Chemistry and Biochemistry, San Francisco State University, (Expected Completion 2015)

Biographical Sketch
Manu Prakash

Assistant Professor, Dept. of Bioengineering, Stanford manup@stanford.edu; www.stanford.edu/~manup
443 Via Ortega, Stanford, CA, 94305 617-820-4811

A. PROFESSIONAL PREPARATION

College/University	Major	Degree &Year
Indian Institute of Technology, Kanpur	Computer Science	B.Tech., 1998-2002
Massachusetts Institute of Technology	Media Arts and Sciences	PhD, 2002-2008
Harvard University	Physics	2008-2011

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

Assistant Professor, Dept. of Bioengineering, Stanford	(2011-present)
Junior Fellow, Harvard Society of Fellows	(2008-2011)

C. PUBLICATIONS (5 most relevant)

1. Katsikis G., Cybulski J., **Prakash M.,** Synchronous Universal Droplet Logic and Control, Nature Physics, *in press* June 2015.
2. Cira N., Benusiglio A., **Prakash M.**, Vapor mediated sensing and motility in two-component droplets, Nature, vol. 519, 446-450, 2015 http://dx.doi.org/10.1038/nature14272
3. Korir G.**, Prakash M.** Punch Card Programmable Microfluidics. PLoS ONE vol. 10(3), 1-17 2015 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0115993
4. Dumont S., **Prakash M**. Emergent mechanics of biological structures, Molecular biology of the cell 25, vol.. 22, 3461-3465 , 2014 http://www.molbiolcell.org/content/25/22/3461.short
5. Cybulski, J., Clements J., and **Prakash M**. Foldscope: Origami-based paper microscope, PloS ONE vol. 9(6), 1-11, 2014 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0098781

Other Significant Publications

1. Ephraim R., Duah E., Cybulski J., **Prakash M**., D'Ambrosio M., Fletcher D., Andrews J., and Bogoch I., Foldscope and Reversed-Lens Mobile Phone Microscopy for the Diagnosis of Schistosoma haematobium infection in Ghana, American Journal of Tropical Medicine and Hygiene, 14-0741, 2015, http://www.ajtmh.org/content/early/2015/04/23/ajtmh.14-0741.abstract
2. Joo J., Chow B., **Prakash M.,** Boyden E., Jacobson J., Face-selective electrostatic control of nanowire synthesis, Nature Materials vol. 10, 596-601, 2011, http://www.nature.com/nmat/journal/v10/n8/full/nmat3069.html
3. **Prakash M.,** Bush J., Interfacial propulsion by directional adhesion. Int. J. of Nonlinear Mechanics, vol. 46, 607-615, 2011, http://www.sciencedirect.com/science/article/pii/S0020746210001836
4. **Prakash M.** Steele M. The Hungry Fly: Hydrodynamics of Feeding in the Common House Fly, Physics of Fluids vol. 23, 091110, 2011 http://scitation.aip.org/content/aip/journal/pof2/23/9/10.1063/1.3640023
5. **Prakash, M.**, and Gershenfeld N., Microfluidic bubble logic, Science vol. 315 (5813), 832-835, 2007, http://www.sciencemag.org/content/315/5813/832.short
6. **Prakash M**.,Quere D., Bush J., Surface tension transport of prey by feeding shorebirds: The capillary ratchet. Science, vol. 320 (5878), 931-934, 2008, http://www.sciencemag.org/content/320/5878/931.short

D. SYNERGISTIC ACTIVITIES

1. Public Speaking, popular science writing and engagement: Outreach through talks to public audiences all around the world including: iBiology Seminar – viewed 26,000 times
http://www.ibiology.org/ibiomagazine/manu-prakash-foldscope-origami-based-paper-microscopes.html
TED Talk – viewed 1.4 million times

https://www.ted.com/talks/manu_prakash_a_50_cent_microscope_that_folds_like_origami?language=en
International talks in developing countries including: Nigeria, Uganda, Ghana, Cameroon, South Africa, India, Thailand, Panama and Costa Rica. Participant at SciFoo, MakerFaire, First White House Maker Faire. Invited speaker 2014 AAAS Annual Meeting – "Using cartons to communicate science."
Writings for public audience:
Prakash M., Curious or What: Role of curiosity Driven Research in Evolving Global Science Landscape. American Society of Microbiology "Cultures" Magazine, Summer 2014.
2. Founder and P.I. of "Foldscope Project" Foldscope is an origami based print-and-fold microscope which costs $1 to make and can achieve 150x-1400x magnification. Foldscope won 2014 Microcopy Today Innovation Award and 2014R&D 100 most innovative technologies of 2014 award. **Prakash Lab built and shipped 50,000 origami microscopes to kids around the world in 130 countries.** The users included anyone who applied for the beta testing program. We further built an online sharing platform where participants can collaborate on projects initiated by the users themselves. The projects include discovery of new insect species, detection of fake drugs, diagnosing parasites in humans and bees. See for details: http://microcosmos.foldscope.com
3. Primary Instructor and course designer:
Physical Biology of Macromolecules: Developed and regularly teach a full-credit core course on physical biology of macromolecules covering statistical mechanical description of macromolecular components, self assembly and self-organization in molecular systems for broad range of students from physics and biology.
Living Soft Matter: Advance graduate level class covering fundamentals and advance topics in soft condensed matter physics including theory and design of active fluids, theoretical aspects of self-assembly and self organization and classical models for organization and development of living matter.
4. National conferences:
Organizing Committee, American Physical Society, Division of Fluid Dynamics Annual Meeting, SF, a premier conference in the field of fluid dynamics with 5,000 participants from around the world. I was the primary organizer for talks/panels in microscale biological fluid dynamics. **Co-organizer, NSF Future Trends in Biological Fluid Dynamics Workshop,** 2014. NSF funded workshop to discuss latest challenges in the field of biological fluid dynamics at multiple length scales.
5. Winner, Society for Science and the Public 21st Century Chemistry Set
Our lab is bringing a new microfluidics tool into the hands of common users, researchers, educators and students. Driven by a paper Punchcard tape; the tool allows for arbitrary programming of microfluidic operations. For details, see http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0115993

E. COLLABORATORS AND OTHER AFFILIATIONS
Collaborators: Issac Bogoch (U. Toronto), Jason Andrews (Stanford) – Diagnostics of Schistosomiasis in Ghana using Foldscope Zev Bryant, Stanford – Engineering active matter using light-controlled molecular motors (reconstitution of cytoplasmic streaming in artificial giant cells), Sophie Dumont, UCSF – Emergent Mechanics applied to cellular biophysics
Graduate and Postdoctoral Advisors: Graduate advisors: Neil Gershenfeld, MIT; John Bush, MIT
Postdoctoral sponsors (Junior Fellow, Harvard Society of Fellows) David Nelson, Dept. of Physics, Harvard University; Naomi Pierce, Dept. of organismic biology, Harvard University
Thesis Advisor and Postgraduate Scholar Sponsors over the Last Five Years:
Graduate students: Matthew Storm Bull (Applied Physics, Stanford); William Gilpin (Applied Physics, Stanford); Deepak Krishnamurthy (Mechanical Engineering, Stanford); Laurel Kroo (Mechanical Engineering, Stanford); Toly Reinberg (Biophysics, Stanford); George Kimutai Korir (Bioengineering, Stanford); Haripriya Mukundarajan (Mechanical Engineering, Stanford); Georgios Katsikis (Mechanical Engineering, Stanford); Jim Cybulski (Mechanical Engineering, Stanford);
Total Number of Graduate Students advised: 9
Postdoctoral Fellows: Total Number of Postdoctoral Scholars Sponsored: 3
Vivek Prakash (Stanford), Shahaf Armon (Stanford), Adrien Benusiglio (Stanford)

Biographical Sketch

Blake Elliott Riggs

(a) Professional Preparation

Institution	Major / Area	Degree	Year
University of California, Santa Cruz	Marine Biology	B.A.	1996
University of California, Santa Cruz	Molecular, Cell, and Developmental Biology	M.A.	2001
University of California, Santa Cruz	Molecular, Cell, and Developmental Biology	Ph.D.	2005
University of California, Berkeley	Molecular and Cell Biology	Post-doc	2006 - 2009

National Institute of Health (NIH) National Research Service Award (NRSA) 2006 - 2009

(b) Appointments

2010-Present Assistant Professor of Biology, San Francisco State University

(c) Publications

(*SFSU student, ^{URM}under-represented minority student, ^female student)

Bergman ZJ, Mclaurin JD*^{URM}, Eritano, AE*^{URM}, Johnson B*$^{URM^}$, Sims AQ*^, and **Riggs B** (2014) Spatial reorganization of the Endoplasm Reticulum during mitosis relies on mitotic kinase cyclin A in the early Drosophila embryo. *Submitted*

Riggs B, Bergman ZJ, and Heald R (2012) Altering membrane topology with Sar1 does not impair spindle assembly in *Xenopus* egg extracts. *Cytoskeleton*, 69(8): 591-599.

Kotadia S, Crest J, Tram U, **Riggs B**, and Sullivan W (2010) Blastoderm Formation and Cellularisation in *Drosophila melanogaster*. Encyclopedia of Life Sciences (ELS). John Wiley and Sons, Ltd.

Loughlin R, **Riggs B**, Heald R (2008) Snapshot: motor proteins in spindle assembly. *Cell* 134(3): 548.

Cao J, Albertson R, **Riggs B**, Field CM, and Sullivan W (2008) Nuf, a Rab11 effector, maintains cytokinetic furrow integrity by promoting local actin polymerization. *Journal of Cell Biology* 182(2):301-13.

Riggs B, Fasulo B, Royou A, Mische S, Cao J, Hays T, and Sullivan W (2007) The role of Microtubles, Dynein, and the Recycling Endosome in furrow formation in the early Drosophila embryo. *Mol Biol Cell* 9:3313-22.

Albertson R, **Riggs B**, and Sullivan W (2005) Membrane traffic: a driving force in cytokinesis. *Trends Cell Biol* 15: 92-101.

Riggs B, Rothwell W, Mische S, Hickson GRX, Mastheson J, Hays T, Gould GW, and Sullivan W (2003) Actin cytoskeleton remodeling during early Drosophila furrow formation requires recycling endosomal components Nuclear-fallout and Rab11. *Journal of Cell Biology*, 163: 143-154.

Tram U, **Riggs B**, and Sullivan W (2001). Cleavage and gastrulation in Drosophila embryos. *Encyclopedia of Life Sciences.* Macmillan Reference Ltd. In Encyclopedia of Life Sciences. Nature Publishing Group. London. www.els.net.

Career development of minority students

Research mentor to minority students: In 4 years I have mentored 14 Masters (7 URM) and 15 undergraduate (8 URM) students (listed below). I participate in programs to enhance URM participation in research science including the STEM program at George Washington Carver Elementary School, the NSF REU program *Biological Research in Ecological and Evolutionary Developmental Biology*, and the CIRM *Bridges to Stem Cell Research Program.*

Program and Course Development

Biology Undergraduate Mentor Program (2012-2013). I created an undergraduate mentoring program funded by the American Cancer Society to pair introductory biology students with upper division biology majors as mentors. Preliminary outcomes include improved academic performance and engagement, ongoing development of leadership and communication skills, and heightened interest in research participation and retention in scientific careers.

Biology 351: Experiments in Cell and Molecular Biology (2010-Present). I developed a 4-unit upper division course for undergraduate biology majors on cell and molecular biology techniques and the practice of science, including intensive student training and integrated scientific writing components to meet national Writing in the Disciplines (WID) standards.

Grant and Publications Reviewer

Frontiers in Cell Biology; California State University Program for Education and Research in Biotechnology (CSUPERB); Nuclear and Cytoplasmic Structure/Function and Dynamics Study Section [NCSD] of the National Institute of Health (NIH) Early Career Reviewer

Service to Professional Science Organizations

Minority Affairs Committee Linkage Fellow for the American Society for Cellular Biology; Abstract reviewer and scientific presentation judge for the Annual Biomedical Research Conference for Minority Students.

(e) Collaborators & Other Affiliations

(i) *Collaborators*

Nasser Rusan, NIH/NHLBI; Kimberly Tanner, San Francisco State University, CA; Pat O'Farrell, University of California, San Francisco, CA; Ron Vale, University of California, San Francisco, CA; Alan Debec, Institut Jacques Monod, Paris, France; James Sutherland, CIC-bioGUME, Spain; Herman Steller, The Rockefeller University, NY.

(ii) *Graduate and Postdoctoral Advisors*

Graduate Advisors: William Sullivan, University of California, Santa Cruz, CA.
Postdoctoral Advisor: Rebecca Heald, University of California, Berkeley, CA.

(iii) *Thesis Advisor and Postgraduate-Scholar Sponsor*

URM - indicates underrepresented minority student

Current: *MS students*: Amanda Sims, Sumitra Nadarajah, Brittany Johnson[URM], Khan Le, Elliott Holt, Arturo Altamirano[URM], *Undergraduate students*: Torey Jaquez[URM] (MARC), Emmanuel Valenciano[URM], Ronnie Marania, Sarah Beyeler, Heidi Hoffman, David Ruvalcaba*(NIH Bridges), Maryann Karunga[URM] (REU)

Past Advisees: *MS students*: Luis Soto[URM] (PhD program Stanford University), Anthony Eritano[URM] (PhD program, Kobe University, Japan), Shamim Butts, Deena Hassanien[URM], Beatriz Alvarado[URM], Rabab Khodary, Arthur Chase, and Justin McLaurin[URM] (PhD program at UCSF). *Undergraduate students*: Rachel Coombs (PhD program at University of Pittsburg), Cleve Sherman[URM] (NIH Bridges), Robert Tracy II[URM] (REU), Jordan Boeck[URM] (REU, MS program, University of San Francisco), Greg Ostlaza[URM] (NIH Bridges), Nick Perotti (PSM, SFSU), Dzu Nguyen, Sara Richardson[URM] (MS program, SFSU)

REBECCA L. SMITH, PhD

Science & Health Education Partnership
University of California at San Francisco
100 Medical Center Way
San Francisco, CA 94143-0905
Rebecca.Smith@ucsf.edu
Ph: 415-514-0588; Fax: 415-502-4846

A. Professional Preparation

Bard College	Biology	B.A., 1993
University of California at San Francisco	Biochemistry	Ph.D., 1998
UCSF Science & Health Education Partnership	Science Education Partnership	Postdoctoral 2000-2001

B. Appointments

2005-present, Co-Director, Science & Health Education Partnership, University of California at San Francisco

2004-2005, Academic Coordinator II, Science & Health Education Partnership, University of California at San Francisco

2001-2003, Academic Coordinator I, Science & Health Education Partnership, University of California at San Francisco

C. Publications

826 National, Pañoringan, J. and Smith, R., *STEM to Story Enthralling and Effective Lesson Plans for Grades 5-8*. Edited by Jennifer Traig. San Francisco: Jossey-Bass, 2015.

Bell, S., Blumstein, J., Brose, K., Carroll, A., Chang. J., Charles, J., Haswell, E.S., Michelitsch, M., Owens, J., Patil, C.K., **Smith, R.**, Tupy, K., Walsh, E., and Ware, T. 2014. Defining Success in Graduate School. *Molecular Biology of The Cell,* 25(13) 1942-1944.. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4072567/)

Smith, R.L., *Inspiring Scientists of All Ages*. Editorial. Careers in Science Supplement to the San Francisco Chronicle. September 2013. (http://project.mediaplanet.com/12961.pdf)

Salter, I., Nielsen, K., Smith, R.L., 2008. Injecting Inquiry into Photosynthesis Investigations. *Science Scope.* (http://biochemistry2.ucsf.edu/programs/sep/pdfs/NSTA_photosynthesis.pdf)

Nielsen, K., Smith, R.L., Grillo-Hill, A., Caldera, P., Johnson, C., Gibson, L., "Example of Complementary Professional Development for Teachers and Scientists: Current Science Seminar Series." In E. Dolan (Ed.), *Education Outreach and Public Engagement* (pp. 58-61). New York, NY: Springer, 2008.

Caldera, P., Chu, J., Grillo-Hill, A., Jeske, S., MacCormack, J., Nielsen, K., Salter, J., Scharff, C., Smith, R.L., SEPLessons, http://seplessons.ucsf.edu, 2007.

Smith, R.L., Lipscomb, R., Cell and Molecular Biology for Minors: Review of *Enjoy Your Cells* by Fran Balkwill and Mic Rolph (solicited book review). *Cell Biology Education,* 2.16-17, 2003. (http://www.cellbioed.org/articles/vol2no1/article.cfm?articleID=41)

Other Significant Publications

Smith, R.L., Johnson, A.D., "Turning Genes Off: A conserved system of transcriptional repression in eukaryotes," *Trends in Biochemical Sciences.* 25:325-330, 2000.

Smith, R.L., Johnson, A.D., "A PTS1-like sequence in the homeodomain of a2 directs the interaction with the tetratricopeptide repeats (TPRs) of Ssn6," *Proceedings of the National Academy of Sciences,* 97:3901-3906, 2000.

Rebecca L. Smith, Michael J. Redd and Alexander D. Johnson. 1995. The tetratricopeptide repeats of Ssn6 interact with the homeodomain of alpha 2. *Genes and Development*. 9:2903-2910.

Schneider, K.L., R. L. Smith and Erin K. O'Shea. 1994. Phosphate-Regulated Inactivation of the Kinase PHO80-PHO85 by the CDK Inhibitor PHO81. *Science.* 266:122-126.

D. Synergistic Activities

2014 - 15	*International Teacher-Scientist Partnership Conference.* San Francisco (Feb 2015). Co-Organizer.
2012 - present	BaySci Science Rich Educational Institutions (SREI) Design Team Member.
2012 - present	*STEM to Story.* 826 National and Time Warner Cable. Formal and informal science learning consultant.
2011 - present	Center for AIDS Research UCSF Gladstone Institute of Virology and Immunology. Scientific Council Permanent Member.
2011 - present	*The Biology of Human.* University of Nebraska State Museum. Project Team and Advisory Board Member.
2011 - present	Community Resources for Science. Berkeley, CA. Advisory Council Member.

E. Collaborators & Other Affiliations

a. Collaborators and Co-Editors

Alberts, Bruce, Professor, Department of Biochemistry & Biophysics, UC San Francisco & Editor-in-Chief, *Science* • **Allison, Linda**, Author & Project Team Member, *The Biology of Human* • **Bass, Kristin,** Senior Researcher, Rockman et al. External Evaluator for NIH NCRR SEPA Award • **Calinger, Betty,** Project Manager, American Association for the Advancement of Science, Grant Collaborator – *International Teacher-Scientist Partnership Conference* • **Diamond, Judy,** Professor and Curator, University of Nebraska State Museum and Principal Investigator, *The Biology of Human* • **Durant, John**, Director, MIT Museum, Grant Collaborator - *Science Festival Alliance* • **Halpern-Felsher, Bonnie,** Professor of Pediatrics, Stanford University School of Medicine. Principal Investigator, *Understanding Facilitators and Deterrents to the STEM Pipeline from Middle School through College* - Proposal to the NIH • **Julius Diaz Panoriñgan:** Director of Education, 826LA • **Rankin, Lynn,** Director, Exploratorium Institute for Inquiry • **Steele, Kait,** Director of Field Operations, 826 National • **Volberding, Paul,** Co-Director UCSF-GIVI Center for AIDS Research.

a. Graduate & Postdoctoral Advisors

1. **Johnson, Alexander**, Vice Chair, Department of Microbiology and Immunology, University of California at San Francisco, Graduate Advisor.
2. **Chatman, Liesl**, Director of Professional Development, Science Museum of Minnesota, Postdoctoral Advisor.

b. Thesis Committee Member

1. **Witzel, Lakisha,** Department of Biology, San Francisco State University. (Graduated 2011)

Sindy Kam-Yan Tang

A. Professional Preparation

California Institute of Technology, Pasadena, CA	Electrical Engineering	B.S., 2003
Stanford University, Stanford, CA	Electrical Engineering	M.S., 2004
Harvard University, Cambridge, MA	Engineering Sciences	Ph.D., 2010
Harvard University, Cambridge, MA	Engineering Sciences	Postdoc, 2011
Woods Hole Marine Biological Lab, Woods Hole, MA	Cell Biology	Jun-Aug 2011

B. Appointments

09/2011- Assistant Professor, Department of Mechanical Engineering, Stanford University

C. Products (full list at http://stanford.edu/group/tanglab/)

Five most relevant publications:

- Ming Pan, Liat Rosenfeld, Minkyu Kim, Manqi Xu, Edith Lin, Ratmir Derda, and Sindy K.Y. Tang, "Fluorinated Pickering Emulsions Impede Interfacial Transport and Form Rigid Interface for the Growth of Anchorage-dependent Cells", *ACS Applied Materials & Interfaces*, 6, 21446-21453, 2014.
- Liat Rosenfeld, Tiras Lin, Ratmir Derda, and Sindy K.Y. Tang, "Review and Analysis of Performance Metrics of Droplet Microfluidics Systems", *Microfluidics and Nanofluidics*, 16, 5, 921-939, 2014.
- Liat Rosenfeld, Lin Fan, Yunhan Chen, Ryan Swoboda, and Sindy K.Y. Tang, "Break-up of Droplets in a Concentrated Emulsion Flowing through a Narrow Constriction", *Soft Matter*, 10, 421-430, 2014.
- Ratmir Derda, Sindy K.Y. Tang, Anna Laromaine, Bobak Mosadegh, Estrella Hong, Martin Mwangi, Akiko Mammoto, Donald E. Ingber, and George M Whitesides, "Multizone Paper Platform for 3D Cell Cultures", *PLoS ONE* 6(5): e18940. doi:10.1371/journal.pone.0018940, 2011.
- Ratmir Derda, Anna Laromaine, Akiko Mammoto, Sindy K. Y. Tang, Tadanori Mammoto, Amy Brock, Donald E. Ingber & George M. Whitesides, "Paper-Supported Three-Dimensional Cell Culture for Tissue-Based Bioassays", *Proceedings of the National Academy of Sciences*, 106, 18457-18462, 2009.

Five other significant publications:

- Ratmir Derda, Sindy K.Y. Tang, and George M. Whitesides "Uniform Amplification of Phage with Different Growth Characteristics in Monodisperse Droplet-Based Compartments", *Angewandte Chemie International Edition,* 49, 5301 –5304, 2010.
- Minkyu Kim, Ming Pan, Ya Gai, Shuo Pang, Chao Han, Changhuei Yang, and Sindy K.Y. Tang, "Optofluidic ultrahigh-throughput detection of fluorescent drops", *Lab on a Chip*, 15, 1417-1423, 2015.
- Lukas Gerber, Liat Rosenfeld, Yunhan Chen, and Sindy K.Y. Tang, "Time Capsule: An Autonomous Sensor and Recorder based on Diffusion-Reaction", *Lab on a Chip*, 14, 4324-4328, 2014.
- Tak-Sing Wong, Sung Hoon Kang, Sindy K. Y. Tang, Elizabeth Smythe, Benjamin Hatton, Alison Grinthal, and Joanna Aizenberg, "Slippery Surfaces with Omniphobicity, Self-Repair, High-Pressure Stability and Optical Transparency", *Nature*, 477, 443, 2011.

- Yunhan Chen, Adi Wijaya, and Sindy K. Y. Tang, "Characterization of Sensitivity and Specificity in Leaky Droplet-based Assays", *Lab on a Chip,* 12, 5093–5103, 2012.

D. Synergistic Activities

- **Instructor at summer cell biology course:** Tang was invited to teach the application of microfluidic methods for cell biology in an intensive 2-week experimental rotation at the summer course of Physiology: Modern Cell Biology Using Microscopic, Biochemical and Computational Approaches at the Woods Hole Marine Biology Laboratory (06/23/2014-07/05/2014). The course enrolls 25-30 graduate students and postdocs each year from biology, physics, and engineering.
- **New course development:** The PI developed a new graduate course on the interface of microfluidics and optics: ME321, Optofluidics: Interplay of Light and Fluids at the Micro and Nanoscale.
- **Mentor for underrepresented undergraduate students**: In her first three years at Stanford, Tang advised 10 undergraduates in directed research projects, where 50% of them are females and two are from Foot Hill College, a local community college. Two (Ryan Swoboda, Manqi Xu) co-authored peer-reviewed papers in *Soft Matter* and *ACS Applied Materials and Interfaces*.
- **Outreach for the general public:** Tang lab hosted a booth on Bubbles, Foams and Soufflés and Microfluidics at the Bay Area Science Festival at AT&T Park (11/3/2012) with more than 30,000 participants; and also at the Third Annual Science Alliance Showcase at Warm Springs Elementary School in Fremont, CA for 3rd – 6th graders (3/22/2013).
- **Popular science:** Tang authored articles for the general public in Harvard's "Science In The News" website on "The Rocket Swimsuit: Speedo's LZR Racer" (2008), "Harnessing the Power of the Sun: The Bright Promise of Solar Cells" (2007), "The Nanotechnology Solution to the Global Water Challenge" (2011).

E. Collaborators & Other Affiliations

Collaborators and co-editors:

• Christian A. Nijhuis	National University of Singapore (Chemistry)
• David A. Weitz	Harvard (Physics)
• Demetri Psaltis	EPFL (Electrical and Electronics Engineering)
• Kyle J. M. Bishop	Penn State (Chemical Engineering)
• Michael D. Dickey	NC State (Chemical & Biomolecular Engineering)
• Ratmir Derda	University of Alberta (Chemistry)
• Scott T. Phillips	Penn State (Chemistry)
• Zhenyu Li	University of George Washington (Electrical Engineering)
• Jianghong Rao	Stanford University (Radiology)
• Changhuei Yang	Caltech (Electrical Engineering)
• Wallace Marshall	University of California, San Francisco (Biochemistry)

Graduate advisor: George M. Whitesides (Harvard University)

Postdoctoral Advisors: Marko Loncar and Joanna Aizenberg (Harvard University)

Thesis Advisees: Ming Pan, Minkyu Kim, Ya Gai, Fengjiao Lyu

Matt W. Thomson

University of California, San Francisco
600 16th Street,
Genentech Hall, Room S472
San Francisco, CA 94143-2240
matthew.thomson@ucsf.edu

A. Professional Preparation

2001	Harvard University, Physics AB
20011	Harvard University, Biophysics PhD
20011-current	UCSF, Systems Biology

B. Appointments

1999-2001	Undergraduate Researcher, Laboratory of Gene Golovchenko
2001-2004	Software and Algorithm Development Zareata
2004-2006	Masters Student Researcher, Laboratory of Jeremy Gunawardena
2006-2007	Graduate Student Researcher, Laboratory of Aviv Regev
2007-2011	Graduate Student Researcher, Laboratory of Sharad Ramanathan
20011-current	UCSF Fellow in Systems Biology
2012-current	NIH Director's Early Independence Award Fellow

C. Publications Most Closely Related to This Project

Ben-Porath I, **Thomson M,** Carey VJ, Ge R, Bell GW, Regev A, Weinberg RA. An embryonic stem cell-like gene expression signature in poorly differentiated aggressive human tumors. ***Nature Genetics,*** 2008; 40(5):499-507.

Thomson M, Gunawardena J. Unlimited multistability in multisite phosphorylation systems. ***Nature,*** 2009; 460(7252):274-7.

Thomson M, Liu SJ, Zou LN, Smith Z, Meissner A, Ramanathan S. Pluripotency factors in embryonic stem cells regulate differentiation into germ layers. ***Cell,*** 2011; 145(6):875-89.

Sivak D, **Thomson M**. Environmental Statistics and Optimal Regulation. **PLOS Computational Biology**, September, 2014.

A Cerchiari J Garbe, N Jee, M Todhunter, D Peehl, T Desai, M Labarge, **M Thomson**, Z Gartner. A strategy for tissue self-organization that is robust to cellular heterogeneity and plasticity**.** *Proceedings of the National Academy of Sciences*, January, 2015.

D. Synergistic Activities

Innovations in graduate education**:** Innovations in graduate education have come in two major areas. I have been intensively involved in developing curricula to teach dynamical systems modeling methods to graduate students in quantitative biology and biochemistry; second, I have developed a course focused on distributed computations in multi-cellular systems. I have taught a three-week mini-courses at UCSF focused on understanding how interactions between distributed agents can lead to functional order over the past three years. The course has two names "Distributed Algorithms in Biology" and "Multicellular

systems Biology". Biological systems often solve problems through distributed computations where individual agents (proteins, cells, organisms) collect information and dynamically interact to accomplish a task. The course focused on development of theoretical tools from statistical physics and computer science for understanding mechanisms that allow cells in particular and to form organized structures and accomplish tasks without centralized control. Second, I developed a month long course to introduce systems to dynamical systems models for chemical reaction networks. I have given this course to quantitative biology students at UCSF and have delivered a truncated form of the course to biochemistry students.

Development and refinement of research tools**:** As a UCSF systems biology fellow, I am actively involved in two areas of technology development. I have developed computational tools for modeling distributed cellular systems. The tools have been introduced widely to graduate students at UCSF and have been used in research projects with the Gartner Lab. Specifically, we have developed software and mathematical infrastructure for combining dynamical systems models of chemical reaction networks with lattice models of interacting cell populations. My lab was awarded the early independence award from the NIH to pioneer the use of optogenetic and advanced microscopy tools to monitor and guide stem cell differentiation in multicellular structures with light. We have made extensive progress in this direction and can currently induce neural and muscle differentiation in embryonic stem cells with light. This work is contained in a manuscript that has been submitted for publication. As a graduate student, I was involved with the development of the littleB computer language for rapid modeling of biochemical reaction systems. My work on the project led to a number of computer models of kinase cascades and drosophila tissues that were disseminated to the scientific community as part of the project.

Broadening participation by groups of under represented minorities**:** At UCSF, I have mentored high-school students as part of the UCSF MSTP-Lowell Science research program. A student from Lowell spent 10 weeks working in my lab last summer as part of the program. As a graduate student, I supervised nine undergraduate students for significant research projects. Of this group three were from underrepresented groups with one student having a significant physical disability.

E. Collaborators & Other Affiliations

Collaborators
Zev Gartner (UCSF)
Hana el-Samad (UCSF)
Wendell Lim (UCSF)
Ophir Klein (UCSF)
Jason Spence (U Michigan)
Eric Siggia (Rockefeller University)
Manu Prakash (Stanford University)
Alshakim Nelson (IBM Research Labs)

Graduate Advisors
Sharad Ramanathan (Harvard University)
Jeremy Gunawardena (Harvard University)
Aviv Regev (MIT, Broad Institute)

Thesis Advisor
Graduate Students: Graham Heimberg (current, joint student). Zairan Liu (current, joint student) **Total = 2**

Orion Weiner
SCVRB-352F Box 3120
Cardiovascular Research Institute and Department of Biochemistry & Biophysics UCSF

(a) Professional Preparation

University of Texas, Austin	Biochemistry	B.A. 1995
University of Texas, Austin	Molecular Biology	B.S. 1995
University of California, San Francisco	Cell Biology	Ph.D. 2001
Postdoctoral: Harvard Medical School	Systems Biology	2001 - 2005

(b) Appointments

2014 - present Professor, UCSF, CVRI and Dept. Biochemistry & Biophysics
2012 - 2014 Associate Professor, UCSF CVRI and Dept. Biochemistry & Biophysics
2005 - 2012 Assistant Professor, UCSF CVRI and Dept. Biochemistry & Biophysics

(c) Publications

(i) **five publications most closely related to proposed project**

Toettcher JE, Gong D, Lim WA, Weiner OD. 2011. Light-based feedback for controlling intracellular signaling dynamics, ***Nature Methods***, 8: 837-9.

Houk A, Jilkine S, Mejean CO, Boltyanskiy R, Dufresne ER, Agenent S, Altschuler SJ, Wu LF, Weiner OD. 2012. Membrane tension maintains cell polarity by confining signals to the leading edge during neutrophil migration. ***Cell***, 148: 175-188.

Millius A, Watanabe N, Weiner OD. 2012. Diffusion, capture, and recycling of SCAR/WAVE and Arp2/3 complexes observed in cells with single-molecule imaging, ***J. Cell Sci.,*** 125: 1165-1176.

Yang X, Jost APT, Weiner OD#, Tang C# 2013. A light-inducible organelle targeting system for dynamically activating and inactivating signaling in budding yeast. ***Mol. Biol. Cell***, 24: 2419-30. (#corresponding author).

Toettcher JE, Weiner OD#, Lim WA# 2013. Using optogenetics to interrogate the dynamic control of signal transmission by the Ras/Erk module, ***Cell***, 155: 1422-1434. (#corresponding author).

(ii) five other significant publications

Levskaya A, Weiner OD, Lim WA, Voigt CA. 2009. Spatiotemporal control of cell signalling using a light-switchable protein interaction, ***Nature***, 461: 997-1001.

Weiner OD#, Marganski WA, Wu LF, Altschuler SJ, Kirschner MW#. 2007. An actin-based wave generator organizes cell motility, ***PLoS Biology***, 5: e221. (#corresponding author)

Peng GE, Wilson SR, Weiner OD. 2011. A pharmacological cocktail for arresting actin dynamics in living cells, ***Mol. Biol. Cell***, 22: 3986-3994.

Dandekar SN, Park J, Peng GE, Onuffer J, Lim WA, Weiner OD. 2013. Actin dynamics rapidly reset chemoattractant receptor sensitivity following adaptation in neutrophils. ***Philosophical Transactions of the Royal Society B***, 368: 20130008.

Wu J, Pipathsouk A, Kizer-Gunnink A, Fusetti F, Alkema W, Liu S, Altschuler S, Wu L, Kortholt A, Weiner OD. 2015. Homer3 regulates the establishment of neutrophil polarity, ***Mol. Biol. Cell***, *in press, May 2015*.

(d) Synergistic Activities

- Interdisciplinary teaching in quantitative cell biology, teaching resources, science of learning: Physiology Course, Marine Biological Lab, Woods Hole MA: Instructor 2015, UCSF: Course Director Tetrad Bootcamp (2008-present)—a mixture of labwork and didactic teaching which brings our incoming students up to speed in Microscopy and Matlab. In 2005, I Founded the Nikon Imaging Center at UCSF. I organized a joint consortium with CVRI, QB3, the

Departments of Biochemistry & Biophysics and Cellular and Molecular Pharmacology and Nikon to establish an advanced light microscopy core at Mission Bay. The core acts as a focal point for both formal and informal microscopy classes at UCSF.

- Meeting Organization: Conference Organizer, Innovations in Light Microscopy Symposium (San Francisco, 2006); Session Chair, Cold Spring Harbor *Computational Cell Biology* Conference 2013; Chair, ASCB Annual Meeting, Molecular Mechanisms of Cell Migration 2013; Vice-Chair and Chair, Gordon Conference on Directed Migration 2017 and 2019.
- Diversity: As Co-Chair of graduate admissions for the Tetrad program at UCSF, I have made it a priority to identify, interview, and recruit top under-represented minorities to our graduate program. This effort has been highly effective, and the proportion of URMs in our graduate class increased from 7% (year before I took on co-chair position) to 45% (my final year as co-chair). A major contributing factor to this effort was my comprehensive statistical analysis of our top and bottom performing graduate students in the Tetrad Program over the past two decades in which I identified the parameters (in written application and interviews) that correlated best with success in graduate school. The results of this study showed that many of the common metrics we use in recruiting students (such as GRE scores and undergraduate institution) are a poor predictor of graduate success. This enabled us to expand our consideration of many students we would have triaged in the past, including many underrepresented minorities. I recently published this work at MBoC to help other programs improve their admissions process.
- Grant review activity: Ad Hoc Reviewer for the following Grant Agencies: American Cancer Society, Biotechnology and Biological Sciences Research Council, Human Frontier Science Program, IST Austria, Israel Science Foundation, NIH (Enabling Bioanalytical and Imaging Technologies Study Section; Molecular and Integrative Signal Transduction Study Section; Transformative Research Award Study Section), National Medical Research Council, National Science Foundation, and Riken Center for Developmental Biology
- Developing new books: Editor, Current Opinion in Cell Biology, Cell Adhesion and Migration Issue (2013), Expert Reviewer, Alberts Molecular Biology of the Cell Textbook, 6th Ed.

(e) Collaborators and Affiliations

Collaborators and co-editors: Stephen Altschuler (UCSF), Sigurd Angenent (Univ. Wisconsin, Madison), Bruce Conklin (UCSF), Mike Davidson (Univ. Florida), Eric Dufresne (Yale), Dan Fletcher (UC Berkeley), Kevin Gardner (UT Southwestern), Phil Hawkins (Babraham Institute, UK), Yuh Nung Jan (UCSF), Rob Kay (LMB, MRC), Tom Kornberg (UCSF), Arjan Kortholt (Univ Groningen, Netherlands), Wendell Lim (UCSF), Carole Parent (NIH), Robert Parton (University of Queensland, Australia), Manoj Puthenveedu (Carnegie Mellon University), Chao Tang (Peking University), John Sedat (UCSF), Xiaokun Shu (UCSF), Didier Stainier (Max Planck), Len Stephens (Babraham Institute, UK), Jack Taunton (UCSF), Julie Theriot (Stanford), Mark Von Zastrow (UCSF), Chris Voigt (MIT), Gerald Weeks (University of British Columbia), Naoki Watanabe (Tohoku University Graduate School of Life Sciences, Japan), Lani Wu (UCSF).

Graduate and postdoctoral advisors: John Sedat and Henry Bourne (UCSF), Marc Kirschner and Lew Cantley (Harvard Medical School)

Thesis advisor and postgraduate scholar sponsor: Jared Toettcher (postdoc, currently Assistant Professor, Princeton); Delquin Gong (postdoc, currently Scientist at BioRad); Anna Jost (Ph.D. student, currently postdoctoral fellow Harvard Medical School); Julie Wu (Ph.D. student, currently Medical Student, UC San Francisco); Sheel Dandekar (Ph.D. student, currently Scientist, 23andMe); Andrew Houk (Ph.D. student, currently postdoc, UC San Diego); Arthur Millius (Ph.D. student, currently postdoc Riken Institute, Kobe, Japan). Total postdocs and graduate students including current and past: 7 postdoctoral, 10 graduate students.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	0.50	0.00	0.00	**6,089**	
2. **Charles Craik - Entrepreneurship Coordinator**	0.50	0.00	0.00	**10,870**	
3. **Shawn Douglas - Co-Investigator**	0.50	0.00	0.00	**5,360**	
4. **Sophie Dumont - Co-Investigator**	0.50	0.00	0.00	**6,408**	
5. **Hana El-Samad - Co-Investigator**	0.50	0.00	0.00	**6,793**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	2.50	0.00	0.00	**27,908**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	5.00	0.00	0.00	**63,428**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**11**) POST DOCTORAL SCHOLARS	132.00	0.00	0.00	**471,240**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**9,996**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**2**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**131,874**	
6. (**3**) OTHER				**77,009**	
TOTAL SALARIES AND WAGES (A + B)				**753,547**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**217,298**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**970,845**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**77,188**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **63,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**63,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**281,216**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,300,000**	
6. OTHER				**288,338**	
TOTAL OTHER DIRECT COSTS				**1,869,554**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,980,587**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 58.5000, Base: 1742587)**					
TOTAL INDIRECT COSTS (F&A)				**1,019,413**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Fung, Jennifer - Co-Investigator	0.50	0.00	0.00	4992
Gartner, Zev J - Principal Investigator	0.50	0.00	0.00	6089
Smith, Rebecca - Co-Investigator	0.50	0.00	0.00	6598
Thomson, Matthew - Co-Investigator	0.50	0.00	0.00	2945
Weiner, Orion - Co-Investigator	0.50	0.00	0.00	7284

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	0.50	0.00	0.50	**6,271**	
2. **Charles Craik - Entrepreneurship Coordinator**	0.50	0.00	0.00	**11,196**	
3. **Shawn Douglas - Co-Investigator**	0.50	0.00	0.50	**5,521**	
4. **Sophie Dumont - Co-Investigator**	0.50	0.00	0.50	**6,601**	
5. **Hana El-Samad - Co-Investigator**	0.50	0.00	0.50	**6,997**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	2.60	0.00	2.60	**28,746**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	5.10	0.00	4.60	**65,332**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**11**) POST DOCTORAL SCHOLARS	132.00	0.00	0.00	**490,116**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**9,996**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**2**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**135,831**	
6. (**3**) OTHER				**78,869**	
TOTAL SALARIES AND WAGES (A + B)				**780,144**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**223,231**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,003,375**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **Incell Microscope** $ **494,573**					
TOTAL EQUIPMENT				**494,573**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**76,600**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **63,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**63,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**159,058**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,450,000**	
6. OTHER				**648,934**	
TOTAL OTHER DIRECT COSTS				**2,257,992**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,895,540**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 58.5000, Base: 1887966)**					
TOTAL INDIRECT COSTS (F&A)				**1,104,460**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**5,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**5,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Fung, Jennifer - Co-Investigator	0.50	0.00	0.50	5142
Gartner, Zev J - Principal Investigator	0.50	0.00	0.50	6271
Smith, Rebecca - Co-Investigator	0.60	0.00	0.60	6796
Thomson, Matthew - Co-Investigator	0.50	0.00	0.50	3034
Weiner, Orion - Co-Investigator	0.50	0.00	0.50	7503

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	0.50	0.00	0.00	**6,459**	
2. **Charles Craik - Entrepreneurship Coordinator**	0.50	0.00	0.00	**11,532**	
3. **Shawn Douglas - Co-Investigator**	0.50	0.00	0.00	**5,687**	
4. **Sophie Dumont - Co-Investigator**	0.50	0.00	0.00	**6,799**	
5. **Hana El-Samad - Co-Investigator**	0.50	0.00	0.00	**7,207**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	2.60	0.00	0.00	**29,608**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	5.10	0.00	0.00	**67,292**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**11**) POST DOCTORAL SCHOLARS	132.00	0.00	0.00	**509,784**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**9,996**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**2**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**139,906**	
6. (**3**) OTHER				**80,786**	
TOTAL SALARIES AND WAGES (A + B)				**807,764**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**231,460**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,039,224**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**76,600**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **63,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**63,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**255,022**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,450,000**	
6. OTHER				**829,154**	
TOTAL OTHER DIRECT COSTS				**2,534,176**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,713,000**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 58.5000, Base: 2200000)**					
TOTAL INDIRECT COSTS (F&A)				**1,287,000**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**5,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**5,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 3

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Fung, Jennifer - Co-Investigator	0.50	0.00	0.00	5296
Gartner, Zev J - Principal Investigator	0.50	0.00	0.00	6459
Smith, Rebecca - Co-Investigator	0.60	0.00	0.00	7000
Thomson, Matthew - Co-Investigator	0.50	0.00	0.00	3125
Weiner, Orion - Co-Investigator	0.50	0.00	0.00	7728

SUMMARY PROPOSAL BUDGET

YEAR 4

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	0.50	0.00	0.00	**6,653**	
2. **Charles Craik - Entrepreneurship Coordinator**	0.50	0.00	0.00	**11,878**	
3. **Shawn Douglas - Co-Investigator**	0.50	0.00	0.00	**5,857**	
4. **Sophie Dumont - Co-Investigator**	0.50	0.00	0.00	**7,003**	
5. **Hana El-Samad - Co-Investigator**	0.50	0.00	0.00	**7,423**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	2.60	0.00	0.00	**30,496**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	5.10	0.00	0.00	**69,310**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**11**) POST DOCTORAL SCHOLARS	132.00	0.00	0.00	**530,112**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**9,996**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**2**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**144,103**	
6. (**3**) OTHER				**82,759**	
TOTAL SALARIES AND WAGES (A + B)				**836,280**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**239,560**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,075,840**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**76,600**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **63,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**63,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**218,182**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,450,000**	
6. OTHER				**829,378**	
TOTAL OTHER DIRECT COSTS				**2,497,560**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,713,000**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 58.5000, Base: 2200000)**					
TOTAL INDIRECT COSTS (F&A)				**1,287,000**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**5,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**5,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 4

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Fung, Jennifer - Co-Investigator	0.50	0.00	0.00	5455
Gartner, Zev J - Principal Investigator	0.50	0.00	0.00	6653
Smith, Rebecca - Co-Investigator	0.60	0.00	0.00	7210
Thomson, Matthew - Co-Investigator	0.50	0.00	0.00	3218
Weiner, Orion - Co-Investigator	0.50	0.00	0.00	7960

SUMMARY PROPOSAL BUDGET

YEAR 5

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	0.50	0.00	0.00	**6,853**	
2. **Charles Craik - Entrepreneurship Coordinator**	0.50	0.00	0.00	**12,234**	
3. **Shawn Douglas - Co-Investigator**	0.50	0.00	0.00	**6,033**	
4. **Sophie Dumont - Co-Investigator**	0.50	0.00	0.00	**7,213**	
5. **Hana El-Samad - Co-Investigator**	0.50	0.00	0.00	**7,646**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	2.60	0.00	0.00	**31,411**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	5.10	0.00	0.00	**71,390**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**11**) POST DOCTORAL SCHOLARS	132.00	0.00	0.00	**551,232**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**9,996**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**2**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**148,426**	
6. (**3**) OTHER				**84,792**	
TOTAL SALARIES AND WAGES (A + B)				**865,836**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**247,944**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,113,780**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**76,600**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **63,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**63,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**163,816**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,450,000**	
6. OTHER				**845,804**	
TOTAL OTHER DIRECT COSTS				**2,459,620**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,713,000**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 58.5000, Base: 2200000)**					
TOTAL INDIRECT COSTS (F&A)				**1,287,000**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**5,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**5,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 5

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Fung, Jennifer - Co-Investigator	0.50	0.00	0.00	5619
Gartner, Zev J - Principal Investigator	0.50	0.00	0.00	6853
Smith, Rebecca - Co-Investigator	0.60	0.00	0.00	7426
Thomson, Matthew - Co-Investigator	0.50	0.00	0.00	3315
Weiner, Orion - Co-Investigator	0.50	0.00	0.00	8198

SUMMARY PROPOSAL BUDGET

Cumulative

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-San Francisco

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Wallace Marshall

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Wallace Marshall - Principal Investigator**	2.50	0.00	0.50	**32,325**	
2. **Charles Craik - Entrepreneurship Coordinator**	2.50	0.00	0.00	**57,710**	
3. **Shawn Douglas - Co-Investigator**	2.50	0.00	0.50	**28,458**	
4. **Sophie Dumont - Co-Investigator**	2.50	0.00	0.50	**34,024**	
5. **Hana El-Samad - Co-Investigator**	2.50	0.00	0.50	**36,066**	
6. (**5**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	12.90	0.00	2.60	**148,169**	
7. (**10**) TOTAL SENIOR PERSONNEL (1 - 6)	25.40	0.00	4.60	**336,752**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**55**) POST DOCTORAL SCHOLARS	660.00	0.00	0.00	**2,552,484**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**5**) GRADUATE STUDENTS				**49,980**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**10**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**700,140**	
6. (**15**) OTHER				**404,215**	
TOTAL SALARIES AND WAGES (A + B)				**4,043,571**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**1,159,493**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**5,203,064**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ **494,573**					
TOTAL EQUIPMENT				**494,573**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**383,588**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **315,000**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**315,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**1,077,294**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**7,100,000**	
6. OTHER				**3,441,608**	
TOTAL OTHER DIRECT COSTS				**11,618,902**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**18,015,127**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**5,984,873**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**24,000,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**24,000,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Michelle Stevens

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Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

BUDGET JUSTIFICATION

Salaries: Pursuant to University of California (UC) policy, salaries in the initial budget period are based on current published UC salary scales and include University mandated range adjustments and merit increases scheduled to occur before the proposed project start date. Pay rate increases in FY02 through FY05 are based on merit review schedules established by UCSF Academic Affairs.

Fringe Benefits: Fringe benefits include health and life insurance, social security, Medicare, dental plan, vision, unemployment insurance, non-industrial disability insurance, worker's compensation insurance, and retirement. Projections for fringe benefits have been prorated to conform to the grant year of this project, based on the escalating rates published on December 06, 2010:

7/1/15 – 6/30/16: Academic – 33.80%, Staff – 41.80%
7/1/16 – 6/30/17: Academic – 33.90%, Staff – 41.90%
7/1/17 – 6/30/18: Academic – 34.15%, Staff – 42.15%
7/1/18 – until amended: Academic – 34.35%, Staff – 42.35%

PERSONNEL

Wallace Marshall, PhD, Principal Investigator (Center Director) (salary requested at 0.5 calendar months over 5 years) will direct overall operations and goals of the Center, including overseeing coordination between the groups and institutions working on the center and integration of the research, teaching, outreach, and knowledge transfer components. Within the Research component he will contribute to development of predictive models for organelle size regulation as part of the CellCAD project, oversee studies of organelle size relative to cellular metabolic function as part of the Living Bioreactor project, and direct the execution of the Cellular Sentinel project. He will contribute his expertise in Maker Faire presentations to the Education component.

Zev Gartner, PhD, Co-Principal Investigator and Research Coordinator (salary requested at 0.5 calendar months over 5 years) will co-direct the overall operation of the center, and will oversee execution of the Cellular Legos project. He will also contribute to experiments engineering cell-cell interactions within the Living Bioreactor project and participate in management of the Cellular Machine Shop core.

Wendell Lim, PhD, Co-Principal Investigator (0.5 calendar months over 5 years), will provide guidance and mentoring to Drs. Marshall and Gartner, drawing on his extensive experience in organizing large multi-PI research programs. He will also direct the operations of the Cellular Machine shop and contribute synthetic biology expertise to all phases of the research program. He will draw on his extensive experience with IGEM team project to help plan and execute project-based educational activities. As a Howard Hughes Medical Institute (HHMI) investigator, Lim's salary is paid by HHMI. In turn, no salary support is requested for his effort on this project.

Charles Craik, PhD, Entrepreneurship and Knowledge Transfer Coordinator, (salary requested at 0.5 calendar months over 5 years), will oversee interactions between Center research groups and IBM's Accelerated Discovery Lab and with Center-funded startup companies. He will help to plan and oversee the startup company program in years 2-5, drawing on his extensive experience in biotech entrepreneurship and mentoring.

Shawn Douglas, PhD, Co-Investigator (salary requested at 0.5 calendar months over 5 years) will draw on his experience developing CAD software, and integrating such software with Autodesk's commercial platform, to oversee the CellCAD project.

Sophie Dumont, PhD, Co-Investigator (salary requested at 0.5 calendar months over 5 years) will contribute her expertise in cellular and molecular biomechanics to guide development of cell-based mechanical sensing devices in the Cellular Sentinel project.

Hana El-Samad, PhD, Co-Investigator and Graduate Education Coordinator (salary requested at 0.5 calendar months over 5 years) will provide high-level input into development of mathematical models in all research components of the project. She will also draw on her extensive experience in diversity-promoting activities at UCSF to promote diversity within center activities.

Jennifer Fung, PhD, Co-Investigator (salary requested at 0.5 calendar months over 5 years) will draw on her expertise in live cell and super-resolution microscopy to supervise imaging experiments in all research components of the project. She will also build on her track record of training undergraduates from diverse backgrounds to help integrate undergraduate students into the research activities of the Center.

Matthew Thomson, Co-Investigator (salary requested at 0.5 calendar months over 5 years) will draw on his expertise in cell differentiation and modeling to help develop predictive models of cell structure and behavior as part of the CellCAD project.

Orion Weiner, Co-Investigator (salary requested at 0.5 calendar months over 5 years) will draw on his expertise in optogenetics to implement novel methods for intracellular patterning as part of the CellCAD project, the Cellular Machine Shop, and the Living Bioreactor projects.

Rebecca Smith, Co-Investigator and Education Coordinator (SEP) (salary requested at 0.6 calendar months over 5 years) will oversee educational and outreach activities of the center, including organizing teacher-student bootcamps and curriculum development.

TBN, Postdoctoral Scholar (Marshall Lab) (salary requested at 12.0 calendar months over 5 years) will work on the Living Bioreactor project, in particular developing and testing approaches for tuning organelle size to improve production of biofuels and other products, and will participate in student-teacher workshops and will perform outreach activities via Maker Faire and Science Expo exhibits around the country.

TBN, Postdoctoral Scholar (Marshall Lab) (salary requested at 12.0 calendar months over 5 years) will work on the Cellular Sentinel projects, with a focus on inferring environmental chemical signals from organelle size, and will participate in student-teacher workshops and will perform outreach activities via Maker Faire and Science Expo exhibits around the country.

TBN, Postdoctoral Scholar (Gartner Lab) (salary requested at 12.0 calendar months over 5 years) will work on development of interchangeable orthogonal cell adhesions systems for Cellular Legos.

TBN, Postdoctoral Scholar (Gartner Lab) (salary requested at 12.0 calendar months over 5 years) will work on methods for generating self-organized multi-layer cell based structures for the Living Bioreactor project.

TBN, Postdoctoral Scholar (Lim Lab) (salary requested at 12.0 calendar months over 5 years) will work on developing synthetic organelle and adhesion systems for the Cellular Machine shop.

TBN, Postdoctoral Scholar (Douglas Lab) (salary requested at 12.0 calendar months over 5 years) will work on developing CellCAD software.

TBN, Postdoctoral Scholar (Dumont Lab) (salary requested at 12.0 calendar months over 5 years) will work on implementing intracellular mechanical sensors for the Cellular Lego and Cellular Sentinel projects.

TBN, Postdoctoral Scholar (El-Samad Lab) (salary requested at 12.0 calendar months over 5 years) will work on inference algorithms for the Cellular Sentinel project.

TBN, Postdoctoral Scholar (Fung Lab) (salary requested at 12.0 calendar months over 5 years) will work on live cell imaging for the Cellular Sentinel project.

TBN, Postdoctoral Scholar (Thomson Lab) (salary requested at 12.0 calendar months over 5 years) will work on CellCAD software development and linking the predictive models of the CellCAD system with the inference models of the Cellular Sentinel project.

TBN, Postdoctoral Scholar (Weiner Lab) (salary requested at 12.0 calendar months over 5 years) will develop optical methods for patterning cell organization within the Cellular Lego and Living Bioreactor projects.

TBN, Center Manager (salary requested at 12.0 calendar months over 5 years) will help to coordinate and manage the administrative and organizational activities of the Center, including organizing meetings between Center groups and with the EAC.

Olivia Viloria, Center Administrator (salary requested at 2.4 calendar months over 5 years) will coordinate the financial activities of the center.

TBN, Web Design Specialist (salary requested at 1.8 calendar months over 5 years) will develop Web resources for the center with a particular emphasis on data dissemination and educational activities.

TBN, Computer Animator (salary requested at 2.4 calendar months over 5 years) will develop computer animation based learning resources in support of the education and outreach activities of the center.

TBN, Graduate Student (salary requested at 6.0 calendar months over 5 years) will help to organize and run the teacher-student workshops for the educational component, including developing experimental projects.

CONSULTANT COSTS None

EQUIPMENT for Cellular Machine Shop Core

GE Incell Microscope Year 2
Our plans to custom-design cells via synthetic biology manipulations with design guidance from the CellCAD system have been developed with the full understanding that unlike in other areas of engineering, synthetic biology constructs often do not work as first designed, requiring evaluation of large numbers of similar but slightly different constructs. Monitoring the alterations in cell structure in many different constructs will require high throughput microscopy. Such high throughput imaging is also central to many of our proposed research experiments such as Cellular Sentinel. Finally, high throughput

microscopy is becoming a critical part of the biotech industry, and we feel it is important to provide training in such systems to our students. Therefore, we request funds to purchase a state of the art high throughput microscopy platform, the Incell 2200 or the InCell 6000, which has unique capabilities of high resolution and multiple imaging modalities compared to other competing imaging platforms. Please see equipment quote attached to this justification.

Nikon Imaging Center
All research and educational components of the Center will require microscopy. Rather than purchase multiple microscopy platforms to carry out the different types of imaging required, we will leverage the existing Nikon Imaging Center at UCSF, providing funds to support use of the facility by all center members.

Gene synthesis
We will contract with Twist Bioscience, a gene synthesis company located in the Mission Bay neighborhood, to provide on-demand total gene synthesis of constructs for the synthetic biology methods that are central to this proposal, in much the same way that an engineering firm might contract with a local foundry for production of custom parts.

Supplies for Core:
As a distributed core, the Cellular Machine Shop will harness existing resources at UCSF by providing our own reagents and supplies to defray costs. We therefore request funds for reagents for DNA sequencing in the Center for Advanced Technology and for small molecule and RNAi library analyses in the Small Molecule Discovery Center. Other Core supplies will be 3D printing supplies to support customized production of novel equipment.

SUPPLIES

Most of the experimental approaches we will use involve standard molecular biology work. We therefore request supply funding to purchase molecular biology kits and reagents, PCR reagents, disposables, and cell culture supplies. These supplies are necessary to achieve the aims of the project, and will be used specifically and exclusively for the projects of the Center.

TRAVEL

The interdisciplinary nature of our Center requires members of the center to be informed about cutting edge developments in both cell biology and engineering, as well as related disciplines such as biophysics and systems biology. We request funds to support travel of one postdoc per research group to one or two annual meetings of direct relevance to the goals of the center, including annual meetings of the American Society for Cell Biology, the Biophysical Society, qBio, and the annual Metabolic Engineering conference. We request funds to cover meeting registration, lodging, and domestic economy flights. Any center members whose travel is paid for using these funds will be required to present their work in order to help with knowledge dissemination.

MEETING and SYMPOSIUM COSTS

Funds are requested in FY01 for an initial retreat, with all STC participants, to launch and coordinate Center activities, and annually for a Symposium to be held on campus at UCSF, with all STC participants and a few guest speakers. We have estimated costs based on costs for Biochemistry Faculty retreats, and Symposia held on campus at the UCSF Mission Bay Conference Center.

PARTICIPANT COSTS

Participant Supplies: Funds are requested for educational activities, specifically reagents and equipment for proposed High school teacher-student workshops, Hackathons, Maker Faire and Science Festival exhibits.

Participant Stipends: Funds are requested to provide stipends to high school teachers and students that will allow them to take the time to participate in the student-teacher bootcamp sessions.

STARTUP COMPANY COSTS

An important part of our knowledge transfer program will be to launch start-up companies to spin off ideas and concepts discovered in the Center, organized by students and postdocs from Center labs or affiliated groups. This program will leverage the available startup incubator spaces available near the Mission Bay campus, and will have advisory support from QB3. Based on preliminary discussions with QB3 staff we have estimated that a small startup can be launched and run for six months for approximately $180,000. Based on this estimate, we budget funds for 2-3 such startups each year starting in year 2.

OTHER EXPENSES

UCSF Data Network Recharge: The data network services recharge provides funding for critical equipment in support of UCSF's electronic information flow. Calculations are based on the percent effort to be charged to the project for each person named in the grant. Per review and agreement by our cognizant federal agency, UCSF data network costs are an allowable direct expense. The recharge rates are provided for under our approved DS-2, will be computed in accordance with applicable OMB requirements, including 2 CFR Part 220 (formerly Circular A-21), and will be reviewed and adjusted annually.

7/1/15 - 6/30/16	$41
7/1/16 - 6/30/17	$44
7/1/17 - 6/30/18	$46
7/1/18 - Until Amended	$47

Computing and Communication Device Support Services (CCDSS): CCDSS provides integral support to campus voice and data technology functions. CCDSS includes software installation/updates, internet security, hardware setup/configuration, and centrally managed patching, storage and backup. The university charges these expenses to all funding sources based on a monthly recharge rate per FTE, consistent with the university's current methodology used for data network services. The recharge rates are provided for under our approved DS-2, will be computed in accordance with applicable OMB requirements, including 2 CFR Part 220 (formerly Circular A-21), and will be reviewed and adjusted annually.

7/1/14 - 6/30/15	$79
7/1/15 - 6/30/16	$81
7/1/16 - 6/30/17	$83
7/1/17 - Until Amended	$83

CONSORTIUM COSTS

See Detailed Budgets following this budget justification.

FACILITIES AND ADMINISTRATIVE EXPENSES

Indirect Costs (F&A): Indirect Costs are established by a standard agreement with the Department of Health and Human Services, dated May 23, 2012. This project will be located on campus and charged the 58.5% indirect rate of modified total direct costs (MTDC). MTDC is comprised of total direct costs less graduate student tuition remission, patient care, off-campus rental costs, participant support costs, capital equipment, and subcontract expenses in excess of $25,000. Proration is based on the number of days at the applicable rate.

GE HEALTHCARE BIO-SCIENCES CORP
800 CENTENNIAL AVE.
PISCATAWAY, NJ 08855-1327

Account: UC SAN FRANCISCO

ZEV GARTNER
600 16TH ST
GENENTECH HALL
SAN FRANCISCO CA
USA 94158

Phone: (415)514-9962
Email:

Valid From: 06/03/2015
Valid To: 08/02/2015
Payment Terms: 30 NET
Freight Terms: FOB DESTINATION

Your GE Healthcare Sales Representative, David McAuliffe is pleased to offer you the following purchase proposal.

Line No	Product	Description	Qty	List Price	Unit Net Price	Discount %	Extended Net Price
1	29027886	INCA2200 IMAGING SYSTEM	1	$256,300.00	$256,300.00	0	$256,300.00
		Cell Analyzer 2200, large chip sCMOS camera High-speed High Content Analysis instrument without compromising imaging quality. IN Cell Analyzer 2200 can be configured to your specification through a range of optional modules and accessories, allowing you to build the instrument you need now, or upgrade as your needs evolve. Whole-well imaging, Preview scan, Slide imaging, Manual microscope mode, On-the-fly Deconvolution techniques and Fully Automated turret, SA collars, Polychroics are some of the unique futures of this equipment.12 month warranty that includes install and training Includes: - Software autofocus - Hardware autofocus - Image restoration options - Selected polychroics, filters, and objectives - Automated objective, correction collar and polychroic changing - IN Cell Analyzer 2200, large chip 5.5 MP sCMOS camera 2560 x 2160 pixels (5.5 Megapixel) - Workstation, Monitor, Keyboard and mouse - 10x 0.45 NA objective and 20X.45 NA objective - Deconvolution SW (2D, 2.5D, Advanced 2D)					
2	28954208	INCA LIVE A TEMP/EC	1	$28,500.00	$28,500.00	0	$28,500.00
		INCA2000 Live A Temp/EC					
3	28953487	INCA TRANS LIGHT	1	$22,800.00	$22,800.00	0	$22,800.00
		IN Cell Analyzer 2000 Transmitted Light Module.					
4	28953477	INCA 4X.2 OBJ LENS	1	$2,483.00	$2,483.00	0	$2,483.00
		IN Cell Analyzer 2000 4× 0.2 NA Objective Lens.					

GE HEALTHCARE BIO-SCIENCES CORP
800 CENTENNIAL AVE.
PISCATAWAY, NJ 08855-1327

Line No	Product	Description	Qty	List Price	Unit Net Price	Discount %	Extended Net Price
5	28953478	INCA 20X.75 OBJ LENS	1	$3,531.00	$3,531.00	0	$3,531.00
	IN Cell Analyzer 2000 20× 0.75 NA Objective Lens.						
6	28954475	INCA SLIDE HDLG(2)	1	$884.00	$884.00	0	$884.00
	IN Cell Analyzer 2000 Slide Handling Module						
7	28922202	KINEDX ROBOT FOR IN CELL	1	$59,500.00	$59,500.00	0	$59,500.00
8	28408971	INVESTIGATOR 1 ST WEB DNLD	1	$47,000.00	$47,000.00	0	$47,000.00
	IN Cell Investigator Software v1.6 offers a flexible and comprehensive solution for automated high-content analysis of live and fixed cell assays.						
9	28408975	INVESTIGATOR 1 ADD ST WEB DNLD	1	$11,600.00	$11,600.00	0	$11,600.00
	IN Cell Investigator Software v1.6 offers a flexible and comprehensive solution for automated high-content analysis of live and fixed cell assays.						
10	28988039	InCell 2000/2200 FullCare	1	$24,900.00	$24,900.00	0	$24,900.00
	A 12 month full coverage agreement including 1 PM, all parts, travel and labor						

Currency Code:	USD
Total List Price:	$457,498.00
Net Price:	$457,498.00
Shipping & Handling:	$4,000.00
Tax:	$33,074.82
Total Net Price:	$494,572.82

PLEASE NOTE THE NET PRICE LISTED ON THIS QUOTATION WILL REMAIN FIXED FOR THE TERM OF THE QUOTATION

Handling charges will be pre-paid and added to your invoice. Applicable handling, insurance, inside delivery, ice charges, and Tax may apply.

Taxes. Prices do not include sales, use, gross receipts, excise, valued-added, services, or any similar transaction or consumption taxes ("Taxes"). Customer acknowledges and agrees it shall be responsible for the payment of any such Taxes to GE Healthcare unless it otherwise timely provides GE Healthcare with a valid exemption certificate or direct pay permit. In

GE HEALTHCARE BIO-SCIENCES CORP
800 CENTENNIAL AVE.
PISCATAWAY, NJ 08855-1327

the event GE Healthcare is assessed Taxes, interest and penalty by any taxing authority, Customer agrees to reimburse GE Healthcare for any such Taxes, including any interest or penalty assessed thereon. Each party is responsible for any personal property or real estate taxes on property that the party owns or leases, for franchise and privilege taxes on its business, and for taxes based on its net income or gross receipts.

NOTE: FOR SHIPMENTS TO CALIFORNIA
The above quoted tax percentage may not reflect
California Manufacturing and R&D Partial Exemption
Cal Rev & Tax Code, Sec 6377.1
Regulation 1525.4 (Proposed)

Purchaser must evaluate whether it is a "qualified person" and provide a special exemption certificate to the retailer. If accepted in good faith, retailer is held harmless and purchaser is liable for any use tax.
When placing order please provide.

- Form BOE-230-M(5-14)
- Certificate by PO or Invoice
- Blanket Certificate
- Reference Quote provided by GEHC LifeSciences.

SEND ORDERS BY E-MAIL
E-mail order to CS-US@ge.com

SEND ORDERS BY FAX
Simply dial 1-877-295-8102 and your fax order will be automatically sent to our Customer Service Department

To place your order by phone or talk to a Customer Service Representative call 1-800-526-3593.
PLEASE REFER TO THIS QUOTATION NUMBER WHEN PLACING YOUR ORDER

Catalog numbers on this quotation are correct as of the date of quotation, but are subject to change.

Remittance Address:
GE Healthcare Bio-Sciences Corp.
P.O. Box 643065
Pittsburgh, PA 15264

If you do not have a Master Agreement in place with GE Healthcare Bio-Sciences Corp ("GEHC"), to expedite processing of your Purchase Order, please accept GEHC's terms and conditions set forth at
http://www.gelifesciences.com/webapp/wcs/stores/servlet/catalog/en/GELifeSciences/about-us/terms-and-conditions
by signing the signature line below and returning a copy of this signed Quote with your Purchase Order to an authorized GEHC Customer Service Representative. All additional and/or different terms are hereby rejected unless explicitly agreed upon in writing by both parties. If this Quote is not signed and Buyer's Purchase Order is accepted by GEHC, our Master Agreement shall apply, or if there is no Master Agreement in place, GEHC's standard terms and conditions of sale shall apply to such Purchase Order. GEHC does not accept Buyer's terms and conditions unless otherwise expressly agreed upon in writing by GEHC.

IN WITNESS WHEREOF, Buyer has caused this Quote to be signed by its authorized representative as of the date written below

Buyer: _____

Signature: _____

Printed Name: _____

GE HEALTHCARE BIO-SCIENCES CORP
800 CENTENNIAL AVE.
PISCATAWAY, NJ 08855-1327

Title: _____

Date: _____

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	0.50	**6,409**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**6,409**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**31,475**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**37,884**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,598**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**41,482**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**4,398**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**21,547**	
TOTAL OTHER DIRECT COSTS				**25,945**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,427**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 48880)**					
TOTAL INDIRECT COSTS (F&A)				**29,572**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**99,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**99,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	0.50	**6,601**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**6,601**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**32,418**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**39,019**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,706**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**42,725**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**2,618**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**22,409**	
TOTAL OTHER DIRECT COSTS				**25,027**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,752**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 48343)**					
TOTAL INDIRECT COSTS (F&A)				**29,248**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	0.50	**6,799**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**6,799**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**33,392**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,191**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,816**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**44,007**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**778**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**23,306**	
TOTAL OTHER DIRECT COSTS				**24,084**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**71,091**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 47785)**					
TOTAL INDIRECT COSTS (F&A)				**28,910**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,001**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,001**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	0.50	**7,003**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**7,003**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**33,375**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,378**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,879**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**44,257**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**2,361**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**23,573**	
TOTAL OTHER DIRECT COSTS				**25,934**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**71,191**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 47618)**					
TOTAL INDIRECT COSTS (F&A)				**28,809**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	0.50	**7,213**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**7,213**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**34,377**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**41,590**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,995**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**45,585**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**445**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**24,516**	
TOTAL OTHER DIRECT COSTS				**24,961**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**71,546**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 47030)**					
TOTAL INDIRECT COSTS (F&A)				**28,453**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**99,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**99,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Board of Trustee of the Leland Stanford Junior University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sindy Tang

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sindy Tang - Co-Investigator**	0.00	0.00	2.50	**34,025**	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.50	**34,025**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**5**) GRADUATE STUDENTS				**165,037**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**199,062**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**18,994**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**218,056**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**11,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,600**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**115,351**	
TOTAL OTHER DIRECT COSTS				**125,951**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**355,007**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**144,992**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**499,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**499,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

This budget was constructed for the period 06/01/2016 to 05/31/2021. The Facilities and Administration rates used are those negotiated between the U.S. Office of Naval Research and Stanford University (provisional agreement dated 08/19/2014). The F&A cost rate used in this proposal is the on-campus organized research rate of 60.5%. The indirect cost rate applied to animal care is 77.9%.

Per our negotiated rate agreement with the Office of Naval Research (dated 09/12/2014) for FY15, the budgeted salary amount for staff includes 8.9% vacation accrual/disability sick leave (DSL) for exempt employees and 7.7% for non-exempt employees. This amount does not exceed total salary. The vacation accrual/DSL rates will be charged at the time of the salary expenditure. No salary will be charged to the award when the employee is on vacation, disability or worker's compensation.

A cost-of-living increase of 3% was assumed for salaries according to guidelines approved by Stanford University. A 3% inflation rate was assumed for all other categories except where noted. These increases have been projected into all years of the budget.

A. SENIOR PERSONNEL
Professor Sindy Tang (PI and Stanford Site Director) (0.5 summer month in each year) will serve as a co-investigator via a subcontract to Stanford. Her areas of expertise are in design and development of microfluidics systems for cell biology. She will participate in study design and interpretation of data in collaboration with other investigators on the project. She will coordinate meetings and sharing information with the collaborative members on the project. She will also supervise the graduate student supported by the project, and will coordinate dissemination of research results, data management, and all education and outreach activities.

B. OTHER PERSONNEL
Support is requested for a graduate student, TBN (50% effort during academic year in each year, 15% effort during summer in year 1,2 and 10% in year 3,4). The student will be responsible for designing, building and testing the proposed experiments and carrying out all research studies.

C. FRINGE BENEFITS
Fringe benefits are calculated based on following rates:

Faculty:	32.45%
Graduate Students:	5.2%

D. EQUIPMENT. No capital equipment is requested for this proposal

E. DOMESTIC TRAVEL. No travel support is requested.

G. OTHER DIRECT COSTS

Materials and supplies: Budget is requested for materials and supplies costs associated with the research and education activities. The costs are intended for fabrication, operation and characterization of microfluidic devices, as well as the purchase and maintenance of biological cultures and supplies.

Other: Graduate Student Tuition: 1993 OMB Circular A-21 revisions require Stanford University to charge tuition directly for Graduate Student Research Assistants working on sponsored projects. The

tuition is scaled for the percent effort of the student on the project. The escalation factor is 4% for the years that follow.

I. INDIRECT COST RATES

Indirect cost is assessed on Modified Total Direct Costs: Stanford University's current negotiated indirect cost rate for a research project of this nature is 60.5% for UFY 2014 and years following. This rate is charged to the modified total direct cost base, which on this budget exclude graduate student tuition and subcontracts in excess of $25,000.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Exploratorium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jennifer Frazier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	4.90	0.00	0.00	**25,063**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	4.90	0.00	0.00	**25,063**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.90	0.00	0.00	**50,884**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**75,947**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**35,201**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**111,148**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**19,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**19,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,148**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 131148)**					
TOTAL INDIRECT COSTS (F&A)				**68,853**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**200,001**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**200,001**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Exploratorium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jennifer Frazier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	4.80	0.00	0.00	**25,213**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	4.80	0.00	0.00	**25,213**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.50	0.00	0.00	**50,733**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**75,946**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**35,201**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**111,147**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**19,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**19,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,147**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 131147)**					
TOTAL INDIRECT COSTS (F&A)				**68,852**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**199,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**199,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Exploratorium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jennifer Frazier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	3.90	0.00	0.00	**21,186**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.90	0.00	0.00	**21,186**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.30	0.00	0.00	**53,394**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**74,580**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**34,568**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**109,148**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**21,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,148**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 131148)**					
TOTAL INDIRECT COSTS (F&A)				**68,853**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**200,001**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**200,001**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Exploratorium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jennifer Frazier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	3.10	0.00	0.00	**17,075**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.10	0.00	0.00	**17,075**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.60	0.00	0.00	**51,355**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**68,430**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**31,717**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**100,147**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**30,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**30,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,147**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 131147)**					
TOTAL INDIRECT COSTS (F&A)				**68,852**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**199,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**199,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Exploratorium

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Jennifer Frazier

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	2.90	0.00	0.00	**16,470**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	2.90	0.00	0.00	**16,470**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**6**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	2.90	0.00	0.00	**51,277**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**67,747**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**31,401**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**99,148**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**31,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**31,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,148**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 52.5000, Base: 131148)**					
TOTAL INDIRECT COSTS (F&A)				**68,853**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**200,001**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**200,001**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **Exploratorium**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Jennifer Frazier**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Jennifer Frazier**	19.60	0.00	0.00	**105,007**	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	19.60	0.00	0.00	**105,007**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**30**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	40.20	0.00	0.00	**257,643**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**362,650**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**168,088**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**530,738**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**5,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**120,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**120,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**655,738**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**344,263**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,000,001**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,000,001**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME: **Jennifer Frazier**

ORG. REP. NAME*: **Michelle Stevens**

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

NSF Proposal

Center for Cellular Construction

June 1, 2016 – June 31, 2021

Budget Justification

Exploratorium, San Francisco, CA

A. Senior Personnel

Jennifer Frazier, Co-Investigator and Exploratorium site director (salary requested at approximately 4 calendar months over 5 years) will provide project leadership and ensure that research, educational design, and scientific content are appropriate for museum visitors and that project objectives are met. Dr. Frazier will also serve as the liaison with other Senior Staff in the Center for Cellular Construction and coordinate the Exploratorium's efforts with others in the Center.

B. Other Personnel

A **Project Manager** (11.2 calendar months) will communicate with staff, consultants, advisors, and partners on budget, reporting, and overall administration of the grant. The **Bio Lab Manager, Angela Armendariz** (12.6 calendar months) will train student interns in lab methods and coordinate development of demonstrations. The **Exhibit Developer**, **Denise King** (16.9 calendar months) will be responsible for designing and fabricating exhibits in collaboration with the student interns. A **Research Associate, Lisa Sindorf** (1.2 calendar months) will coordinate the data collection and qualitative and quantitative coding for formative evaluation. A **Writer-Editor, Kevin Boyd** (3.0 calendar months) will write and edit virtual copy to incorporate into the prototypes. A **Graphic Designer** (0.8 calendar months) will create exhibit labels to incorporate into the prototypes.

C. Fringe Benefits

Employee fringe benefits are calculated at an estimated 46.35% of salaries. The rate includes benefits such as, FICA, 403b Retirement, and the following insurance: Health, Dental, Unemployment, Disability, Workers' Compensation and LTD**.**

E. Travel
Funds to cover local and domestic travel to partner sites for collaborative meetings and laboratory visits ($1K/year in Yrs 1-5).

G. Other Direct Costs

G1. Materials and Supplies

(1) Materials for exhibit fabrication and exhibition treatment ($100K cumulative), such as metal, counter materials, microscopes, physical models, or other physical materials necessary.
(2) Materials for creating demonstrations ($25K cumulative), such as lab equipment, materials for culturing or displaying organisms, and graphics supplies.

I. Indirect Costs

The Exploratorium's FY15 provisional rate has been approved by NSF at 52.50% of total direct costs excluding capital expenditures, sub-awards greater than $25,000 and participant support costs.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	3.60	0.00	0.00	**43,674**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.60	0.00	0.00	**43,674**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**207,294**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	4.78	0.00	0.00	**58,022**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**2**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**308,990**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**308,990**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**22,170**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,364**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**1,364**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**332,524**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.3650, Base: 332524)**					
TOTAL INDIRECT COSTS (F&A)				**167,476**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**500,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**500,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	3.60	0.00	0.00	**46,198**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.60	0.00	0.00	**46,198**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**200,248**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.24	0.00	0.00	**105,745**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**2**) OTHER				**50,062**	
TOTAL SALARIES AND WAGES (A + B)				**402,253**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**402,253**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**22,170**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**3,672**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,672**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**428,095**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 51.8350, Base: 428095)**					
TOTAL INDIRECT COSTS (F&A)				**221,903**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**649,998**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**649,998**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	3.60	0.00	0.00	**47,207**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.60	0.00	0.00	**47,207**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**205,487**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.21	0.00	0.00	**99,494**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**2**) OTHER				**51,372**	
TOTAL SALARIES AND WAGES (A + B)				**403,560**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**403,560**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**22,170**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**5,100**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,100**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**430,830**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.8720, Base: 430830)**					
TOTAL INDIRECT COSTS (F&A)				**219,172**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**650,002**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**650,002**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	3.60	0.00	0.00	**48,237**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.60	0.00	0.00	**48,237**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**210,862**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.01	0.00	0.00	**93,884**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**2**) OTHER				**52,716**	
TOTAL SALARIES AND WAGES (A + B)				**405,699**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**405,699**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**22,170**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**5,151**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,151**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**433,020**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.1080, Base: 433020)**					
TOTAL INDIRECT COSTS (F&A)				**216,978**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**649,998**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**649,998**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	3.60	0.00	0.00	**49,270**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.60	0.00	0.00	**49,270**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	24.00	0.00	0.00	**216,378**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.43	0.00	0.00	**88,085**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**2**) OTHER				**54,095**	
TOTAL SALARIES AND WAGES (A + B)				**407,828**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**407,828**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**22,170**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**5,203**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,203**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**435,201**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 49.3560, Base: 435201)**					
TOTAL INDIRECT COSTS (F&A)				**214,798**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**649,999**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**649,999**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
IBM Almaden Research Center

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Simone Bianco

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Simone Bianco - Lead**	18.00	0.00	0.00	**234,586**	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	18.00	0.00	0.00	**234,586**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**10**) POST DOCTORAL SCHOLARS	120.00	0.00	0.00	**1,040,269**	
2. (**10**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	38.67	0.00	0.00	**445,230**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**10**) OTHER				**208,245**	
TOTAL SALARIES AND WAGES (A + B)				**1,928,330**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,928,330**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**110,850**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**20,490**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**20,490**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,059,670**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**1,040,327**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**3,099,997**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**3,099,997**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

IBM Budget Justification

IBM Cost Proposal in response to NSF 14-600 – Prepared for UCSF Science and Technology Centers: Integrative Partnerships

Cover Sheet	
Solicitation number;	NSF 14-600
Name and address of the Offeror;	IBM Almaden Research Center 650 Harry Road, San Jose, CA 95120-6099 **PI:** Simone Bianco Email: sbianco@us.ibm.com
Name and telephone number of contract point of contact;	Carl E. (Ed) Taylor, Sr. C&N Manager IBM Research, 2C-10, 1 North Castle Drive Armonk, NY 10504-1785 Phone: 713-797-4625 Email: cetaylor@us.ibm.com
Name, address, telephone number of the offeror's Defense Contract Management Agency (DCMA) administration office or equivalent cognizant contract administration entity, if known	Richard Parnacott, ACO, DCMA P. O. Box 232, French Camp, CA 92531-0232 Phone: 209-941-7066 Email: richard.parnacott@dcma.mil
Name, address, telephone number of the offeror's Defense Contract Audit Agency (DCAA) audit office or equivalent cognizant contract audit entity, if known	Dave Roncace, Supervisory Auditor New York Branch Office, Northeastern Region 201 Varick Street, Room 615; New York, NY 10014-4882; Phone: 914-766-4047 Email: David.Roncace@dcaa.mil
Type of Contract	Grant – Cost Reimbursement; no fee
Proposed cost, profit or fee and total;	Cost - $3,100,000
DUNS number	183717651

IBM is proposing five (5) 12-month periods for a total cost of $3,100,000. The start date is assumed to be 6/1/2016.

Summary of Costs	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Direct Labor						
Regular Labor	$101,696	$151,943	$146,701	$142,121	$137,355	$679,816
Non Reg Labor	$207,294	$250,310	$256,858	$263,578	$270,473	$1,248,514
Direct Labor Subtotal	**$308,991**	**$402,253**	**$403,559**	**$405,699**	**$407,828**	**$1,928,329**
Indirect Costs						
Indirect Subtotal	**$167,476**	**$221,905**	**$219,171**	**$216,980**	**$214,800**	**$1,040,331**
Other Direct Costs						
Publications	$1,364	$3,672	$5,100	$5,151	$5,202	$20,489
Travel	$22,170	$22,170	$22,170	$22,170	$22,170	$110,850
Other Direct Subtotal	**$23,534**	**$25,842**	**$27,270**	**$27,321**	**$27,372**	**$131,339**
Totals	**$500,000**	**$650,000**	**$650,000**	**$650,000**	**$650,000**	**$3,100,000**

IBM Research accounting system has been deemed adequate by the Defense Contract Audit Agency (DCAA). The provisional 2015 rates have been submitted to the DCAA. Indirect Rate Letter and calculation details will be provided directly to the NSF upon request.

IBM Budget Justification

Direct Labor Costs

Labor: Based on salaries of IBM full time employees expected to work on the project. The cost estimates were based on the employees shown in the table below. Regular labor is based on 2010.81 hours per year. Non-Regular labor is based on 2123.52 hours per year.

IBM Labor Hours	Year 1	Year 2	Year 3	Year 4	Year 5
Regular Labor					
Simone Bianco	603	603	603	603	603
Stefan Edlund	701	1280	1171	1074	978
Julie Pope Equivalent - PM Support	101	101	101	101	101
Non-Regular Labor					
Post Doc #1	2124	2124	2124	2124	2124
Post Doc #2	2124	2124	2124	2124	2124
Intern #1	0	531	531	531	531
Intern #2	0	531	531	531	531
Total	**5652**	**7293**	**7183**	**7086**	**6991**

Publications: Publication charges are based on fees listed by the representative journal(s) below. The publication, if it were to be made, would be relevant to this project.

Publications	Year 1	Year 2	Year 3	Year 4	Year 5
PloS One					
# of Articles	1	1	2	2	2
Cost per Article	$1,350	$1,350	$1,350	$1,350	$1,350
# of Pages	0	0	0	0	0
Cost per Page	$0	$0	$0	$0	$0
TOTAL ====>	**$1,350**	**$1,350**	**$2,700**	**$2,700**	**$2,700**
Plos Computational Biology					
# of Articles	0	1	1	1	1
Cost per Article	$0	$2,250	$2,250	$2,250	$2,250
# of Pages	0	0	0	0	0
Cost per Page	$0	$0	$0	$0	$0
TOTAL ====>	**$0**	**$2,250**	**$2,250**	**$2,250**	**$2,250**
Subtotal	**$1,350**	**$3,600**	**$4,950**	**$4,950**	**$4,950**
1% Annual Inflation	$14	$72	$150	$201	$252
Total	**$1,364**	**$3,672**	**$5,100**	**$5,151**	**$5,202**

Travel: The air fare where applicable is obtained from American Express which holds the IBM Corporate contract and is responsible to get us the lowest possible fare. Per Diem Misc costs associated with travel are in compliance with the Federal Travel Regulations for domestic and the Joint Travel Regulations published by the US Dept. of State for overseas travel. Per Diem includes taxi fares, parking, tips, etc. Car rental, when used, is based on IBM Corporate agreement with Hertz Corp. Car Rental includes $113 for round trip to the airport. Travel destinations and expenses are estimates based on current information at the time of pricing.

Annual Travel TRAVEL	# OF PEOPLE	# OF DAYS	AIR FARE	HOTEL & MEALS	PER DIEM MISC	AUTO RENTAL	OTHER	TOTAL	# OF TRIPS	TOTAL COST
San Francisco to Santa Fe, NM - Qbio Annual Conference										
Inputs/person	3	4	$559	$165	$10	$0	$550			
Calculation		12	$1,677	$1,980	$120	$339	$1,650	$5,766	1	$5,766
San Francisco to Salt Lake City, UT - SIAM Dynamical Systems										
Inputs/person	3	5	$489	$167	$10	$0	$315			
Calculation		15	$1,467	$2,505	$150	$339	$945	$5,406	1	$5,406
San Francisco to San Antonio, TX - Annual Mtg - American Physical Society										
Inputs/person	3	5	$516	$181	$10	$0	$375			
Calculation		15	$1,548	$2,715	$150	$339	$1,125	$5,877	1	$5,877
San Francisco to San Diego, CA - Annual Mtg - American Society for Cell Biology										
Inputs/person	3	5	$229	$213	$10	$0	$250			
Calculation		15	$687	$3,195	$150	$339	$750	$5,121	1	$5,121
								TOTAL ====>		$22,170

Indirect Costs

Burden: Based on a rate provisionally approved by the DCAA. It contains areas which have common application across all departments. Examples of charges contained in this rate would be mail room, security, safety, purchasing, and secretaries. The rate is applied directly proportionate with the hours worked on this project.

GEB: This is the benefit allocation to all regular employees which has been provisionally approved by the DCAA.

Lost Time: The lost time costs are based on a rate provisionally approved by the DCAA and is applied against both GEB for regular employees, and labor and burden for regular and non-regular employees.

Variable Pay Provision: This is the annual bonus which is/is not given out dependent upon how well the Corporation has done in the prior year. Individuals are awarded/not awarded depending upon how well the individuals achieve their goals.

Space Allocation: This is a proration of the space charge for offices, labs, etc. within the individual departments working on this project. The proration is based on the actual hours worked on this project.

Depreciation Allocation: This is the proration of the capital costs contained within the departments working on this project. The proration is based on the actual hours worked on this project.

Computer Usage Allocation: This reflects the costs associated with use of items such as PCs, servers, and the support to maintain them, etc. It does not contain the costs of actually buying equipment. This rate is charged directly proportionate to the hours worked by the individuals on this project.

G&A: General and administrative charges are based on a rate provisionally approved by the DCAA. It contains areas which have common application across all departments. Examples of the charges contained in this rate are: Human Resources and, Business Development, etc.

FCCM: Facilities Capital Cost of Money reflects costs as allowed by the Federal Acquisition Regulations and reflects a recovery for capital assets. The cost is calculated based upon DCAA provisionally approved rates.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
San Francisco State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Frank Bayliss

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	0.84	0.00	0.00	**3,433**	
2. **Mark Chan**	2.00	0.00	0.00	**15,245**	
3. **Diana Chu**	0.84	0.00	0.00	**3,433**	
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	3.68	0.00	0.00	**22,111**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**22,111**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,160**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**30,271**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **147,000**					
2. TRAVEL **8,400**					
3. SUBSISTENCE **0**					
4. OTHER **74,200**					
TOTAL NUMBER OF PARTICIPANTS (**7**) TOTAL PARTICIPANT COSTS				**229,600**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**17,948**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**17,948**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**277,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 46.0000, Base: 48219)**					
TOTAL INDIRECT COSTS (F&A)				**22,181**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**300,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**300,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
San Francisco State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Frank Bayliss

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	0.84	0.00	0.00	**3,433**	
2. **Mark Chan**	2.00	0.00	0.00	**15,702**	
3. **Diana Chu**	0.84	0.00	0.00	**3,433**	
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	3.68	0.00	0.00	**22,568**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**22,568**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,338**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**30,906**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **147,000**					
2. TRAVEL **8,400**					
3. SUBSISTENCE **0**					
4. OTHER **74,200**					
TOTAL NUMBER OF PARTICIPANTS (**7**) TOTAL PARTICIPANT COSTS				**229,600**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**17,313**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**17,313**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**277,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 46.0000, Base: 48219)**					
TOTAL INDIRECT COSTS (F&A)				**22,181**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**300,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**300,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
San Francisco State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Frank Bayliss

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	0.84	0.00	0.00	**3,433**	
2. **Mark Chan**	2.00	0.00	0.00	**16,173**	
3. **Diana Chu**	0.84	0.00	0.00	**3,433**	
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	3.68	0.00	0.00	**23,039**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**23,039**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,522**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**31,561**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **147,000**					
2. TRAVEL **8,400**					
3. SUBSISTENCE **0**					
4. OTHER **74,200**					
TOTAL NUMBER OF PARTICIPANTS (**7**) TOTAL PARTICIPANT COSTS				**229,600**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**16,658**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**16,658**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**277,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 46.0000, Base: 48219)**					
TOTAL INDIRECT COSTS (F&A)				**22,181**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**300,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**300,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
San Francisco State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Frank Bayliss

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	0.84	0.00	0.00	**3,433**	
2. **Mark Chan**	2.00	0.00	0.00	**16,658**	
3. **Diana Chu**	0.84	0.00	0.00	**3,433**	
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	3.68	0.00	0.00	**23,524**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**23,524**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,711**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**32,235**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **147,000**					
2. TRAVEL **8,400**					
3. SUBSISTENCE **0**					
4. OTHER **74,200**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**229,600**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**15,984**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**15,984**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**277,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 46.0000, Base: 48219)**					
TOTAL INDIRECT COSTS (F&A)				**22,181**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**300,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**300,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
San Francisco State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Frank Bayliss

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	0.84	0.00	0.00	**3,433**	
2. **Mark Chan**	2.00	0.00	0.00	**17,158**	
3. **Diana Chu**	0.84	0.00	0.00	**3,433**	
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	3.68	0.00	0.00	**24,024**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**24,024**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,906**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**32,930**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **147,000**					
2. TRAVEL **8,400**					
3. SUBSISTENCE **0**					
4. OTHER **74,200**					
TOTAL NUMBER OF PARTICIPANTS (**7**) TOTAL PARTICIPANT COSTS				**229,600**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**15,289**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**15,289**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**277,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 46.0000, Base: 48219)**					
TOTAL INDIRECT COSTS (F&A)				**22,181**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**300,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**300,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **San Francisco State University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Frank Bayliss**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Frank Bayliss**	4.20	0.00	0.00	**17,165**	
2. **Mark Chan**	10.00	0.00	0.00	**80,936**	
3. **Diana Chu**	4.20	0.00	0.00	**17,165**	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**3**) TOTAL SENIOR PERSONNEL (1 - 6)	18.40	0.00	0.00	**115,266**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**115,266**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**42,637**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**157,903**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **735,000**					
2. TRAVEL **42,000**					
3. SUBSISTENCE **0**					
4. OTHER **371,000**					
TOTAL NUMBER OF PARTICIPANTS (**28**) TOTAL PARTICIPANT COSTS				**1,148,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**83,192**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**83,192**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,389,095**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**110,905**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,500,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,500,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME: **Frank Bayliss**

ORG. REP. NAME*: **Michelle Stevens**

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Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

NSF Center for Cellular Construction

1) Personnel: Principal Investigators
    a. Frank Bayliss, PhD, Professor of Biology, Director Student Enrichment Opportunities Office (SEO) and Diversity Coordinator. Dr. Bayliss will provide administrative leadership through the SEO office including managing the budget, appointing the faculty and students and participating in the Center activities. He will dedicate 7% time (1/15) over the academic year. Dr. Bayliss will work with Drs. Chu and Chan in the selection/admission of incoming Center for Cellular Construction (CCC) MS students and he will also maintain a data base to track CCC students after they graduate for at least 10 years.
    b. Diana Chu, Associate Professor of Biology, and Biology Department Graduate Advisor will provide leadership for the other participating Cell Biology & Engineering faculty. She will serve as the CCC contact for the Cell and Molecular Imaging Center (CMIC). She will also lead the recruitment and selection of new CCC MS students. She will dedicate 7% time (1/15) on an academic year basis.
    c. Mark Chan, Assistant Professor of Biology and SFSU site director recently completed post-doctoral study with Dr. Wallace Marshall at UCSF who is a Co-PI on this NSF CCC proposal. Mark was involved during the initial development of the pre-proposal and is well situated to assume the role of the SFSU/UCSF liaison in the partnership. He will facilitate interactions between SFSU faculty and the UCSF Core facilities and faculty. Mark will also represent SFSU on appropriate partnership committees. Mark will commit 20% time to these efforts.

2) Participant Support Costs: MS Graduate Students
    a. We plan to admit a total of 7 MS students (3 second-year and 4 new first-year students in year 1 and then replace the graduating students each year thereafter (3 in year 2, 4 in year 3, 3 in year 4 and 4 in year 5).
    b. CCC MS Students will receive our standard stipend of $21,000/year, Full Tuition ($7,800), $1,200 annually for travel to present research at national scientific meetings, $2,800/year for each MS student to purchase a computer, software, books, and supplies to support their research.

3) Supplies:
    a. $83,435 Total ($17,949 Yr1; $17,313 Yr2; $16,900 Yr3; $15,984 Yr4; $15,289 Yr5) The Cell and Molecular Imaging Center (CMIC) at SFSU charges $20/hour for training, supplies and use of their equipment. Students will first receive at least two four-hour training sessions on use of the Zeiss LSM710 laser point scanning confocal microscope and/or the Zeiss CellObserver Spinning Disk confocal microscope or other equipment that is described in the Resources section. Dr. Annette Chan, the facility manager, will then track hourly usage of SFSU Center students at the normal SFSU rate of $20/hour for use of facility equipment related to their research projects (see Facilities and Equipment Section).

SUMMARY PROPOSAL BUDGET

YEAR 1

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.12	0.00	0.00	**1,602**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.12	0.00	0.00	**1,602**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	6.00	0.00	0.00	**26,110**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**27,712**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,835**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**34,547**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**24,758**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**24,758**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**62,305**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 62305)**					
TOTAL INDIRECT COSTS (F&A)				**37,695**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.12	0.00	0.00	**1,602**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.12	0.00	0.00	**1,602**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	6.00	0.00	0.00	**26,893**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**28,495**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,040**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**35,535**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**23,770**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**23,770**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**62,305**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 62305)**					
TOTAL INDIRECT COSTS (F&A)				**37,695**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.12	0.00	0.00	**1,602**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.12	0.00	0.00	**1,602**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	6.00	0.00	0.00	**27,700**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**29,302**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,251**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**36,553**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**22,752**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**22,752**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**62,305**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 62305)**					
TOTAL INDIRECT COSTS (F&A)				**37,695**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.12	0.00	0.00	**1,602**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.12	0.00	0.00	**1,602**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	6.00	0.00	0.00	**28,531**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,133**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,469**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**37,602**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**21,703**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,703**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**62,305**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 62305)**					
TOTAL INDIRECT COSTS (F&A)				**37,695**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.12	0.00	0.00	**1,602**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.12	0.00	0.00	**1,602**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	6.00	0.00	0.00	**29,386**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,988**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,693**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**38,681**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**20,624**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**20,624**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**62,305**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 62305)**					
TOTAL INDIRECT COSTS (F&A)				**37,695**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Stanford University School of Medicine

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Manu Prakash

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Manu Prakash - Co-Investigator**	0.60	0.00	0.00	**8,010**	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.60	0.00	0.00	**8,010**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**5**) POST DOCTORAL SCHOLARS	30.00	0.00	0.00	**138,620**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**146,630**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**36,288**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**182,918**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**15,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**113,607**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**113,607**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**311,525**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**188,475**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**500,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**500,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Michelle Stevens

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C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

BUDGET JUSTIFICATION

INTRODUCTION

This budget was constructed for the period 06/01/2016 to 05/31/2021. The Facilities and Administration rates used are those negotiated between the U.S. Office of Naval Research and Stanford University (provisional agreement dated 08/19/2014). The F&A cost rate used in this proposal is the on-campus organized research rate of 60.5%. The indirect cost rate applied to animal care is 77.9%.

The staff benefit rates used are those negotiated between Stanford University and the Office of Naval Research (agreement dated 09/12/2014). The rates are: Faculty and staff 30.6%; Postdoctoral Affiliates 24.3%; Graduate Students 5.2%; and Temporary or Casual Employees 8.8%.

The maximum Graduate Student appointment is 50%. 100% of the salary associated with that appointment is dedicated to this project. (100% of budget base salary = 50% appointment; 50% of budget base salary = 25% appointment).

Per our negotiated rate agreement with the Office of Naval Research (dated 09/12/2014) for FY15, the budgeted salary amount for staff includes 8.9% vacation accrual/disability sick leave (DSL) for exempt employees and 7.7% for non-exempt employees. This amount does not exceed total salary. The vacation accrual/DSL rates will be charged at the time of the salary expenditure. No salary will be charged to the award when the employee is on vacation, disability or worker's compensation.

A cost-of-living increase of 3% was assumed for salaries according to guidelines approved by Stanford University. A cost-of-living increase of 6.8% (FY15 & FY16) and 6.90% (FY17) was assumed for Animal Care costs. A 3% inflation rate was assumed for all other categories except where noted. These increases have been projected into all years of the budget.

PERSONNEL

Manu Prakash (PhD.) (Principal Investigator, 1%. 12 cm effort). Dr. Prakash will serve as a co-Investigator via a subcontract to Stanford. His areas of expertise are in soft condensed matter physics, organismic biophysics, instrumentation (imaging, optics, microfluidics) and reconstitution of active matter. He will engage in study design and interpretation of data in collaboration with other investigators on the project. He will coordinate meetings and sharing information with the collaborative members on the project. Asana will be used as a collaboration tool.

Postdoc – TBD (Postdoc candidate 50% 6.00 cm) primarily based in Prakash Lab will be engaged in all parts of the project. The candidate will have a background in physics and biology science.

EQUIPMENT

None

SUPPLIES-$113,109

A budget is set for supplies including molecular biology reagents, antibodies, and any other services related to wet bench work. The supplies also include plastic ware and general lab supplies for the project. The cost also accounts for soft-lithography fabrication facilities and imaging cost center shared facility access.

TRAVEL-$15,000

Travel funds are requested for the Principal Investigator and one student to travel to one conference per year.

OTHER EXPENSES

None

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**48,192**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**48,192**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**8,675**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**56,867**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**6,827**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**6,827**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,694**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 63694)**					
TOTAL INDIRECT COSTS (F&A)				**36,306**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**49,156**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**49,156**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,340**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**58,496**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**5,198**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,198**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,694**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 63694)**					
TOTAL INDIRECT COSTS (F&A)				**36,306**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**50,139**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**50,139**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,526**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**59,665**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**4,029**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**4,029**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,694**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 63694)**					
TOTAL INDIRECT COSTS (F&A)				**36,306**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**51,142**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**51,142**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,206**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**60,348**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**3,346**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,346**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,694**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 63694)**					
TOTAL INDIRECT COSTS (F&A)				**36,306**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**52,165**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**52,165**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,911**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,076**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**1,618**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**1,618**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,694**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0000, Base: 63694)**					
TOTAL INDIRECT COSTS (F&A)				**36,306**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**100,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Daniel Fletcher

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**0**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**5**) POST DOCTORAL SCHOLARS	60.00	0.00	0.00	**250,794**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**250,794**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**46,658**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**297,452**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**21,018**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,018**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**318,470**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**181,530**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**500,000**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**500,000**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Michelle Stevens

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

Daniel Fletcher
UC Berkeley

Personnel:

- Dr. Daniel Fletcher, UC Berkeley site director (Effort as needed, no salary requested). Dr. Fletcher will be responsible for guiding reconstitution of membrane interfaces using giant unilamellar vesicles and transmembrane adhesion proteins. He has extensive experience reconstituting proteins on synthetic vesicles and studying the basic biophysics of membrane shape change and organization, and he will be responsible for working with the Postdoc to design experiments interpret data, and prepare publications and presentations.

- TBN, Postdoctoral Researcher, (12 Calendar Months, 100% Effort). The Postdoc will be responsible for carrying out the membrane interface reconstitution experiments including formation of giant unilamellar vesicles, purification of proteins, and fluorescence imaging of the membrane interfaces. The Postdoc will also contribute to Monte Carlo modeling of protein organization at the membrane interface, and he/she will assist with designing experiments, analyzing data, and preparing publications and presentations.

Salary is increased at a rate of **2**% per year for the Post-doc to allow for cost of living adjustment.

Fringe Benefits:

- Fringe benefits for the **Postdoctoral Researcher** are calculated at the University of California rate of 18%. Based on current projections, this rate escalates to 19%, in Years 2-5.

Materials and Supplies:

Funds are requested for materials for preparation of purified proteins and synthetic vesicles and fluorescent imaging of samples, including standard laboratory supplies (pipette tips, plasticware, glass slides and coverslips) and reagents (purification buffers, synthetic lipids, solvents).

Indirect Charges:

The On-Campus Facilities and Administrative Cost Rate of **57**% is used to determine IDC.
Indirect cost charges are calculated using modified total direct costs (which excludes equipment and the graduate student's tuition remission and health insurance, participant support, and subaward costs in excess of $25,000 per subaward). This reflects the on-campus indirect cost rate established by the University and DHHS in an agreement dated **August 8, 2014**.

WALLACE MARSHALL

Other Support- Current and Pending

Current research support

Marshall Current Support

MCB-1411898 PI: Marshall 8/1/2014 - 7/31/2019 1.0 calendar
NSF $2,300,000
Building a community to pursue quantitative cell biology.
The goal of this project is to catalyze the development of quantitative cell biology as a discipline through a series of interactive workshops and meetings, combined with student and personnel exchange programs, to bring together researchers and educators working at the interface between cell biology and quantitative sciences. This grant is aimed at the same general topic as the current proposal, but whereas this grant is strictly focused on meetings and exchanges and does not support any research activities, the current proposal seeks to develop quantitative cell biology through a specific inter-disciplinary research project.
Role: PI

R01 GM097017 PI: Marshall 5/1/2011 - 4/30/2019 2.64 calendar
NIH/NIGMS $1,220,291
Modeling and Analysis of the Flagellar Length Control System
The goal of this project is to analyze the mechanisms that regulate the length of the eukaryotic flagellum, using a combination of quantitative live-cell analysis methods and computational modeling. The aims of this proposal are:
1. Analysis of transcription-mediated feedback loop regulation flagellar assembly by inducing gene expression during rapid phases of flagellar growth.
2. Statistical time-series analysis of intraflagellar transport, using live cell TIRF microscopy and automated image analysis tools.
3. Integration of transcription and intraflagellar transport into a complete model for flagellar length control.
4. Model verification and parameter estimation for the flagellar length control system using scaling and fluctuation analysis.
This proposal focuses strictly on computational analysis and modeling of flagellar transport, and there is no overlap with the current proposal.
Role: PI

R01 GM077004PI: Marshall 3/1/2006-7/31/2015 3.12 calendar
NIH/NIGMS $1,152,760
Genetic analysis of centriole orientation
The goal of this study is to identify centriole proteome components and their role in controlling centriole position and orientation, with a particular focus on orientation of basal bodies in multiciliated epithelia. The specific aims are:
1. Determine the function of ASQ2 in centriole positioning.
2. Identify and characterize the ASQ1 gene
3. Systematic identification of genes required for centriole orientation in multiciliated epithelia
This grant is focused entirely on experimental studies on centrioles and there is no overlap with the current proposal.
Role: PI

P50 GM081879 PI: Lim 9/1/2010 - 6/30/2015 0.12 cal. effort only
NIH/NIGMS $55,000 annual direct
Exploring design principles of cellular control circuits.
The goal of this P50 funded center is to enumerate the possible computational functions that can be performed by cellular signaling pathways, using a combination of computational and synthetic biology approaches. My lab receives direct funding as part of this grant to develop synthetic biology tools for reprogramming the size of the yeast vacuole. This grant is focused entirely on experimental studies in synthetic biology and there is no overlap of this project with the current proposal.
Role: co-investigator.

R01 GM113602 PI: Marshall 2/01/2015 – 1/31/2019 2.40 calendar
NIH/NIGMS $1,587,169
Pattern formation and regeneration in a single cell
The goal of this proposal is to determine the genomic program underlying regeneration and morphogenesis in the giant single-celled organism *Stentor coeruleus*.
Role: PI
Overlap: none.

Pending research support

Marshall Pending Support
DP1 OD020513 Marshall (PI) 2015 – 2020
Linking organelle size to cell function through cancer cytopathology
The goal of this proposal is to determine the molecular pathways that give rise to changes in cell morphology that are the basis of clinical cytopathology.
Role: PI
Overlap: none.

R21 CA185693 Marshall (PI) 2015-2017
Method for Quantifying Cellular Dysplasia in Cancer Progression
The goal of this study is to test the ability of an algorithm, recently developed in our lab for quantifying the statistical order within cells, to discriminate cancer cells from normal cells, using cell array slides and automated image analysis.
Role: PI.
Overlap: none.

1515456 Marshall (PI) 2015 – 2018
NSF $900,000
Quantitative Cell Geometry – Defining Cell State at the Organelle Level
A single cell can be viewed as a complex machine, like a tiny robot, capable of computations and decision making. We will use organelle-level cell geometry to identify cell states and their transitions as the basis for a finite state automata model of cell behavior. Our goal is to build a statistically rigorous FSA model for living cells and ask whether it can be effectively used to predict cell behavior under different conditions.
Role: PI.
Overlap: none.

OTHER SUPPORT

GARTNER, ZEV J.

ACTIVE

W81XWH-10-1-1023 (PI: Gartner) 09/22/10—09/21/15 6.0 calendar
BCRP Era of Hope Scholars Award $3,121,314 total costs
A role for tissue microstructure in breast cancer progression?
This grant application outlines our ongoing efforts to synthesize *in vitro* a three dimensional acinar structure composed of luminal and myoepithelial cell lines and to understand the tumor-suppressive role of myoepithelial cells.

W81XWH-13-1-0221 (PI: Gartner) 09/30/13—09/29/18 0.6 calendar
DOD Era of Hop Scholar Expansion Award $3,037,574 total costs
A multiscale and multicomponent in vitro model of the human mammary gland
This proposal aims to develop a preclinical model of the human breast and breast cancer for drug screening. It has four goals. First, to vascularize an epithelial tissue and test its permeability to low and high molecular weight compounds; second, to reconstruct a stable mammary stem cell niche and test its ability to self-renew both epithelial compartments; third, to integrate hormone responsiveness to the tissue and test its ability to expand and involute in response to estrogen; fourth, to integrate subsets of functional immune cell and adipocytes to the tissue to model tumor-immune cell interactions. Some overlap exists between the tools and techniques of this proposal and the NIH DP2.

DP2HD080351-01 (PI: Gartner) 09/30/13—07/31/2018 3.0 calendar
NIH/OD $2,372,625 total costs
Total Synthesis of the Human Mammary Gland.
The first goal is to establish conditions to direct the self-assembly of multiple cell types into a model of the human mammary gland. The second goal is to use these tissues to challenge basic assumptions about the collective behavior of cells in human tissues.

MCB-1330864 (PI: Gartner) 12/01/13—11/30/17 0.24 calendar
NSF Investigator Initiated Award $400,000 total costs
Spatial coordination of emergent cell behaviors by Ras.
This proposal aims to build a quantitative and mechanistic model for how spatial patterns of Ras activity coordinate specific emergent behaviors in groups of interacting epithelial cells.

R21CA195709 (PI: Gartner) 09/18/14—08/31/16 0.6 calendar
NIH/NCI $376,958 total costs
Identifying the intercellular networks regulating estrogen receptor expression with a high definition single cell printer
The proposed study seeks to develop a technology for printing single primary human cells into arrays of small multicellular tissues with the ability to specify the precise cell printed at every position. This printing technology is broadly relevant to human health, which we will demonstrate by using it to study the mechanism that drives estrogen receptor positive breast cancer. Ultimately, in addition to studying and experimenting on individual cells, we believe our groundbreaking technology will be able to print whole, functional tissues for organ replacement.

P50 GM081879 (PI: Lim) 07/01/2012—06/30/2015 0.64 calendar
UCSF/NIH Center for Synthetic and Systems Biology $517,997 total costs
New tools for the study of mechanical homeostasis in 3D tissues
The long-term goal of my portion of this proposal is to understand how networks of cells respond dynamically to changes in the mechanical properties of their neighbors.
Role on Project: Co-Investigator

PENDING

P50 Renewal (Wendell)

OVERLAP

Some overlap exists between the first goal of the DP2 (NIH) proposal and the DOD Era of Hope Expansion Award. Specifically, both proposals will utilize a complex 3D *in vitro* model of the human breast that will be implemented in the lab. However, the DOD proposal aims to develop this model as a platform for preclinical drug screening of breast cancer drugs. The DP2 (NIH) proposal will focus on using this model as a "test bed" to better understand human tissue self-organization, normal human tissue biology, and how tissue properties changes during cancer.

Other Support- Current and Pending

LIM, WENDELL A.

ACTIVE

No Project Number (Lim) 9/1/08 - 8/31/15 0.6 Cal. Mos
Howard Hughes Medical Institute $4,365,146 (total award)
The Design Logic of Cell Signaling Systems ($675,849 ADC)
This grant supports our studies on dissecting and engineering cell signaling molecules and networks in yeast and mammalian cells. My lab currently receives funding for operations (lab supplies and services, travel, publications, equipment maintenance, etc.) and personnel (salary for 2 postdoctoral associates, 2 technicians and an administrative assistant). All HHMI budgets are determined annually.

PN2 EY016546-11 (Lim) 9/30/04 – 7/31/15 1.0 Cal Mos
NIH/NEI $16,000,102 enter center
Cellular Control: Synthetic Signaling/Motility (RMI)
This transition-funding proposal outlines a two-year phase-out plan for the Cell Propulsion Lab at the UCSF/UCB Nanomedicine Development Center. The specific aims of this phase of the project are 1) use synthetic biology to tune and optimize signaling pathways of anti-cancer T Cells (T cells expressing artificial chimeric antigen receptors – "CARs" – that are directed against tumor antigens) such that they show improved discrimination against cancer vs. non-cancer cells and 2) demonstrate the potential of microfluidic jetting vesicles as a platform for engineering smart therapeutics.

SA5285 (Lim) 7/1/06 – 6/30/15 0.6 Cal Mos
UC Berkeley (Prime: NSF / # EEC-0540879, PI Keasling) $53,858 (Lim lab ADC)
Synthetic Biology Engineering Center (SynBERC) $2,600,947 – entire multi investigator Center
This is a multi-institutional NSF Engineering Research Center (UC Berkeley, UCSF, MIT, Harvard, TAMU-Prairie View). The goal of this center is to establish a framework for engineering bacteria and other cells for useful purposes.

P50 GM081879–05 (Lim) 9/1/10 – 6/30/15 3.6 Cal Mos
NIH/NIGMS National Centers for Systems Biology $14,911,087 entire Center
Exploring Design Principles of Cellular Control Circuits ($1,978,500 Lim total; $185,000 Lim lab ADC)
This multi-investigator center is aimed at understanding and applying design principles of cellular response networks, using computational, synthetic and comparative analysis. This grant also supports independent Systems Biology Fellows, and education/outreach in this area with local high school students.

R01 GM096164-03 (Weiner, Voigt, Lim) 3/1/12 - 1/31/16 0.6 Cal Mos
NIH/NIGMS $1,807,583 entire project
A Toolkit for Light-Control of Molecular Processes in Living Cells $493,472 Lim lab total award
The goal of this project is to develop a molecular tool in which red and infrared light can be used to control the location and activity of specific protein molecules within living cells.

R01 GM055040-15 (Lim) 8/1/12 – 7/31/16 1.2 Cal Mos
NIH/NIGMS $1,170,028 total award
Protein Recognition in Signal Transduction
This grant focuses on the mechanism of recognition by modular domains, and their use in building protein signaling networks.

No Project Number (Lim) 8/1/12 - 7/31/15 0.5 Cal Mos
Weston Havens Foundation $380,000 (total award)
New Approaches for Engineering Cell Fate & Behavior $140,000 (Lim lab ADC)
Funds will be used to support the salary and benefits of two Systems and Synthetic Biology Fellows. The Fellows will perform the studies on cell fate logic and on novel RNA-based circuits.

MCA00008318 (Lim) 9/15/13 – 8/31/18 0.6 Cal Mos
UC Berkeley (Prime: NSF MCB-1330914; PI: Keasling) $513,431 total award
Synthetic Biology of Yeast
We are part of a collaborative project developing parts and devices for synthetic biology of S. cerevisiae, an important biofermentation chassis. These include gated transcriptional switches and synthetic cellular compartments that could be used for precision strain engineering.

R01 DA036858-02 (Weissman, Lim, Qi) 10/1/13 – 9/30/18 1.2 Cal Mos
NIH/NIDA $2,561,631 entire project
Harnessing CRISPR for Targeted and Inducible Epigenomic Reprogramming $853,877 total, Lim lab
The aim of this project is to develop a universal RNA-guided platform for precise spatial and temporal regulation of the epigenome, which will be widely applicable to write and erase multiple epigenetic marks for almost any endogenous genomic locus. These capabilities will be critical for studying the interplay between multiple epigenetic modifiers at different loci, understanding the relationship between epigenomic programming and disease, and facilitating the development of therapeutic methods to rewrite and reprogram epigenetic marks.

R01 CA196277-01 (Lim) 9/23/14 – 8/31/19 0.6 Cal Mos
NIH/NCI $3,346,301 total award
Redesigning the T cell: Using Synthetic Biology to Engineer Therapeutic Cells
The aim of this project is to develop systematic and reliable strategies to engineer immune cells so that we can harness them as therapeutic agents to treat diseases such as cancer or autoimmunity.

<u>PENDING</u>
None

<u>OVERLAP</u>
None

LIM, WENDELL A.

Current and Pending Support

CURRENT

No Project Number (Lim) 9/1/08 - 8/31/15 0.6 Cal. Mos
Howard Hughes Medical Institute $4,365,146 (total award)
The Design Logic of Cell Signaling Systems
This grant supports our studies on dissecting and engineering cell signaling molecules and networks in yeast and mammalian cells. My lab currently receives funding for operations (lab supplies and services, travel, publications, equipment maintenance, etc.) and personnel (salary for 2 postdoctoral associates, 2 technicians and an administrative assistant). All HHMI budgets are determined annually.

PN2 EY016546-11 (Lim) 9/30/04 – 7/31/15 1.0 Cal Mos
NIH/NEI $16,000,102 (total award - entire center)
Cellular Control: Synthetic Signaling/Motility (RMI)
This transition-funding proposal outlines a two-year phase-out plan for the Cell Propulsion Lab at the UCSF/UCB Nanomedicine Development Center. The specific aims of this phase of the project are 1) use synthetic biology to tune and optimize signaling pathways of anti-cancer T Cells (T cells expressing artificial chimeric antigen receptors – "CARs" – that are directed against tumor antigens) such that they show improved discrimination against cancer vs. non-cancer cells and 2) demonstrate the potential of microfluidic jetting vesicles as a platform for engineering smart therapeutics.

SA5285 (Lim) 7/1/06 – 6/30/15 0.6 Cal Mos
UC Berkeley (Prime: NSF / # EEC-0540879, PI Keasling) $2,600,947 (Lim lab allocation)
Synthetic Biology Engineering Center (SynBERC)
This is a multi-institutional NSF Engineering Research Center (UC Berkeley, UCSF, MIT, Harvard, TAMU-Prairie View). The goal of this center is to establish a framework for engineering bacteria and other cells for useful purposes.

P50 GM081879–05 (Lim) 9/1/10 – 6/30/15 3.6 Cal Mos
NIH/NIGMS National Centers for Systems Biology $14,911,087 (total award – entire center)
Exploring Design Principles of Cellular Control Circuits $1,978,500 (Lim lab allocation)
This multi-investigator center is aimed at understanding and applying design principles of cellular response networks, using computational, synthetic and comparative analysis. This grant also supports independent Systems Biology Fellows, and education/outreach in this area with local high school students.

R01 GM096164-04 (Weiner, Voigt, Lim) 3/1/12 - 1/31/16 0.6 Cal Mos
NIH/NIGMS $1,807,583 (total award - entire project)
A Toolkit for Light-Control of Molecular Processes in Living Cells $493,472 (Lim lab award allocation)
The goal of this project is to develop a molecular tool in which red and infrared light can be used to control the location and activity of specific protein molecules within living cells.

R01 GM055040-15 (Lim) 8/1/12 – 7/31/16 1.2 Cal Mos
NIH/NIGMS $1,170,028 (total award)
Protein Recognition in Signal Transduction
This grant focuses on the mechanism of recognition by modular domains, and their use in building protein signaling networks.

No Project Number (Lim) 8/1/12 - 7/31/15 0.5 Cal Mos
Weston Havens Foundation $380,000 (total award)
New Approaches for Engineering Cell Fate & Behavior
Funds will be used to support the salary and benefits of two Systems and Synthetic Biology Fellows. The Fellows will perform the studies on cell fate logic and on novel RNA-based circuits.

MCA00008318 (Lim) 9/15/13 – 8/31/18 0.6 Cal Mos
UC Berkeley (Prime: NSF MCB-1330914; PI: Keasling) $513,431 (Lim lab allocation)
Synthetic Biology of Yeast
We are part of a collaborative project developing parts and devices for synthetic biology of S. cerevisiae, an important biofermentation chassis. These include gated transcriptional switches and synthetic cellular compartments that could be used for precision strain engineering.

R01 DA036858-03 (Weissman, Lim, Qi) 9/30/13 – 5/31/18 1.2 Cal Mos
NIH/NIDA $2,561,631 (total award - entire project)
Harnessing CRISPR for Targeted and Inducible Epigenomic Reprogramming $853,877 (Lim lab allocation)
The aim of this project is to develop a universal RNA-guided platform for precise spatial and temporal regulation of the epigenome, which will be widely applicable to write and erase multiple epigenetic marks for almost any endogenous genomic locus. These capabilities will be critical for studying the interplay between multiple epigenetic modifiers at different loci, understanding the relationship between epigenomic programming and disease, and facilitating the development of therapeutic methods to rewrite and reprogram epigenetic marks.

R01 CA196277-01 (Lim) 9/23/14 – 8/31/19 0.6 Cal Mos
NIH/NCI $3,346,301 (total award)
Redesigning the T cell: Using Synthetic Biology to Engineer Therapeutic Cells
The aim of this project is to develop systematic and reliable strategies to engineer immune cells so that we can harness them as therapeutic agents to treat diseases such as cancer or autoimmunity.

PENDING
2 P50 GM081879–06 (Lim) 7/1/15 – 6/30/20 3.0 Cal Mos
NIH/NIGMS National Centers for Systems Biology $15,778,644 (total award – entire center)
Exploring Design Principles of Cellular Control Circuits
This multi-investigator center is aimed at understanding and applying design principles of cellular response networks, using computational, synthetic and comparative analysis. The project will support independent Systems Biology Fellows, and education/outreach in this area with local high school students.

Not Applicable.

Not Applicable.

Not Applicable.

Not Applicable.

Not Applicable.

Not Applicable.

Not Applicable.

Not Applicable.

FACILITIES, EQUIPMENT, AND OTHER RESOURCES

UCSF has an exceptional atmosphere for scientific collaboration between faculty members from different disciplines, and for the intellectual development of students and postdoctoral fellows.

Selected specialized shared resources include excellent core facilities for high throughput DNA sequencing, FACS sorting, peptide synthesis, gene expression mapping, mass spectrometry. The **Center for Advanced Technology (CAT)** contains high throughput instrumentation for sample preparation and liquid handling, deep-sequencing, array fabrication and analysis, spectrophotometric analysis, proteomics, cell analysis, and microscopy. This facility houses a Bioforce Nano eNabler providing micron resolution printing capabilities relevant to this project. The **Nikon Imaging Center** provides access to cutting edge light microscopy equipment including spinning disk confocal, swept-field confocal, TIRF, time lapse live-cell, 6D high throughput, and spectral confocal microscopes. The **Small Molecule Discovery Center (SMDC)** uses modern robotic instrumentation for high-throughput biochemical and cell biology assays. **QB3 computing cluster** is equipped with 4346 Xeon and Opteron cores and more than 20 Tb of storage. **UCSF's Teaching Laboratory**, a dedicated open-floorplan space with moveable lab benches, white boards, and commonly used lab equipment such as centrifuges and electrophoresis equipment.

Science and Health Education Partnership (SEP) is recognized worldwide as a model organization in support of high quality science education for K-12 students. SEP's Resource Center houses more than 3,000 educational materials available to any teacher in San Francisco public schools, and to scientists working with public school teachers and students. SEP's website (http://seplessons.ucsf.edu/) houses a database of freely available science lessons. Cellular engineering classroom lesson guides developed with this NSF support will be posted on this website for national dissemination. All lessons on the site are indexed to the Next Generation Science Standards (NGSS).

SFSU's College of Science and Engineering has three core facilities run by full-time PhD level staff that manages equipment and trains students/staff -the Mass Spectrometry Core, the Cell and Molecular Imaging Center (CMIC), and the Electron Microscopy Facility. The EMF houses a Zeiss Ultra 55 Field Emission Scanning Electron Microscope (FE-SEM), the most powerful analytical microscope in northern California, along with a fully equipped specimen preparation laboratory for biological specimens.

SF Exploratorium, an internationally renowned museum and educational center, designs and exhibits state-of-the art science installations for children and adults, and science education materials. Facilities support life sciences exhibit development, with research-grade microscopes, a cell culturing facility, a greenhouse, and saltwater table, a machine shop for building exhibits. Center partner Autodesk is located next door. The Exploratorium's 330,000 square foot space features 6 main exhibit galleries; a theater; life sciences laboratory; wired classrooms and labs; machine, wood, and electronics shops. More than 500 educators participate in on-site Exploratorium **Teacher Institute** programs every year. The Web site (www.exploratorium.edu) receives approximately 11.5 million annual visits to over 50,000 pages of original content. The **Moving Images team** produces 75 live webcasts, videos and other media each year.

The **IBM Almaden Research Center** hosts about 400 full time research staff members, with scientific capabilities ranging from theoretical computer science to computational biology, nanomaterials fabrication, cognitive computing and digital image processing. Summer interns will have complete access to IBM Research spectrum of computational resources (IBM software suites, local server time, Accelerate Discovery Lab cluster time, wireless access, etc.) A technical program manager will provide assistance for administrative tasks, and coordinate knowledge transfer via the Accelerated Discovery Lab.

UC Berkeley, **Fletcher Lab.** The Biomolecular Nanofabrication Center (BNC), a core facility of the QB3 Institute, provides access to fabrication and characterization equipment.

Stanford University. The Department of Mechanical Engineering has a state of the art facility with all necessary equipment for lithography and microfluidic device fabrication.

DATA MANAGEMENT PLAN

Data Sharing Plan

Data generated under this project will be administered in accordance with both University and federal policies. In conformance with NSF policy on dissemination and sharing of research results, we will share primary data, samples, software, curriculum materials and other supporting materials created or gathered in the course of this funded project.

As described in detail in the management plan of the proposal, the Knowledge Transfer Coordinator will collect and manage all the datasets created by investigators working on each Project described in the Research Objectives. After publication of each major paper, the Knowledge Transfer Coordinator will assemble a complete dataset with full documentation linked to each publication. Data will be provided in comma separated variables (CSV) text format rather than a proprietary format either on a CD or through a password-protected download from our website. The documentation of the data will clearly describe each variable in the dataset, which instrument supplied that variable, and what each code for each variable represents. Copies of the instruments will be included in a PDF format. The documentation will also include explanatory notes regarding the collection of the data and any special codes used for missing data, as well as the name of a contact person for questions and all relevant references to publications, which are based on the data. Complete sequence data for all synthetic gene constructs will be included with each dataset as well as collected in an open-access SQL database available through our center web site.

During the research activities, prior to publication, as individual datasets are finalized we will transfer the data to public use datasets that will be available without restriction to any member of the public. Such datasets will be made publicly available through DataShare (http://datashare.ucsf.edu), which was developed by a partnership of the UCSF Clinical & Translational Science Institute, UCSF Library, and UC Curation Center at the California Digital Library. This service provides public access via persistent URLs, tools for long-term data management, and permits permanent storage options. Data will be discoverable by either searching or browsing the website. Each dataset will be required to include the following metadata: title of dataset, creator, description, technical description, subject headings, and related publications. All required fields will be searchable, as will optional fields. Cell image data will also be made available through the Cell Image Library project (http:// www.cellimagelibrary.org).

Curriculum Materials Sharing Plan

High school level instructional modules prepared as described in the Education and Human Resources section will be disseminated through the Center's web site. Exhibits and demonstration projects developed for Maker Faire, Science Festivals, and through planned hackathon events (all described in the Education and HR section) will be written up with detailed plans for construction and presentation, including stl files for 3D printing components, and will be made available through our center web site as well as through the open access projects portal at http://sciencefestivals.org. All of these modules and project descriptions will be completely free to the public.

Data Archiving Plan

Data for this project will be stored and analyzed in UCSF's Secure MyResearch environment, hosted on servers housed at the UCSF Data Center on Minnesota Street. The MyResearch environment is hosted on six Dell PowerEdge R710s and Five EqualLogic PS6100E SAN, which are located inside the locked rack. There are two layers of physical redundant Cisco firewalls that protect the servers and SAN.

Data sets will be stored in the Principal Investigator's group network folder in the remote MyResearch environment, where only the research team members are able to view the data sets, and this access is audited. This folder is physically located in a data store on the SAN in the locked rack. Network traffic between MyResearch and the UCSF campus network traverses a SSL VPN tunnel in encrypted format. Analysis tools are hosted in the environment contiguous to data storage.

Individual investigators will also utilize data-storage methods that include Windows-based local area networks of PC-compatibles and Macintosh computers. The computers share access to laser printers and print, file, and application servers. In this context, project data may reside in a Microsoft Access database or Microsoft SQL Server databases. There is an on-site, self-managed electronic mail/group collaboration system (Microsoft Exchange) that is used extensively for memos, document transfer, and outside communications with project collaborators via email on the Internet, as well as web servers, an automated forms-processing system and a computerized voice-mail system. All servers are physically housed within a restricted-access server room within a restricted-access computer support suite. All systems (i.e., network and servers) are monitored 24 hours a day, seven days a week. The LAN features a 100 MB uplink to the Internet. All servers and workstations run anti-virus software that is automatically updated hourly from the vendor site via the Internet. The LAN is protected from intrusion by private, redundant firewalls. All servers and workstations are backed-up nightly.

Taken together, these secure storage measures will ensure that all data is maintained without risk of loss, but we emphasize that as the data are finalized in a usable form, they will be immediately copied into public access databases as described in the previous section.

Postdoctoral Researcher Mentoring Plan

One on one meetings with advisors All postdocs will meet with their respective advisors on a monthly basis to discuss research progress as well as career goals, and will present their work at their own individual weekly lab meetings, providing them with input from other lab members not working on this joint project. Once per month, all postdocs and investigators working on this joint project will have a combined group meeting to specifically discuss the project. Once per quarter, each postdoc will meet with one other investigator in the group who is not the official advisor, rotating through PIs so that each postdoc has the opportunity to have detailed scientific interaction with several investigators. Given the diverse backgrounds and viewpoints of participating investigators, we expect that this will give STC postdocs a truly inter-disciplinary training that would be extremely difficult to acquire under the normal one advisor - one postdoc mentoring model. Advising meetings will also be devoted to discussing career development, what types of jobs the postdocs seek and how best to position themselves to obtain such jobs. We will mentor the postdocs in written communication by asking them to write a progress report each year in the format of a grant progress report.

Career development activities Postdocs will be encouraged to broaden their knowledge of current literature, through weekly individual lab journal clubs and also in a once per month journal club for the joint project. The postdocs will write any publications associated with this proposal, guided by their respective advisor. All postdocs will participate in annual courses for postdocs on the practice of science including practical issues such as preparing faculty job applications, starting up a new lab, etc. The UCSF Office of Career & Professional Development (OCPD) offers resources for postdocs to develop teaching, presentation and writing skills, as well as individual career guidance, workshops and courses on how to pursue academic or biotech career paths. The curriculum for trainees involved in the STC at UCSF will include Ethics and the Responsible Conduct of Science offered through the OCPD. Postdocs will present their work once every two years to the entire UCSF community at the weekly Research in Progress (RIP) series, presented by students and postdocs, and at the annual Cell Biology Retreat. Through local talks, presentations at national meetings, and presentation in lab meetings, the postdocs will gain experience in presenting their research that will stand them in good stead in their future career.

Interdisciplinary cross-training An essential element of our training plan is the concept of cross-training. Each of our postdocs comes from different academic backgrounds, and we view this as a tremendous strength of the group for training purposes. For all phases of the project, the postdoc with primary responsibility for that phase will be paired with a second postdoc whose background is entirely different; for example, during experiments to differentiate stem cells, a postdoc with expertise in this area would be teamed with a postdoc skilled in bioinformatics. By arranging such pairwise interactions, which will be evaluated and updated on an ongoing basis during monthly PI meetings, we will help postdocs learn to speak a common language and to teach each other. Learning how to work in an interdisciplinary team is a critical skill for the future of research, and we believe that our collaborative project will provide an excellent experience for our postdocs in exactly this type of team-science.

Training in education and public communication To gain experience in teaching and mentorship - essential skills for academic science - we will give the postdocs primary responsibility for running the summer course in quantitative cell biology, with PIs constantly available for input and advice but giving the postdocs the opportunity to make their own decisions about the direction of the course. The postdocs will not only design and supervise the experimental projects used as the centerpiece of the course for hands-on learning, but they will also present lectures within the course, 1-2 lectures per postdoc per course session. PIs will meet with the postdocs on a weekly basis leading up to the course, on a daily basis during the course to monitor progress and discuss any potential problems or concerns, and in a joint discussion after the course to evaluate the experience. In order to give our postdocs training in communicating science to the public, our postdocs will travel to the Maker Faire events, as described in the Education and Human Resources component, and present the exhibits side-by-side with PIs.

Ethics Plan

The Center for Cellular Construction and its team are dedicated to train the next generation of cellular engineers. As essential aspect of this training is ethics, responsible conduct of research and intellectual property (IP) rights. As the Center aims to develop technologies in the new discipline of cellular engineering, intersecting cell biology and engineering, it will also develop a module for ethics and responsible conduct of research training that specifically addresses the potential issues associated with manipulating the structure of the cell and building novel structures inside living cells. The Center will leverage the Ethics and Responsible Conduct of Research course offered through the UCSF Office of Career and Professional Development for other topics. This course uses lecture and case study formats, this course is designed to address key issues affecting the responsible conduct of scientific research, including:

- Scientific Misconduct: Plagiarism, Falsification and Fabrication of Data;
- Scientific Record Keeping and Data Management;
- Animals in Research: Animal Rights and Welfare;
- Human Subjects in Research;
- Publication, Responsible Authorship and Peer Review Practices;
- Conflicts of Interest; and
- Mentoring and Being Mentored

All participating academic institutions offer similar courses and we will work to ensure that they cover the same topics, and if not, we will arrange for participants from those institutions to attend the course at UCSF. As this proposal involves the development of a new area of technology – cellular engineering – and its applications to real world problems, there is high probability to develop novel intellectual property. Thus, training in topics such as ownership of research and ideas, and roles and responsibilities regarding intellectual property is especially critical for those involved in the Center for Cellular Construction. We will utilize the substantial resources available at UCSF in this area, including those through the UCSF Clinical and Translational Science Institute (CTSI), part of the Clinical and Translational Science Award program funded by the National Center for Advancing Translational Sciences (Grant Number UL1 TR000004) at the National Institutes of Health (NIH), to develop an appropriate training module for the Center's personnel. Some of the leveraging materials include the IP knowledge base developed by the UCSF Innovation, Technology and Alliances (ITA) Office and available online (http://accelerate.ucsf.edu/research/industry-faq#alliance) through the CTSI. This knowledge base includes topics such as: Types of industry collaboration, Partnership implications, Conflict of interest; Industry-sponsored clinical trials; Consulting for a company, Testing a technology platform, Contract Research Organizations (CROs), Licenses, technology assessment and company formation, Disclosing and developing an invention, and Commercialization resources.

New Shared Facilities

High Throughput Imaging in Cellular Machine Shop Core

The main new instrumentation for the Cellular Machine Shop core activity is the GE InCell 2200. The InCell Analyzer 2200 is a high-end, automated microscopy imaging platform specifically designed for high-content imaging-based assays and screens. With a scientific-grade CMOS camera and bright solid-state light source as standard, IN Cell Analyzer 2200 reduces exposure times and maximizes speed while delivering high-quality images. Confocal-like images can also be obtained using the rapid image restoration options in the control software. The InCell Analyzer 2200 can image a two-color 96-well plate assay in less than 2.5 min., providing the Cellular Machine Shop core project with the ability to rapidly analyze large numbers of constructs and parameter variations. In support of the high throughput imaging capability, the Cellar Machine Shop will maintain a collection of organelle-specific antibodies and stains, along with a database that stores high throughput staining protocols for each specific marker, thus reducing the barrier for new center members to use the system.

Members of the Marshall and Fung group have extensive experience with the Incell platform technology and with high throughput imaging in general, and will be able to train and assist all Center members in the use of this system. Outside users will be granted access on a recharge basis (strictly to recover costs incurred by their use of the system), which will be administered by UCSF using standard procedures. This device will be housed in the UCSF Center for Advanced Technology (CAT), a shared-access facility housing many large pieces of automated equipment including liquid handling robotic systems. By housing the system in the CAT, we can leverage these technical resources. CAT access policies are designed to maintain ownership by a primary research group (in this case the CCC) while providing organized coordination of access by outside users.

UCSF MakerSpace

The Department of Biochemistry and Biophysics at UCSF is currently in the planning stages of creating a 1200 sq. ft Maker Space in the Genentech Hall building. Space has already been committed for this purpose by the department, and existing tools and equipment from other facilities are now being coordinated into this one space, including a Tormach CNC milling machine, welding equipment, laser cutters, and several Stratasys 3D printers. We will help to build this Maker Space, which we will use for hands-on building projects within the student-teacher bootcamp program, for creating novel exhibits for Maker Faire and Science Festivals, and for Hackathon activities, all of which are discussed in the Education and Human Resources section of this proposal. We will also utilize this space, and the rapid prototyping capability that we will help to build there, for constructing physical devices such as bioreactors, scale model pond and raceway systems for the Living Bioreactor project, microfluidic devices, and mechanical stretching systems for testing purposes in the Cellular Sentinel project. Supply funds from research and educational components will support equipping the Maker Space.

The space will be shared by others in the community, allowing the CCC to share our goals and interests with enthusiastic like-minded community members. Furthermore, our Maker Space will become part of the broader Bay Area Makerspace community, which includes both engineering-oriented makerspaces such as Noisebridge, as well as biology-oriented makerspaces such as Counterculture Labs and Biocurious, with whom CCC members have already established productive interactions. Thus, by establishing a Makerspace, we will forge ties with the citizen science community, creating a novel form of public outreach.

All Makerspace users will be required to undergo safety training in the use of equipment, and particularly in the case of heavy machine tools we will enforce a strict policy that no individual will be allowed to use the equipment unless at least one experienced user is present to observe and advise. Because the Makerspace will be located within an existing campus lab building, the entire facility will be under supervision of the UCSF Department of Environmental Health and Safety (EH&S) who will carry out regular inspections and training certification to ensure OSHA compliance.

10a and 10b. PROJECT PERSONNEL (key personnel)

Proposal #
Proposal Title *Center for Cellular Construction*
PI Wallace Marshall
Lead Organization University of California San Francisco (UCSF)

Project personnel: those who have a role in the management, research, education, broadening participation and/or knowledge transfer components of the center (1 per row)	**Role**	**Institutional Affiliation for the Project Personnel**
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Burrus, Laura W.	Research group leader, SFSU	SFSU
Chan, Annette	Research group leader, SFSU	SFSU
Chan, Mark	**SFSU Site Director** and research group leader	SFSU
Chu, Diane	Research group leader, SFSU	SFSU
Craik, Charles	**Entrepreneurship and Knowledge Transfer Coordina**	UCSF
Denetclaw, Wilfred	Research group leader, SFSU	SFSU
Domingo, Carmen	Research group leader, SFSU	SFSU
Dumont, Sophie	Research group leader	University of California, San Francisco (UCSF)
Douglas, Shawn	Research group leader	UCSF
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Frazier, Jennifer	**Exploratorium Site Director**	SF Exploratorium
Fung, Jennifer	Research group leader	UCSF
Gartner, Zev	**Co-Director and Research Coordinator**	UCSF
Hayzelden, Clive	Research group leader, SFSU	SFSU
Lim, Wendell	**Co-Director**	UCSF
Marshall, Wallace	**Center Director**	UCSF
Prakash, Manu	Research group leader, Stanford	Stanford University
Riggs, Blake	Research group leader, SFSU	SFSU
Smith, Rebecca	**Education Coordinator**	UCSF / SEP
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Thomson, Matthew	Research group leader	UCSF
Weiner, Orion	Research group leader	UCSF

Center for Cellular Construction
Wallace Marshall, PI. UCSF
Proposal #
Proposal Title **Center for Cellular Construction**
PI **Wallace Marshall**
Lead Organizatior University of California San Francisco (UCSF)

Center Personnal		**Institution for Project Personnel**	**Departmental Affiliation for the Project Personnel**	**Type of Institution:** academic, national labs, federal govt, industry, NGO, state/local govt, international, or other	**Collaborators/Individuals with Conflicts of Interest**: e.g., Co-authors & collaborators (w/in past 48 months); co-editors (w/in past 24 months); PhD advisors and advisees; external advisory committee members; subcontractors; consultants on STC proposal		**Nature of the Conflict of Interest**	**Institutional Affiliation for the person who is conflicted**	**Departmental Affiliation for the person who is conflicted**
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(2) PROJECT SUMMARY

Rationale, Mission and Vision. The long-term vision of the Center for Cellular Construction is to turn cell biology into an engineering discipline. We will realize this vision through four subgoals, including (i) building the tools and concepts to implement a full design-build-test cycle in biology; (ii) educating a new breed of scientist/engineer; (iii) broadening awareness and participation; and (iv) driving innovation through applications. Accomplishing these goals will allow the design, building, and testing and deployment of self-assembling biological systems as a new paradigm for tackling the most important global challenges of the 21st century. These include sustainable production of energy, materials, and foodstuffs, as well as new means of melding biological systems with sensors and devices with applications in extending human performance and improving human health. Unlike synthetic biology, which has primarily focused on engineering metabolic pathways in single compartments of single organisms, the vision of the Center is to master the engineering of interconnected pathways and processes operating in many cellular compartments, between many cell types, and even among multiple organisms. Unlike bioengineering, which has primarily focused on biomedical applications of the classical engineering disciplines, the Center's goal is to merge the design concepts of engineering with the physics, chemistry, and mathematical principles that underlie cell biological phenomena. Success will rely on mastering the tools of self-organization. By learning how cells build themselves, the Center for Cellular Construction will develop the tools and concepts necessary to re-engineer the structure of the cell, and to build novel structures inside living cells. By learning how groups of cells use these subcellular structures to self-organize and work together, the Center will learn how to use cells as building blocks to assemble novel devices and materials composed of multiple cells.

Intellectual Merit Statement. The primary Intellectual Merit of the Center is the ***vision of merging engineering and cell biology with the goal of using the living cell as an engineering medium***. Engineering is defined here as research and innovation that implements a design-build-test cycle and is driven by applications. This is a novel approach in the context of cell biology. A second major intellectual merit is the ***Multidisciplinary Research Focus of the Center.*** To achieve this vision, the Center must confront major conceptual and technological challenges. Unlike molecular biology, that can be understood in terms of chemistry, or physiology, that can be understood in terms of the principles of biomechanics and homeostasis, cell biology operates at a meso-scale of organization. At the meso-scale, direct determination of structure is non-trivial and both macroscopic intuitions as well as assumptions about solution-phase chemistry can easily lead us astray. Indeed, the unique physics of biology at the spatial scale of the cell poses deep conceptual challenges for basic science, but also represents a tremendous opportunity for innovation and development of new technologies. If scientists can learn to control biological structure at these subcellular and multicellular length scales, cells can be used as a new engineering medium to build new devices and enable new applications [Lim et al., 2012]. It is these challenges and opportunities that the Center for Cellular Construction is designed to tackle.

Even though cells are the basic building blocks for life, cell biologists know remarkably little about how cells build themselves. Indeed, cell biology is replete with engineering problems whose solution is currently unknown (Rafelski and Marshall, 2008). For example - how do cells determine the size or position of organelles? The question of how cells specify patterns and structures was identified as a key question for the new millennium (Kirschner, Gerhart and Mitchison, 2000) yet little is known about how cells determine organelle structure. These types of problems remain unanswered for a simple reason – they span multiple scientific disciplines and spatial scales.

Therefore, the Center's research programs will be populated with scientists from the multiple disciplines necessary to engineer cellular properties: physics, chemistry, engineering, information theory, and cell biology. The Center's research efforts will also span across the ***multiple spatial scales*** at which cells operate: organelle level, whole-cell level, and cell-collective level. Organelle scale research will focus on individual organelles with a focus on integrating models of regulatory pathways into models of organelle dynamics. Whole cell level studies will focus on cell shape and polarization and the link between cell

mechanics and structure. Cell collective level studies will focus on the assembly properties of small but precisely controlled 3D aggregates of cells to span the cell to tissue levels. Sustained collaboration between academic labs and industry (including at IBM and Autodesk) will combine design and modeling software tools that will span the molecular, pathway, cellular, and tissue scales.

Broader Impacts Statement. The first broader impact will be the ***creation of a new branch of engineering education based on cell biology***. The challenge of turning cell biology into and engineering disciplines has been largely unanswered because it requires scientists from multiple disciplines working across multiple spatial scales. The traditional STEM education system is not designed to train scientists and engineers with the appropriate shared skills and scientific language to tackle this problem. Therefore, a new paradigm in scientific education is necessary. This paradigm will be, by definition, multi-disciplinary. It will focus on teaching a quantitative analytical approach to problem solving. Quantitative analytical thinking will be complemented with foundational knowledge specific to cell biology but presented using established physical concepts of chemistry, physics, engineering, and information science. Indeed, no single discipline possesses the tools necessary to understand and manipulate cellular structure at multiple scales. Training a new workforce for engineering cell biology will not only provide new insights into the basic biology of cells, but will also open up whole new realms of biology-based engineering, as outlined by the National Research Council in "A New Biology for the 21st Century." The second broader impact will be ***knowledge transfer to industry***, which we will accomplish via our partnership with the IBM Accelerated Discovery lab, our ongoing collaboration with Autodesk, industry internships by Center students and postdocs, and our innovative "summer startup" entrepreneurship training program. Through these means we will rapidly bring center discoveries to real world applications in the commercial sector.

The **potential legacy and global impact** of the Center for Cell Construction would be nothing less than to spawn an entirely new branch of engineering. This would have a national and global impact, particularly if the Center can rapidly disseminate the approach into an industrial setting.

Partner Institutions and Their Contribution to the Center. The Center for Cell Construction is organized as an interconnected network of labs and educators at UCSF, San Francisco State University, UC Berkeley, Stanford University, IBM Almaden Research Center (ARC), and the Exploratorium museum in San Francisco. The Center's informal partner Autodesk will exchange software tools through existing collaborations and their fully supported internship program. The geographical focus builds on the strength of the Bay Area in biological science and technology development. The interdisciplinary team combines experts in cell biology, tissue engineering, biophysics, mathematics, bioengineering, and industrial design, including both research and education experts. We have also set up pipelines to integrate undergraduates and high school students at teaching-focused institutions into Center research.

UCSF, UC Berkeley and Stanford University provide a backbone of world-class research groups at both graduate and postdoc training levels. UC Berkeley and Stanford additionally provide core training expertise in classical engineering disciplines. The **SF State** biology and engineering programs for Masters degree URM students currently provides their students with a 2-year intensive research experience prior to moving on to Ph.D. studies. Center labs will host students in this program. The SFSU postbac program has a tremendous track record of identifying and propelling the best underprivileged students towards PhD programs by placing them in good labs with excellent mentoring. **IBM**'s established internship program will host students and postdocs in ARC research labs, ideally working on a collaborative project between IBM and one or more of the other participating STC labs. In association with the **SF Exploratorium**, we will develop new interactive presentations, including hands on displays, public lectures, and demonstrations by students, coupled with a coordinated media and web based dissemination strategy targeting the lay audience. We will partner with the UCSF **Science and Health Education Partnership** (**SEP**) who currently run a number of highly successful outreach activities with local public schools. For high school students, SEP will oversee participation by students in summer research experiences in center labs at all participating institutions.