List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

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1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Marshall, Wallace	University of California, San Francisco	current

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Sedat, John	University of California, San Francisco	
T:	Keller, Lani	Bishop School, San Diego	
T:	Feldman, Jessica	Stanford University	
T:	Engel, Benjamin	Helmholz University, Munich	
T:	Ludington, Will	Carnegie Institute, Baltimore	
T:	Apte, Zachary	uBiome Inc.	
T:	Wemmer, Kimberly	Zymergen	
T:	Kimmel, Jacob	Calico, Inc.	
T:	Slabodnick, Mark	University of North Carolina, Chapel Hill	
T:	Navarro, Erik	UCSF	
T:	Yan, Connie	UCSF	
T:	Lin, Athena	UCSF	
T:	Lewis, Greyson	UCSF	
T:	Hendel, Nathan	UCSF	
T:	McGillivary, Rebecca	UCSF	
T:	Perlaza, Karina	UCSF	
T:	Diaz, Ulises	UCSF	
T:	Bauer, David	UCSF	

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Agard, David	University of California, San Francisco		
A:	Basto, Renata	Institute Curie, Paris		
A:	Iwasa, Janet	University of Utah		current
A:	Kamiya, Ritsu	University of Tokyo		
A:	Lechtreck, Karl	University of Georgia		
A:	Pazour, Gregory	UMASS Worcester		
A:	Ross, Jennifer	Syracuse University		
C:	Qin, Hongmin	Texas A&M		current
C:	Sanchez Alvarado, Alejandr	Stowers Institute		current
C:	Tang, Sindy	Stanford University		current
A:	Witman, George	UMASS Worcester		
A:	Wan, Kirsty	University of Exeter, UK		
A:	Yates, John	Scripps Research Institute\		
C:	Niyogi, Krishna	UC Berkeley		current
A:	Phillips, Rob	Caltech		current

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	David Drubin	UC Berkeley	Molecular Biology of the Cell	current

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1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Gartner, Zev J	University of California, San Francisco	now
		CZ Biohub	now

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	Cole, Russel	Co-founder of Scribe Biosciences		now

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Liu, David	Harvard University	Chemistry
T:	Jennifer Liu	Plexxicon	
T:	Michael Todhunter	City of Hope	
T:	Justin Farlow	Serotiny	
T:	Noel Jee	Illumina	
T:	Samantha Liang	Abbvie	
T:	Alec Cerchiari	Cook Medical	
T:	Amanda Paulson	UCSF	
T:	Kade Southard	UC Berkeley	
T:	Robert Weber	UCSF	
T:	Katie Cabral	UCSF	
T:	Danny Conrad	UCSF	
T:	Olivia Creasey	UCSF	
T:	Jennifer Hu	UCSF	
T:	Chris McGinnis	UCSF	
T:	Hikaru Miyazaki	UCSF	
T:	Kiet Phong	UCSF	
T:	Efren Reyes	UCSF	

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
C:	Thomson, Matt	Caltech		now
A:	Goga, Andrei	UCSF		now
C:	Sneddon, Julie	UCSF		now
A:	Schneider, Rich	UCSF		now
A:	Hughes, Alex	Upenn		now
A:	Krummel, Max	UCSF		now
A:	Weissman, Jonathan	UCSF		now
A:	Craik, Charly	UCSF		now
A:	Bianco, Simone	IBM		now
A:	Tsly, Thea	UCSF		now
A:	Chow, Eric	UCSF		now
A:	Klein, Ophir	UCSF		now
A:	Royer, Loic	Biohub		now
A:	Werb, Zena	UCSF		now

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
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	Frank Bayliss	San Francisco State University	
		University of California, San Francisco	

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2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

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3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	John Igraham	UC Davis	Department of Bacteriology
T:	N/A		

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Alegra Eroy-Reveles	San Francisco State Univerity	Dept Chemistry & Biochemistry	1/1/15
A:	Eric Hsu	San Francisco State Univerity	Dept. Mathematics	
C:	Alan Peterfreund	SageFox Associates	Amherst, MA	
C:	Kenneth Rath	SageFox Associates	Amherst, MA	

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	Fung, Jennifer C.	University of California, San Francisco (assoc.prof)	

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2	Name:	Type of Relationship	Optional (email, Department)	Last Active

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Sedat, John W.	University of California, San Francisco	
T:	Chen, Stacy	DRB University	

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Blackburn, Elizabeth	University of California, San Francisco		
A:	Hochwagen, Andreas	New York University		
A:	Burgess, Sean	University of California, Davis		
A:	Matos, Joao	ETH Zurich		
A:	Conti, Marco	University of California, San Francisco		

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B:	Glover, David	University of Cambridge	Open Biology	current
E:				

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1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Smith, Rebecca L	University of California San Francisco	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Johnson, Alexander, PhD	University of California San Francisco	Microbiology

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Diamond, Judy	University of Nebraska Lincoln	jdiamond1@unl.edu	5/1/18
A:	Allison, Linda		allisonwritesdraws@gmail.com	5/1/18
C:	McQuillan, Julia	University of Nebraska Lincoln	JMcQuillan2@unl.edu	
A:	Spiegel, Amy N	University of Nebraska Lincoln		5/1/18
A:	Wonch Hill, Patricia	University of Nebraska Lincoln		5/1/18
A:	West, John	Nebraska Center for Virology		5/12/16
A:	Wood, Charles	Nebraska Center for Virology		5/12/16
C:	Marshall, Wallace	University of California San Francisco	wallace.marshall@ucsf.edu	
C:	Bayliss, Frank	San Francisco State University		
C:	Frazier, Jennifer	Exploratorium	jfrazier@exploratorium.edu	
C:	Chu, Diana	San Francisco State University	chud@sfsu.edu	
C:	Robert McGinn	Stanford University	mcginn@stanford.edu	
C:	Wilson, Mark	University of California Berkeley	MarkW@berkeley.edu, Graduate School of Education	
C:	Morell, Linda	University of California Berkeley	lindamorell@berkeley.edu	
C:	Bathia, Shruti	University of California Berkeley	shruti_bathia@berkeley.edu	
C:	Phillips, Michelle	Phillips & Associates		
A:	Steele, Kait	826 National		3/1/15
C:	Apedoe, Xornam	University of San Francisco		
C:	Judi Fusco	Digital Promise Global		
A:	Traig, Jennifer	Author (Unaffiliated)		3/1/15

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Dolan, Erin	University of Georgia Athens	Cell Biology Education	12/31/18
B:	Shepard, Virginia	Vanderbilt University	Journal of STEM Outreach	
E:	Bass, Kristin	Rockman et al	Journal of STEM Outreach	
E:	Chester, Ann	West Virginia University	Journal of STEM Outreach	
E:	Meiri, Karina	Tufts University	Journal of STEM Outreach	

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Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
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1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Weiner, Orion D	University of California at San Francisco	

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2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Sedat, John	UCSF	
G:	Bourne, Henry	UCSF	
T:	Houk, Andrew	UCSD	
T:	Millius, Arthur	Osaka	
T:	Dandekar, Sheel	Intuit	
T:	Wu, Julie	Vanderbilt	
T:	Jost, Anna	Harvard	
T:	Reade, Anna	National Resources Defence Council	
T:	Tischer, Doug	UW Seattle	
T:	Liu, Zairan	IQVIA	
T:	Mclaurin, Justin	ZS Associates	

T:	Genuth, Miriam	Yale	

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
C:	Groves, Jay	UC Berkeley		
C:	Stamou, Dimitris	Univ. Copenhagen		
C:	Marshall, Wallace	UCSF		
C:	Gartner, Zev	UCSF		
A:	Gov, Nir	Weizmann		
A:	Diz-Munoz, Alba	EMBL Heidelberg		
A:	Kralj-Iglic, Veronica	University of Ljubljana		
A:	Iglic, Ales	University of Ljubljana		
A:	Lomvardas, Stavros	Columbia		
A:	Huang, Bo	UCSF		
A:	Shen, Yin	UCSF		
A:	Fletcher, Dan	UC Berkeley		
A:	Toettcher, Jared	Princeton		
A:	Woo, Stephanie	UC Merced		
A:	Mikawa, Takashi	UCSF		
A:	Allen, Chris	UCSF		
A:	Wu, Min	Yale		
A:	Stainier, Didier	Max Planck		
A:	Gardner, Kevin	CUNY		
A:	Altschuler, Stephen	UCSF		
A:	Wu, Lani	UCSF		
A:	Devreotes, Peter	Johns Hopkins		
A:	Zhao, Min	UC Davis		
A:	Huang, Chuan-Hsiang	Johns Hopkins		
A:	Clarke, John	King's College		
A:	Buckely, Clare	Univ. Cambridge		

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Lehmann, Ruth	Whitehead	Annual Reviews Cell and Developmental Biology (ARCD	
E:	Lippincott-Schwartz, Jennif	Janelia Farm	ARCDB	
E:	Schier, Alex	Harvard	ARCDB	
E:	Dustin, Michael	Oxford	ARCDB	
E:	Arlotta, Paula	Harvard	ARCDB	
E:	Schuman, Erin	Max Planck	ARCDB	
E:	Yao, Hao	National University of Singapore	ARCDB	

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1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Douglas, Shawn	University of California San Francisco	

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Church, George	Harvard Medical School	church_lab_admin@hms.harvard.edu
G:	Shih, William	Harvard Medical School	william.shih@wyss.harvard.edu
T:	Nafisi, Parsa	Emerald Cloud Lab	parsa.nafisi@gmail.com
T:	Makhija, Suraj	University of California San Francisco	suraj.makhija@ucsf.edu
T:	Tran, Ngoc-han	University of California San Francisco	han.tran@ucsf.edu
T:	Navarro, Erik	University of California San Francisco	erik.navarro@ucsf.edu

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Aksel, Tural	University of California San Francisco		11/12/19
C:	Aksimentiev, Oleksii	University of Illinois	aksiment@illinois.edu	11/12/19
C:	Gang, Oleg	Brookhaven National Laboratory		6/30/19
C:	Kumar, Sanat	Columbia University		6/30/19
C:	Klavins, Eric	University of Washington		7/31/18
C:	Murray, Richard	Caltech		7/31/18
C:	Pierce, Niles	Caltech		7/31/18
C:	Rothemund, Paul	Caltech		7/31/18
C:	Qian, Lulu	Caltech		7/31/18
C:	Winfree, Erik	Caltech		7/31/18
C:	Yin, Peng	Harvard University		7/31/18
C:	Seelig, Georg	University of Washington		7/31/18
C:	Bruck, Shuki	Caltech		7/31/18
C:	Lim, Wendell	University of California San Francisco		11/12/19
C:	Marshall, Wallace	University of California San Francisco		11/12/19
C:	Gartner, Zev	University of California San Francisco		11/12/19
C:	Craik, Charles	University of California San Francisco		11/12/19
C:	Damasceno, Pablo	University of California San Francisco		11/12/19
C:	Dumont, Sophie	University of California San Francisco		11/12/19
C:	El-Samad, Hana	University of California San Francisco		11/12/19
C:	Fung, Jennifer	University of California San Francisco		11/12/19
C:	Weiner, Orion	University of California San Francisco		11/12/19
C:	Tang, Sindy	Stanford		11/12/19
C:	Prakash, Manu	Stanford		11/12/19
C:	Fletcher, Daniel	University of California Berkeley		11/12/19
C:	Bianco, Simone	IBM, Inc		11/12/19
C:	Bayliss, Frank	San Francisco State University		11/12/19
C:	Esquerra, Raymond	San Francisco State University		11/12/19
C:	Riggs, Blake	San Francisco State University		11/12/19
C:	Denetclaw, Wilfred	San Francisco State University		11/12/19
C:	Domingo, Carmen	San Francisco State University		11/12/19
C:	Burrus, Laura	San Francisco State University		11/12/19
C:	Chu, Diana	San Francisco State University		11/12/19

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B:				
E:				

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	Dumont, Sophie	University of California, San Francisco	current

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Bustamante, Carlos	University of California, San Francisco	

T:	Hueschen, Christina	Stanford University	
T:	Kuhn, Jonathan	Johns Hopkins School of Medicine	
T:	Long, Alexandra	UCSF	
T:	Suresh, Pooja	UCSF	
T:	Neahring, Lila	UCSF	
T:	Manuela, Richter	UCSF	
T:	Chong, Megan	UCSF	
T:			
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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Phillips, Rob	Caltech		current
A:	Bandyopadhyay, Sourav	UCSF		current
A:	Bivona, Trever	UCSF		current
A:	Goga, Andrei	UCSF		current
A:	McCormick, Franck	UCSF		current
A:	Xu, Ke	University of California, Berkeley		current
A:	Mitchison, Tim	Harvard Medical School		current
A:	Elting, Mary	North Carolina State University		current
A:	Sullivan, William	University of California, Santa Cruz		current
A:	Lowe, Todd	University of California, Santa Cruz		current
A:	Revzin, Alexander	University of California, Davis		current
C:	Weaver, Valerie	UCSF		current
C:	Mehta, Shalin	Biohub		current
C:	Straight, Aaron	Stanford University		current
C:	Chang, Fred	UCSF		current

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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Lim, Wendell A	University of California San Francisco	Current
		Howard Hughes Medical Institute	Current

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Sauer, Robert T	MIT	
T:	Nguyen, Jack	Adamas Pharmaceuticals	
T:	Harris, Baruch	Metera Pharmaceuticals	
T:	Zarrinpar, Ali	University of Florida Colledge of Medicine	
T:	Papayannopoulos, Veniz	The Francis Crick Institute	
T:	Bhattacharyya, Roby	Massachusetts General Hospital	
T:	Dueber, John	University of California, Berkeley	
T:	Petrosky, Keiko	Bluebird Bio	
T:	Nathan Sallee	Five Prime Therapeutics	
T:	Yeh, Brian	Evolent Health	
T:	Bashor, Caleb	Rice University	
T:	Good, Matt	University of Pennsylvania	
T:	Rhau, Benjamin	Ebates	
T:	Chau, Angela Hoi-Yee	The Nueva School	
T:	Levskaya, Anselm	Google	
T:	Won, Angela	Treacy and Company	
T:	Park, Jason	University of California, San Francisco	
T:	Gerardin, Jaline	Northwestern University	
T:	Williams, Reid	IDEO	
T:	Coyle, Scott	University of Wisconsin-Madison	
T:	Stevens, Thomas	Bolt Threads	
T:	Choe, Joseph	University of California, San Francisco	
T:	Williams, Jasper	University of California, San Francisco	
T:	Reddy, Nishith	University of California, San Francisco	
T:	Kim, Ki	University of California, San Francisco	

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C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active

A:	Roybal, Kole	University of California, San Francisco		
A:	Bluestone, Jeffrey	University of California, San Francisco		
A:	Tang, Sindy	University of California, San Francisco		
A:	Mostov, Keith	University of California, San Francisco		
C:	Okada, Hideho	University of California, San Francisco		Current
C:	El-Samad, Hana	University of California, San Francisco		Current
C:	Bluestone, Jeffrey	University of California, San Francisco		Current
C:	Loh, Mignon	University of California, San Francisco		Current
C:	Roybal, Kole	University of California, San Francisco		Current
C:	Desai, Tejal	University of California, San Francisco		Current
C:	Troyanskaya, Olga	Princeton University		Current

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B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:				

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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Tang, Sindy KY	Stanford University	current appointment

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

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T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Whitesides, George M	Harvard University	
G:	Aizenberg, Joanna	Harvard University	
G:	Loncar, Marko	Harvard University	
T:	Gai, Ya	Princeton University	
T:	Lyu, Fengjiao	UberEats	
T:	Khor, Jian Wei	Stanford University	

T:	Blauch, Lucas	Stanford University	
T:	Bick, Alison	Stanford University	
T:	Castano, Nicolas	Stanford University	
T:	Cordts, Seth	Stanford University	
T:	Zhang, Kevin	Stanford University	
T:	Pan, Ming	Broad Institute of MIT and Harvard	
T:	Kim, Minkyu	Samsung	
T:	Koppaka, Saisneha	Stanford University	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Marshall, Wallace	University of California, San Francisco		current
A:	Lim, Wendell	University of California, San Francisco		current
A:	Schneider, Tobias	École polytechnique fédérale de Lausanne		current
A:	Zheng, Xiaolin	Stanford University		current
A:	Pratx, Guillem	Stanford University		current
A:	Cai, Wei	Stanford University		current
A:	Criddle, Craig	Stanford University		current
A:	Luby, Stephen	Stanford University		current
A:	Ermon, Stefano	Stanford University		current
A:	Lippincott-Schwartz, Jennif	HMMI Janelia Research Campus		current
A:	Morsut, Leonardo	University of Southern California		current
A:	Matin, AC	Stanford University		current
A:	Andrews, Jason	Stanford University		current
C:	Nadeau, Kari	Stanford University		current
C:	Galli, Stephen	Stanford University		current
C:	Gartner, Zev	University of California, San Francisco		current
C:	Marshall, Wallace	University of California, San Francisco		current
C:	Lim, Wendell	University of California, San Francisco		current
C:	Bianco, Simone	IBM		current
C:	Bayliss, Frank	San Francisco State University		current
C:	El-Samad, Hana	University of California, San Francisco		current
C:	Craik, Charles	University of California, San Francisco		current
C:	Fung, Jennifer	University of California, San Francisco		current
C:	Chan, Mark	San Francisco State University		current
C:	Fletcher, Daniel	University of California, Berkeley		current
C:	Douglas, Shawn	University of California, San Francisco		current
C:	Dumont, Sophie	University of California, San Francisco		current
C:	Weiner, Orion	University of California, San Francisco		current
C:	Chu, Diana	San Francisco State University		current
C:	Burrus, Laura	San Francisco State University		current
C:	Denetclaw, Wilfred	San Francisco State University		current
C:	Domingo, Carmen	San Francisco State University		current
C:	Esquerra, Raymond	San Francisco State University		current
C:	Riggs, Blake	San Francisco State University		current
C:	Prakash, Manu	Stanford University		current
C:	Liu, Allen	University of Michigan, Ann Arbor		current

C:	Ha, Taekjip	Johns Hopkins University		current
C:	Das, Moumita	Rochester Institute of Technology		current
C:	Harthorn, Barbara	University of California, Santa Barbara		current
C:	Yuan, Chongli	Purdue University		current
C:	St Pierre, Francois	Baylor College of Medicine		current

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Yeo, Leslie	RMIT University, Melbourne	Biomicrofluidics	current
E:	Shen, Amy	Okinawa Inst. of Sci & Tech Graduate U.	Biomicrofluidics	current
E:	den Toonder, Jaap	Eindhoven University of Technology	Biomicrofluidics	current
E:	Kim, Sung Jae	Seoul National University	Biomicrofluidics	current
E:	Shum, Anderson	Hong Kong University	Biomicrofluidics	

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	Dueber, John	University of California, Berkeley	current

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to disambiguate common names

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T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Lim, Wendell	University of California, San Francisco	

T:	Whitaker, Weston	co-founder and CSO Novome Biotechnologies	
T:	DeLoache, William	co-founder and CEO Novome Biotechnologies	
T:	Lee, Michael	Scientist at Bolt Threads	
T:	Russ, Zachary	co-founder and Scientist Novome Biotechnologies	
T:	Latimer, Luke	co-founder and CTO of ZestBio	
T:	Protzko, Ryan	co-founder and CEO of ZestBio	
T:	Hsu, Tammy	co-founder and CTO of Tinctorium Bio	
T:	Modavi, Cyrus	postdoc in Adam Abate lab at UCSF	
T:	Savitskaya, Judy	Investment Partner at Andreessen Horowitz Bio Fund	
T:	Halperin, Shakked	Founder and CEO of Evolve Biotechnologies	
T:	Andrew Ng	Cell Design Fellow at UCSF	
T:	Grewal, Parbir	UC Berkeley	
T:	Hurtado, Juan	UC Berkeley	
T:	Abrams, Melanie	UC Berkeley	
T:	Baker, Jordan	UC Berkeley	

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Arkin, Adam	University of California, Berkeley		
A:	Benz, J. Philipp	TU Munchen		
A:	Cate, Jamie	University of California, Berkeley		current
A:	El-Samad, H.	University of California, San Francisco		current
A:	Lim, Wendell	University of California, San Francisco		current
A:	Martin, Vincent	Concordia University		current
A:				
C:				
C:				
C:				
A:				
A:				
A:				
C:				
A:				

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

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	Fletcher, Daniel A	UC Berkeley	current
		Lawrence Berkeley National Laboratory	current
		Marine Biological Laboratory	current

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to disambiguate common names

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G:	Goodson, Kenneth	Stanford University	
G:	Kino, Gordon (deceased)	Stanford University	
G:	Quake, Calvin (deceased)	Stanford University	
T:	Bakalar, Matthew	Broad Institute	
T:	Friedman, Daniel	Ioptix, Inc.	
T:	Chaduhuri, Ovijit	Stanford University	
T:	Crow, Ailey	Stanford University	
T:	Hansen, Wendy	University of Washington	
T:	Jreij, Pamela	Genentec	
T:	Liu, Allen	University of Washington	
T:	Ng, Win Pin	L'Oreal	
T:	Parekh, Sapun	UT Austin	
T:	Stachowiak, Jeanne	UT Austin	
T:	Richmond, David	IBM	
T:	Risca, Viviana	The Rockefeller University	
T:	Rosenbluth, Michael	Veracyte, Inc.	
T:	Skandarajah, Arunan	Bill and Melinda Gates Foundation	
T:	Switz, Neil	San Jose State University	
T:	Venugopalan, Gautham	US Department of State	
T:	Webster, Kevin	McKinsey & Co	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last
A:	Harris, Andrew	Department of Bioengineering, University of California, Berkeley, CA 94720, USA.		
A:	Belardi, Brian	Department of Bioengineering, University of California, Berkeley, CA 94720, USA.		
A:	Jreij, Pamela	Department of Bioengineering, University of California, Berkeley, CA 94720, USA.		
A:	Wei, Kathy	Department of Bioengineering, University of California, Berkeley, CA 94720, USA.		
A:	Shams, Hengameh	Molecular Cell Biomechanics Laboratory, Departments of Bioengineering and Mechanical Engineering, University of California, Berkeley, CA 94720, USA.		
A:	Bausch, Andreas	Lehrstuhl für Biophysik (E27), Technische Universität München, Garching 85748, Germany.		
A:	Bhandari, Naleen	Division of Pharmaceutical Evaluation and Policy, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Payakachat, Nalin	Division of Pharmaceutical Evaluation and Policy, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Sung, Yi-Shan	Institute for Digital Health & Innovation, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Eswaran, Hari	Department of Obstetrics and Gynecology, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Benton, Tina	Institute for Digital Health & Innovation, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Lowery, Curtis	Department of Obstetrics and Gynecology, University of Arkansas for Medical Sciences, Little Rock, Arkansas.		
A:	Pion, Sébastien	French Research Institute for Development-Unité Mixte Internationale 233, University of Montpellier Montpellier, France		
A:	Nana-Djeunga, Hugues	Centre for Research on Filariasis and other Tropical Diseases, Yaounde, Cameroon.		
A:	Niamsi-Emalio, Yannick	Centre for Research on Filariasis and other Tropical Diseases, Yaounde, Cameroon.		
A:	Chesnais, Cedric	French Research Institute for Development-Unité Mixte Internationale 233, University of Montpellier Montpellier, France		
A:	Mackenzie, Charles	Department of Pathobiology and Diagnostic Investigation, Michigan State University, East Lansing, MI, USA		
A:	Stolk, Wilma	Department of Public Health, Erasmus University Medical Centre, Rotterdam, The Netherlands.		
A:	Klion, Amy	Laboratory of Parasitic Diseases, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, MD, USA.		
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Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last
B:	King, Michael	Vanderbilt University	Cell and Molecular Bioengienering	
B:	Way, Michael	Crick Institute	Journal of Cell Science	

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

There are five separate categories of information which correspond to the five tables in the COA template:

COA template Table 1:
List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **The individual's Ph.D. advisors; and**
- **All of the individual's Ph.D. thesis advisees.**

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and**
- **Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.**

COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
- **Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and**
- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

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This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Chu, Diana	San Francisco State University	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

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3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Payne, Gregory	UC Los Angeles	
T:	Swadha Singh	UC Merced	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Yates, John R.	Scripps Research Institute		
A:	Bianco, Simone	IBM Almaden Research		
C:	Das, Moumita	Rochester Institute of Technology		
C:	Dumont, Sophie	UCSF		
C:	Gartner, Zev	UCSF		
C:	Marshall, Wallace	UCSF		
C:	Muller-Reichert, Thomas	Univ of Technology, Dresden		
C:	Powers, James	Indiana Univ Bloomington		
C:	Roy, Scott	SFSU		
C:	Strome, Susan	UC Santa Cruz		
C:	Ward, Jordan	UC Santa Cruz		
C:	Zahler, Alan	UC Santa Cruz		
C:				
C:				
C:				

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Tim Schedl	Washington University	Micropublication: Biology	
B:	Paul Sternberg	Cal Tech	Micropublication: Biology	

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

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- **The individual's Ph.D. advisors; and**
- **All of the individual's Ph.D. thesis advisees.**

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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Burrus, Laura W	San Francisco State University	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Olwin, Bradley B	University of Colorado-Boulder	Molecular, Cellular and Developmental Biology
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Tanner, KD	SFSU	kdtanner@sfsu.edu	
A:	Apollon, C	UCSF	chantilly.apollon@gmail.com	6/30/18
A:				

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Tanner, KD	SFSU	CBE Life Science Education	
E:				

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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Riggs, Blake Elliott	San Francisco State University	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	Anne Royou	collaborator	a.royou@iecb.u-bordeaux.fr, IECB	

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Sullivan, William	UC Santa Cruz	wtsulliv@ucsc.edu, MCD
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Ahna Skop	University of Wisconsin	skop@wisc.edu, UW	
A:	Wallace Marshall	UCSF	wallace.ucsf@gmail.com, UCSF	
A:	Nasser Rusan	NIH (NHLBI)	nasser@nih.gov, NHLBI	1/1/17
A:	Kimberly Tanner	SFSU	kdtanner@sfsu.edu, Biology SFSU	
C:	Kimberly Tanner	SFSU	kdtanner@sfsu.edu, Biology SFSU	
C:	Laura Burrus	SFSU	lburrus@sfsu.edu, Biology, SFSU	

must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

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to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:				

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	Esquerra, Raymond	San Francisco State Univeristy	current

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to disambiguate common names

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G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Kliger, David	University of California, Santa Cruz	

T:			
T:			
T:			
T:			
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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
C:	Bayliss, Frank	San Francisco State University		current
A:	Chen, Eefei	University of California, Santa Cruz		current
C:	Fung, Jennifer	University of California, San Francisco		current
A:	Goldbeck, Roberrt	University of California, Santa Cruz		current
A:	Hayden, Celine	Univeristy of Toronto		
A:	He, Zheng-Hui	san Francisco State University		current
A:	Howard, John,	Applied Biotechnology		current
A:	Hung, Chiung-Yu	University of Texas, San Antonio		
C:	Ingraham, Holly	University of California, San Francisco		current
A:	Kliger, David	University of California, Santa Cruz		current
A:	Olson, John	Rice University		current
A:	Osteroff, Gary	University of Massachuesutts		
C:	Zimmerman, Tom	IBM		current
C:				
A:				

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	Prakash, Manu	Stanford University	current

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to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Gershenfeld, Neil	Massachusettes Institute of Technology	

T:	Cybulski, James	Foldscope Instruments	
T:	Katsikis, Yorgos	Massachusettes Institute of Technology	
T:	Mukundarajan, Haripriya	University of California, Los Angeles	
T:	Korir, George	Intutive Surgical	
T:	Gilpin, William	Harvard University	
T:	Bull, Matthew	Stanford	
T:	Krishnamurthy, Deepak	Stanford	
T:	Vyas, Pranav	Stanford	
T:	Kroo, Laurel	Stanford	
T:	Gong, Xingting	Stanford	
T:	Mollina, Anton	Stanford	
T:	Li, Ethan	Stanford	
T:	Flaum, Ellie	Stanford	
T:	Zhong, Grace	Stanford	
T:	Li, Hongquan	Stanford	

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Bhamla, Saad	Georgia Tech		
A:	Marshall, Wallace	UCSF		Current
A:	Jan, Lily	UCSF		
A:	Coyle, Scott	University of Wisconsin, Madison		Current
A:	Crosby, Alfred	University of Massachusettes, Amherst		
A:	Pazour, Gregory	UMASS Worcester		
A:	Sutton, Gregory	University of Bristol		
A:	Wood, Robert	Harvard University		
A:	Azizi, Emanuel	University of California, Irvine		
A:	Bergbrietier, Sarah	University of Maryland		
A:	Patek, Sheila	Duke University		
C:	Dumont, Sophie	UCSF		Current
C:	Thomson, Matt	Caltech		Current
C:	Chitlapilly, Sapna	TAMU		Current
C:	Brenner, Michael	Harvard University		Current

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
E:	Vale, Ron	UCSF	Xbio	

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	Simone, Bianco	IBM Research	

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G:	Grigolini, Paolo	University of North Texas	grigo@unt.edu, Physics

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Nieddu, GT	Montclair state university		
A:	Billings, L	Montclair state university		
A:	Forgoston, E	Montclair state university		
A:	Kaufman, JH	IBM Research	jhkauf@us.ibm.com, Genomics	
A:	Schwartz, Ira B	US Naval Research Lab		07/2017
A:	Porco, Travis	UCSF		07/2017
A:	Worden, Lee	UCSF		07/2017
A:	Weimer, Bart	Davis University		
A:	Rouzine, Igor	UCSF		
A:	Jones, Barbara	IBM Research		
A:	Hu, Kun	IBM Research		12/2015
A:	Edlund, Stefan	IBM Research		12/2015
A:	Stern, Adi	Tel Aviv University		12/2014
A:	Tang, Chao	Peking University		
C:	Gartner, Zev	UCSF		
C:	Lim, Wendell	UCSF		
C:	Marshall, Wallace	UCSF		
C:	El-Samad, Hana	UCSF		
C:	Chan, Mark	San Francisco State University		
C:	Burrus, Laura	San Francisco State University		
C:	Douglas, Shawn	UCSF		
C:	Chu, Diana	San Francisco State University		
C:	Andino, Raul	UCSF		
C:	Frydman, Judith	Stanford University		
C:	Brodsky, Leonid	Haifa University		

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E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

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E:				

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If there are more than 10 individuals designated as senior project personnel on the proposal, or if there are print preview issues, each completed template must be saved as a .txt file [select the Text (Tab Delimited) option] rather than as an .xlsx or .xls file. This format will still enable preservation of searchable text and avoid delays in processing and review of the proposal. Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

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"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Yee-Hung Mark Chan	San Francisco State University	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Steven Boxer	Stanford University	Chemistry

G:	W. E. Moerner	Stanford University	Chemistry
G:	Vijay Pande	Stanford University	Chemistry

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Wallace Marshall	UC San Francisco	Biochemistry & Biophysics	12/31/16
A:	Lorena Reyes	San Francisco State University	Biology	12/31/16
A:	Nancy Tran	San Francisco State University	Biology	12/31/16
A:	Saba Sohail	San Francisco State University	Biology	12/31/16
C:	Jennifer Fung	UC San Francisco	Obstetrics, Gynecology, Reproductiv	
C:	Simone Bianco	IBM Almaden		
C:	Orion Weiner	UC San Francisco	Cardiovascular Research Institute	

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	none			
E:	Christine Cosma	Current Biology, Scientific Editor		4/30/18

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Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Craik, Charles S	University of California San Francisco	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	Patel, Dinesh	CEO of Protagonist		1.2.2019
R:	Luke Evin	MPM Captial		3.4.2019
R:	Robert Dubridge	Maverick Therapeutics		4.9.2019

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Beychok, Sherman	Columbia University	
G:	Cantor, Charles	Columbia University	
T:	Evnin, Luke	MPM, Asset Management	
T:	Vasquez, John	Zuckerberg San Francisco General Hospital	
T:	Wilke, Majorie	Texas A&M University	
T:	Rosé, Jason	Kings Academy	
T:	Tsu. Chris	Exo Therapeutics	
T:	Willett, Scott	Promedior	
T:	Yang, Steve, Q.	WuXi AppTech	
T:	Eakin, Ann	NIH/NIAID/DMID	
T:	Harris, Jennifer	Novartis	
T:	Dauber, Deborah	WWMR, Inc.	
T:	Pray, Todd	Strategic Partnership, LBNL	
T:	Selvarajan, Sushma	Roche Pharmaceuticals	
T:	Waugh, Sandra	Summit Rock Strategy Consulting	
T:	Eggers, Christopher	Promega	
T:	Mahrus, S.	Genentech	
T:	Rodriguez (Castro), Helena	Univ. Federal, Rio de Janiero, Brazil	
T:	Greenbaum, Doron	Biogen	
T:	Nomura, Anson	Mintz,Levin,Cohn,Ferris, Glovsky & Popeo	
T:	Bhatt, Ami	Stanford	
T:	Marnett, Alan	Benchfly	
T:	Klein, Carly	Dermira	
T:	Tauheed, Jannah	Harvard	
T:	O'Donoghue, Anthony	UCSD	
T:	Farady, Christopher	Novartis	
T:	Darragh, Molly	Ocean Nanotechm LLC	
T:	Brown, Chris	Point 360	
T:	Ray, Manisha	Seven Bridges	
T:	Barkan, David	Novartis Institutes for BioMedical Research	
T:	Shahian, Tina	Science Editors Network	
T:	Tajon, Cheryl	Trilo Therapeutics	
T:	Lee, Melody	Roche	
T:	Gable, Jonathan	Novartis	
T:	Clarke, Starlynn	Caribou	
T:	Meyer (Olson), Nicole	SFSU	
T:	Goupil, Louise	USF	
T:	Ivry, Sam	McKinsey & Company	
T:	Lourenco, Andre	UCSF (Postdoc)	
T:	Ravalin, Matt	Stanford	
T:	Hulce, Kaitlin	UCSF	
T:	Rohweder, Peter	UCSF	
T:	Conner, Bardine	UCSF	
T:	Salcedo, Eugenia	UCSF	
T:	Ary, Beatrice	UCSF	
T:	Connly, Emily	UCSF	

the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Gestwicki, Jason	UCSF		

A:	Stroud, Robert	UCSF		
A:	Rabuka, David	Catalent, Emeryville, CA		
A:	Cheng, Yifan	UCSF		
A:	Gartner, Zev	UCSF		
A:	Van't Veer, Laura	UCSF		
A:	Arkin, Michelle	UCSF		
A:	Kirkwood, Kimberly	UCSF		
A:	Jacobson, Matthew	UCSF		
A:	Kao, Aimee	UCSF		
A:	Hoyer-Hansen, Gunila	Copenhagen University Hospital, Copenhagen		
A:	Abraham, Vivek	Abbvie, Renal Discovery, Chicago		
A:	Vincenti, Flavio	UCSF		
A:	O'Donoghue, Anthony	UCSD, San Diego		
A:	Janetka, James	Washington University, St Louis		
A:	Schneidman-Duhovny, Din	Weizmann Inst of Science		
A:	Pratt, Kathleen	Uniformed Services Univ of the Health Sciences, Bethesda		
A:	Aswad, Fred	Bayer Healthcare, San Francisco		
A:	Khosla, Chaitan	Stanford University		
A:	McKerrow, James	UCSD, San Diego		
A:	Tort, Jose	Universidad de la República, Montevideo, Uruguay		
A:	Horn, Martin	The Czech Academy of Sciences, Prague		
A:	Minor, Dan	Lawrence Berkeley National Laboratory, Berkeley		
A:	Jan, Lily	UCSF		
A:	Arastu-Kapur, Shirin	Onyx Pharmaceuticals, Inc., an Amgen subsidiary, San Francisco		
A:	Wang, Cheng-I	Singapore Immunology Network, Agency for Science, Technology and Research (A*STAR)		
A:	Moroz, A	Skolkovo Institute of Science and Technology, Moscow		
A:	Truillet, C	Université Paris Sud, CNRS		
A:	Rowan, Andrew	Newcastle University, Newcastle upon Tyne		
A:	Kanse, Sandip	University of Oslo, Oslo		
A:	Castro, Helena	Universidade Federal Fluminense, Niterói, RJ, Brazil		
A:	Wolan, Dennis	The Scripps Research Institute, La Jolla, California		
A:	Cravatt, Ben	The Scripps Research Institute, La Jolla, California		
A:	Clardy, Jon	Harvard Medical School, Boston		
A:	Voight, Chris	Massachusetts Institute of Technology, Cambridge, MA		
A:	Donia, Mohamed	Princeton Univ, Princeton		
A:				
A:				

must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

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5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:	Michael Marletta, PhD	Univ of California Berkeley	eLife	1/2/19

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1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	Denetclaw, Wilfred F	San Francisco State University, Biology	11/12/2019

<u>Table 2:</u> List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

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			to disambiguate common names	
2	**Name:**	**Type of Relationship**	**Optional (email, Department)**	**Last Active**
R:				

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T: All of the individual's Ph.D. thesis advisees.

			to disambiguate common names
3	**Advisor/Advisee Name:**	**Organizational Affiliation**	**Optional (email, Department)**

G:	Steinhardt, Richard A	UC Berkeley	Department of Molecular Cell Biology
T:			

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4	**Name:**	**Organizational Affiliation**	**Optional (email, Department)**	**Last Active**
A:	Harrison, Clive D	San Francisco State University	Biology	1/1/19
A:	Owens, Melissa T	San Francisco State University	Biology	1/1/18
C:	Mikawa, Takashi	UC San Francisco	Cardiovascular Research Institute	10/1/19
C:	Fung, Jennifer	UC San Francisco	Biochemistry and Molecular Biology	9/1/19
C:	Bianco, Simone	IBM Research Almaden	sbianco@us.ibm.com	11/3/19

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E:				

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1	Your Name:	Your Organizational Affiliation(s), last 12 r	Last Active Date
	El-Samad, Hana	University of San Francisco, California	current
		Chan-Zuckerberg Biohub	current

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	Al-Sady, Bassem	Husband		

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and

T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Khammash, Mustafa	ETH, Zurich	Dept. of Biosystems and Eng.
T:	Bhatnagar, Raj	Verge Genomics	
T:	Pincus, David	U. of Chicago	
T:	Neves, Lauren	Thermofisher	
T:	Oguz, Cihan	NIH	
T:	Fonseca, Joao	University of San Francisco, California	Dept. of Biochemistry & Biophysics
T:	Zuleta, Ignacio	Planet Labs	
T:	Camarillo, David	Stanford	
T:	Stewart-Ornstein, David	U. of Pittsburgh	Department of Comptational and Systems Biology
T:	Ng, Andrew	Cell Design Institute, UCSF	

T:	Chen, Susan	L.E.K. Consulting	
T:	Harrigan, Partrick	Zymergen	
T:	Mace, Kieran	Genetech	
T:	Heimberg, Graham	Broad Institute	
T:	Silvestre-Ryan, Jordi	UC Berkeley	
T:	Lipinske-Kruszka, Joanna	3Scan	
T:	Biddle-Snead, Charles	Seattle Genetics, Inc.,	
T:	Venurelli, Ophelia	University of Wisconsin, Madison	Department of Biochemistry
T:	Heineke, Benjamin	University of San Francisco, California	Dept. of Biochemistry & Biophysics
T:	Chevalier, Michael	University of San Francisco, California	Dept. of Biochemistry & Biophysics

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C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
C:	Walter, Peter	University of San Francisco, California		
C:	Li, Hao	University of San Francisco, California		
C:	Hoffman, Alexander	University of Los Angeles, California		
C:	Wollman, Roy	University of Los Angeles, California		
C:	Lim, Wendell	University of San Francisco, California		
C:	Weissman, Jonathan	University of San Francisco, California		
A:	Madhani, Hiten	University of San Francisco, California		
A:	Johnson, Alexander	University of San Francisco, California		
A:	Baker, David	UW, Seattle		
A:	Chen, Zibo	California Institute of technology		
A:	Chevalier, Michael	University of San Francisco, California		
A:	Gomez-Schiavon, Mariana	University of San Francisco, California		
A:	Fonseca, Joao	University of San Francisco, California		
A:	Harrigan, Patrick	Zymergen		
A:	Osimiri, Lindsey	University of San Francisco, California		
A:	Dueber, John	University of California, Berkely		
A:	Mace, Kieran	Genentech		
A:	Zuleta, Ignacio	Planet Labs		
A:	Langen, Robert	Lyell Pharma		
A:	Boyken, Scott	Lyell Pharma		
A:	Ng, Andrew	University of California, San Francisco		
A:	Kistler, Amy	Chan-Zuckerberg Biohub		
A:	Pincus, David	University of chicago		
A:	Stewart-Ornstein, Jacok	University of Pittsubrgh		
A:	Heineike, Ben	University of San Francisco, California		
A:	Bugaj, Luca	University of Pennselvenia		
A:	Neves, Lauren	Thermofisher		
A:	Rosenberg, O.S.	University of California, San Francisco		
A:	Savage, D.F.	University of California, Berkely		
A:	Doudna, J.A.	University of California, Berkely		
A:	Kortemme, T.	University of California, San Francisco		

must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

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to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active

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	Frazier, Jennifer A.	Exploratorium	Present

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active

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T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Mitchison, Timothy	Harvard Medical School	Systems Biology
T:			

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4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Ma, Kwan-Liu	University of California, Davis		Present
A:	Yu, Kristina	Exploratorium		Present
A:	Ma, Joyce	Exploratorium		Present
C:	Marshall, Wallace	University of California, San Francisco	Biochemistry and Biophysics	Present
C:	Ma, Kwan-Liu	University of California, Davis	Computer Science	Present

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	Hart, Charles P.	UCSF Catalyst Program	
		UCSF Dept. of Pharmaceutical Chemistry	

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to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

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G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Ruddle, Frank H.	(deceased)	Yale
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Ahluwalia, Dharmendra	Threshold Pharmaceuticals		
A:	Andreef, Michael	MD Anderson Cancer Center		
A:	Baker, Amanda	Arizona Cancer Center		
A:	Bankson, James, A.	MD Anderson Cancer Center		
A:	Benito, Juliana	MD Anderson Cancer Center		
A:	Bhattacharya, Pratip, K.	MD Anderson Cancer Center		
A:	Bohlander, Stefen, K.	University of Auckland		
A:	Brayton, Cory, F.	Johns Hopkins Hospital		
A:	Brenner, Andrew	University of Texas Health Sciences Center at San Antonio		
A:	Budhani, Pratha	MD Anderson Cancer Center		
A:	Butt, Sehrish	University of Toronto		
A:	Caflisch, Laura	University of Texas Health Sciences Center at San Antonio		
A:	Caporiccio, Laura	Princess Margaret Cancer Centre		
A:	Cavosas, David	University of Texas Health Sciences Center at San Antonio		
A:	Chang, Kevin, K.	Memorial Sloan Kettering Cancer Center		
A:	Chapiro, Julius	Yale University School of Medicine		
A:	Chaplin, John, M.	Auckland City Hospital		
A:	Chiorean, E, Gabriela	Fred Hutchinson Cancer Research Center		
A:	Cornell, Hether, H.	Moffit Cancer Center		
A:	Cornish, Toby, C.	johns Hopkins University School of Medicine		
A:	Cortes, Jorge, E.	MD Anderson Cancer Center		
A:	Curran, Michael, A,	MD Anderson Cancer Center		
A:	Davis, R, Eric	MD Anderson Cancer Center		
A:	Deasy, Joseph, O.	Memorial Sloan Kettering Cancer Center		
A:	Devasahayam, Nailathamb	Radiation Biology Branch, NCI, NIH		
A:	Devaux, Jules, B.L.	University of Auckland		
A:	Dillies, Robert, J.	Moffit Cancer Center		
A:	Duran, Rafael	Yale University School of Medicine		
A:	Ferraro, Damien	Threshold Pharmaceuticals		
A:	Fichtel, Linda	South Texas Oncology and Hematology		
A:	Floyd, John	University of Texas Health Sciences Center at San Antonio		
A:	Frangakis, Constantine	Johns Hopkins School of Public health		
A:	Geschwind, Jean-Francois	Yale University School of Medicine		
A:	Goodman, Karym, A.	University of Colorado		
A:	Gorodetski, Boris	Johns Hopkins Hospital		
A:	Grenman, Reidar, A.	Turku University Hospital		
A:	Gruslova, Aleksandra	University of Texas Health Sciences Center at San Antonio		

A:	Haimovitz-Friedman, Adria	Memorial Sloan Kettering Cancer Center		
A:	Hajj, Carla	Memorial Sloan Kettering Cancer Center		
A:	Harutyunyan, Karine, G.	MD Anderson Cancer Center		
A:	Hickey, Anthony, J.R.	University of Auckland		
A:	Hicks, Kevin	Auckland Cancer Society Research Centre		
A:	Hong, Cho, R.	Auckland Cancer Society Research Centre		
A:	Huang, Shiliang	University of Texas Health Sciences Center at San Antonio		
A:	Humm, John, L.	Memorial Sloan Kettering Cancer Center		
A:	Hunter, Francis, W.	Auckland Cancer Society Research Centre		1/1/17
A:	Jalal, Shadia, I.	Indiana University		
A:	Jamieson, Stephem, M.F.	Auckland Cancer Society Research Centre		
A:	Jacarno, Rodrigo	MD Anderson Cancer Center		
A:	Jung, Don	Threshold Pharmaceuticals		
A:	Kakadia, Purvi, M.	University of Auckland		
A:	Kanniappan, Shanhugasund	Johns Hopkins Hospital		
A:	Kee, Dennis	Auckland City Hospital		
A:	Ketela, Troy, W.	Princess Margaret Genomics Centre		
A:	Khan, Aziza	Auckland Cancer Society Research Centre		
A:	Kishimoto, Shun	Radiation Biology Branch, NCI, NIH		
A:	Knowlton, Nicholas, S.	University of Auckland		
A:	Kondratyev, Maria, K	Princess Margaret Cancer Centre		
A:	Konoplev, Srgei	MD Anderson Cancer Center		
A:	Konopleva, Marina	MD Anderson Cancer Center		
A:	Krishna, Murali, C.	Radiation Biology Branch, NCI, NIH		
A:	Kroll, Stew	Threshold Pharmaceuticals		
A:	Lee, Jaehyuk	MD Anderson Cancer Center		
A:	Lee, Jun, Ho	Memorial Sloan Kettering Cancer Center		
A:	Lee, Tat, Woo	Auckland Cancer Society Research Centre		
A:	Li, Dan	Auckland Cancer Society Research Centre		
A:	Lin, MingDe	Yale University School of Medicine		
A:	Liu, Arthur	MD Anderson Cancer Center		
A:	Liu, Qian	Threshold Pharmaceuticals		
A:	Liu, Yicju	University of Texas Health Sciences Center at San Antonio		
A:	Lodi, Alessia	University of Texas		
A:	Lowery, Maeve, A.	Memorial Sloan Kettering Cancer Center		
A:	Lu, Hongbo	MD Anderson Cancer Center		
A:	Lynch, Courtney, R.H.	Auckland Cancer Society Research Centre		
A:	Ma, Helen	MD Anderson Cancer Center		
A:	Macann, Andrew, M.J.	Auckland City Hospital		
A:	Marastoni, Stefano	Princess Margaret Cancer Centre		
A:	Marszalek, Joseph, R.	MD Anderson Cancer Center		
A:	Martinez, Gary, V.	Moffit Cancer Center		
A:	Matsumoto, Shingo	Radiation Biology Branch, NCI, NIH		
A:	Matre, Polina	MD Anderson Cancer Center		
A:	Matteucci, Mark, D.	Threshold Pharmaceuticals		
A:	McIvor, Nicholas, P.	Auckland City Hospital		
A:	McKee, Trevor, D.	University of Toronto		
A:	McQueen, Teresa	MD Anderson Cancer Center		
A:	Meng, Fanying	Threshold Pharmaceuticals		
A:	Millward, Niki, Zacharias	MD Anderson Cancer Center		
A:	Mirpour, Sahar	Johns Hopkins Hospital		
A:	Mitchell, James, B.	Radiation Biology Branch, NCI, NIH		
A:	Mu, Hong	MD Anderson Cancer Center		

A:	Munasinghe, Jeeva, P.	Radiation Biology Branch, NCI, NIH		
A:	Naz, Sarwat	Radiation Biology Branch, NCI, NIH		
A:	Nemunaitis, John, J.	University of Toledo		
A:	Pekursky, Vasily	Johns Hopkins Hospital		
A:	Poonawala-Lohani, Nooriya	University of Auckland		
A:	Print, Cristin, G.	University of Auckland		
A:	Protoprova, Marina	MD Anderson Cancer Center		
A:	Quarles, C, Chad	Vanderbilt University		
A:	Ramirez, Marc, S.	MD Anderson Cancer Center		
A:	Reyes, Juvenal	Johns Hopkins Hospital		
A:	Russell, James	Memorial Sloan Kettering Cancer Center		
A:	Saito, Keita	Radiation Biology Branch, NCI, NIH		
A:	Schemthaner, Rudiger,E.	Yale University School of Medicine		
A:	Senzer, Neil, N.	Mary Crowley Cancer Research Center		
A:	Shalev, Zhi	Princess Margaret Cancer Centre		
A:	Sharma, Indumati	Auckland Cancer Society Research Centre		
A:	Shi, Yue-xi	MD Anderson Cancer Center		
A:	Shome, Avik	Auckland Cancer Society Research Centre		
A:	Simon, M, Celeste	University of Pennsyvania		
A:	Stokes, Ashley, M.	Vanderbilt University		
A:	Sun, Jessica, D.	Threshold Pharmaceuticals		
A:	Takakusagi, Yoichi	Radiation Biology Branch, NCI, NIH		
A:	Tap, William, D.	Memorial Sloan Kettering Cancer Center		
A:	Tiziani, Stefano	University of Texas		
A:	Tsai, P.	University of Auckland		
A:	Tsai, Peter	University of Auckland		
A:	Velez, Juliana	MD Anderson Cancer Center		
A:	Volgin, Andrei	MD Anderson Cancer Center		
A:	Wamg, Yan	Threshold Pharmaceuticals		
A:	Wilson, William, R.	Auckland Cancer Society Research Centre		
A:	Wojtkowiak, Jonathan, W.	Moffit Cancer Center		
A:	Wong, Way, W.	Auckland Cancer Society Research Centre		
A:	Wouters, Bradly, G.	Princess Margaret Cancer Centre		
A:	Yoon, Changhwan	Memorial Sloan Kettering Cancer Center		
A:	Yoon, Sam, S.	Memorial Sloan Kettering Cancer Center		
A:	Zaidi, Mark	Princess Margaret Cancer Centre		
A:	Zhang, Xiaomeng	Moffit Cancer Center		
A:	Zuniga, Richard	University of Texas Health Sciences Center at San Antonio		

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to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	Robert Campbell	Society for Laboratory Automation and Scr	SLAS Discvery	
E:				

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	McGinn, Robert E.	University of California, San Francisco	current
		Stanford University	1/6/2019

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3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Patrick Suppes	Stanford University (**now deceased**)	

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

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The template has been developed to be fillable, however, the content and format requirements must not be altered by the user. This template must be saved in .xlsx or .xls format, and directly uploaded into FastLane as a Collaborators and Other Affiliations Single Copy Document. Using the .xlsx or .xls format will enable preservation of searchable text that otherwise would be lost. It is therefore imperative that this document be uploaded in .xlsx or .xls only. Uploading a document in any format other than .xlsx or .xls may delay the timely processing and review of the proposal.

This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Zimmerman, Thomas G.	IBM Research-Almaden	
		SFSU (instructor)	

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:				

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	Gershenfeld, Neil	MIT Media Lab, Center for Bits and Atoms	
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	Bianco,Simone	IBM Research-Almaden		
A:	Pastore,Vito	IBM Research-Almaden		
A:	Biswas,Sujoy	IBM Research-Almaden		
A:	Antipa,Nick	UC Berkeley		
A:	Waller,Laura	UC Berkeley		
A:	Fung, Jennifer	UCSF		

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:				

The following information regarding collaborators and other affiliations (COA) must be separately provided for each individual identified as senior project personnel. The COA information must be provided through use of this COA template.

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc. Do not upload .pdf.

Please note that some information requested in prior versions of the PAPPG is no longer requested. THIS IS PURPOSEFUL AND WE NO LONGER REQUIRE THIS INFORMATION TO BE REPORTED. Certain relationships will be reported in other sections (i.e., the names of postdoctoral scholar sponsors should not be reported, however if the individual collaborated on research with their postdoctoral scholar sponsor, then they would be reported as a collaborator). The information in the tables is not required to be sorted, alphabetically or otherwise.

There are five separate categories of information which correspond to the five tables in the COA template:

COA template Table 1:
List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

COA template Table 2:
List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

COA template Table 3:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **The individual's Ph.D. advisors; and**
- **All of the individual's Ph.D. thesis advisees.**

COA template Table 4:
List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:
- **Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and**
- **Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.**

COA template Table 5:
List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.
- **Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and**
- **Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.**

The template has been developed to be fillable, however, the content and format requirements must not be altered by the user. This template must be saved in .xlsx or .xls format, and directly uploaded into FastLane as a Collaborators and Other Affiliations Single Copy Document. Using the .xlsx or .xls format will enable preservation of searchable text that otherwise would be lost. It is therefore imperative that this document be uploaded in .xlsx or .xls only. Uploading a document in any format other than .xlsx or .xls may delay the timely processing and review of the proposal.

This information is used to manage reviewer selection. See Exhibit II-2 for additional information on potential reviewer conflicts.

1 Note that graduate advisors are no longer required to be reported.
2 Editorial Board does not include Editorial Advisory Board, International Advisory Board, Scientific Editorial Board, or any other subcategory of Editorial Board. It is limited to those individuals who perform editing duties or manage the editing process (i.e., editor in chief).

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department
Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and
To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
For "Last Active Date" and "Last Active" columns dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.
"Last Active Date" and "Last Active" columns may be left blank for ongoing or current affiliations.

Table 1: List the individual's last name, first name, middle initial, and organizational affiliation in the last 12 months.

1	Your Name:	Your Organizational Affiliation(s), last 12	Last Active Date
	Singer, Debra	University of California, San Francisco	current

Table 2: List names as last name, first name, middle initial, for whom a personal, family, or business relationship would otherwise preclude their service as a reviewer.

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

2	Name:	Type of Relationship	Optional (email, Department)	Last Active
R:	N / A			

Table 3: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following.

G: The individual's Ph.D. advisors; and
T: All of the individual's Ph.D. thesis advisees.

to disambiguate common names

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)

G:	N / A		
T:			

Table 4: List names as last name, first name, middle initial, and provide organizational affiliations, if known, for the following:

A: Co-authors on any book, article, report, abstract or paper with collaboration in the last 48 months (publication date may be later); and

C: Collaborators on projects, such as funded grants, graduate research or others in the last 48 months.

to disambiguate common names

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
A:	N / A			
A:				
C:				

Table 5: List editorial board, editor-in chief and co-editors with whom the individual interacts. An editor-in-chief must list the entire editorial board.

B: Editorial Board: List name(s) of editor-in-chief and journal in the past 24 months; and

E: Other co-Editors of journal or collections with whom the individual has directly interacted in the last 24 months.

to disambiguate common names

5	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:	N / A			
E:				

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 19-1

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY
NSF PROPOSAL NUMBER
2017753

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
OIA - STCs - 2016 Class

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
01/15/2020	1	01060000 OIA	031Y	094878337	01/15/2020 6:33pm

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
946036493

SHOW PREVIOUS AWARD NO. IF THIS IS
☒ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL
1548297

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.941034249

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) ☐ 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
$ 22,470,000	60 months	10/01/21	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Center**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE ☐ FUNDING OF FOREIGN ORG
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED

☒ COLLABORATIVE STATUS
A collaborative proposal from one organization (PAPPG II.D.3.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
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CO-PI/PD **Zev J Gartner**	DPhil	2004	415-514-9962	zev.gartner@ucsf.edu
CO-PI/PD				
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 (PAPPG). 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 PAPPG Chapter IX.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 Proposal & Award Policies & Procedures 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 Proposal & Award Policies & Procedures 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 Proposal & Award Policies & Procedures 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, Chapter IX.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.

Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Sharon Louie**	**Electronic Signature**	**Jan 15 2020 6:30PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
415-290-3478	**Sharon.Louie@ucsf.edu**	**415-476-5367**

See Supplementary Documents section for the Project Summary.

TABLE OF CONTENTS

For font size and page formatting specifications, see PAPPG 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.

Project Description is included as a supplementary document.

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Wallace Marshall
Professor, Department of Biochemistry & Biophysics | UCSF
600 16th Street, GH-N372F, Box 2200
San Francisco, CA 94158

(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

2016 - present Director, NSF Center for Cellular Construction
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**

Rafelski SM, Viana MP, Chan YM, Thorn KS, Yam P, Fung JC, Li H, Costa L, Marshall WF. 2012. Mitochondrial network size scaling in budding yeast is achieved in the bud at the expense of the mother. ***Science***. 338, 822-4.

Ludington WB, Wemmer KA, Lechtreck KF, Witman GB, Marshall WF. 2013. Avalanche-like behavior in ciliary length control. ***Proc. Natl. Acad. Sci. U.S.A.*** 110, 3925-30

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

Kimmel JC, Chang AY, Brack A, Marshall WF. 2018. Inferring cell state by quantitative motility analysis reveals a dynamic state system and broken detailed balance. ***PLoS Computational Biology.*** 14, e1005927

Chang AY, Marshall WF. 2019. Dynamics of living cells in a cytomorphological state space. ***Proc. Natl. Acad. Sci. U. S. A.*** 116, 21556-21562

(ii) **five other significant publications**

Azimzadeh J, Wong ML, Downhour DM, Sanchez Alvarado A, Marshall WF. 2012. The centrosome was lost in the evolution of planarians. ***Science***. 335, 461-3.

Ludington WB, Ishikawa H, Serebrenik YV, Ritter A, Hernandez-Lopez RA, Gunzenhauser J, Kannegaard E, Marshall WF. 2015. A systematic comparison of mathematical models for inherent measurement of ciliary length: how a cell can measure length and volume. ***Biophys. J.*** 108, 1361-79

Chan YH, Reyes L, Sohail SM, Tran NK, Marshall WF. 2016. Organelle size scaling of the budding yeast vacuole by relative growth and inheritance. ***Curr. Biol***. 26, 1221-8

Hendel N, Thomson M, Marshall WF. 2018. Diffusion as a ruler: modeling kinesin diffusion as a length sensor for intraflagellar transport. ***Biophys. J.*** 114, 663-674

Kimmel JC, Brack A, Marshall WF**.** 2019. Deep convolutional and recurrent neural networks for cell motility discrimination and prediction. ***IEEE/ACM Trans. Comp. Biol. Bioinformatics*** doi: 10.1109/TCBB.2019.2919307

(d) Synergistic Activities

- Interdisciplinary teaching in quantitative cell biology: Physiology Course, Marine Biological Lab, Woods Hole MA: Instructor 2009-2013, Director 2014 - 2018. UCSF: Developed graduate

level minicourse on "cellular cognition" exploring the computational capacity of living cells using hands-on project based learning in 2012, 2014, 2015, and 2016. Developed a minicourse on "cellular computation" in 2018 and helped develop a minicourse on "Fab at Lab" in 2019 that teaches students how to build laboratory equipment.

- 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. Gordon Conference on Stochastic Physics in Biology Vice-Chair 2017, Chair 2019.
- Public outreach: Presented hands-on demonstration of an Arduino-controlled device for testing learning in single cells at Maker Faire Bay Area 2014-2019, as well as at the Mendocino County Mini Maker Faire (May 2013), the East Bay Mini Maker Faire in Oakland, CA (October 2013), and Benicia Mini Maker Faire (March 2015). Recorded iBiology video on "ten craziest things cells do" (2017).
- Grant review activity: Member NSF Cytoskeleton peer review panel (2010 and 2011) and MCB panel (2008, 2009). Member, NIH NCSD Study Section, 2012 - 2016.
- 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 *Karp's Cell and Molecular Biology, concepts and experiments*, Wiley Inc, 2016. 9th edition in progress.

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(a) Professional Preparation

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

(b) Appointments

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

(c) Publications

(i) five publications most closely related to proposed project

Cerchiari A, Garbe JC, Todhunter ME, Jee NY, Broaders K, Peehl D, LaBarge MA, Desai T, Thomson M, **Gartner ZJ**. "A strategy for tissue self-organization that is robust to cellular heterogeneity and plasticity." Proc. Natl. Acad. Sci. USA **112**(7) 2287 (2015) PMCID: PMC4343104

McGinnis CS, Patterson DM, Winkler J, Conrad DN, Hein MY, Srivastava V, Hu JL, Murrow LM, Weissman JS, Werb Z, *Chow ED, ***Gartner ZJ**. MULTI-seq: sample multiplexing for single-cell RNA sequencing using lipid-tagged indices. Nat Methods. 2019 Jul;16(7):619-626. doi: 10.1038/s41592-019-0433-8. Epub 2019 Jun 17. PubMed PMID: 31209384
***co-corresponding authors**

Todhunter ME, Jee NY, Cerchiari A, Hughes AJ, Farlow J, Garbe JC, LaBarge MA, Desai TA, **Gartner ZJ**. "Programmed synthesis of 3D tissues." *Nature Methods* **12**(10) 975 (2015)

Hughes AJ, Mornin JD, Biswas SK, Beck LE, Bauer DP, Raj A, Bianco S, **Gartner ZJ**. Quanti.us: a tool for rapid, flexible, crowd-based annotation of images. Nat Methods. 2018 Aug;15(8):587-590. doi: 10.1038/s41592-018-0069-0. Epub 2018 Jul 31. PubMed PMID: 30065368

Hughes AJ, Miyazaki H, Coyle MC, Zhang J, Laurie MT, Chu D, VavruÅ¡ovÃ¡ Z, Schneider RA, Klein OD, **Gartner Z**. Engineered Tissue Folding by Mechanical Compaction of the Mesenchyme. Dev Cell. 2018 Dec 27. PMID: 29290586

(ii) five other significant publications

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)

Seo D, Southard KM, Kim JW, Lee HJ, Farlow J, Lee JU, Litt DB, Haas T, Cheon J, Alivisatos P, ***Gartner ZJ**, *Jun YW. "A mechanogenetic toolkit for interrogating cell signaling in space and time." *Cell* (2016)
***co-corresponding authors**

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)

Cole RH, Tang SY, Siltanen CA, Shahi P, Zhang JQ, Poust S, **Gartner ZJ**, Abate AR. Printed droplet microfluidics for on demand dispensing of picoliter droplets and cells. Proc Natl Acad Sci U S A. 2017 Aug 15; 114(33):8728-8733. PMID: 28760972

Taylor MJ, Husain K, **Gartner ZJ**, Mayor S, Vale RD. "A DNA-Based T Cell Receptor Reveals a Role for Receptor Clustering in Ligand Discrimination." *Cell*. 169(1):108-119 (2017)

(d) 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 led a mini course with Dr. Matt Thomson on the topic of multicellular systems biology. We critically read papers and built mathematical models to understand organizing principles of distributed control in biology. I led another minicourse on bioconjugate techniques in 2015. 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: Development of DNA Encoded Chemical Libraries based a DNA-Templated Synthesis; Use of nucleic acids as chemical adhesion molecules to control the structure of tissues; Tools for sample multiplexing for single-cell RNAseq and have share the reagents and computational tools we've developed with over 200 labs in the last year.

Broadening participation by groups of under represented minorities: Presented 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 volunteer with my lab annually at local public elementary schools where we give microscopy demonstrations for first graders of diverse backgrounds.

Service to the Scientific Community: Peer reviewer for the Department of Defense, the NSF, and several European funding agencies. ad hoc integration panel member for the Department of Defense Breast Cancer Research Program for over 7 years. Organizing committee for the 2013 International Conference of Biomolecular Engineering, the 2015 ACS meeting in Denver, and the TERMIS meeting in 2020.

Biographical Sketch

Frank Bayliss, Professor of Biology
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(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:**

UC San Francisco	2016-present	Adjunct Prof. Biochem & Biophysics
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:**

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

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

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*. 9, 4: pp. 487-503

Frank Bayliss, Alan Peterfreund and Ken Rath. 2009. "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

Bayliss, F., Peterfreund, A., & Rath, K. 2018. Programmatic Mentoring. In J. McClinton, D. S. Mitchell, G. B. Hughes, & M. A. Melton (Eds.) *Mentoring at Minority Serving Institutions (MSIs): Theory, Design, Practice, and Impact*. Information Age Publishing, 440 pp.

A. Alegra Eroy-Reveles*, Eric Hsu^, Kenneth A. Rath**, Alan R. Peterfreund** and Frank Bayliss. 2019. History And Evolution of STEM Supplemental Instruction at San Francisco State University, a Large, Urban, Minority-Serving Institution. in "*Diversity in Higher Education*" series by Emerald Publishing.

(ii) **five other significant publications**

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, 199

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

(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, The Genentech Foundation 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, is 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.

Biographical Sketch

Simone Bianco, PhD
Research Staff Member
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sbianco@us.ibm.com

(a) Professional Preparation

UC San Francisco	Bioengineering	postdoc, 2010-2014
The College of William and Mary	Applied Science	postdoc, 2007-2010
University of North Texas	Physics	PhD, 2004-2007
University of Pisa	Physics	MS, 2004
University of Pisa	Physics and Astrophysics	BS, 2004

(b) Appointments

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

(c) Publications

(i) five publications related to current activity

Hughes, A., Mornin, J. D., Biswas, S. K., Bauer, D. P., Bianco, S., Gartner, Z. J. (2017). "Quantius: a tool for rapid, flexible, crowd-sourced based annotation", Nature Methods, 15, 587-590 (2018), https://www.nature.com/articles/s41592-018-0069-0

Biswas, SK., Zimmerman, T., Maini, L., Adebiyi, A., Bozano, L., Brown, C., Pastore, VP. & Bianco, S. (2019, February). High throughput analysis of plankton morphology and dynamic. In Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XXVI (Vol. 10881, p. 1088109). International Society for Optics and Photonics.

Pastore, VP., Zimmerman, T., Biswas, SK. & Bianco, S. (2019, February). Establishing the baseline for using plankton as biosensorIn Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XXVI (Vol. 10881, p. 108810H). International Society for Optics and Photonics.

Zimmerman, T., Antipa, N., Elnatan, D., Murru, A., Biswas, S., Pastore, V., ... & Bianco, S. (2019, February). Stereo in-line holographic digital microscope. In Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XXVI (Vol. 10883, p. 1088315). International Society for Optics and Photonics.

Chin, W., Zhong, G., Pu, Q., Yang, C., Lou, W., De Sessions, P. F., ..., Bianco, S. & Gao, S. (2018). A macromolecular approach to eradicate multidrug resistant bacterial infections while mitigating drug resistance onset. Nature communications, 9(1), 917.

(ii) other significant publications

G. T. Nieddu, L. Billings, J.H. Kaufman, E. Forgoston, and S. Bianco, “Extinction pathways and outbreak vulnerability in a stochastic Ebola model”, Journal of The Royal Society Interface (2017).

Y. Xiao, I. Rouzine, S. Bianco, A. Acevedo, E. F. Goldstein, M. Farkov, L. Brodsky, and R. Andino, “RNA Recombination Enhances Adaptability and Is Required for Virus Spread and Virulence”, Cell Host & Microbe, 19(4), 493 - 503 (2016).

B. Jones, J. Lessler, S. Bianco, and J. Kaufman, “Statistical Mechanics and Thermodynamics of Viral Evolution”, PloS One 10(9), e0137482 (2015).
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).

Schwartz, I. B., Forgoston, E., Bianco, S., & Shaw, L. B. (2011). Converging towards the optimal path to extinction. Journal of The Royal Society Interface, 8(65), 1699–1707. https://doi.org/10.1098/rsif.2011.0159

(d) Synergistic Activities

Diversity and Inclusion Outreach: Since 2018 I have served as an External Advisory Board member for the *SFSU Promoting Inclusivity in Computing (PINC), an NSF funded educational program at* San Francisco State University

Professional Society Service*:* In 2018 I was the Visiting lecturer fellow for the Society for Industrial and Applied Mathematics , in recognition of my contribution to advancement and educational activities in the field of dynamical systems

Public Outreach: I have presented TED talks on “The wonderful world of life in a drop of water” and on “Cellular Engineering as the industry of the future.”

Service to Funding Agencies: In 2019 I presented a “provocateur” talk for the NSF IDEAS lab on synthetic and artificial cells.

BIOGRAPHICAL SKETCH

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(a) 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

(b) Appointments

2017-	Chair, Department of Biology, San Francisco State University
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

(c) Publications

(i) related to proposal (out of 28 total)

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

1. Galli LM, Santana F**[U], Apollon C, Szabo LA*, Ngo K**[U], Burrus LW. Direct visualization of the Wntless-induced redistribution of WNT1 in developing chick embryos. Dev Biol. 2018 Jul 15;439(2):53-64.
2. Galli, L.M., Zebarjadi, N.*, Li, L.*, Lingappa, V.R., and Burrus, L.W. (2016) Divergent effects of Porcupine and Wntless on WNT1 trafficking, secretion, and signaling. Exp Cell Res 347(1):171-83.
3. 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* 588(24):4815-24.
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.

(ii) five other significant publications

1. Seidel, S.B., Reggi, A.L.*[F], Schinske, J.N., Burrus, L.W., and Tanner, K.D. (2015) Beyond the biology: a systematic investigation of noncontent instructor talk in an introductory biology course. CBE life sciences education *14*, ar43.
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., 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.

5. 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.

(d) Synergistic Activities

1. Research mentor to under-represented minority undergraduate and master's level students: In 21 years, I have mentored 41 under-represented minority students (Lisa Acosta, Eric Alonzo, Adolph Anglade, Raymund Bueno, Rocio Cisneros, Ricardo Collaco, Jayden Dalton, Lisa Dorsey, Edward Elizarraras, Michael Enriquez, Dorothy Estrada, Anthony Eritano, Eugenel Espiritu, Gabriel Fraley, Jorge Franco, Muryam Gourdet, Maura Granados, David Hernandez, Joni Jones, Robert Monroy, Ouma Onguka, Angela Lane, Destinee Lanns, Jacquelyn Leiva, Jessica Magaña, Yurixsa Martinez, Matilde Miranda, Leisha Moroney, Roeben Munji, Madu Nzerem, Walter Orellana, Gina Pay, Joe Ramahi, Lluvia Rodriguez, Luis Sanchez, Frederick Santana, Rowena Suriben, Camilla Teng, Da'Sani Tillery, Baouyen Tran, Michelle Wallace). Of these students, 13 have already received their PhDs (from Albert Einstein, Baylor, Johns Hopkins, UCSF, UC-Davis, USC, Memorial Sloan Kettering/Cornell, and UT-Southwestern) while 8 are currently in PhD programs (NYU, The Riken Institute, UCSF). I am also a mentor for NIH MARC, RISE, and BRIDGES fellows as well as an NSF STC fellow.
2. Co-director, HHMI Inclusive Excellence Award: The goal of this effort is to have students from under-represented backgrounds partner with Biology faculty to promote the retention and graduation of students from under-represented backgrounds in STEM fields. Students will develop scientist spotlights to assist with the introduction of culturally relevant curriculum into Biology classes. Students will further serve as in class peer mentors to increase faculty capacity to use innovative curriculum to actively engage our upper division students in their own learning.
3. Chair, SFSU Department of Biology: As chair of Biology, my goals are to 1) increase the retention and graduation rates of students in Biology, 2) reduce the gap in retention and graduation for our students from under-represented backgrounds 3) increase the flow of socially engaged students into the STEM workforce and 4) foster an environment that promotes discovery. I further aspire to ensure the longevity of these efforts by implementing institutional changes.
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. I have also engaged young students in scientific inquiry at Jose Ortega and Francis Scott Elementary Schools in San Francisco.
5. Diversity Advocate: I have facilitated workshops on Equity and Diversity and am a member of the Society for Developmental Biology Inclusion and Outreach Committee. I am also on the advisory committee for the Minority Biomedical Research Support – Support of Continuous Research Excellence (MBRS-SCORE) program at SFSU.

Biographical Sketch

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(a) Professional Preparation

Harvard University	Chemistry	B.A.	1997
Stanford University	Chemistry	Ph.D.	2008
UC San Francisco	Biochemistry & Biophysics	Postdoc	2009-2014

(b) Appointments

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

(c) Publications

(i) Five publications closely related to the proposal

1. **Chan Y-HM**, Reyes L, Sohail, SM, Tran N, Marshall WF. "Organelle Size Scaling of the Budding Yeast Vacuole by Relative Growth and Inheritance." *Current Biology* (2016) 26: 1221-8.
2. **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.
3. 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.
4. **Chan Y-HM,** Marshall WF. "How cells know the size of their organelles." *Science* (2012) 337:1186-1189.
5. **Chan Y-HM,** Marshall WF. "Threshold-free method for three-dimensional segmentation of organelles." *Proc. SPIE* (2012) 8225: 822529.

(ii) Five other significant publications

6. **Chan, Y-HM,** Marshall WF. "Scaling properties of cell and organelle size." *Organogenesis* (2010) 6:88-96.
7. 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.
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

1. Undergraduate course development – Co-instructor, Introduction to Optical Engineering for the Biological Sciences, SFSU, 2019: Developed a new course where students assemble digital microscopes, implement design improvements, and deploy them to characterize protist samples.

2. Development of research workshop – Co-director, NSF STC "Summer of Cells", hosted at SFSU, 2019: Developed an intensive, 2-week research workshop engaging students from diverse backgrounds in projects related to cellular engineering.
3. Meeting organization – Member, Program and Organization Committees qBio summer meeting, hosted at SFSU, 2019.
4. STC leadership – Site director, SFSU, 2016 - 2020: Coordinate SFSU efforts with the overall NSF STC Center for Cellular Construction.
5. Teaching mentorship – Faculty mentor for IRACDA* Fellow Erica Sanchez, SFSU, 2017: Helped train the fellow in curricular design and undergraduate education in the upper-division cell biology course.

*Institutional Research and Academic Career Development Awards

Diana Chu
Professor, San Francisco State University
1600 Holloway Ave, San Francisco, CA 94132
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(a) Professional Preparation

Univ. of California, Berkeley	Berkeley	Biochemistry	BS	1991
Univ. of California, Los Angeles	Los Angeles	Molecular Biology	PhD	1997
Univ. of California, Berkeley	Berkeley	Developmental Biology	Post-doc	1998-2003

(b) Appointments

Research Positions

San Francisco State University	2015-present	Professor, Department of Biology
San Francisco State University	2010-2015	Associate Professor, Department of Biology
San Francisco State University	2004-2010	Assistant Professor, Department of Biology
University of California, Berkeley	1998-2004	Postdoctoral Fellow

(c) Publications

(*SFSU student author, [URM]under-represented minority author)

(i) five publications most closely related to proposed project

Fabig G, Kiewisz R, Lindow N, Powers JA, Cota V, Mateo L, Brugués J, Prohaska S, Chu DS, Müller-Reichert T Male meiotic spindle features that efficiently segregate paired and lagging chromosomes Submitted to eLife 2019, published on BioRxiv 8/19/2019 doi: https://doi.org/10.1101/737494

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

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 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

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.

(ii) five other significant publications

Chu DS Zinc: A small molecule with a big impact on sperm function.
PLoS Biol. 2018 Jun 7;16(6):e2006204. doi: 10.1371/journal.pbio.2006204. eCollection 2018 Jun.

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

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

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 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.

(d) Synergistic Activities

1. Career development of minority students:
   Research mentor: 41 Masters/Post-bac (22 URM) and 40 undergraduate (28 URM) students have conducted research in my lab over the last 13 years. URM students have entered PhD programs at Stanford, Harvard, Princeton, UNC Chapel Hill, UW Madison, UC Santa Cruz, UC Davis, UC Riverside, and professional schools including Stanford, UCSF, and UC Berkeley.

   Programs: I participate in programs to diversify STEM including the NSF Research Experience for Undergraduates (REU) *SFSU Biological Research in Ecological and Evolutionary Developmental Biology* program, the CIRM *Bridges to Stem Cell Research Program, the NIH Research Initiative for Scientific Enhancement (RISE), Bridges to the Baccalaureate, Bridges to the PhD, Maximizing Access to Research Careers (MARC) and SEPA: Spectrum: Building Pathways to Biomedical Research Careers for Girls and Women of Color* Programs.

2. Graduate Coordinator: Department of Biology: I administer and manage the graduate programs in Biology, which consists of oversight of over 250 students in Cell and Molecular Biology, Marine Biology, Ecology, Evolution, and Conservation Biology.
   Center for Cellular Construction, an NSF Science and Technology Center that is a partnership of UCSF, SFSU, UC Berkeley, Stanford, IBM, and the Exploratorium. I am the coordinator of SFSU graduate student participation and training.

3. Innovations in Teaching and Training:
   Skills in Scientific Proposal Writing: I co-developed a course where graduate students learn to write proposals on their own research, which serve as the basis for our program's requirements for a prospectus or can be submitted to funding agencies like the NSF.

   Skills in Science Communication: I developed a interdisciplinary course to experiment with tools that communicate our students' goals and ideas about science and technology. Students prepared and filmed 3-minute thesis talks, developed public engagement projects, explored literature on science communication, and engaged the public through social media.

   Molecular Genetics: I incorporate alternative teaching strategies to this undergraduate majors core course (70-80 students/semester), including equity strategies to engage all students, group projects with oral presentations and writing assignments on research articles to promote written communication skills.

4. Public Outreach: *Hosting visits from K-12 schools:* My lab and I host visits from local K-12 schools, including the Carver Scholars Program, an elementary school STEM program based out of George Washington Carver Elementary School in the Bayview/Hunter's point neighborhood of San Francisco and the Green Academy, a science program for under-represented students at Skyline High School in Oakland, CA.
   Bay Area Maker Faire: My lab and I volunteer with the Center for Cellular Construction to engage the public (200,000 visitors) in our research on cellular engineering.

   Social Media Manager: I curate the twitter feed for the Center for Cellular Construction. Our goal is to engage the public with the beauty and power of science, promote the research and activities of the center, show support for policies that advance STEM and diversity in STEM, and show the public the diversity of our scientists.

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

Charles S. Craik, Ph.D
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(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

2012-present	Co-Director UCSF Comprehensive Cancer Center Exprmntl Therapeutics Prog
2010-present	Director, Quantitative Biosciences Consortium of Graduate Programs
1999-2018	Director, Chemistry and Chemical Biology Graduate Program
1997-present	Member of the UCSF AIDS Institute
1995-present	Prof, Depts. of Pharm.Chem, Pharmacology and Biochem. & Biophysics, UCSF
1994-present	Prof, Depts. of Pharm. Chemistry, and Biochem. & Biophysics, UCSF
	Assoc. Prof, Depts. of Pharm. Chemistry and Biochem. & Biophysics, UCSF
1985-91	Asst. Prof, Depts. of Pharm. Chemistry and Biochem. & Biophysics, UCSF

(c) Publications

(i) five publications most closely related to proposed project

1. Antagonistic anti-urokinase plasminogen activator receptor (uPAR) antibodies significantly inhibit uPAR-mediated cellular signaling and migration. Duriseti S, Goetz DH, Hostetter DR, LeBeau AM, Wei Y, **Craik CS**. J Biol Chem. 2010;285:26878-88.PMC2930687
2. Imaging PD-L1 Expression with ImmunoPET. Truillet C, Oh H, Yeo S, Lee C, Huynh L, Wei J, Parker M, Blakely C, Sevillano N, Wang YH, Shen YS, Olivas V, Jami KM, Moroz A, Jego B, Jaumain E, Fong L, **Craik CS**, Chang A, Bivona T, Wang CI, Evans M. Bioconjug Chem. 2018;29:96-103: PMC5773933
3. Why recombinant antibodies - benefits and applications. Basu K, Green EM, Cheng Y, **Craik CS**.Curr Opin Biotechnol. 2019;60:153-158.
4. Discovery and Characterization of a Thioesterase-Specific Monoclonal Antibody That Recognizes the 6-Deoxyerythronolide B Synthase. Li X, Sevillano N, La Greca F, Hsu J, Mathews II, Matsui T, **Craik CS**, Khosla C. *Biochemistry*. 2018;57(43):6201-08. PMC6424575
5. 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;110(1):93-8. PMC3538269

(ii) five other significant publications

1. 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;73:2070-81
2. Page MJ, Lourenço AL, David T, LeBeau AM, Cattaruzza F, Castro HC, VanBrocklin HF, Coughlin SR, **Craik CS**. Non-invasive imaging and cellular tracking of pulmonary emboli by near-infrared fluorescence and positron-emission tomography. Nat Commun. 2015 Oct 01; 6:8448

3. Tajon CA, Seo D, Asmussen J, Shah N, Jun YW, **Craik CS**. Sensitive and selective plasmon ruler nanosensors for monitoring the apoptotic drug response in leukemia. ACS Nano. 2014 Sep 23; 8(9):9199-208
4. 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**. Global identification of peptidase specificity by multiplex substrate profiling. Nat Methods. 2012 Nov; 9(11):1095-100
5. Winter MB, La Greca F, Arastu-Kapur S, Caiazza F, Cimermancic P, Buchholz TJ, Anderl JL, Ravalin M, Bohn MF, Sali A, O'Donoghue AJ, **Craik CS**. Immunoproteasome functions explained by divergence in cleavage specificity and regulation. Elife. 2017 11 28; 6.

(d) Synergistic Activities

NSF iCorps: Former 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/

Founder and former 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/. I currently serve as the co-director of the program and am the PI of the NIH T32 training grant that partially supports the program in its 21st year.

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

Amgen Scholars Undergraduate Program: I have served as the annual keynote 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/

Fellow of the American Association of Arts & Sciences (2011), National Academy of Inventors (2015) , and American Academy of Arts & Sciences (2017)

Biographical Sketch

Wilfred F. Denetclaw
Department of Biology, San Francisco State University
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(a) Professional Preparation

Fort Lewis College	Department of Biology	B.S.	1983
Univ. California, Berkeley	Department of Zoology	Ph.D.	1991
Postgraduate: Univ. California, Berkeley	Molecular Cell Biology	1992	1994
Postdoctoral: Univ. California, San Francisco	Department of Anatomy	1994	1999

(b) Appointments

2006-Present	Associate Professor, Department of Biology, San Francisco State University
2000-2006	Assistant Professor, Department of Biology, San Francisco State University
1999-2000	Assistant Research Anatomist, Department of Anatomy, UC San Francisco
1994-1999	Postdoctoral Fellow, Univ. of California, San Francisco
1992-1994	Postgraduate Research, UCB and Athena Neurosciences, South San Francisco, CA

(c) Publications

(i) Five most closely related to the proposed project

Estrada M, Burnett M, Campbell AG, Campbell PB, **Denetclaw WF**, Gutiérrez CG, Hurtado S, John GH, Matsui J, McGee R, Okpodu CM, Robinson TJ, Summers MF, Werner-Washburne M, Zavala M. (2016). Improving Underrepresented Minority Student Persistence in STEM. CBE Life Sci Educ. 15(3). pii: es5.

Denetclaw, WF, Berdougo, E, Venters, SJ, and Ordahl, CP (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.

Denetclaw, WF Jr, and Ordahl, CP (2000). The growth of the dermomyotome and formation of early myotome lineages in thoracolumbar somites of chicken embryos. *Development* 127:893-905.

Denetclaw, WF Jr, Christ, B, and Ordahl, CP (1997). Location and growth of epaxial myotome precursor cells. *Development.* 124:1601-10.

Fong PY, Turner PR, **Denetclaw WF**, Steinhardt RA. (1990). Increased activity of calcium leak channels in myotubes of Duchenne human and *mdx* mouse origin. Science. 250(4981):673-6.

(ii) Other Publications

Campbell AG, Leibowitz MJ, Murray SA, Burgess D, **Denetclaw WF**, Carrero-Martinez FA, Asai DJ. (2013). Partnered research experiences for junior faculty at minority-serving institutions enhance professional success. CBE Life Sci Educ. 12:394-402.

Karpuj MV, Giles K, Gelibter-Niv S, Scott MR, Lingappa VR, Szoka FC, Peretz D, **Denetclaw W**, Prusiner SB. (2007). Phosphorothioate oligonucleotides reduce PrP levels and prion infectivity in cultured cells. Mol Med. 13(3-4):190-8.

Galli, LM, Willert, K, Nusse, R, Yablonka-Reuveni, Z, Nohno, T, **Denetclaw, W**, and Burrus, LW. (2004). A proliferative role for Wnt-3a in chick somites. *Dev. Biol.* 269:489-504.

Ordahl CP, Williams BA, **Denetclaw W.** (2000). Determination and morphogenesis in myogenic progenitor cells: an experimental embryological approach. *Curr Top Dev Biol.* 48:319-67. Review.

Denetclaw, WF Jr, Bi, G, Pham, DV, and Steinhardt, RA. (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.

(d) Synergistic Activities

Innovation in teaching and training. Biology 351 GWAR course instructor 2012-2019, required upper division lecture and laboratory course in Biology major. Updated several laboratory modules utilizing the chicken embryo investigating molecular signaling of early heart development by qPCR of cardiac transcription factors, by investigating nitric oxide signaling in heart tube formation and heart looping morphogenesis, and by investigating toxicity of Round Up™ weed killer and pure glyphosate in cell growth and proliferation effects in chicken embryo finite cell line cultures. In addition to skills in cell molecular biology, GWAR courses develop writing competency in the student's major.

Teaching and Research mentoring. Research mentor NIH-RISE, NIH-MARC, NIH-Bridges, and NSF-REU programs. UCSF-SFSU IRACDA teaching mentor, 2007-2009. Crossing Borders Award, 4th Annual Border Learning Conference, El Paso, TX, 2004; SACNAS Presidential Service Award, Dallas, TX, 2009. Faculty Director, Cell and Molecular Imaging Facility, Biology Department, 2002-2019.

Invited Speaker. Sonderforschungsbereich (SFB-Seminars) Program, Institute of Anatomy and Cell Biology, University of Freiburg, Freiburg, Germany, 2005; Institutional Research and Academic Career Development Awards (NIH-IRACDA) Conference, Kansas City, KS, 2006; New Perspectives in Contemporary Research, Speaker Series, Colorado State University, Fort Collins, CO, 2008; Insights to Success: Real-Life Adventures of SACNAS Scientists, SACNAS Annual Meeting, San Jose, CA, 2011; MARC Invited Speaker, Fort Lewis College, Durango, CO, 2013.

Meeting Organization: ASCB-MAC Junior Faculty and Postdoctoral Fellows Career Developmental Workshop (Washington, DC, 2008; Chicago, IL, 2009; San Antonio, TX, 2012); Co-Chair and Speaker "Cell Biology Mini-Symposia", 2008 and 2011 SACNAS Annual Meetings.

Professional Society Membership: American Society for Cell Biology (1992-Present); Member, ASCB Minorities Affairs Committee (3 terms, completed in 2013); Society for Advancement of Chicanos and Native Americans in Science (Life Member); SACNAS Council of Senior Advisors Member (COSA) 2012-2014; SACNAS Board Member (1996-98); Society for Developmental Biology (2003-Present); Society for Redox Biology and Medicine (SfRBM), 2019.

Shawn Douglas
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(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	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. 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 60,000+ visitors and the software has been downloaded 30,000+ times.
2. GELBOX software, 2018. http://douglaslab.org/gelbox/ Gelbox is a simulation tool that helps the user understand how changing experimental input parameters can affect the data output from gel electrophoresis.
3. Nafisi PM., Aksel T., Douglas SM. (2018). Construction of a novel phagemid to produce custom DNA origami scaffolds. Synthetic Biology, ysy005, doi: 10.1093/synbio/ysy015
4. 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
5. 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

(ii) Significant

1. Book chapter: Explorer's Guide to Biology, Gel Electrophoresis Activity. url: https://explorebiology.org/activities/agarose-gel-electrophoresis
2. 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".
3. Patent: SM Douglas, I Bachelet, GM Church. WO/2012/061719 "DNA origami devices".
4. 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 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 San Francisco in the fall to present their work and win awards. During the first nine years of the competition (2011–2019), over 1500 undergraduate students, graduate students, and faculty mentors from 15 different countries have participated. In 2016, Dr. Douglas founded BIOMOD Foundation, a 501(c)3 non-profit California public benefit corporation to manage the competition. A description and recent highlights of the competition are available at http://biomod.net/.

2. Dr. Douglas collaborated with artist Jason Brown to create animations to disseminate our work, including a whiteboard animation "**What is Bionanotechnology?**" which is available at http://youtu.be/ITtGJUGXFKc and has over 78,000 views, and a traditional frame-by-frame stick-figure animation "**What is Biomod**?" which is available at http://youtu.be/dR31pBvMUV8 and has over 6,000 views.

3. Dr. Douglas created a **Virtual Reality Toolkit** for scientific communication. We have created photorealistic digital models of various tools, instruments, reagents, vessels, and furniture from our laboratory at UCSF, and software applications using the Unity3D game engine to enable remote VR teleconferencing within our laboratory space. We are able to show rich visual representations in the virtual laboratory for information that is normally hidden in the real laboratory, such as the molecular components of a test tube, which normally appears to the naked eye as a transparent liquid. We recently appeared on an episode of The Foo Show, a virtual-reality talk show, the episode is available for download at https://store.steampowered.com/app/593931/. In the episode, we tour the lab environment, shrink down inside the shaker incubator for some discussion about bacterial culture, and finally shrink to the nanoscale inside the bacterial culture flask and walk around on the surface of a digital *E.coli* that we use for DNA origami ssDNA scaffold production.

4. Dr. Douglas developed course materials and contributed to a book chapter for the new free online textbook, The Explorer's Guide to Biology (https://explorebiology.org/). We built a series of simulation exercises around our interactive gel electrophoresis simulation software, Gelbox, to help students build mental models for the relationships between biological molecules and "band" patterns in gel image data.

Biographical Sketch

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Energy Biosciences Building, Room 512D
2151 Berkeley Way
Berkeley, CA 94704

(a) Professional Preparation

University of Delaware	Biochemistry	B.S. 1999
University of California, San Francisco	Biochemistry	Ph.D. 2005
Postdoctoral: University of California, Berkeley	Chemical Engineering	2005 - 2009

(b) Appointments

2016 - present Associate Professor, UC Berkeley Dept. Bioengineering
2010 - 2016 Assistant Professor, UC Berkeley Dept. Bioengineering

(c) Publications

(i) Five publications most closely related to proposed project

Dueber, J.E., Wu, G.C, Malmirchegini, G.R., Moon, T.S., Petzold C.J., Ullal, A.V., Prather, K.L.J., Keasling, J.D. 2009. "Synthetic protein scaffolds provide modular control over flux through an engineered metabolic pathway." ***Nature Biotechnology***. 27(8), 753–759.

Deloache, W. C., Russ, Z. N., Narcross, L., Gonzales, A. M., Martin, V. J. J., & Dueber, J. E. 2015. An enzyme-coupled biosensor enables (S)-reticuline production in yeast from glucose. ***Nature Chemical Biology.*** 11(7), 465–471.

Lee, M.E., DeLoache, W.C., Cervantes, B., Dueber, J.E. 2015. A Highly-characterized Yeast Toolkit for Modular, Multi-part Assembly. ***ACS Synthetic Biology.*** 4(9):975-86.

Chen, R. Rishi, H.S., Potapov, V., Yamada, M.R., Yeh, V.J., Chow, T., Cheung, C.L., Jones, A.T., Johnson, T.D., Keating, A.E., DeLoache, W.C., Dueber, J.E. 2015. A Barcoding Strategy Enabling Higher-Throughput Library Screening by Microscopy. ***ACS Synthetic Biology.*** 4(11):1205-16.

Deloache, W. C., Russ, Z. N., & Dueber, J. E. 2016. Towards repurposing the yeast peroxisome for compartmentalizing heterologous metabolic pathways. ***Nature Communications.*** 7, 11152.

(ii) Five other significant publications

Whitaker, W.R., Davis, S.A., Arkin, A.P.*, and Dueber, J.E. 2012. Engineering robust control of two-component system phosphotransfer using modular scaffolds. ***Proceedings of the National Academy of Sciences.*** 109(44), 18090–18095.

Lee, M. E., Aswani, A., Han, A. S., Tomlin, C. J., & Dueber, J. E. 2013. Expression-level optimization of a multi-enzyme pathway in the absence of a high-throughput assay. ***Nucleic Acids Research.*** 41(22), 10668–10678.

Hsu, T. M., Welner, D. H., Russ, Z. N., Cervantes, B., Prathuri, R. L., Adams, P. D., & Dueber, J. E. 2018. Employing a biochemical protecting group for a sustainable indigo dyeing strategy. ***Nature Chemical Biology.*** 89, 44.

Halperin, S. O., Tou, C. J., Wong, E. B., Modavi, C., Schaffer, D. V., & Dueber, J. E. 2018. CRISPR-guided DNA polymerases enable diversification of all nucleotides in a tunable window. ***Nature.*** 560(7717), 248–252.

Protzko, R. J., Latimer, L. N., Martinho, Z., de Reus, E., Seibert. T., Benz, J. P., & Dueber, J. E. 2018. Engineering *Saccharomyces cerevisiae* for co-utilization of D-galacturonic acid and D-glucose from citrus peel waste. ***Nature Communications.*** 9(1), 5059.

(d) Synergistic Activities

Council and Membership Committee member of Engineering Biology Research Consortium (EBRC): Consortium of synthetic biologists with annual research meetings as well as an annual meeting for organization. Monthly activities for roadmapping field goals, recruiting new members in research areas of desired growth for synthetic biology, and developing a strong community. Also a member of the predecessor Synthetic Biology Engineering Research Center (SynBERC) (2006-2016).

Special Projects in Synthetic Biology: Advisor for five to seven undergraduate students of diverse backgrounds year-round in a cutting-edge research project (2014-present). This project is devised to include students of under-represented backgrounds and be composed of both underclassmen and seniors as well as from diverse majors.

Synthetic Biology Institute: Member 2012-present. Co-director 2019. Institute in UC Berkeley stimulating and funding synthetic biology research through workshops every six monthscollaborations between UC Berkeley faculty and assisting interaction with industry.

Innovative Genomics Institute: Faculty member 2017-present. Research organization for the development and deployment of genome engineering to cure disease, ensure food security, and sustain the environment for current and future generations.

UC Berkeley Bioengineering PhD Program: Vice-Chair: 2015-2019. I was responsible for all matters concerning the Bioengineering PhD program at U.C. Berkeley. Relatedly, I was the Chair of the joint graduate program in Bioengineering between U.C. Berkeley and U.C. San Francisco.

Sophie Dumont
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(a) Professional Preparation

Princeton University, Princeton, NJ	Physics, *magna cum laude*	B.A.	1999
University of Oxford, UK	Theoretical Physics	D.Phil candidate	2000
University of California, Berkeley, CA	Biophysics	Ph.D.	2005
Harvard University	Cell Biophysics	Junior Fellow	2006-9
Harvard Medical School	Cell Biophysics	Postdoc	2006-12

(b) Appointments

01/2020-present	Associate Professor, UCSF Dept of Bioengineering & Therapeutic Sciences
7/2018-12/2019	Associate Professor, UCSF Dept of Cell & Tissue Biology
7/2012-06/2018	Assistant Professor, UCSF Dept of Cell & Tissue Biology

(c) Publications

(i) Five most closely related to proposal project

1) Suresh P, Long AF, **Dumont S**. Microneedle manipulation of the mammalian spindle reveals specialized, short-lived reinforcement near chromosomes. *BioRxiv* (2019): 10.1101/843649v1.

2) Kuhn J, **Dumont S**. Mammalian kinetochores count attached microtubules in a sensitive and switch-like manner. *Journal of Cell Biology* 218, 3583-3596 (2019).

3) Hueschen CL, Galstyan V, Amouzgar M, Phillips R, **Dumont S**. Microtubule end-clustering maintains a steady-state spindle shape. *Current Biology* 29, 700-708 (2019).

4) Elting MW, Prakash M, Udy DB, **Dumont S**. Mapping load-bearing in the mammalian spindle reveals local kinetochore-fiber anchorage that provides mechanical isolation and redundancy. *Current Biology* 27, 2112-2122 (2017).

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

(ii) Five other significant publications

***equal contribution**

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

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

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

- Interdisciplinary teaching in quantitative cell biology: At UCSF, I develop curriculum for multiple courses on quantitative cell biology, focusing on the mechanics of cells and cellular machines. These include Tetrad Cell Biology (2012-present), Biophysics Macromolecules (2014-present), Bioengineering Cell & Tissue Mechanics (2016-present).
- Meeting session organization: I am organizing a new subgroup and session at the American Society for Cell Biology annual meeting called "Mechanics of Large Cellular Machines (2019-present).
- Public outreach and mentoring of underserved students: Together with my lab I organized a booth at the Bay Area Science Festival's Discovery day on the topic of "Mechanics in Cell Biology" (2019-present), and built a display box on our research that is currently part of the Exploratorium's Cells to Self exhibit (2019-2020). Every month, I mentor underserved middle and high school students in the Bay Area and help them identify future opportunities in the science space (through Aim High and other programs, 2018-present).
- Grant review activity: I review grants for NIH (2019-present), NSF (2019-present), European Research Council (2014-present), Medical Research Council UK (2015-present), and the Wellcome Trust (2017-present).
- Advocacy for family friendly policy: At UCSF and beyond, I advocate for family friendly policies (2016-present). For example, through advocacy UCSF now has programs to pay or reimburse for additional child care expenses during work travel.

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(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

2017 – present	Senior Investigator, Chan-Zuckerberg Biohub
2017 – present	Vice Chair, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
2017 – present	Professor, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
2013 – 2017	Associate Professor, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
2008 – 2013	Assistant Professor, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)
2005 – 2005	Fellow, Department of Biochemistry & Biophysics, University of California San Francisco (UCSF)

(c) Publications

(i) publications most closely related to proposed project

1. Chevalier M., Schiavon-Gomez M., Ng A.H., and **El-Samad H.** Design and analysis of a Proportional-Integral-Derivative controller with biological molecules. Cell systems, Volume 9, Issue 4, 23 October 2019 and bioRxiv DOI: 10.1101/248419
2. Fonseca J.P., Bonny A.R., Kumar F.R., Ng A.H., Town J., Wu Q.C., Aslankoohi E., Chen S.Y., Dods G., Harrigan P., Osimiri L.C., Kistler A.K., **El-Samad H.** A Toolkit for Rapid Modular Construction of Biological Circuits in Mammalian Cells. *ACS Synth. Biol.* Volume 8, issue 11, 2593-2606, 2019 and BioRxiv DOI: 10.1101/506188
3. Langan, R.A., Boyken, S.E., Ng, A.H., Samson, J.A., , Dods, G., Westbrook, A., Nguyen, T.H., Lajoie, M.J., Chen, Z., Berger, S., Khipple Mulligan, V., Dueber, J.E., Novak, W.R.P., **El-Samad, H.**, Baker, D. De novo design of bioactive protein switches. Nature. 2019. doi:https://doi.org/10.1038/s41586-019-1432-8
4. Ng, A.H., Nguyen, T.H., Gómez-Schiavon, M., Dods, G., Langan, R.A., Boyken, S.E., Samson, J.A., Waldburger, L.M., Dueber, J.E., Baker, D., **El-Samad** Modular and tunable bioloical feedback control using a de novo protein switch. Nature, 2019; doi:https://doi.org/10.1038/s41586-019-1425-7

(ii) other significant publications

1. Chen S.Y., Osimiri L.C., Chevalier M.W., Bugaj L.J., Ng A.H., Stewart-Ornstein J., Neves L.T., **El-Samad H.** (2019) Optogenetic control reveals differential promoter interpretation of transcription factor nuclear translocation dynamics. In revisions Cell Systems and BioRxiv. DOI: 10.1101/548255
2. Harrigan P., Madhani H.D, **El-Samad H.,** Real-time genetic compensation operationally defines the dynamic demands of feedback control. Cell. 175(3), 877-886, 2018. DOI: 10.1016/j.cell.2018.09.044 PMID: 30340045. PMCID: PMC6258208

3. 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.

4. 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.

(d) Synergistic Activities

Systems Biology Education at UCSF: Faculty mentor for the UCSF iGem team, 2007-2009; Developer of the Systems Biology Curriculum at UCSF.

Diversity: Member of the diversity committee at UCSF.

Service to scientific journals: Reviewer for Proceedings of the National Academy of Sciences, Biophysical Journal, Journal of Molecular Biology, Science, Nature, Cell. Member of editorial board of Cell Reports and cell systems.

Service to Federal Funding Agencies: Permanent member of the MABS NIH study section.

Professional Society Activities: Member of the IEEE, Women in Engineering and Women in Control Association; Elected fellow of the AIMBE (2020); Referee and session organizer for IEEE Conference on Decision and Control, American Control Conference, International Conference on Systems Biology.

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(a) Professional Preparation

Stanford University	Physics	B.S.	1990
University of California, Santa Cruz	Chemistry	Ph.D.	1998
University of California, Santa Cruz	Biophysics	Post. Doc.	1998-2000

(b) Appointments

2011 – present	Professor of Chemistry and Biochemistry, San Francisco State University
2010 – present	Program Director, SFSU MARC Program: Maximizing Access to Research Careers
2012 – present	Academic Coordinator and co-PD, UCSF/SFSU Institutional Research and Academic Career Development Award (IRACDA)
2006 – present	Visiting Research Scientist, The University of California, Santa Cruz
2006 – 2011	Associate Professor Chemistry and Biochemistry, San Francisco State University
2000 – 2006	Assistant Professor Chemistry and Biochemistry, San Francisco State University

(c) Publications

(i) Five Closely Related Publications

C.L. Leasure, H. Tong, X. Hou, A.S. Shelton, M.R. Minton, S. Roje, H. Hellmann, **R.M. Esquerra**, and Z-H He. *Root UV-B Sensitive Sutants are Suppressed by Specific Mutations in Aspartate Aminotransferase2 and by Exogenous Vitamin B6,* Molecular Plant, 4(4): 759-70, 2011.

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. *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, 2010.

R.M Esquerra, R.A. Jensen, S. Bhaskaran, M.L. Pillsbury, J.L. Mendoza, B.W. Lintner, D.S. Kliger, and R.A. Goldbeck. *The Ph Dependence Of Heme Pocket Hydration And Ligand Rebinding Kinetics In Photodissociated Carbonmonoxymyoglobin*, J Biol. Chem. 283:14165-75, 2008.

E. Chen, **R.M. Esquerra**, P.A. Meléndez, S.S. Chandrasekaran, and D.S,. Kliger. *Microviscosity in E. coli Cells from Time-Resolved Linear Dichroism Measurements*, The Journal of Physical Chemistry B. 10.1021/acs.jpcb.8b07362, 2018.

C. A Hayden, C.Y. Hung, H. Zhang, A. Negron, **R.M. Esquerra**, G. Ostroff, A. Abraham, A. G. Lopez, J. E. Gonzales, and J.A. Howard. *Maize-produced Ag2 as a Subunit Vaccine for Valley Fever*. The Journal of Infectious Diseases, jiz196, https://doi.org/10.1093/infdis/jiz1965, 2019.

(ii) Five Other Significant Publications

Y. Wang, Y., A. Suzuki, M. Pastore, **R.M. Esquerra**, and N.C. Geber. *Expression Isolation, and Characterization of Cytochrome P450fas*, Proceedings of the 14th International Conference on Cytochromes P450: Biochemistry, Biophysics and Bioinformatics, 14:145-150, 2006.

D.L. Mendez, R.A. Jensen, L.A. McElroy, J.M. Pena, and **R.M. Esquerra**. *The Effect of Nonenzymatic Glycation on the Unfolding of Human Serum Albumin*, Arch. Biochem. Biophys., 444:92-9, 2005.

R.A. Goldbeck, **R.M Esquerra**, and D.S. Kliger. *Hydrogen Bonding to Trp Beta37 is the First Step in a Compound Pathway for Hemoglobin Allostery*, J Am. Chem. Soc., 124:7646-7647, 2002.

R.A. Goldbeck, S. Bharaskaran, C. Ortega, J.L. Mendoza, J.S. Olson, D.S Kliger, and **R.M. Esquerra**. *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, 2006.

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**. *Optical Detection of Disordered Water Within a Protein Cavity*, J Am. Chem. Soc., 131:12265-72, 2009.

(d) Synergistic Activities

Teaching Coordinator and co-PD for the *UCSF/SFSU Institutional Research and Academic Career Development Award (UCSF-IRACDA) Postdoctoral Fellowship Program.* To date, I have coordinated over 30 UCSF postdoctoral scholars in SFSU teaching experiences.

Program Director for SFSU Maximizing Access to Research Careers (MARC) program (24 MARC scholars in program per year). I have helped more than 100 SFSU under-represented students from the MARC program to transition into competitive PhD programs.

Advisory board for both SFSU NIH Bridges and NIH RISE programs.

Served on the Executive committee for the Beckman Scholars program (2009-2014).

Member of the NIH TWD-C study section (2009-2015; chair 2015), which evaluates NIGMS funded training programs, including IRACDA programs.

Biographical Sketch

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(a) Professional Preparation

Stanford University School of Medicine	Biochemistry & Physics	Postdoc	2002
Stanford University	Mechanical Engineering	Ph. D.	2001
Oxford University	Engineering Science	D. Phil.	1997
Princeton University	Mechanical Engineering	B.S.	1994

(b) Appointments

University of California, Berkeley, CA

3/17 – present	Chan-Zuckerberg Investigator
7/16 – present	Chief Technologist, Blum Center
7/10 – present	Professor, Department of Bioengineering
7/07 – present	Affiliated Faculty, Department of Molecular and Cell Biology
7/06 – present	Faculty Affiliate, Center for IT Research in the Interest of Society
7/02 – present	Faculty Affiliate, California Institute for Quantitative Biomedical Research
7/02 – present	Member, Biophysics Graduate Group
7/02 – present	Member, UCSF/UCB Bioengineering Graduate Group
7/15 – 6/19	Chair, Department of Bioengineering
7/11 – 6/15	Associate Chair, Department of Bioengineering
7/10 – 6/13	Lester John and Lynne Dewar Lloyd Distinguished Professorship
7/07 – 6/10	Associate Professor, Department of Bioengineering
7/02 – 6/07	Assistant Professor, Department of Bioengineering

Lawrence Berkeley National Laboratory, Berkeley, CA

10/15 – present	Faculty Scientist, Biological Systems & Engineering Division
1/08 – 9/15	Deputy Director, Physical Biosciences Division
7/03 – 9/15	Faculty Scientist, Physical Biosciences Division

Marine Biological Laboratory, Woods Hole, MA

2019 – present	Co-Director, Physiology Course
2008 – present	Instructor, Physiology Course

(c) Publications

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

Vahey MD, Fletcher DA. Influenza A virus surface proteins are organized to help penetrate host mucus. *Elife*. 2019 May 14;8. pii: e43764. doi: 10.7554/eLife.43764.

Bakalar MH, Joffe AM, Schmid EM, Son S, Podolski M, Fletcher DA. Size-Dependent Segregation Controls Macrophage Phagocytosis of Antibody-Opsonized Targets. *Cell*. 2018 Jun 28;174(1):131-142.e13.

Schmid EM, Bakalar MH, Choudhuri K, Weichsel J, Ann HS, Geissler PL, Dustin M, Fletcher DA. Size-dependent protein segregation at membrane interfaces. *Nature Physics*. 2016; 12:704+.

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. *Nature Cell Biology*. 2012 Sep;14(9):944–949.

(ii) List of 5 other significant publications:

Kim TN, Myers F, Reber C, Loury PJ, Loumou P, Webster D, Echanique C, Li P, Davila JR, Maamari RN, Switz NA, Keenan J, Woodward MA, Paulus YM, Margolis T, Fletcher DA. A Smartphone-Based Tool for Rapid, Portable, and Automated Wide-Field Retinal Imaging. *Translational Vision Science and Technology*. 2018 Oct 1;7(5):21.

Kamgno J, Pion SD, et al. A Test-and-Not-Treat Strategy for Onchocerciasis in Loa loa-Endemic Areas. *New England Journal of Medicine*. 2017 Nov 23;377(21):2044-2052.

D'Ambrosio MV, Bakalar M, Bennuru S, Reber C, Skandarajah A, Nilsson L, Switz N, Kamgno J, Pion S, Boussinesq M, Nutman TB, Fletcher DA. Point-of-care quantification of blood-borne filarial parasites with a mobile phone microscope. *Science Translational Medicine*. 2015 May 6;7(286):286re4.

Skandarajah A, Reber CD, Switz NA, Fletcher DA. Quantitative imaging with a mobile phone microscope. *PLoS ONE*. 2014;9(5):e96906.

Breslauer DN, Maamari RN, Switz NA, Lam WA, Fletcher DA. Mobile phone based clinical microscopy for global health applications. *PLoS ONE*. 2009;4(7):e6320.

(d) Synergistic Activities

iMBL Physiology Course: I co-Direct and serve as an Instructor in the summer Physiology Course at the Marine Biology Laboratory in Woods Hole, MA, which teaches an international group of graduate students and postdoctoral fellows quantitative methods in cell and molecular biology through research on fundamental questions.

Practical Light Microscopy: I teach a lecture and laboratory course on Optics and Microscopy at UC Berkeley 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. The class is based around an optical rail teaching kit that I co-developed and has been made broadly available by ThorLabs.

CellScope: My laboratory developed CellScope, a compact, mobile phone based microscope for disease diagnosis in low-resource areas of developing countries. We have explored diagnostic applications in Thailand, Vietnam, the Philippines, and Cameroon, where we have developed a diagnostic device to advance efforts to eliminate River Blindness in regions co-endemic with *Loa loa*.

Microscopy for elementary education: My laboratory developed a set of iPad-based microscopes for an elementary education program at the California Academy of Sciences and for educational activities organized by the American Society for Cell Biology.

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 at the beginning of the Obama administration.

Biographical Sketch

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(a) Professional Preparation

University of California at Davis	Highest Honors, Bioethics	B.S.	1994
Citation for Outstanding Research, Department of Genetics			
University of California at San Francisco	Cell Biology	Ph.D.	1999
National Science Foundation Fellow			1996-99
American Association for the Advancement of Science Mass Media Fellow			1999

(b) Appointments

Exploratorium, San Francisco	
Senior Scientist	11/17 – present
Program Director, Living Systems	2/10 - 11/17
Project Director, Visualization Laboratory	2/07 - 2/10
Content Developer, Microscope Imaging Station	2/04 - 2/07
Tech Museum of Innovation, San Jose	
Consulting Exhibit Developer, Genetics: Technology with a Twist	10/03 – 2/04
University of California at Davis	
Lecturer, Molecular and Cellular Biology	1/03 – 10/03
National Academy of Sciences, Washington, D.C.	
Museum and Educational Projects Developer	8/99 – 1/03
NOVA, WGBH Public Television	
Editorial Intern	1/99 – 5/99

(c) Publications and Presentations

(i) Publications Relevant to Proposed Project

Ma, J., Ma, K.L., & Frazier, J. Decoding Complex Visualizations in a Science Museum – An Empirical Study. *IEEE Transactions on Visualization and Computer Graphics.* 2019.

Hsueh C.H., Chu, J., Ma, K.L., Ma, J., Frazier, J.: Fostering comparisons: Designing an interactive exhibit that visualizes marine animal behaviors. *Proceedings of IEEE PacificVis* 2016: 259-263.

Ma, J., Sindorf, L., Liao, I. & Frazier, J. (2015). Using a tangible versus a multi-touch graphical user interface to support data exploration at a museum exhibit. In A. Antle, A. Mazalek, & F. Mueller (Eds.), *Proceedings of the 9th International Conference on Tangible, Embedded and Embodied Interaction*. Paper to be presented at TEI'14, Stanford, California. NY: ACM Press.

Ma, J., Liao, I., Ma, K. L., & Frazier, J. (2012). Living Liquid: Design and Evaluation of an Exploratory Visualization Tool for Museum Visitors. *IEEE Transactions on Visualization and Computer Graphics, 18*(12), 2799-2808.

Ma, K.L., Liao, I., Frazier, J., Hauser, H., & Kostis, H.N. (2012). Scientific storytelling using visualization. *IEEE Computer Graphics and Applications, 32*(1), 12-19.

(ii) Oral Presentations Relevant to Proposed Project

Communicating Science to the Public. Invited seminar at the University of Hawai'i at Manoa, 2017, Honolulu, HI.

Creating Interactive Visualizations with Scientists, Designers, and Programmers. American Geophysical Union Meeting, 2016, San Francisco, CA.

Creating New Genres of Museum Exibits with Scientific Visualization. Presentation at the Gordon Research Conference on Visualization in Science and Education, 2015, Maine.

Collaborative Visualization Development. NSF-NIH Conference on Visualizing Biological Data, 2015, MIT, Cambridge, MA.

Creating New Genres of Museum Exhibits with Scientific Visualization. NSF Cyberlearning Summit, 2012, Washington, D.C.

Living Liquid: Creating Ways for the Public to Engage with Environmental Genomics. NSF NIH Conference on Visualizing Biological Data, 2011, Cambridge, MA.

d. Synergistic Activities

Committee member, AAAS Annual Meeting Scientific Program Committee, 2014 – 2020

Reviewer, NSF STEM + C Review Panel, 2016

Reviewer, NSF Informal Science Education Review Panel, 2003, 2014, 2015

Reviewer, NOAA Office of Ocean Exploration and Research (OER), 2016

Mentee Advising, U.C. Davis Center for Visualization, 2011 - present

Biographical Sketch

Jennifer Fung
Professor
Department of Obstetrics, Gynecology, and Reproductive Sciences, UCSF
600 16th Street, GH-N412B Box 2240
San Francisco, CA 94158

(a) Professional Preparation

University of California, Berkeley	Biophysics		B.A. 1987
University of California, San Francisco	Biophyscis		Ph.D. 1996
Yale University	Genetics	Postdoctoral	1997 - 2003

(b) Appointments

2016 - present	Associate Professor, UCSF Dept. Obstetrics, Gynecology and Reproductive Sciences
2009 - 2015	Assistant Professor, UCSF Dept. Obstetrics, Gynecology and Reproductive Sciences
	Adjunct Assistant Professor, UCSF Dept. Biochemistry & Biophysics
2003 - 2009	Sandler Fellow, UCSF Dept. Biochemistry & Biophysics

(c) Publications

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

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(10):e25509

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.

Marshall WF, Fung JC. (2016) Modeling meiotic chromosome pairing: nuclear envelope attachment, telomere-led active random motion, and anomalous diffusion. Physical Biology 13:026003.

Marshall WF, Fung JC. (2019) Modeling meiotic chromosome pairing: a tug of war between telomere forces and a pairing-based Brownian ratchet leads to increased pairing fidelity. Phys Biol. 16:046005. doi: 10.1088/1478-3975/ab15a7.

Smith DL, Oke A, Pollard M, Anderson CM, Zhuge T, Yam P, Gromova T, Conant K, Chu DB, Patel NJ, Gonzalez F, Stoddard C, Burgess SM, Hochwagen A, Marshall WF, Blackburn E, Fung JC. A New Role for Telomerase in Promoting Meiotic Homolog Pairing Fidelity. biorxiv. 2019 May; doi: 10.1101/654376.

(ii) **Five other significant publications**

Anderson CM, Oke A, Yam P, Zhuge T, Fung, JC. (2015) Reduced crossover interference and increased ZMM-independent recombination in the absence of Tel1/ATM. PLoS Genetics 11(8):e1005478.

Faire M, Skillern A, Arora R, Nguyen DH, Wang J, Chamberlain C, German MS, Fung JC, Laird DJ. (2015). Follicle dynamics and global organization in the intact mouse ovary. Dev. Biol. S0012-1606(15)00186-4. doi: 10.1016/j.ydbio.2015.04.006.

Vincenten N, Kuhl L-M, Lam I, Oke A, Kerr A, Hochwagen A, Fung J.C, Keeney S, Vader G. and Marston AL. (2015) The kinetochore controls crossover recombination during meiosis. Elife. pii: e10850 PMCID: PMC4749563

Sousa Martins J.P., Liu X., Oke A., Arora R., Laird, D.J., Fung, J.C., Conti M. (2016). Synergistic interaction between Dazl and CPEB1 in the translation of maternal mRNA during mouse oocyte maturation. J. Cell Sci. 129:1271-82.

Wild P, Susperregui A, Piazza I, Dörig C, Oke A, Arter M, Yamaguchi M, Hilditch AT, Vuina K, Chan KC, Gromova T, Haber JE, Fung JC, Picotti P, Matos J. (2019) Network Rewiring of Homologous Recombination Enzymes during Mitotic Proliferation and Meiosis. Mol Cell 75:859-874.

(d) Synergistic Activities

Interdisciplinary teaching in quantitative cell biology: UCSF: Developed graduate level minicourse on cellular robotics using robotics to mimic and understand signaling and behavior of living cells using hands-on project based learning in 2017-2019.

Algorithm development: Developed RecSeq to analyze recombination by sequencing.

Public outreach: Presented hands-on demonstration of LEGO robotics and stentor learning at Francis Scott Key Elementary community Maker's Faire (May 2017), coach for First Lego League for 2015-2017 for robotics training of elementary and middle school children. Volunteer for Bay Area Science Festival (2013-2014).

Grant review activity: Adhoc reviewer, NIH Special Emphasis Panel - Endocrinology, Metabolism and Reproductive Biology Special Emphasis Panel (ZRG1 EMNR-V (02) M) (2018-2019), NIGMS Investigator's Research Award (MIRA) for ESI (2018), NIH Special Emphasis Panel - 2018/01 ZRG1 EMNR-V (02) M Reproductive and Perinatal Biology (2017), French National Research Agency (2017), NIH Special Emphasis Panel- ZRG1 CB-T(30) for S10 Equipment Grants (2016), NIH Genes, Genomes, and Genetics IRG (2014)

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(a) Professional Preparation

University of California	Cell Biology	AB	1977
Stanford University	Developmental Biology	MS	1980
Yale University	Molecular Biology & Genetics	PhD	1987
Université Louis Pasteur	Molecular Biology	Postdoc	1990

(b) Appointments

2018 – present	Director, Catalyst Program	UCSF	Translational Science
2004 – 2017	Sr. Vice President	Threshold Pharmaceuticals	Drug Discovery and Development
2001 – 2004	Senior Director	Galileo Pharmaceuticals	Drug Discovery
2000 – 2001	Director	Signature Bioscience	Drug Discovery
1990 - 2000	Director	Affymax Research Institute	Drug Discovery
1993 - 1997	Instructor	U.C. Berkeley Extension	Molecular Biology
Summer 1986	Acting Instructor	Yale University	Biochemistry and Cell Biology
1977 - 1981	Cell Biologist	SRI International	Electron Microscopy

(c) Publications

(i) five (5) publications/products most closely related to the proposed project

1. Meng F, Evans JW, Bhupathi D, Banica M, Lan L, Lorente G, Duan JX, Cai X, Mowday AM, Guise CP, Maroz A, Anderson RF, Patterson AV, Stachelek GC, Glazer PM, Matteucci MD, Hart CP Molecular and cellular pharmacology of the hypoxia-activated prodrug TH-302. Mol Cancer Ther. 2012 Mar;11(3):740-51. PMID: 22147748

2. Sun JD, Liu Q, Wang J, Ahluwalia D, Ferraro D, Wang Y, Duan JX, Ammons WS, Curd JG, Matteucci MD, Hart CP. Selective tumor hypoxia targeting by hypoxia-activated prodrug TH-302 inhibits tumor growth in preclinical models of cancer. Clin Cancer Res. 2012 Feb 1;18(3):758-70. PMID: 22184053

3. Liu Q, Sun JD, Wang J, Ahluwalia D, Baker AF, Cranmer LD, Ferraro D, Wang Y, Duan JX, Ammons WS, Curd JG, Matteucci MD, Hart CP. TH-302, a hypoxia-activated prodrug with broad in vivo preclinical combination therapy efficacy: optimization of dosing regimens and schedules. Cancer Chemother Pharmacol. 2012 Jun;69(6):1487-98. PMID: 22382881

4. Sun JD, Liu Q, Ahluwalia D, Li W, Meng F, Wang Y, Bhupathi D, Ruprell AS, Hart CP Efficacy and safety of the hypoxia-activated prodrug TH-302 in combination with gemcitabine and nab-paclitaxel in human tumor xenograft models of pancreatic cancer. Cancer Biol Ther. 2015;16(3):438-49. PMID: 25679067.

5. Hart CP. Finding the target after screening the phenotype. Drug Discov Today. 2005 Apr 1;10(7):513-9. PMID: 15809197

(ii) five (5) other significant publications/products

1. Hart CP, Martin JE, Reed MA, Keval AA, Pustelnik MJ, Northrop JP, Patel DV, Grove JR. Potent inhibitory ligands of the GRB2 SH2 domain from recombinant peptide libraries. Cell Signal. 1999 Jun;11(6):453-64. PMID: 10400318

2. Northrop JP, Nguyen D, Piplani S, Olivan SE, Kwan ST, Go NF, Hart CP, Schatz PJ. Selection of estrogen receptor beta- and thyroid hormone receptor beta-specific coactivator-mimetic peptides using recombinant peptide libraries. Mol Endocrinol. 2000 May;14(5):605-22. PMID: 10809226

3. Dias JM, Go NF, Hart CP, Mattheakis LC. Genetic recombination as a reporter for screening steroid receptor agonists and antagonists. Anal Biochem. 1998 Apr 10;258(1):96-102. PMID: 9527854.

4. Hart CP, Awgulewitsch A, Fainsod A, McGinnis W, Ruddle FH. Homeo box gene complex on mouse chromosome 11: molecular cloning, expression in embryogenesis, and homology to a human homeo box locus. Cell. 1985 Nov;43(1):9-18. PMID: 3000607

5. McGinnis W, Hart CP, Gehring WJ, Ruddle FH. Molecular cloning and chromosome mapping of a mouse DNA sequence homologous to homeotic genes of Drosophila. Cell. 1984 Oct;38(3):675-80. PMID: 6091896

(d) Synergistic Activities

New Products Editor, Journal of Biomolecular Screening, 2003–2014; Editorial Board, SLAS Discovery, 2014–present

Advisor, SPARK Translational Research Program, Stanford University School of Medicine, 2015–2018

GTC's Novel Cancer Therapeutics Summit, scientific advisory board and invited speaker, 2015

14th International Tumor Microenvironment Workshop (TMW), invited speaker, 2015

3rd Aegean International Conference on Tumor Microenvironment, invited speaker, 2014

Biographical Sketch

Wendell A. Lim
University of California at San Francisco
Department of Cellular & Molecular Pharmacology
600 16th St, Genentech Hall N412E
San Francisco, CA 94143

(a) Professional Preparation

Harvard University, Cambridge, MA	AB	1986	Chemistry
Mass. Institute of Technology, Cambridge, MA	PhD	1991	Biochemistry & Biophysics
Yale University, New Haven, CT	Postdoc	1992-1996	Biophysics & Biochemistry

(b) Appointments

1996-2000	Assistant Professor, Department of Cellular & Molecular Pharmacology, UCSF
2000-2003	Associate Professor, Department of Cellular & Molecular Pharmacology, UCSF
2003-present	Professor, Department of Cellular & Molecular Pharmacology, UCSF
2006-2015	Deputy Director, NSF Synthetic Biology Engineering Research Center
2006-2016	Director, UCSF/UCB NIH Nanomedicine Development Center
2008-present	Investigator, Howard Hughes Medical Institute, San Francisco, CA
2010-2019	Director, UCSF Center for Systems & Synthetic Biology (NIH SysBio Center)
2015-present	Chair, Department of Cellular & Molecular Pharmacology, UCSF
2019-present	Director, UCSF Center for Synthetic Immunology (NIH/NCI IOTN Center)

(c) Publications

(i) Five publications most closely related to proposed project

1. Toda S, Blauch LR, Tang SKY, Morsut L, Lim WA. Programming self-organizing multicellular structures with synthetic cell-cell signaling. Science, 2018. PMID: 29853554. PMCID: PMC6492944
2. Toda, S, Frankel NW, Lim WA. Engineering cell-cell communication networks: programming multicellular behaviors. Current Opinion in Chemical Biology, 2019. Epub 2019 May 28. PMID:29853554
3. Gordley RM, Williams RE, Bashor CJ, Toettcher, JE, Yan S, Lim WA. Engineering Dynamical Control of Cell Fate Switching Using Synthetic Phospho-Regulons. PNAS, 2016. PMID 27821768, PMCID: PMC5127309.
4. Roybal KT, Williams JZ, Morsut L, Rupp LJ, Kolinko I, Choe JH, Walker WJ, McNally KA, Lim WA. Engineering T cells with Customized Therapeutic Response Programs Using Synthetic Notch Receptors. Cell, 2016. PMID: 27693353, PMCID: PMC5072533.
5. Morsut L, Roybal KT, Xiong X, Gordley RM, Coyle SM, Thomson M, Lim WA. Engineering Customized Cell Sensing and Response Behaviors Using Synthetic Notch Receptors. Cell, 2016. PMID 26830878, PMCID: PMC4752866.

(ii) Five other significant publications

1. Mitchell A, Wei P, Lim WA. Oscillatory stress stimulation uncovers an Achilles' heel of the yeast MAPK signaling network. Science, 2015. PMID: 26586187, PMCID: PMC4721531.
2. Wu CY, Roybal KT, Puchner EM, Onuffer J, Lim WA. Remote control of therapeutic T cells through a small molecule-gated chimeric receptor. Science, 2015. PMID 26405231, PMCID: PMC4721629.

3. Roybal KT, Rupp LJ, Morsut L, Walker WJ, McNally KA, Park JS, Lim WA. Precision Tumor Recognition by T Cells With Combinatorial Antigen Sensing Circuits. Cell, 2016. PMID 26830879, PMCID: PMC4752902.
4. Bugaj LJ, Sabnis AJ, Mitchell A, Garbarino JE, Toettcher JE, Bivona TG, Lim WA. Cancer mutations and targeted drugs can disrupt dynamic signal encoding by the Ras/Erk pathway. Science, 2018. PMID: 30166458. PMCID: PMC6430110
5. Gerardin J,Reddy NR, Lim WA. The design principles of biochemical timers: circuits that discriminate between transient and sustained stimulation. Cell Systems, 2019. PMID: 31521602 PMCID: PMC6763348

(d) Synergistic Activities

Interdisciplinary teaching in quantitative cell biology: Developed Synthetic Biology mini-courses for UCSF IPQB, Modularity in Biological Regulation, Evolution, and Engineering | Domains, Circuits and Engineered Therapeutic Cells (2018) and Modularity in Biology | *the Evolution and Engineering of New Cellular Function* (2019*)*

Meeting Organization: Organizing committee, Winter Q-Bio (2013-present), Hawaiian Islands, USA. Organizing committee EMBO|EMBL Symposia: Synthetic Morphogenesis: From Gene Circuits to Tissue Architecture, Heidelberg, Germany, March 2019

Public outreach: 'Turning Cells into Superheroes' Bay Area Science Festival, UCSF (2018) and San Francisco Friends School, 7th graders (2019), 'Cells to Self', exhibition and workshop, The Exploratorium, San Francisco (2019), California College of the Arts, Biodesign collaboration (2019)

Professional service: Board member, Burroughs Wellcome Fund (2018 to present). Scientific Advisory Board, Allogene, Inc. (2019 to present); grant reviewer for NIH/NBIB, K and R13 reviewer (2019)

Textbook: Co-author, *Cell Signaling: Principles and Mechanisms*, Garland Science 2015. Wendell Lim, Bruce Mayer, Tony Pawson.

Biographical Sketch
Robert McGinn

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Robert.Mcginn@ucsf.edu

(a) Professional Preparation

Stevens Institute of Technology	Unified Science and Engineering	B.S. 1963
Stanford University	Mathematics	M.S. 1965
Stanford University	Philosophy and Humanities	Ph.D. 1969

(b) Appointments

4/2018 - present	Adjunct Professor (part time), UCSF Dept. of Biochemistry & Biophysics
2000 – 1/2019	Professor, Management Science and Engineering, and Science, Technology, and Society (STS), Stanford University
1979 -- 2000	Professor, Industrial Engineering and Engineering Management, and Science, Technology, and Society (STS), Stanford University
1978 – 1979	Group Supervisor, Science and Society Program, Bell Telephone Laboratories
1975 – 1978	Assistant Professor of Values, Technology, and Society, Stanford University

(c) Publications

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

1. THE ETHICAL ENGINEER (Princeton University Press, 2018)
2. "Ethics and Nanotechnology: Views of Nanotech Researchers," *Nanoethics,* Vol. 2, No. 2, 2008, 101-131.
3. "Ethical Responsibilities of Nanotechnology Researchers: A Short Guide," *Nanoethics*, Vol. 4, No. 1, April 2010, 1-12.
4. "What Is Different, Ethically, About Nanotechnology? Foundational Questions and Answers," *Nanoethics*, Vol. 4, No. 2, August 2010, 115-128.
5. "Discernment and Denial: Nanotechnology Researchers' Recognition of Ethical Responsibilities Related to Their Work," *Nanoethics*, Vol. 7, No. 2, August, 2013, 93-105.

(ii) **Five other significant publications**

1. "Optimization, Option Disclosure, and Problem Redefinition: Derivative Moral Obligations of Engineers and the Case of the Composite-Material Bicycle," *Professional Ethics*, Vol. 6, No. 1, 1997, 5-25. Reprinted in J. R. Rowen and S. Zinaich, eds., *Ethics for the Professions* (Harcourt, 2001).
2. "Ethical Issues in Nanoscience and Nanotechnology: Reflections and Suggestions," in *Nanotechnology: Social Implications II – Individual Perspectives* (Springer, 2006), Mihail C. Roco and William S. Bainbridge, eds., 169-172.
3. "'Mind the Gaps': An Empirical Approach to Engineering Ethics, 1997-2001," *Science and Engineering Ethics,* Vol. 9, No. 3, October 2003, 1-26.
4. SCIENCE, TECHNOLOGY, AND SOCIETY (Prentice-Hall, 1990)
5. "The Anatomy of Modern Technology," *Daedalus*, Vol. 109, Winter, 1980, 25-54. Issue Topic: "Modern Technology: Problem or Opportunity."

(d) Synergistic Activities

- interdisciplinary teaching about science, technology and society (48 years), and about ethical issues in engineering (26 years)

- management of interdisciplinary programs: directed STS program for 16 years, associate director of France-Stanford Center for Interdisciplinary Studies for 10 years
- ethics investigator for National Nanotechnology Infrastructure Network (NNIN), a consortium of nanotechnology research laboratories at 13 universities (2004-14)
- public outreach: presenter at 1994 Institute for Electrical and Electronics Engineers (IEEE) conference on "The Information Superhighway" (on ethics, engineering, and the National Information Infrastructure), at 2006 Forum on Nanotechnology at Exploratorium in San Francisco (on ethical and social issues at of nanotechnology), at 2007 meeting of City of Berkeley Nano Club (on ethics issues as perceived by nanotechnology researchers), in 2008 short course on organic electronics and optoelectronics at Indian Institute of Technology (IIT), Kanpur, India, in 2013 Oringer Lecture Series, Information Science and Technology Program, School of Engineering and Applied Science, California Institute of Technology (on ethics education and engineering practice), and at 2014 hearing of U.S. Presidential Commission for the Study of Bioethical Issues (on ethical issues of nanotechnology-enabled brain research).
- conference organization: organized and led international interdisciplinary conference on risks and responsibilities of scientists and engineers for the France-Stanford Center for Interdisciplinary Studies (FSCIS).

Biographical Sketch

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(a) Professional Preparation

Indian Institute of Technology, Kanpur	Computer Science	B.Tech	2002
MIT, Cambridge	Media Arts and Sciences	Ph.D.	2008
Harvard University	Applied Physics	Postdoctoral:	2008-2011

(b) Appointments

2018 - present Associate Professor, Stanford Dept. of Bioengineering
2011 - 2018 Assistant Professor, Stanford Dept. of Bioengineering

(c) Publications

(i) Five publications most closely related to proposed project

Guillermina R. Ramires-San Juan, Arnold J.T.M. Mathijssen, Mu He, Lily Jan, Wallace Marshall, Manu Prakash**,** 2019 Multi-scale spatial heterogeneity enhances particle clearance in airway ciliary arrays, ***BioRxiv***: https://doi.org/10.1101/665125

Arnold Mathijssen, Joshua Culver, M. Saad Bhamla, Manu Prakash, 2019, Collective intercellular communication through ultra-fast hydrodynamic trigger waves, ***Nature*** 10, 571

Coyle, Scott M., Eliott M. Flaum, Hongquan Li, Deepak Krishnamurthy, and Manu Prakash, 2019 Coupled Active Systems Encode an Emergent Hunting Behavior in the Unicellular Predator *Lacrymaria olor*. ***Current Biology.***

Vivek N. Prakash, Matthew S. Bull, Manu Prakash. 2019. Motility induced fracture reveals a ductile to brittle crossover in the epithelial tissues of a simple animal, ***BioRxiv***.

Shahaf Armon, Matthew Storm Bull, Andres Jesus Aranda-Diaz, Manu Prakash, 2018. Ultra-fast cellular contractions in the epithelium of T. adhaerens and the "active cohesion" hypothesis ***PNAS***, 115 (44)

(ii) Five other significant publications

Manu Prakash, Neil Gershenfeld, 2007. Microfludic Bubble Logic, ***Science*** 315, 832-835

Manu Prakash, David Quere, John Bush, 2008. Surface tension transport of prey by feeding shorebirds: The capillary ratchet, ***Science***, 320 (5878)

James S. Cybulski, James Clements and Manu Prakash, 2014. Foldscope: Origami based paper microscope, ***PLoS ONE,*** 9 (6)

Nate Cira, Adrien Benusiglio and Manu Prakash, 2015. Vapor mediated sensing and motility in two-component droplets, ***Nature*** 519

Deepak Krishnamurthy, Georgios Katsikis, Arjun Bhargava, Manu Prakash, 2017. Schistosoma mansoni cercariae exploit an elastohydrodynamic coupling to swim efficiently ***Nature Physics*** 13(3)

(d) Synergistic Activities

- Foldscope: Inventor of an ultra-low cost microscope, that utilizes Origami to demonstrate 700 nm resolution imaging at a price point of one dollar.

- Deployment of 1 Million Foldscope in 150+ countries around the world to bring access to scientific tools to people around the world. The work done with a Foldscope is documented by the community at http://microcosmos.foldscope.com. Foldscope reaches hundreds of thousands of kids in United States alone with low resources in rural and urban communities. This approach brings engineering, life sciences and design to enable participants to not only learn about science but actually do science in their own communities.
- Paperfuge: Inventor of an ultra-low cost centrifuge (20 cents) for centrifugation in the field without electricity. Paperfuge currently holds the world record for fastest spinning object with human power (125,000 rpm).
- Board member of PIVOT, a community health care delivery organization that brings health services to a community in Madagscar.
- PlanktonPlanet: Co-founder of a community based "seatizen science" project bringing scientific and measurement tools for sailors to explore the diversity of life in the ocean. Head of the imaging modules being deployed with sailors to directly measure living behavior of plankton by recreational sailors in communities sailing world-wide.

Biographical Sketch
Blake Elliott Riggs
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Department of Biology San Francisco State University
1600 Holloway Ave. | San Francisco, CA 94132

(a) Professional Preparation

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

(b) Appointments

2016-present Associate Professor of Biology, San Francisco State University
2010-2016 Assistant Professor of Biology, San Francisco State University

(c) Publications

(*SFSU student, URMunder-represented minority student, ^female student)

(i) five publications most closely related to proposed project

Diaz U*URM, Bergman Z, Sims A, **Riggs B**. (2019) Microtubules are necessary for proper Reticulon localization during mitosis. *PloS One* in press. Preprint: bioRxiv. Jan 1:516773.

del Castillo U, Gnazzo MM, Sorensen Turpin CG, Nguyen KC, Semaya E, Lam Y*^, de Cruz MA, Bembenek JN, Hall DH, **Riggs B**, Gelfand VI. (2019) Conserved role for Ataxin-2 in mediating endoplasmic reticulum dynamics. Traffic. Jun;20(6):436-47.

Owens, M. T., Trujillo, G., Seidel, S. B., Harrison, C. D., Farrar, K. M., Benton, H. P.,…**Riggs, B**.... & Byrd, D. T. (2018). Collectively Improving Our Teaching: Attempting Biology Department–wide Professional Development in Scientific Teaching. *CBE-Life Sciences Education*, *17*(1), ar2.

Eritano, A. S. *URM, A. Altamirano*URM, S. Beyeler*, ^, Norma Gaytan*URM, ^, Mark Velasquez URM and **B. Riggs**. (2017) Asymmetric Endoplasmic Reticulum partitioning is dependent on Jagunal in the early Drosophila embryo. Mol Bio Cell . vol 28 pp. 1530 – 1538

Owens, M. T., Seidel, S. B., Wong, M., Bejines, T. E., Lietz, S., Perez, J. R.,…**Riggs, B**.,... & Balukjian, B. (2017). Classroom sound can be used to classify teaching practices in college science courses. *Proceedings of the National Academy of Sciences*, 201618693.

(ii) five other significant publications

Trujillo, G. URM, ^, PG. Aguinaldo*URM, ^, C. Anderson*URM, ^, J. Bustamante*URM, DR. Gelsinger*URM, MJ. Pastor*URM, ^, J. WrightURM, ^, L. Márquez-MagañaURM, ^, and **B. Riggs**. (2015) Near-peer STEM Mentoring Offers Unexpected Benefits for Mentors from Traditionally Underrepresented Backgrounds. *Perspect Undergrad Res Mentor. 2015;4(1). pii:* *http://blogs.elon.edu/purm/files/2015/11/Riggs.GT-et-al-PURM-4.1.pdf*.

Smyth JT, Schoborg TA, Bergman ZJ, **Riggs B**, and Rusan, NM (2015) Proper symmetric and asymmetric ER partitioning requires functional microtubule organizing centers. *Open Biol. 5: 150067.* *http://dx.doi.org/10.1098/rsob.150067*

Bergman ZJ, Mclaurin JD*URM, Eritano, AE*URM, Johnson B*URM^, Sims AQ*^, and **Riggs B** (2015) Spatial reorganization of the Endoplasm Reticulum during mitosis relies on mitotic kinase cyclin A in

the early Drosophila embryo. *PloS one*, *10*(2), e0117859
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.

(d) Synergistic Activities

Career development of minority students
Research mentor to minority students: In 7 years, I have mentored 21 Masters (13 URM) and 25 undergraduate (16 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 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
PLOSone; Frontiers in Cell Biology; Molecular and Cellular Biosciences (MCB) Cytoskeleton panel, National Science Foundation (NSF); 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
Session Co-Chair, 60th Drosophila Research Conference, Dallas, Tx; Minority Affairs Committee (MAC) member for the American Society for Cellular Biology; Abstract reviewer and scientific presentation judge for the Annual Biomedical Research Conference for Minority Students.

Debra Singer
Department of Biochemistry & Biophysics, UCSF
600 16th Street, GH S412A
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(a) Professional Preparation

University of Washington, Seattle, B.A. History, 1980, with a minor in ballet, classical violin and art.

California College of Arts and Crafts, B.F.A. Graphic Design, 1995
Visual communication arts, with a focus on abstraction of complex ideas.

Certificate in Sustainable Design, UC Berkeley Extension, San Francisco, 2012
Focus on environmental sciences, ecology, ethical issues and conflicts in urban and natural environment interfaces, water and energy resource management. Sustainable design encompasses history, policy, urban planning, agro-ecology and nature-based systems design for the built and natural environment. Created low-impact design proposals to mitigate pollution impacts in the urban/ natural environment, including studies of superfund sites in the Bay Area and other states in the USA.

Permaculture Design Certificate, Urban Permaculture Institute San Francisco, 2015
Collaborative studies and proposals for mitigation of urban water filtration issues, Lake Merritt, Oakland, and studies of sea-level rise and mitigation recommendations for sites in Alameda County and San Francisco. Some studies have been integrated into white paper analyses for local government policy assessment.

(b) Appointments

2018 – present	Managing Director, NSF Center for Cellular Construction
2016- 2018	Manager, Center for Cellular Construction, UCSF Dept. Biochemistry & Biophysics
2000- 2018	Research Grant Program Officer, UCSF Dept. Biochemistry & Biophysics
1990- 2000	Grants Specialist, UCSF Dept. Biochemistry & Biophysics

Other Professional Activities -

2000-2014	Consortium and Financial Management and consulting for UCSF beamlines (BL5.3.1 and BL8,) Advanced Light Source, Lawrence Berkeley National Labs

Design, Teaching - selected relevant professional work

2000 -2009	Designer and Artistic Associate, The Cutting Ball Theater, San Francisco 2000-2009 Photography and print design for theater productions
1999-2005	Instructor, University of California Berkeley Extension, Graphic & Interactive Design Program Developed and taught graphic Design Studios I, II, III, and IV, comprising fundamental design concepts, visual communication through advanced portfolio and logo / symbol design.

(c) Publications / Products:

Design / Branding Materials: Designed posters and fabric banner signage and art.

1. CCC Center Logo: Art-directed logo development for the Center for Cellular Construction, supervising an externally hired team of graphic designers.

2. CCC Fabric Banner: Designed visual imagery and layout for signage used for CCC events.

3. Integrated set of theater posters and photography for promotion materials for Cutting Ball Theater, San Francisco.

4. Poster and program for a performance of Carl Djerassi's play, 'Calculus' at the San Francisco Performing Arts Library and Museum.

(d) Synergistic Activities

Mentoring /Training: Created an interim position for a student from our SFSU CCC cohort to participate in strategic planning, site visit preparation and logistics, contribute to reporting processes and contribute ideas to CCC leads.

Broadening Participation: Created a reserve budget in our Strategic Reserve funds to allow us to recruit especially talented students from SFSU who are interested in science communication, grantsmanships and overall program management, to assist with special projects.
Mentoring and teaching gifted and motivated students from URM backgrounds from CCC labs who may not get into their graduate or PhD programs of choice the first round gives students the opportunity to work with the CCC administrative team and receive personal mentoring and make connections at the university level.

Conference Organization: Served as lead local organizer for the 13th Annual qBio Conference, San Francisco, CA 2019, an international science conference held over 4 days on the SFSU campus that drew over 200 people from around the world. Developed revenue structure for the event and raised target revenue of ~ $150K for conference expenses. Worked with the SACNAS student chapter at SFSU, the qBio Board, Wallace Marshall, Mark Chan, and Frank Bayliss. Organized and managed working groups from UCSF, SF State University and Emory University, and oversaw logistics for communication, website, facilities and event support.

Outreach: Liaison between the CCC and other STCs. Active in local and larger community environmental organizations and policy groups.

Rebecca L. Smith
Science & Health Education Partnership
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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	Science Education Partnership		
	Postdoctoral Partnership		2000-2001

(b) Appointments

2005-present	Co-Director, Science & Health Education Partnership, UCSF
2004-2005	Academic Coordinator II, Science & Health Education Partnership, UCSF
2001-2003	Academic Coordinator I, Science & Health Education Partnership, UCSF

(c) Products

(i) five products most closely related to proposed project

1. Morell, L., Bathia, S., Koo, B., **Smith, R**., & Wilson, M. 2019. *The Construction and Validation of a Researcher Identity Scale*. Session presented at the American Educational Research Association (AERA) Annual Meeting, Toronto, Ontario, Canada.
2. *From STEM to Story: Engaging and Effective Lessons for Grades 5-8. J.* Traig (Ed.). San Francisco, CA: Josey-Bass (Wiley). 2015. Science Lead and Contributing Author. (see: http://tinyurl.com/STEMtoStory)
3. Diamond, J., McQuillan, J., Spiegel, A.N., Wonch Hill, P., **Smith, R**., West, J., and Wood, C. 2016. Viruses, Vaccines, and the Public. Museums and Social Issues.11:1, 9-16. (http://dx.doi.org/10.1080/15596893.2016.1131099)
4. *Watch Your Mouth & Discover What's Alive Inside!* Linda Allison, **Rebecca Smith**, and Judy Diamond. Altadena, CA: Bitingduck Press. 2016. (http://tinyurl.com/y344kejh)
5. 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.

(ii) five other significant products & publications

1. San Francisco Health Investigators Health Message Campaigns. Health messages developed by San Francisco high school students participating in NIH SEPA funded project (role: PI, lead instructor). http://sep.ucsf.edu/hs_programs/sf-health-investigators/
    a. 2018 - www.screeningcancer.org
    b. 2017 - www.superdrugdefenders.org
    c. 2016 - www.bewiseimmunize.org
2. **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)
3. 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 (https://doi.org/10.1091/mbc.e14-03-0793)

4. Salter, I., Nielsen, K., **Smith, R.L**., 2008. *Injecting Inquiry into Photosynthesis Investigations. Science* Scope. (https://www.nsta.org/store/product_detail.aspx?id=10.2505/4/ss08_032_01_34#)
5. **Smith, R.L.,** Johnson A. S. 2000. *A sequence resembling a peroxisomal targeting sequence directs the interaction between the tetratricopeptide repeats of Ssn6 and the homeodomain of alpha 2.* Proc. Natl. Acad. Sci. U.S.A. 97(8):3901-6

(d) Synergistic Activities

Public Engagement with Science

Co-founded the Bay Area Science Festival (2011). Now in its ninth year, the Festival is a 10-day celebration of science, technology, and engineering. The Festival's events seek to connect the public with scientists and engineers through innovative programming that includes hands-on activities, public demonstrations, and behind the scenes tours. Each year the Festival engages more than 50,000 attendees in a wide variety of events. Significant numbers of federally funded (NSF, NIH, USGS, NASA, and others) groups share their work with the public at Festival events.

Expertise developed through work on the Festival has informed other projects including the development of a STEM Career Day for high school students from backgrounds underrepresented in the sciences, as well as coaching researchers in the design of interactive, hands-on experiences for diverse learners that help members of the public understand complex scientific ideas and cutting-edge research.

Advise a number of UCSF departments and Centers on broadening participation in science and public outreach initiatives.

Innovative Learning Experiences for K-12

Designed a novel, year-long public health internship program for high school students with funding from an NIH SEPA award. In this program, students from San Francisco's public schools learn about a different health topic that impacts their community each year in a month-long summer intensive that engages students deeply in project-based learning. Students conduct a community based-research project and use the data from this survey to inform the design of a health message campaign. Work with students continues through the school year as they disseminate their campaign and evaluate its effectiveness. As part of this project developed a validated instrument to measure students' identities as a researcher, in collaboration with Mark Wilson, Linda Morell, and Shruti Bathia from the UC Berkeley Evaluation and Assessment Research Center. Manuscripts about the Researcher Identity Scale (RIS) are in preparation.

Facilitate Teacher-Scientist partnerships as custom, in situ professional development for both K-12 teachers and early career scientists. Evaluation demonstrates that through these partnerships, teachers learn how to integrate current research developments into their curricula (high school), gain confidence to teach science (elementary school), and develop/try lessons they otherwise would not have had the confidence to implement as the sole adult in their classrooms (all levels). Scientists gain skills in communicating science simply, and to diverse audiences. K-12 students benefit from sustained exposure to scientist role models in their classrooms.

Service to the Science Education Community

Currently serve and have served on numerous Advisory Boards for a wide range of science education organizations and federally funded projects. Recently completed a term on the Editorial Board of *CBE – Life Science Education* and currently serve on the Editorial Board of the Journal of *STEM Outreach*.

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(a) Professional Preparation

California Institute of Technology	Electrical Engineering	B.S., 2003
Stanford University	Electrical Engineering	M.S., 2004
Harvard University	Engineering Sciences	Ph.D., 2010
Harvard University	Engineering Sciences	Postdoc, 2010-2011
Woods Hole Marine Biological Lab	Physiology/Cell Biology	June – August, 2011

(b) Appointments

Stanford University

Associate Professor, Department of Mechanical Engineering	2018-present
Associate Professor (by courtesy), Department of Radiology	2018-present
Assistant Professor, Department of Mechanical Engineering	2011-2018

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

(i) Five most relevant publications:

- Sindy K.Y. Tang, and Wallace Marshall, "Primer: Cell Learning", ***Current Biology***, 28, PR1180-R1184, 2018.
- Lucas R. Blauch, Ya Gai, Jian Wei Khor, Pranidhi Sood, Wallace F. Marshall, and Sindy K.Y. Tang, "Microfluidic guillotine for single-cell wound repair studies", ***Proceedings of the National Academy of Sciences***, 114, 7283-7288, 2017.
- Sindy K.Y. Tang, and Wallace F. Marshall, "Self-healing Cells: How single cells heal membrane ruptures and restore lost structures", ***Science***, 356, 1022-1025, 2017.
- Satoshi Toda, Lucas R. Blauch, Sindy K.Y. Tang, Leonardo Morsut, Wendell A. Lim, "Synthetic morphologies: Programming self-organizing multi-cellular structures using engineered cell-cell signaling cascades", ***Science,*** 361, 156-162, 2018.
- Sindy K.Y. Tang, Malte Renz, Tom Shemesh, Meghan Driscoll, and Jennifer Lippincott-Schwartz, "Cytoplasmic self-organization established by internal lipid membranes in the interplay with either actin or microtubules", ***bioRxiv***, DOI: https://doi.org/10.1101/506436, 2018.

(ii) Five other significant publications:

- Jian Wei Khor, Neal Jean, Eric S. Luxenberg, Stefano Ermon, and Sindy K.Y. Tang, "Using Machine Learning to Discover Shape Descriptors for Predicting Emulsion Stability", ***Soft Matter***, 15, 1361-1372, 2019.
- Ya Gai, Chia Leong, Wei Cai, and Sindy K. Y. Tang, "Spatiotemporal periodicity of dislocation dynamics in a two-dimensional microfluidic crystal flowing in a tapered channel", ***Proceedings of the National Academy of Sciences***, 113, 12082-12087, 2016.
- 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.

- 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***, DOI: 10.1021/am506443e, 2014.
- Ming Pan, Minkyu Kim, Lucas Blauch and Sindy K. Y. Tang, "Surface-Functionalizable Amphiphilic Nanoparticles for Pickering Emulsions with Designer Fluid-Fluid Interfaces", ***RSC Advances***, 6, 39926-39932, 2016.

(d) Synergistic Activities

- **Instructor at summer physiology / cell biology courses:** 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. Tang also taught the 2-week summer course at the NSF Center for Cellular Construction at SF State (07/15/2019-07/26/2019) aimed to bring microfluidics tools to cell biology, for approximately 20-25 students at the undergraduate and master level.
- **Mentor for underrepresented undergraduate students**: Tang has advised 15 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 for 4 years (2012, 2016, 2018, 2019) with more than 30,000 participants.
- **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.
- **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).

Orion Weiner
Cardiovascular Research Institute and
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UCSF
SCVRB-352F Box 3120
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(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**

1. Toettcher JE, Gong D, Lim WA, Weiner OD. 2011. Light-based feedback for controlling intracellular signaling dynamics, ***Nature Methods***, 8: 837-9.
2. 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.
3. 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).
4. Graziano BR, Gong D, Anderson KE, Pipathsouk A, Goldberg AR, Weiner OD. 2017. A module for Rac temporal signal integration revealed with optogenetics, ***J. Cell Biol.***, 216: 2515-2531.
5. Tischer D, Weiner OD (2019). Light-based tuning of ligand half-life supports kinetic proofreading model of T cell activation, ***eLife***, 8: e42498.

(ii) **five other significant publications**

1. Jost APT, Weiner OD (2015). Probing yeast polarity with acute, reversible, optogenetic inhibition of protein function, ***ACS Synthetic Biology***, *4: 1077-85.*
2. Hoeller O, Toettcher JE, Cai H, Sun Y, Huang CH, Freyre M, Zhao M, Devreotes PN, Weiner OD (2016). Gβ regulates coupling between actin oscillators for cell polarity and directed migration, ***PLoS Biology***, 14: e1002381.
3. Diz-Munoz A, Thurley K, Chintamen S, Altschuler SJ, Wu LF, Fletcher DA, Weiner OD. 2016. Membrane tension acts through PLD2 and mTORC2 to constrain actin assembly during neutrophil migration, ***PLoS Biology***, 14: e1002474.
4. Graziano BR, Town JP, Sitarska E, Nagy TL, Fošnarič M, Penič S, Iglič A, Kralj-Iglič V, Gov NS, Diz-Muñoz A, Weiner OD (2019). Cell confinement reveals a branched-actin independent circuit for neutrophil polarity, ***PLoS Biology***, 17: e3000457.
5. Alexander JM, Guan J, Li B, Maliskova L, Song M, Shen Y, Huang B, Lomvardas S, Weiner OD (2019) Live-cell imaging reveals enhancer-dependent Sox2 transcription in the absence of enhancer proximity, ***eLife,*** 8: e41769.

(d) Synergistic Activities

- 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.
- Chair, Gordon Conference on Directed Migration 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 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 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 shared the results of this analysis with the other graduate programs here to globally improve the admissions process at UCSF and also published the work in MBoC to improve the admissions process in other universities. One of the key outcomes of this work is to de-emphasize our focus on some metrics like GRE and undergraduate institution that have typically disadvantaged under-represented minorities. In consultation with the primary graduate programs at UCSF, this helped prompt many basic science departments at UCSF to remove the GREs from our graduate admissions applications.
- Founder, Chair of Advisory Committee, Nikon Advanced Light Microscopy Imaging Center at UCSF.
- Co-Chair of Integrated Program in Complex Biological Systems (2017- present)

Thomas G. Zimmerman
Research Staff Member
IBM Research-Almaden
650 Harry Road, San Jose CA 95138
408 7 1836 tzim@us.ibm.com

(a) Professional Preparation

Massachusetts Institute of Technology Media Arts and Sciences M.S. 1995
Thesis "Personal Area Networks (PAN): Near-field Intrabody Communication"

Massachusetts Institute of Technology Humanities & Engineering B.S. 1980
(History of Technology & Mechanical Engineering)
Thesis "Yaw stability of Horizontal Axis Down-wind turbines Enhanced by Coning Angle"

University of Massachusetts Mechanical Engineering 1980
Teaching Assistant Measurement and Instrumentation Lab
Graduate classes on solar and wind energy technologies

(b) Appointments

1995- now **IBM Research-Almaden**, Research Staff Member, San Jose, CA
Research Staff Member. Developing AI networked microscopes to monitor the health of the environment by in situ detection of morphological and behavioral changes of plankton. Design and deployed network of wireless motion and temperature sensors to predict sea turtle hatching. Designed system for airport self check-in and boarding using a wireless PDA and RFID card system. Led a team of scientists that developed a dynamic signature verification system. Invented devices for personal computing interface including a capacitive pointing sensor, electric field identification and communication system, wireless asset tracking system, fingerprint authentication system, and pen input devices. Co-principle Investigator of a $879k NSF-funded science enrichment program for 60 Latino high school students to provide hands-on experience and encourage science and engineering careers. Designed bio-inspired spiking neural network circuits to extract features in streaming video and audio signals. Developed AI programs to predict human personality and interests based on text and images posted on social media.

1994-1995 **MIT Media Laboratory**, Cambridge, MA
Research Assistant. Developed the Personal Area Network, a method of sending data through the body and measure body location. Designed signal processing hardware and software for analyzing electric field sensing and communication.

1987-1994 **Zimmerman and Associates**, San Francisco, CA
Founder and Director of consulting group that provides innovative human interface technologies. Services include design concept development, prototype development and construction, creation of intellectual property and securing letters of patent.

1985-1987 **VPL Research**, Redwood City, CA
Co-Founder and Director of Engineering. Invented the DataGlove. Designed a microprocessor based DataGlove interface unit. Designed original prototype for the PowerGlove including ultrasonic tracking system resulting in Mattel product that sold 1.3 million units.

1985 **Breakaway**, San Mateo, CA
Co-Founder and Design Engineer. Designed and prototyped a voice controlled musical synthesizer, resulting in commercial Vocalizer product. Implemented real time pitch tracker written in assembler running on an 8088 microprocessor.

1982-1985 **Atari, Inc**., Sunnyvale, CA
Research Engineer. Programmed microcontroller (8051) for custom digital additive sound synthesizer. Designed consumer musical product prototypes.

(c) Products

(i) products most closely related to proposed project

1. **Stereo In-Line Holographic Digital Microscope**, Thomas Zimmerman, Nick Antipa, Daniel Elnatan, Alessio Murru, Sujoy Biswas,Vito Pastore Mayara Bonani, Laura Waller, Jennifer Fung,Gianni Fenu, Simone Bianco, Proc. SPIE 10883, Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XXVI, 1088315 (21 February 2019) https://www.biorxiv.org/content/10.1101/790535v1
2. **High Throughput Analysis of Plankton Morphology and Dynamic**, Sujoy Biswas, Thomas Zimmerman, Lucrezia Maini, Aminat Adebiyi, Luisa Bozano, Cecelia Brown, Vito Paolo Pastore, and Simone Bianco. Proc. SPIE 10883, Three-Dimensional and Multidimensional Microscopy: Image Acquisition and Processing XXVI, 1088315 (21 February 2019)
3. **Establishing the baseline for using plankton as biosensor**, Vito P. Pastore, Thomas Zimmerman, Sujoy K. Biswas, and Simone Bianco. Proc. SPIE 10881, Imaging, Manipulation, and Analysis of Biomolecules, Cells, and Tissues XVII, 108810H (4 March 2019)
4. **Contact microscope using point source illumination** US Patent 7,936,501

(ii) other significant products

1. **Power Glove** US Patent 4,988,981, US Patent 4,542,291
2. **Personal Area Network** US Patent 5,914,701, US Patent 5,796,827
3. **Methods and apparatus for detecting metals in liquids,** US Patent 9,389,181
4. **System and method for providing time-limited access to people,** US Patent 7,058,814

(d) Synergistic Activities

Creator and Co-PI of Extreme Experience Lab, NSF Grant 0737631 ($899k). The Extreme Experience Lab program of the National Hispanic University and its Latino College Preparatory Academy, is a youth-based project designed to give 60 under-represented Hispanic high school students a two-year experience with three weekly meetings: FAB (building); LAB (data collection/measurement); and GAB (analysis and communicating) during the school year. In the interdisciplinary projects, science and IT concepts of scale, units, and calculations are combined with the development of critical observation skills.

Maker Community. Authored seven articles on hands-on activities for young people (https://makezine.com/author/tom-zimmerman/), including several booths at Makers Faires (https://makezine.com/2007/04/23/maker-faire-tom-zimmerman/).

Co-Creator "Introduction to Optical Engineering for the Biological Sciences" undergraduate laboratory class at SFSU teaching hands-on computational microscopy where each student builds a holographic video microscope and use it to conduct improvements and research. First offered Fall 2019. Created and taught with Raymond Esquerra and Mark Chan, SFSU.

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**	3.00	0.00	0.00	**54,631**	
2. **Frank Bayliss - Diversity Coordinator**	2.40	0.00	0.00	**29,642**	
3. **Charles Craik - Knowledge Transfer Coordinator**	0.36	0.00	0.00	**9,952**	
4. **Shawn Douglas - Co-Investigator**	0.36	0.00	0.00	**5,108**	
5. **Sophie Dumont - Co-Investigator**	0.48	0.00	0.00	**8,502**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	6.76	0.00	0.00	**96,337**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	13.36	0.00	0.00	**204,172**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**9**) POST DOCTORAL SCHOLARS	81.00	0.00	0.00	**357,048**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**13,543**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**8**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**392,723**	
6. (**1**) OTHER				**106,943**	
TOTAL SALARIES AND WAGES (A + B)				**1,074,429**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**373,517**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,447,946**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**42,800**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **32,200**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **76,729**					
TOTAL NUMBER OF PARTICIPANTS (**47**) TOTAL PARTICIPANT COSTS				**108,929**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**131,368**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**16,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**10,250**	
5. SUBAWARDS				**1,696,446**	
6. OTHER				**329,730**	
TOTAL OTHER DIRECT COSTS				**2,183,794**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,783,469**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 61.5000, Base: 1978097)**					
TOTAL INDIRECT COSTS (F&A)				**1,216,530**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,999,999**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,999,999**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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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 COMMENTS - Year 1

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
El-Samad, Hana - Co-Investigator	0.12	0.00	0.00	2115
Fung, Jennifer - Informatics Coordinator	0.48	0.00	0.00	5831
Gartner, Zev J - Co-Principal Investigator	1.20	0.00	0.00	19881
Hart, Charles - Knowledge Transfer Advisor	0.12	0.00	0.00	2011
Lim, Wendell - Co-Investigator	0.50	0.00	0.00	8999
McGinn, Robert - Lead Ethics Advisor	2.40	0.00	0.00	29642
Smith, Rebecca - Center Education Coordinator	1.80	0.00	0.00	25050
Weiner, Orion - Graduate Education Coordinator	0.14	0.00	0.00	2808

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**	3.00	0.00	0.00	**56,270**	
2. **Frank Bayliss - Diversity Coordinator**	2.28	0.00	0.00	**29,004**	
3. **Charles Craik - Knowledge Transfer Coordinator**	0.36	0.00	0.00	**10,251**	
4. **Shawn Douglas - Co-Investigator**	0.36	0.00	0.00	**5,261**	
5. **Sophie Dumont - Co-Investigator**	0.48	0.00	0.00	**8,757**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	6.64	0.00	0.00	**97,702**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	13.12	0.00	0.00	**207,245**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**10**) POST DOCTORAL SCHOLARS	90.00	0.00	0.00	**380,555**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**13,543**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**8**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**407,305**	
6. (**1**) OTHER				**110,151**	
TOTAL SALARIES AND WAGES (A + B)				**1,118,799**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**387,566**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,506,365**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**46,800**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **32,200**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **76,438**					
TOTAL NUMBER OF PARTICIPANTS (**47**) TOTAL PARTICIPANT COSTS				**108,638**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**139,084**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**16,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**10,361**	
5. SUBAWARDS				**1,619,571**	
6. OTHER				**307,266**	
TOTAL OTHER DIRECT COSTS				**2,092,282**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,754,085**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 61.5000, Base: 2025876)**					
TOTAL INDIRECT COSTS (F&A)				**1,245,914**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,999,999**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,999,999**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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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
El-Samad, Hana - Co-Investigator	0.12	0.00	0.00	2179
Fung, Jennifer - Co-Invetsigator	0.48	0.00	0.00	6006
Gartner, Zev J - Principal Investigator	1.20	0.00	0.00	20478
Hart, Charles - Co-Investigator	0.12	0.00	0.00	2072
Lim, Wendell - Co-Investigator	0.50	0.00	0.00	9269
McGinn, Robert - Lead Ethics Advisor	2.28	0.00	0.00	29004
Smith, Rebecca - Co-Investigator	1.80	0.00	0.00	25802
Weiner, Orion - Co-Investigator	0.14	0.00	0.00	2892

SUMMARY PROPOSAL BUDGET

YEAR 3

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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**	3.00	0.00	0.00	**57,958**	
2. **Frank Bayliss - Diversity Coordinator**	2.28	0.00	0.00	**29,874**	
3. **Charles Craik - Knowledge Transfer Coordinator**	0.36	0.00	0.00	**10,558**	
4. **Shawn Douglas - Co-Investigator**	0.36	0.00	0.00	**5,419**	
5. **Sophie Dumont - Co-Investigator**	0.48	0.00	0.00	**9,019**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	6.64	0.00	0.00	**100,632**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	13.12	0.00	0.00	**213,460**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**9**) POST DOCTORAL SCHOLARS	81.00	0.00	0.00	**383,940**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**13,543**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**8**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**419,524**	
6. (**1**) OTHER				**113,456**	
TOTAL SALARIES AND WAGES (A + B)				**1,143,923**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**397,492**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,541,415**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**42,800**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **32,200**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **76,143**					
TOTAL NUMBER OF PARTICIPANTS (**47**) TOTAL PARTICIPANT COSTS				**108,343**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**128,181**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**16,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**10,255**	
5. SUBAWARDS				**1,580,068**	
6. OTHER				**311,869**	
TOTAL OTHER DIRECT COSTS				**2,046,373**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,738,931**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 61.5000, Base: 2050520)**					
TOTAL INDIRECT COSTS (F&A)				**1,261,070**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**5,000,001**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**5,000,001**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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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 COMMENTS - Year 3

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
El-Samad, Hana - Co-Investigator	0.12	0.00	0.00	2244
Fung, Jennifer - Co-Investigator	0.48	0.00	0.00	6186
Gartner, Zev J - Principal Investigator	1.20	0.00	0.00	21092
Hart, Charles - Co-Investigator	0.12	0.00	0.00	2134
Lim, Wendell - Co-Investigator	0.50	0.00	0.00	9547
McGinn, Robert - Lead Ethics Advisor	2.28	0.00	0.00	29874
Smith, Rebecca - Co-Investigator	1.80	0.00	0.00	26576
Weiner, Orion - Co-Investigator	0.14	0.00	0.00	2979

SUMMARY PROPOSAL BUDGET

YEAR 4

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**	3.00	0.00	0.00	**59,697**	
2. **Frank Bayliss - Diversity Coordinator**	2.28	0.00	0.00	**30,771**	
3. **Charles Craik - Knowledge Transfer Coordinator**	0.36	0.00	0.00	**10,875**	
4. **Shawn Douglas - Co-Investigator**	0.36	0.00	0.00	**5,582**	
5. **Sophie Dumont - Co-Investigator**	0.48	0.00	0.00	**9,290**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	6.64	0.00	0.00	**103,652**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	13.12	0.00	0.00	**219,867**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**9**) POST DOCTORAL SCHOLARS	38.88	0.00	0.00	**191,484**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**13,543**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**8**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**429,430**	
6. (**1**) OTHER				**116,860**	
TOTAL SALARIES AND WAGES (A + B)				**971,184**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**365,310**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,336,494**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**36,800**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **16,100**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **2,985**					
TOTAL NUMBER OF PARTICIPANTS (**35**) TOTAL PARTICIPANT COSTS				**19,085**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**111,241**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**16,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**7,446**	
5. SUBAWARDS				**1,312,571**	
6. OTHER				**237,125**	
TOTAL OTHER DIRECT COSTS				**1,684,383**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,076,762**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 61.5000, Base: 1745102)**					
TOTAL INDIRECT COSTS (F&A)				**1,073,238**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,150,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,150,000**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 4

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
El-Samad, Hana - Co-Investigator	0.12	0.00	0.00	2312
Fung, Jennifer - Co-Investigator	0.48	0.00	0.00	6371
Gartner, Zev J - Principal Investigator	1.20	0.00	0.00	21725
Hart, Charles - Co-Investigator	0.12	0.00	0.00	2198
Lim, Wendell - Co-Investigator	0.50	0.00	0.00	9833
McGinn, Robert - Lead Ethics Advisor	2.28	0.00	0.00	30771
Smith, Rebecca - Co-Investigator	1.80	0.00	0.00	27373
Weiner, Orion - Co-Investigator	0.14	0.00	0.00	3069

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**	3.00	0.00	0.00	**61,488**	
2. **Frank Bayliss - Diversity Coordinator**	1.92	0.00	0.00	**26,690**	
3. **Charles Craik - Knowledge Transfer Coordinator**	0.36	0.00	0.00	**11,201**	
4. **Shawn Douglas - Co-Investigator**	3.00	0.00	0.00	**5,749**	
5. **Sophie Dumont - Co-Investigator**	0.48	0.00	0.00	**9,569**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	6.28	0.00	0.00	**101,758**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	15.04	0.00	0.00	**216,455**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**9**) POST DOCTORAL SCHOLARS	32.40	0.00	0.00	**165,528**	
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. (**6**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**357,892**	
6. (**1**) OTHER				**120,366**	
TOTAL SALARIES AND WAGES (A + B)				**860,241**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**325,923**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,186,164**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**16,000**	
2. INTERNATIONAL				**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				**24,851**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**16,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**6,392**	
5. SUBAWARDS				**1,049,368**	
6. OTHER				**156,558**	
TOTAL OTHER DIRECT COSTS				**1,253,169**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,455,333**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 61.5000, Base: 1405964)**					
TOTAL INDIRECT COSTS (F&A)				**864,668**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**3,320,001**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**3,320,001**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 5

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
El-Samad, Hana - Co-Investigator	0.12	0.00	0.00	2381
Fung, Jennifer - Co-Investigator	0.48	0.00	0.00	6563
Gartner, Zev J - Principal Investigator	1.20	0.00	0.00	22377
Hart, Charles - Co-Investigator	0.12	0.00	0.00	2264
Lim, Wendell - Co-Investigator	0.50	0.00	0.00	10128
McGinn, Robert - Lead Ethics Advisor	1.92	0.00	0.00	26690
Smith, Rebecca - Co-Investigator	1.80	0.00	0.00	28194
Weiner, Orion - Co-Investigator	0.14	0.00	0.00	3161

SUMMARY PROPOSAL BUDGET

Cumulative

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**	15.00	0.00	0.00	**290,044**	
2. **Frank Bayliss - Diversity Coordinator**	11.16	0.00	0.00	**145,981**	
3. **Charles Craik - Knowledge Transfer Coordinator**	1.80	0.00	0.00	**52,837**	
4. **Shawn Douglas - Co-Investigator**	4.44	0.00	0.00	**27,119**	
5. **Sophie Dumont - Co-Investigator**	2.40	0.00	0.00	**45,137**	
6. (**8**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	32.96	0.00	0.00	**500,081**	
7. (**13**) TOTAL SENIOR PERSONNEL (1 - 6)	67.76	0.00	0.00	**1,061,199**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**46**) POST DOCTORAL SCHOLARS	323.28	0.00	0.00	**1,478,555**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**4**) GRADUATE STUDENTS				**54,172**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**38**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**2,006,874**	
6. (**5**) OTHER				**567,776**	
TOTAL SALARIES AND WAGES (A + B)				**5,168,576**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**1,849,808**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**7,018,384**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**185,200**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **112,700**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **232,295**					
TOTAL NUMBER OF PARTICIPANTS (**176**) TOTAL PARTICIPANT COSTS				**344,995**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**534,725**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**80,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**44,704**	
5. SUBAWARDS				**7,258,024**	
6. OTHER				**1,342,548**	
TOTAL OTHER DIRECT COSTS				**9,260,001**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**16,808,580**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**5,661,420**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**22,470,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**22,470,000**	

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

PI/PD NAME
Wallace Marshall

ORG. REP. NAME*
Sharon Louie

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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.

Note: Effort is noted for fy 06, with reduced effort in accord. with NSF reduced budgets in fys 09-10.

A. SENIOR PERSONNEL

Executive Committee

Wallace Marshall, PhD, Principal Investigator (Center Director) (salary requested at 3.0 calendar months) will provide executive leadership for the Center, including overseeing activities between center-affiliated groups and institutions. He will also oversee the integration of the research, teaching, outreach, and knowledge transfer components. He will lead research that contributes to the development of predictive models for organelle size regulation (CellCAD and Living Bioreactor themes). He will also teach and contribute to curriculum development for CCC education programs.

Zev Gartner, PhD, Co-Principal Investigator and Research Coordinator (salary requested at 1.2 calendar months) will co-direct the overall research operation of the center, focusing on integrating research activities between groups and ensuring progress is coordinated with the four research themes. In addition, he will oversee execution and coordination of the Cellular Legos theme.

Debra Singer, Managing Director (salary requested at 12.0 calendar months) will coordinate and manage the administrative and organizational activities of the Center, including overseeing special events, organizing meetings between Center groups and with the EAC and Ethics advisors. She helps oversee educational and ELSI components, budgetary and strategic review, and contributes to strategic planning, writing and reporting for all components.

Faculty Leads

Frank Bayliss, Ph.D. Diversity Coordinator, Adjunct Professor Emeritus (salary requested at 2.4 calendar months) will coordinate overall diversity programs for the Center, contributing to budgetary review, strategic planning and integrating broadening participation with research programs. Dr. Bayliss will work with Drs. Chu and Chan in the selection/admission of incoming Center for Cellular Construction (CCC) MS students at SFSU and he will also maintain a data base to track CCC students after they graduate for at least 10 years.

Charles Craik, PhD, Knowledge Transfer Coordinator (salary requested at 0.36 calendar months) will oversee knowledge transfer activities, provide instruction and advice as necessary to move ideas along a knowledge transfer path, and guide CCC participants to resources available through UCSF Innovation Ventures, Catalyst Programs, Entrepreneurship events and VC access. He will provide planning and oversight of seed funding and knowledge transfer programs drawing on his extensive experience in biotech entrepreneurship, entrepreneurship education, and mentoring.

Charles Hart, PhD, Knowledge Transfer Advisor (salary requested at 0.12 calendar months) will provide high-level strategic guidance concerning commercial potential of CCC ideas and help with selection of seed award proposals.

Jennifer Fung, PhD, Informatics Coordinator and Co-Investigator (salary requested at 0.48 calendar months) will draw on her expertise in live cell and super-resolution microscopy to supervise imaging experiments in all CCC research components. 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. She will contribute her expertise in yeast cell biology and genetics to both the Living Bioreactor and Cell Probe research themes.

Robert McGinn, Ph.D., Lead Ethics Advisor and Investigator, Adjunct Prof. Emeritus (salary requested at 2.4 calendar months) will consult with lead researchers on their projects and provide guidance on Ethical, Legal and Social Implications (ELSI) of the Center's research. He will contribute to designing ethics training for cellular engineering courses and workshops in development to address complexities emerging in the field of cellular engineering, policy and governance.

Rebecca Smith, Center Education Coordinator (SEP) and Co-Investigator (salary requested at 1.8 calendar months) will oversee educational and outreach activities of the center, including providing oversight for MS/PhD courses, organizing teacher-student workshops, and curriculum development.

Orion Weiner, Graduate Education Coordinator and Co-Investigator (salary requested at 0.14 calendar months) will draw on his expertise in optogenetics to implement novel methods for intracellular patterning as part of the Living Bioreactor and Cell Probe themes. He will also contribute to diversity efforts for the Center in his role on several graduate diversity and admissions committees at UCSF.

Other Key Personnel - Research

Shawn Douglas, PhD, Co-Investigator (salary requested at 0.36 calendar months) will draw on his experience developing CAD software, and integrating such software with other software platforms to design user interface schemas for the CellCAD theme.

Sophie Dumont, PhD, Co-Investigator (salary requested at 0.48 calendar months) will contribute her expertise in cellular and molecular biomechanics to the Cell Probe theme.

Hana El-Samad, PhD, Co-Investigator (salary requested at 0.12 calendar months) will provide high-level input into development of mathematical models in all research components of the Center, particularly in the CellCAD theme and will develop new cellular control mechanisms in the CellProbe theme.

Wendell Lim, PhD, Co-Investigator (0.5 calendar months) will contribute synthetic biology expertise to the Cellular Legos theme, as well as providing expertise in applications of cellular engineering. As a Howard Hughes Medical Institute (HHMI) investigator, Lim's salary is paid by HHMI. No salary support is requested for his effort on this project.

B. <u>OTHER PERSONNEL</u>

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

TBN Admin Officer (Center Admin) (salary requested at 11.04 calendar months) will help coordinate events and manage logistical and operational needs.

TBN Admin Assistant (Center Admin) (salary requested at 12 calendar months) will assist with trainee tracking, demographic data for reporting, and with events and special program needs.

TBN Student Admin Liaision (Center Admin) (salary requested at 6 calendar months)**.** Funds are requested for a student research administrative position, allowing us to recruit exceptional students from the Center for assistance with special projects and attend Center management meetings.

Funds for postdoctoral scholars are requested for each participating PI at UCSF. This represents funds for either a graduate student and tuition, or for a postdoc. Given that greatest needs for strengthening diversity in URM representation is for postdoc positions, we have used postdoc salary and fringe benefits.

Jessica Allen, (Education Component, SEP) (salary requested at 6.6 calendar months) will help coordinate course planning between Education Coordinator and leads, faculty students, postdocs and staff in partner institutions.

Solange Arbesu-Salas, Admin Ass't 3, (Education Component, SEP) (salary requested at 0.3 calendar months) to provide logistics and operations support for courses in development.

Luz Marin, Research Admin 3, (Education Component, SEP) (salary requested at 0.3 calendar months) to manage stipend payments for students, TAs and provide financial coordination between partner institutions for implementation of summer course and other special educational initiatives in collaboration with all partner organizations.

TBN, Postdoctoral Scholar (Marshall Lab) (salary requested at 9.0 calendar months per year) will work on the CellCAD project, in particular developing and testing mathematical models for organelle size regulation, and will participate in student-teacher workshops and outreach activities.

TBN, Postdoctoral Scholar (Marshall Lab) (salary requested at 9.0 calendar months) will work on the Living Bioreactor project, with a focus on engineering the flagellar axoneme as a protein nanoarray, and will participate in student-teacher workshops and outreach activities.

TBN, Postdoctoral Scholar (Gartner Lab) (salary requested at 9.0 calendar months) will work on development of interchangeable orthogonal cell adhesions systems for the Cellular Lego theme.

TBN, Postdoctoral Scholar (Gartner Lab) (salary requested at 9.0 calendar months) will work on methods for probing cell state at a molecular level as part of the CellProbe theme.

TBN, Postdoctoral Scholar (Lim Lab) (salary requested at 9.0 calendar months) will work on developing synthetic organelle and adhesion systems for the Cellular Lego theme.

TBN, Postdoctoral Scholar (Dumont Lab) (salary requested at 9.0 calendar months) will work on implementing methods for probing mechanical forces inside spindles in living cells as part of the Cell Probe theme.

TBN, Postdoctoral Scholar (El-Samad Lab) (salary requested at 9.0 calendar months) will work on algorithms for harnessing coarse grained models as design tools for the CellCAD theme.

TBN, Postdoctoral Scholar (Fung Lab) (salary requested at 9.0 calendar months) will work on live cell imaging and image analysis as part of the Cell Probe and Living Bioreactor themes.

TBN, Postdoctoral Scholar (Weiner Lab) (salary requested at 9.0 calendar months) will develop optical methods for controlling and lysing cells as part of the Living Bioreactor theme.

TBN, Graduate Student (Education Component) (salary requested at 6.0 calendar months) will assist with undergraduate/graduate courses and help organize and run teacher-student workshops, including developing experimental projects.

Ashwini Oke- Fung lab, Data Specialist (salary requested at 12.0 calendar months) will establish center-wide protocols for information management, and will act as liaison between individual labs collecting microscopy data and the microscopy facilities at UCSF and SFSU, as well as with industrial experts at IBM, with the primary responsibility of guiding Center researchers and trainees in modern approaches for image analysis.

C. FRINGE BENEFITS

Fringe Benefits: *Effective October 15, 2019 in preparation for the introduction of UCPath (a new University-wide payroll system) the Composite Benefit Rates (CBR) are being applied to proposal budgets. Benefits supported include retirement, payroll taxes and assessments, and health & welfare. CBRs are an average of all eligible benefits applicable to a benefits group. Employees are assigned to a benefits group based on job code and benefits eligibility. The composite benefit rate equals the total cost of benefits for the group divided by the total salaries for the group. See Rates website (https://brm.ucsf.edu/cbr/rates) for a breakdown of groups and their respective rates. The CBRs escalate July 1, 2020 and are prorated to conform to the grant year of this project.*

Note: This campus implements a Faculty Family-Friendly policy to provide faculty a childbearing and childrearing leave benefit, which are assessed separately (see Benefits Supported website: https://brm.ucsf.edu/cbr/overview). The assessment rate is 1.25% of requested salary for faculty in addition to the CBR.

D. EQUIPMENT N/A

E. TRAVEL

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, the annual Metabolic Engineering conference, and conferences related to ELSI fields, such as the annual symposium of the National Science Policy Network. Funds will cover meeting registration, lodging, and domestic economy flights. Center members whose travel is paid by these funds will be required to present their work and contribute to knowledge dissemination.

Travel also includes costs for 4-5 leads to attend required Annual STC Directors Meetings, and for Center advisors to travel to San Francisco for our Annual External Advisory Committee (EAC) meeting.

F. PARTICIPANT SUPPORT COSTS

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 workshops, until that program attains financial independence, and for Teaching Assistants and students for the CCC Summer Course.

Other Participant Expenses: reagents and equipment for workshops and undergrad and graduate courses.

G. OTHER DIRECT COSTS

G.1. 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 will be used specifically and exclusively for the projects of the Center. Costs per lab are based on historical needs.

Shared Resource CORE Supplies and Services: We 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, computing, and DNA synthesis.

Immunology Core: We request funds for custom production of monoclonal antibodies and nanobodies as part of the effort to develop a toolkit of orthogonal antibody-based cell linkers for the Cellular Lego theme.

Microscopy - Nikon Imaging Center All research and educational components of the Center will require microscopy. We will leverage the existing Nikon Imaging Center at UCSF, and use microscopy instruments available to the Center at the Gladstone Institute.

G.2. PUBLICATIONS Each UCSF lab has been apportioned $10,000 total for publication costs.

G.3. SUBAWARDS See Detailed Budgets following this budget justification.

Board of Trustee Leland Stanford Junior College – PI: Sindy Tang	$449,400
Exploratorium	$759,040
IBM Almaden Research Center	$2, 896,160

San Francisco State University	$1,727,720
Stanford University School of Medicine – PI: Manu Prakash	$449,400
University of California Berkeley – PI: Dueber	$449,400
University of California Berkeley – PI: Fletcher	$449,400

G.4. OTHER

Seed Funds: We are setting aside seed funds for two specific strategic purposes. First, as part of our overall knowledge transfer strategy, we will provide seed funding to develop key findings or insights that derive from Center funded research to the stage that they would be competitive for outside support for commercialization from such sources as the Catalyst Program. We are also setting aside further seed funds to support small research projects related to Center themes, that will be made available not only to Center faculty to develop new ideas but also to non-Center faculty as a way to bring them into the center and expand our intellectual footprint.

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.

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.

Meeting and Symposium Costs: Funds are requested for center-wide quarterly meetings and a 2-day annual retreat for face to face coordination among all Center participants. Our meetings give time for PI meetings, working group collaborations, mentoring sessions and full group presentations on research, education, diversity and KT initiatives. We have estimated costs based on our Center's meetings since 2016, held at the UCSF Mission Bay campus or using SFSU facilities and other affordable locations in SF or nearby in the Bay Area. Expenses include facility rental, AV assistance, catering for full day meetings, and other meeting support. These funds also support yearly NSF Site Visit expenses. Meeting funds have been reduced in years 9 and 10.

Special programming including science communication workshops and symposia with outside speakers may be supplemented by annual Strategic Reserve funds.

H. 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 Nov. 27, 2017.

This project will be located on campus and charged the 61.5% 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. Additionally, the total amount of subawards to other UC campuses are excluded.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Children's Hospital at Stanford

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	**2,137**	
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	**2,137**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**15,714**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**11,028**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**28,879**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**5,005**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**33,884**	
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. INTERNATIONAL				**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				**18,848**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**12,110**	
TOTAL OTHER DIRECT COSTS				**30,958**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**67,842**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 55733)**					
TOTAL INDIRECT COSTS (F&A)				**32,158**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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 2

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

ORGANIZATION
Children's Hospital at Stanford

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	**2,201**	
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	**2,201**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**16,186**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**11,358**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**29,745**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**5,155**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**34,900**	
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. INTERNATIONAL				**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				**17,832**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**12,110**	
TOTAL OTHER DIRECT COSTS				**29,942**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**67,842**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 55733)**					
TOTAL INDIRECT COSTS (F&A)				**32,158**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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
Children's Hospital at Stanford

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	**2,267**	
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	**2,267**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**16,671**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**11,699**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,637**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**5,310**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**35,947**	
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. INTERNATIONAL				**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				**16,785**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**12,110**	
TOTAL OTHER DIRECT COSTS				**28,895**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**67,842**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 55733)**					
TOTAL INDIRECT COSTS (F&A)				**32,158**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
Children's Hospital at Stanford

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	**2,335**	
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	**2,335**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**17,171**	
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)				**19,506**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**4,855**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**24,361**	
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. INTERNATIONAL				**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				**25,271**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**25,271**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**52,632**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 52631)**					
TOTAL INDIRECT COSTS (F&A)				**30,368**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**83,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**83,000**	

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

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Sharon Louie

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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
Children's Hospital at Stanford

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	**2,406**	
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	**2,406**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**17,687**	
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)				**20,093**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**5,001**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**25,094**	
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. INTERNATIONAL				**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				**14,011**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**14,011**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**42,105**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 42105)**					
TOTAL INDIRECT COSTS (F&A)				**24,295**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**66,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**66,400**	

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

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Sharon Louie

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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

Cumulative

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

ORGANIZATION
Children's Hospital at Stanford

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	**11,346**	
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	**11,346**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**5**) POST DOCTORAL SCHOLARS	15.00	0.00	0.00	**83,429**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**3**) GRADUATE STUDENTS				**34,085**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**128,860**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**25,326**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**154,186**	
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. INTERNATIONAL				**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				**92,747**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**36,330**	
TOTAL OTHER DIRECT COSTS				**129,077**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**298,263**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**151,137**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**449,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**449,400**	

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

PI/PD NAME
Manu Prakash

ORG. REP. NAME*
Sharon Louie

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

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

STANFORD UNIVERSITY BUDGET JUSTIFICATION

INTRODUCTION
This budget was constructed for the 5 years period 10/01/21 through 09/30/26.

The indirect cost and benefit rates used are those most recently negotiated with the Office of Naval Research and are the rates appropriate for the time frame proposed.

For each subsequent year, an increase of 1.03% was assumed for salaries and a 4% inflation rate was assumed for tuition. All effort and expenses charged to this project will be for services specific to the project and not for the general support of the academic activity of the faculty or department.

A.**PERSONNEL**
Manu Prakash, Ph.D., Principal Investigator (effort = 0.12 calendar months). Prof. Prakash will be responsible for the overall coordination and supervision of all aspects of the study. This includes hiring, training, and supervising staff/students; recruiting study participants; coordinating treatment and assessment components; scheduling and staff assignments; and data management. In addition, he will conduct the orientation sessions, assist with statistical analyses, and be responsible for reporting the study's findings.

B.**OTHER PERSONNEL**
TBA Post Doctoral Associate (effort = 3 Calendar Months effort). This individual will be responsible for day to day experiments and data analysis. The team members will regularly participate and share results at team wide meeting at UCSF.

TBA Research Assistant (effort = 1.5 Calendar Months). This individual will be responsible for day to day experiments and data analysis. The team members will regularly participate and share results at team wide meeting at UCSF.

C. **Fringe Benefits**

UFY 2020 & following

Faculty and Staff:	29.2%	
Postdoc:	24.3%	
Graduate Students:	5.1%	(health insurance subsidy)

The budgeted salary amount is comprised of the direct effort for the project plus 8.70% vacation accrual/disability sick leave (DSL) for exempt and non-exempt employees. These amounts do not exceed total salary. The vacation accrual/DSL rates will be charged at the time of the salary expenditure. No net salary will be charged when the employee is on vacation, disability or worker's compensation.

D. **EQUIPMENT –** None

E. **TRAVEL** - $3000/yr is requested. We are requesting travel funds for the PI, postdoc and grad student to attend required and relevant scientific meetings and conferences. The exact conferences and locations have not yet been determined.

F. **PARTICIPANT /TRAINEE SUPPORT COSTS** - None

G. **OTHER DIRECT COSTS**

G.1 Materials and Supplies
General research supplies - Research supplies are calculated at approximately $18,848; $17,832;$16,785;
$25,271and $14,011 for the 5 years respectively.

Funding will also be used for chemical reagents, general supplies and computer peripherals such as: software, data memory storage, computer peripherals, and conference posters

G.2 Publication – N/A

G.3 Consultant Services – N/A

G.4 Computer Services – N/A

G.5 Sub awards – N/A

G.6 Other – Graduate Student Tuition

Stanford University charges tuition directly for Graduate Student Research Assistants working on sponsored projects. Therefore, we have budgeted for tuition for the research assistant's salary. The escalation factor is 4% for the years that follow.

H. **DIRECT COST -** $298,263 for five years

I.**INDIRECT COSTS -** $151,137 for five years

Assessed on "Modified Total Direct Costs":
Stanford University's current negotiated indirect cost rate for a research project of this nature is 57.7% for FY20 and following. This rate will be charged to the modified total direct cost base, which excludes tuition.

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 - Co-Investigator**	1.80	0.00	0.00	**19,161**	
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)	1.80	0.00	0.00	**19,161**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**9**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.08	0.00	0.00	**54,673**	
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)				**73,834**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,381**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**93,215**	
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. INTERNATIONAL				**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				**21,391**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,391**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**114,606**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0600, Base: 114606)**					
TOTAL INDIRECT COSTS (F&A)				**65,394**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**180,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**180,000**	

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

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Sharon Louie

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INDIRECT COST RATE VERIFICATION		
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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
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 - Co-Investigator**	1.80	0.00	0.00	**19,737**	
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)	1.80	0.00	0.00	**19,737**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**9**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.08	0.00	0.00	**54,097**	
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)				**73,834**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,381**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**93,215**	
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. INTERNATIONAL				**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				**21,391**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,391**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**114,606**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0600, Base: 114606)**					
TOTAL INDIRECT COSTS (F&A)				**65,394**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**180,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**180,000**	

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

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Sharon Louie

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 ***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 - Co-Investigator**	1.80	0.00	0.00	**20,328**	
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)	1.80	0.00	0.00	**20,328**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**9**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.08	0.00	0.00	**52,727**	
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)				**73,055**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,177**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**92,232**	
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. INTERNATIONAL				**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				**9,640**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**9,640**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**101,872**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0600, Base: 101872)**					
TOTAL INDIRECT COSTS (F&A)				**58,128**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**160,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**160,000**	

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

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Sharon Louie

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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 - Co-Investigator**	1.80	0.00	0.00	**20,938**	
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)	1.80	0.00	0.00	**20,938**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**7**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.28	0.00	0.00	**38,755**	
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)				**59,693**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**15,669**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**75,362**	
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. INTERNATIONAL				**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				**9,191**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**9,191**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**84,553**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0600, Base: 84553)**					
TOTAL INDIRECT COSTS (F&A)				**48,246**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**132,799**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**132,799**	

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

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Sharon Louie

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INDIRECT COST RATE VERIFICATION		
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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
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 - Co-Investigator**	1.10	0.00	0.00	**13,275**	
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)	1.10	0.00	0.00	**13,275**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**7**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.04	0.00	0.00	**34,050**	
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)				**47,325**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**12,423**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**59,748**	
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. INTERNATIONAL				**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				**4,895**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**4,895**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**67,643**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.0600, Base: 67643)**					
TOTAL INDIRECT COSTS (F&A)				**38,597**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**106,240**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**106,240**	

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

PI/PD NAME
Jennifer Frazier

ORG. REP. NAME*
Sharon Louie

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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

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 - Co-Investigator**	8.30	0.00	0.00	**93,439**	
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)	8.30	0.00	0.00	**93,439**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**41**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	31.56	0.00	0.00	**234,302**	
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)				**327,741**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**86,031**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**413,772**	
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. INTERNATIONAL				**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				**66,508**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**66,508**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**483,280**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**275,759**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**759,039**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**759,039**	

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

PI/PD NAME: **Jennifer Frazier**

ORG. REP. NAME*: **Sharon Louie**

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Date Checked	Date Of Rate Sheet	Initials - ORG

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

NSF Proposal

Center for Cellular Construction

October 1, 2021 – September 30, 2026

Budget Justification

Exploratorium, San Francisco, CA

A. Senior Personnel

Jennifer Frazier, Co-Principal Investigator (8.4 calendar months) 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** (6. 0 calendar months) will communicate with staff, consultants, advisors, and partners on budget, reporting, and overall administration of the grant. The **Program Evaluator, Joyce Ma** (6.0 calendar months) will coordinate the data collection and qualitative and quantitative coding for formative evaluation and work with other Center evaluators. A **Production Coordinator** (6.0 calendar months) will coordinate public programming. The **Exhibit Developer**, **Denise King** (5.4 calendar months) will be responsible for designing and fabricating exhibits in collaboration with the student interns. The **Bio Lab Manager, Dana Carrison-Stone** (3.0 calendar months) will train student interns in lab methods and coordinate development of demonstrations. A **Lab Tech** (3.0 calendar months) will maintain specimens used in the exhibits and demonstrations. The **Writer-Editor, Kevin Boyd** (1.1 calendar months) will write and edit virtual copy to incorporate into exhibits and programs. A **Graphic Designer** (1.1 calendar months) will create exhibit labels to incorporate into the exhibits and programs.

C. Fringe Benefits

Employee fringe benefits are calculated at an estimated 26.25% of salaries. The rate includes benefits such as, FICA, 403b Retirement, and the following insurance: Health, Dental, Unemployment, Disability, Workers' Compensation and LTD**.**

D. Equipment

E. Travel

$3,000 will be used to travel to a conference in Year 5 to disseminate lessons learned from the outreach work in the CCC.

G. Other Direct Costs

$65,815 will be used for Production Materials and Supplies needed to build exhibits and produce public programs, such as microscopes, corian, signage, and fabrication materials.

I. Indirect Costs

The Exploratorium's FY20 provisional rate has been approved by NSF at 57.06% 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 - Research Staff Member**	1.41	0.00	0.00	**21,070**	
2. **Thomas Zimmerman - Research Staff Member**	2.81	0.00	0.00	**42,140**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	4.22	0.00	0.00	**63,210**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	14.40	0.00	0.00	**155,296**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.60	0.00	0.00	**188,777**	
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)				**407,283**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**407,283**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**14,079**	
2. INTERNATIONAL				**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				**2,135**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**32,097**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**34,232**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**455,594**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 42.6710, Base: 455594)**					
TOTAL INDIRECT COSTS (F&A)				**194,407**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**650,001**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**650,001**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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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 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 - Research Staff Member**	1.15	0.00	0.00	**17,814**	
2. **Thomas Zimmerman - Research Staff Member**	2.31	0.00	0.00	**35,628**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	3.46	0.00	0.00	**53,442**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	14.40	0.00	0.00	**161,197**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.60	0.00	0.00	**194,379**	
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)				**409,018**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**409,018**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**14,079**	
2. INTERNATIONAL				**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				**2,182**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**32,803**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**34,985**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**458,082**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 41.8960, Base: 458082)**					
TOTAL INDIRECT COSTS (F&A)				**191,918**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**650,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**650,000**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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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 - Research Staff Member**	0.79	0.00	0.00	**12,466**	
2. **Thomas Zimmerman - Research Staff Member**	1.58	0.00	0.00	**24,931**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	2.37	0.00	0.00	**37,397**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	14.40	0.00	0.00	**167,322**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.60	0.00	0.00	**199,127**	
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)				**403,846**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**403,846**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**14,079**	
2. INTERNATIONAL				**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				**2,230**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**33,525**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**35,755**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**453,680**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 41.0680, Base: 453680)**					
TOTAL INDIRECT COSTS (F&A)				**186,317**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**639,997**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**639,997**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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 ***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 - Research Staff Member**	0.00	0.00	0.00	**9,547**	
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	**9,547**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**146,614**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	11.70	0.00	0.00	**186,565**	
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)				**342,726**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**342,726**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**8,586**	
2. INTERNATIONAL				**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				**0**	
3. CONSULTANT SERVICES				**23,821**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**23,821**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**375,133**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 41.6030, Base: 375133)**					
TOTAL INDIRECT COSTS (F&A)				**156,067**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**531,200**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**531,200**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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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
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 - Research Staff Member**	0.60	0.00	0.00	**9,958**	
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)	0.60	0.00	0.00	**9,958**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**152,185**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.75	0.00	0.00	**112,096**	
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)				**274,239**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**274,239**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**8,586**	
2. INTERNATIONAL				**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				**0**	
3. CONSULTANT SERVICES				**24,345**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**24,345**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**307,170**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 38.3460, Base: 307170)**					
TOTAL INDIRECT COSTS (F&A)				**117,787**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**424,957**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**424,957**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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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

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 - Research Staff Member**	3.95	0.00	0.00	**70,855**	
2. **Thomas Zimmerman - Research Staff Member**	6.70	0.00	0.00	**102,699**	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	10.65	0.00	0.00	**173,554**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**10**) POST DOCTORAL SCHOLARS	67.20	0.00	0.00	**782,614**	
2. (**10**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	56.25	0.00	0.00	**880,944**	
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)				**1,837,112**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**1,837,112**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**59,409**	
2. INTERNATIONAL				**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				**6,547**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**146,591**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**153,138**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,049,659**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**846,496**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,896,155**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**2,896,155**	

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

PI/PD NAME
Simone Bianco

ORG. REP. NAME*
Sharon Louie

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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 UCSF Request for Renewal Proposal

NSF Center for Cellular Construction

Cover Sheet	
Solicitation number;	Renewal
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 - $2,896,160
DUNS number	183717651

IBM is proposing five (5) 12-month periods for a total cost of $2,896,160. The start date is assumed to be 10/1/2021.

Cost Summary	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Direct Labor						
Regular Labor	$251,987	$247,821	$236,524	$196,112	$122,055	$1,054,500
Non Reg Labor	$155,296	$161,197	$167,322	$146,614	$152,185	$782,614
Total Direct Labor	**$407,283**	**$409,018**	**$403,847**	**$342,726**	**$274,239**	**$1,837,113**
Indirect Cost						
Total Indirect	**$194,406**	**$191,918**	**$186,320**	**$156,068**	**$117,790**	**$846,501**
Other Direct Cost						
Materials	$2,135	$2,182	$2,230	$0	$0	$6,547
Contracted Svcs	$32,097	$32,803	$33,525	$23,821	$24,345	$146,590
Travel	$14,079	$14,079	$14,079	$8,586	$8,586	$59,409
Total Other Direct	**$48,311**	**$49,064**	**$49,834**	**$32,407**	**$32,931**	**$212,546**
Total	**$650,000**	**$650,000**	**$640,000**	**$531,200**	**$424,960**	**$2,896,160**

IBM Research accounting system has been deemed adequate by the Defense Contract Audit Agency (DCAA). The provisional 2019 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 2023.89 hours per year. Non-Regular labor is based on 2115.92 hours per year.

IBM Labor Hours	Year 1	Year 2	Year 3	Year 4	Year 5
Regular Labor					
Simone Bianco	237	195	133	101	101
Thomas Zimmerman	474	390	266	0	0
Mark Kunitomi	2024	2024	2024	1876	1038
Project manager	101	101	101	101	101
Non-Regular Labor					
Sara Capponi	2116	2116	2116	2116	2116
Vito Paolo Pastore	423	423	423	0	0
Total	**5376**	**5248**	**5063**	**4195**	**3356**

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 $150 for round trip to the airport. Travel destinations and expenses are estimates based on current information at the time of pricing.

Annual Years 1-3 TRAVEL	# OF PEOPLE	# OF DAYS	AIR FARE	HOTEL & MEALS	PER DIEM MISC	TRANSP	OTHER	TOTAL	# OF TRIPS	TOTAL COST
San Jose to Hawaii, HI - Winter Quantitative biology conference										
Inputs/person	3	4	$346	$319	$10	$0	$1,050			
Calculation		12	$1,038	$3,828	$120	$450	$3,150	$8,586	1	$8,586
San Jose to Portland, OR - Conference on Applications of Dynamical Systems										
Inputs/person	3	5	$181	$223	$10	$0	$335			
Calculation		15	$543	$3,345	$150	$450	$1,005	$5,493	1	$5,493
								TOTAL ====>		**$14,079**

Annual Years 4-5 TRAVEL	# OF PEOPLE	# OF DAYS	AIR FARE	HOTEL & MEALS	PER DIEM MISC	TRANSP	OTHER	TOTAL	# OF TRIPS	TOTAL COST
San Jose to Hawaii, HI - Winter Quantitative biology conference										
Inputs/person	3	4	$346	$319	$10	$0	$1,050			
Calculation		12	$1,038	$3,828	$120	$450	$3,150	$8,586	1	$8,586
								TOTAL ====>		**$8,586**

Other Direct Costs

Contracted Service costs are estimated for Independent Audit and Cloud Services.

Contracted Services	Annual Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Independent Audit	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$60,000
	Rate/Mo @ 95%						
Softlayer Server	$1,560.83	$18,730	$18,730	$18,730	$9,365	$9,365	$74,920
Subtotal		**$30,730**	**$30,730**	**$30,730**	**$21,365**	**$21,365**	**$134,920**
Non Labor Inflation Rate (2.2%)		$1,367	$2,073	$2,795	$2,456	$2,980	$11,671
Total		**$32,097**	**$32,803**	**$33,525**	**$23,821**	**$24,345**	**$146,590**

IBM Budget Justification

Material Costs are itemized as follows:

Materials	Quantity	Unit Price	Year 1	Year 2	Year 3	Total
4292	42	$45.00	$630.00	$630.00	$630.00	$1,890
Arducam OV9281 MIPI 1MP Monochrome Global Shutter Camera Module with M12 Mount lens for Raspberry Pi 4/3B+/3 SKU:B0165	42	$41.99	$587.86	$587.86	$587.86	$1,764
Black	42	$25.75	$360.50	$360.50	$360.50	$1,082
Peristaltic Pump,Dosing Pump DC 6V DIY Peristaltic Liquid Pump Miniature Silent Peristaltic Pump Self-Priming Pump(No plug-6V Right Angle Black)	42	$14.69	$205.66	$205.66	$205.66	$617
Comgrow Creality Ender 3 Pro 3D Printer with Removable Build Surface Plate and UL Certified Power Supply 220x220x250mm	5	$259.99	$259.99	$259.99	$259.99	$780
Subtotal			**$2,044**	**$2,044**	**$2,044**	**$6,132**
Non Labor Inflation Rate (2.2%)			$91	$138	$186	$415
Total			**$2,135**	**$2,182**	**$2,230**	**$6,547**

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. **Laura Burrus - Faculty**	0.00	0.60	0.00	**9,530**	
2. **Mark Chan - Faculty**	0.00	0.60	0.00	**5,805**	
3. **Diana Chu - Faculty**	0.00	0.60	0.00	**7,844**	
4. **Wilfred Denetclaw - Faculty**	0.00	0.60	0.00	**6,583**	
5. **Ray Esquerra - Faculty**	0.00	0.60	0.00	**7,164**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.60	0.00	**6,700**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	3.60	0.00	**43,626**	
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. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**28,262**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**71,888**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**49,159**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**121,047**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **126,000**					
2. TRAVEL **15,000**					
3. SUBSISTENCE **0**					
4. OTHER **67,000**					
TOTAL NUMBER OF PARTICIPANTS (**6**) TOTAL PARTICIPANT COSTS				**208,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**329,047**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.0000, Base: 121047)**					
TOTAL INDIRECT COSTS (F&A)				**60,524**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**389,571**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**389,571**	

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

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Sharon Louie

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
Riggs, Blake - Faculty	0.00	0.60	0.00	6700

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. **Laura Burrus - Faculty**	0.00	0.60	0.00	**9,530**	
2. **Mark Chan - Faculty**	0.00	0.60	0.00	**5,805**	
3. **Diana Chu - Faculty**	0.00	0.60	0.00	**7,844**	
4. **Wilfred Denetclaw - Faculty**	0.00	0.60	0.00	**6,583**	
5. **Ray Esquerra - Faculty**	0.00	0.60	0.00	**7,164**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.60	0.00	**6,700**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	3.60	0.00	**43,626**	
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. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**28,262**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**71,888**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**49,159**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**121,047**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **126,000**					
2. TRAVEL **15,000**					
3. SUBSISTENCE **0**					
4. OTHER **67,000**					
TOTAL NUMBER OF PARTICIPANTS (**6**) TOTAL PARTICIPANT COSTS				**208,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**329,047**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.0000, Base: 121047)**					
TOTAL INDIRECT COSTS (F&A)				**60,524**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**389,571**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**389,571**	

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

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Sharon Louie

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
Riggs, Blake - Faculty	0.00	0.60	0.00	6700

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. **Laura Burrus - Faculty**	0.00	0.60	0.00	**9,530**	
2. **Mark Chan - Faculty**	0.00	0.60	0.00	**5,805**	
3. **Diana Chu - Faculty**	0.00	0.60	0.00	**7,844**	
4. **Wilfred Denetclaw - Faculty**	0.00	0.60	0.00	**6,583**	
5. **Ray Esquerra - Faculty**	0.00	0.60	0.00	**7,164**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.60	0.00	**6,700**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	3.60	0.00	**43,626**	
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. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**28,262**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**71,888**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**49,159**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**121,047**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **126,000**					
2. TRAVEL **9,000**					
3. SUBSISTENCE **0**					
4. OTHER **63,500**					
TOTAL NUMBER OF PARTICIPANTS (**6**) TOTAL PARTICIPANT COSTS				**198,500**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**319,547**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.0000, Base: 121047)**					
TOTAL INDIRECT COSTS (F&A)				**60,524**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**380,071**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**380,071**	

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

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Sharon Louie

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 3

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Riggs, Blake - Faculty	0.00	0.60	0.00	6700

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. **Laura Burrus - Faculty**	0.00	0.60	0.00	**9,530**	
2. **Mark Chan - Faculty**	0.00	0.60	0.00	**5,805**	
3. **Diana Chu - Faculty**	0.00	0.60	0.00	**7,844**	
4. **Wilfred Denetclaw - Faculty**	0.00	0.60	0.00	**6,583**	
5. **Ray Esquerra - Faculty**	0.00	0.60	0.00	**7,164**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.60	0.00	**6,700**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	3.60	0.00	**43,626**	
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. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**28,262**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**71,888**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**49,159**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**121,047**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **84,000**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **51,000**					
TOTAL NUMBER OF PARTICIPANTS (**4**) TOTAL PARTICIPANT COSTS				**135,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**256,047**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.0000, Base: 121047)**					
TOTAL INDIRECT COSTS (F&A)				**60,524**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**316,571**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**316,571**	

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

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Sharon Louie

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 4

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Riggs, Blake - Faculty	0.00	0.60	0.00	6700

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. **Laura Burrus - Faculty**	0.00	0.60	0.00	**9,530**	
2. **Mark Chan - Faculty**	0.00	0.60	0.00	**5,805**	
3. **Diana Chu - Faculty**	0.00	0.60	0.00	**7,844**	
4. **Wilfred Denetclaw - Faculty**	0.00	0.60	0.00	**6,583**	
5. **Ray Esquerra - Faculty**	0.00	0.60	0.00	**7,164**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.60	0.00	**6,700**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	3.60	0.00	**43,626**	
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. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**28,262**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**71,888**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**49,159**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**121,047**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **42,000**					
2. TRAVEL **6,000**					
3. SUBSISTENCE **0**					
4. OTHER **23,000**					
TOTAL NUMBER OF PARTICIPANTS (**2**) TOTAL PARTICIPANT COSTS				**71,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**192,047**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 50.0000, Base: 121047)**					
TOTAL INDIRECT COSTS (F&A)				**60,524**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**252,571**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**252,571**	

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

PI/PD NAME
Frank Bayliss

ORG. REP. NAME*
Sharon Louie

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 5

Other Senior Personnel

Name - Title	Cal	Acad	Sumr	Funds Requested
Riggs, Blake - Faculty	0.00	0.60	0.00	6700

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. **Laura Burrus - Faculty**	0.00	3.00	0.00	**47,650**	
2. **Mark Chan - Faculty**	0.00	3.00	0.00	**29,025**	
3. **Diana Chu - Faculty**	0.00	3.00	0.00	**39,220**	
4. **Wilfred Denetclaw - Faculty**	0.00	3.00	0.00	**32,915**	
5. **Ray Esquerra - Faculty**	0.00	3.00	0.00	**35,820**	
6. (**1**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	3.00	0.00	**33,500**	
7. (**6**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	18.00	0.00	**218,130**	
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. (**5**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**141,310**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**359,440**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**245,795**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**605,235**	
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. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **504,000**					
2. TRAVEL **45,000**					
3. SUBSISTENCE **0**					
4. OTHER **271,500**					
TOTAL NUMBER OF PARTICIPANTS (**24**) TOTAL PARTICIPANT COSTS				**820,500**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,425,735**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**302,620**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,728,355**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,728,355**	

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

PI/PD NAME: **Frank Bayliss**

ORG. REP. NAME*: **Sharon Louie**

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 NSF CCC Renewal 10/1/21 to 9/30/26

1) Funding is requested to provide one WTU RRT per semester (2 WTU/yr) for professors Laura Burrus, Mark Chan, Diana Chu, Wilfred Denetclaw, Ray Esquerra and Blake Riggs each academic year. Each faculty members lab is part of the CCC research enterprise and the release time is necessary to allow time to conduct CCC related research projects.
2) Support is requested to support a 0.5 time administrative staff person to support the faculty and to hire and support the six MS students supported by the CCC. This position is responsible for scheduling activities, tracking student progress and interacting with the leadership of the CCC at UCSF.
3) Support is requested for 6 full-time MS students who each receive $21,000 years 1-3 as well as in-state tuition and travel and supply funds. Year 4 supports 4 MS students and year 5 supports 2 MS students. This funding is at the established rate for all grant funded MS students.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Stanford 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	0.30	**5,291**	
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	0.30	**5,291**	
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				**36,588**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**41,879**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**3,411**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**45,290**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**1,171**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**23,577**	
TOTAL OTHER DIRECT COSTS				**24,748**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**72,038**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 48461)**					
TOTAL INDIRECT COSTS (F&A)				**27,962**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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 2

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

ORGANIZATION
Stanford 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	0.15	**2,725**	
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	0.15	**2,725**	
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				**37,686**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,411**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,718**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**43,129**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**2,734**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**24,520**	
TOTAL OTHER DIRECT COSTS				**27,254**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**72,383**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 47863)**					
TOTAL INDIRECT COSTS (F&A)				**27,617**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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INDIRECT COST RATE VERIFICATION		
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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
Stanford 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	0.15	**2,807**	
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	0.15	**2,807**	
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				**38,817**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**41,624**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,800**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**44,424**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**817**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**25,501**	
TOTAL OTHER DIRECT COSTS				**26,318**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**72,742**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 47241)**					
TOTAL INDIRECT COSTS (F&A)				**27,258**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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
Stanford 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	0.15	**2,891**	
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	0.15	**2,891**	
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				**27,987**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,878**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,271**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**33,149**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**5,711**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**18,564**	
TOTAL OTHER DIRECT COSTS				**24,275**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**59,424**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 40860)**					
TOTAL INDIRECT COSTS (F&A)				**23,576**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**83,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**83,000**	

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

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Sharon Louie

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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
Stanford 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	0.15	**2,978**	
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	0.15	**2,978**	
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				**20,590**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**23,568**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**1,920**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**25,488**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**5,872**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**13,791**	
TOTAL OTHER DIRECT COSTS				**19,663**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**47,151**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 57.7000, Base: 33360)**					
TOTAL INDIRECT COSTS (F&A)				**19,249**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**66,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**66,400**	

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

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Sharon Louie

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
Stanford 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	0.90	**16,692**	
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	0.90	**16,692**	
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				**161,668**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**178,360**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**13,120**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**191,480**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**10,000**	
2. INTERNATIONAL				**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				**16,305**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**105,953**	
TOTAL OTHER DIRECT COSTS				**122,258**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**323,738**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**125,662**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**449,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**449,400**	

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

PI/PD NAME
Sindy Tang

ORG. REP. NAME*
Sharon Louie

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

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

STANFORD UNIVERSITY BUDGET JUSTIFICATION
PI: Sindy Tang

This budget was constructed for the 5 year period 10/1/2021 through 9/30/2026.

The indirect cost and benefit rates used are those most recently negotiated with the Office of Naval Research and are the rates appropriate for the time frame proposed.

For each subsequent year, an increase of 3% was assumed for salaries and a 4% inflation rate was assumed for tuition. All effort and expenses charged to this project will be for services specific to the project and not for the general support of the academic activity of the faculty or department.

Stanford University's fiscal year runs from September 1st through August 31st. Calendar effort is committed during this same period for faculty and other senior personnel. For faculty on an academic appointment, effort committed can include effort during the academic year (October 1st through June 30) and/or during the summer (July 1st through September 30).

SENIOR PERSONNEL:
Sindy Tang, Professor and Co-Principal Investigator (10% / 0.3 summer months for year 1 and 5% / 0.15 summer months in years 2-5). Professor Tang will oversee all aspects of this study and supervise the graduate students working on this project. 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.

OTHER PERSONNEL:
TBN, Graduate Student (50% / 4.5 academic months for years 1-3, 35% / 3.15 academic months for year 4, and 25% / 2.25 academic months for year 5) - The graduate student will be responsible for designing, building and testing the proposed experiments and carrying out all research studies.

FRINGE BENEFITS: UFY 2020 & following

Faculty and Staff:	29.2%	
Graduate Students:	5.1%	(health insurance subsidy)

The budgeted salary amount is comprised of the direct effort for the project plus 8.7% vacation accrual/disability sick leave (DSL) for exempt and non-exempt employees. These amounts do not exceed total salary. The vacation accrual/DSL rates will be charged at the time of the salary expenditure. No net salary will be charged when the employee is on vacation, disability or worker's compensation.

TRAVEL: Funding is requested for domestic travel to disseminate results of research and to discuss future experiments: $2,000 a year is request for domestic travel for scientific conferences, workshops, and education outreach.

The estimates are based on prior Stanford Travel.

Round trip flight to east coast (eg, Boston): $500
Hotel for 2 nights at $250/night: $500
For PI and trainee (2 people). 1 meeting a year.
Total: $1000 x 2 = $2000

MATERIALS AND SUPPLIES- $16,305 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 to quantify cells as factories and as sensors for environmental changes.

GRADUATE STUDENT TUITION:
Stanford University charges tuition directly for Graduate Student Research Assistants working on sponsored projects. Therefore, we have budgeted for tuition for the research assistant's salary. The escalation factor is 4% for the years that follow.

INDIRECT COST RATES Assessed on "Modified Total Direct Costs":
Stanford University's current negotiated indirect cost rate for a research project of this nature is 57.7% for FY20 and following. This rate will be charged to the modified total direct cost base, which excludes tuition, subcontracts in excess of $25,000, and equipment costing more than $5,000 with a useful life in excess of one year.

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
John Dueber

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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,642**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**61,286**	
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. INTERNATIONAL				**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				**8,433**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**8,433**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**69,719**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 50052)**					
TOTAL INDIRECT COSTS (F&A)				**30,281**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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
John Dueber

ORG. REP. NAME*
Sharon Louie

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
John Dueber

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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**21,625**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,269**	
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. INTERNATIONAL				**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				**7,820**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**7,820**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,089**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 49439)**					
TOTAL INDIRECT COSTS (F&A)				**29,911**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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
John Dueber

ORG. REP. NAME*
Sharon Louie

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
UNIVERSITY OF CALIFORNIA, BERKELEY

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
John Dueber

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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**22,657**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**63,301**	
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. INTERNATIONAL				**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				**7,177**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**7,177**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,478**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 48797)**					
TOTAL INDIRECT COSTS (F&A)				**29,522**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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
John Dueber

ORG. REP. NAME*
Sharon Louie

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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
John Dueber

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. (**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				**30,483**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,483**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**23,498**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**53,981**	
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. INTERNATIONAL				**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				**6,314**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**6,314**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**60,295**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 37529)**					
TOTAL INDIRECT COSTS (F&A)				**22,705**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**83,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**83,000**	

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

PI/PD NAME
John Dueber

ORG. REP. NAME*
Sharon Louie

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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
UNIVERSITY OF CALIFORNIA, BERKELEY

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
John Dueber

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. (**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				**20,322**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**20,322**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**24,393**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**44,715**	
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. INTERNATIONAL				**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				**5,667**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,667**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**50,382**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 26476)**					
TOTAL INDIRECT COSTS (F&A)				**16,018**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**66,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**66,400**	

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

PI/PD NAME
John Dueber

ORG. REP. NAME*
Sharon Louie

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
John Dueber

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. (**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				**172,737**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**172,737**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**112,815**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**285,552**	
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. INTERNATIONAL				**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				**35,411**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**35,411**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**320,963**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**128,437**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**449,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**449,400**	

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

PI/PD NAME
John Dueber

ORG. REP. NAME*
Sharon Louie

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

Engineering increased protein cargo capacity into Saccharomyces cerevisiae peroxisomes

UC Berkeley PI: John Dueber

A. SENIOR PERSONNEL:

A.1. Principal Investigator: Professor Dueber, at the University of California at Berkeley, will be the Principal Investigator (PI) of this project and will provide overall direction and oversight of the research.

B. OTHER PERSONNEL:

B.1. Graduate Student Researcher (TBD): The GSR will assist the PI, as directed, in conducting research and contribute to the drafting and dissemination of results. The GSR will commit 4.5 academic months and 1.5 summer months in years 1 – 3, 4.5 academic months in year 4, 2.25 academic months and .75 summer months in year 5.

Both the PI and the graduate student will participate in the Center activities – i.e., annual retreat, student groups, NSF site visits, the educational summer course, etc.

Salaries are based on current actual salaries and are projected to include a 3% annual cost-of- living adjustment (and merit, if applicable) effective each year. For the purposes of determining NSF's 2-month annual effort limit on senior personnel compensation, UC Berkeley defines a "year" as the organization's fiscal year that spans from July 1 – June 30.

C. FRINGE BENEFITS:

The University of California, Berkeley Composite Fringe Benefit Rates (CFBR) have been reviewed and federally approved by the Department of Health and Human Services (DHHS) for use by all fund sources for FY20. Rates beyond June 30, 2020 are estimates and are provided for planning purposes only. Future CFBR rates are subject to review and approval by DHHS on an annual or bi-annual basis. Fringe benefits are assessed as a percentage of the respective employee's salary. The benefit rates are as follows:

	Approved	Projections for Planning Purposes ->			
CBR Rate Group	FY20	FY21	FY22	FY23	FY24
Academic	36.5%	36.5%	36.5%	36.5%	36.5%
Staff	45.5%	45.5%	45.5%	45.5%	45.5%
Limited	17.4%	17.4%	17.4%	17.4%	17.4%
Employees with No Benefit Eligibility	5.6%	5.6%	5.6%	5.6%	5.6%
Students	2.4%	2.4%	2.4%	2.4%	2.4%

For more information, please see: http://www.spo.berkeley.edu/policy/benefits/benefits.html

The University of California provides full remission of tuition, fees, and graduate student health insurance to all graduate students who are employed on-campus 45% time or greater during the academic year. The rate for in-state remission is $9,833.25 per semester, which is escalated annually in the budget at a rate of 5% per year. The rate for out-of-state remission is $17,384.25 per semester, which is escalated annually in the budget at a rate of 5% per year. Additional information regarding the fee remission program can be found at: http://grad.berkeley.edu/financial/fee-remissions/.

D. OTHER DIRECT COSTS:

D.1. Materials and Supplies: A total materials and supplies budget of $35,411($8,33 in year 1, $7,820 in year 2, $7,177 in year 3, $6,314 in year 4 and $5,667 in year 5) is

requested for materials and supplies required to conduct the research described in the Statement of Work.

E. INDIRECT COSTS:

Indirect costs are based on University negotiated rates with the cognizant federal authority and are applied at a rate of 57% for the period from 7/1/2019 – 6/30/2020; increasing to 59% from 7/1/2020 – 6/30/21; and increasing to 60.5% from 7/1/2021 – 6/30/22. Indirect costs are applied using the Modified Total Direct Cost (MTDC) formula, per rate agreement dated October 24, 2019. Modified total direct costs exclude equipment, capital expenditures, charges for patient care, student tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000. For more information, please see: http://www.spo.berkeley.edu/policy/fa.html. The rates after July 1, 2022 are provisional and subject to change based upon our updated federally negotiated indirect cost rate agreement.

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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,642**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**61,286**	
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. INTERNATIONAL				**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				**8,433**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**8,433**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**69,719**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 50052)**					
TOTAL INDIRECT COSTS (F&A)				**30,281**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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 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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**21,625**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,269**	
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. INTERNATIONAL				**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				**7,820**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**7,820**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,089**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 49439)**					
TOTAL INDIRECT COSTS (F&A)				**29,911**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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 ***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. (**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				**40,644**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,644**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**22,657**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**63,301**	
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. INTERNATIONAL				**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				**7,177**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**7,177**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,478**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 48797)**					
TOTAL INDIRECT COSTS (F&A)				**29,522**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**100,000**	
K. 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*
Sharon Louie

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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. (**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				**30,483**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,483**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**23,498**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**53,981**	
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. INTERNATIONAL				**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				**6,314**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**6,314**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**60,295**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 37529)**					
TOTAL INDIRECT COSTS (F&A)				**22,705**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**83,000**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**83,000**	

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

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Sharon Louie

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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
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. (**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				**20,322**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**20,322**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**24,393**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**44,715**	
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. INTERNATIONAL				**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				**5,667**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**5,667**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**50,382**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 60.5000, Base: 26476)**					
TOTAL INDIRECT COSTS (F&A)				**16,018**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**66,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**66,400**	

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

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Sharon Louie

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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
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. (**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				**172,737**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**172,737**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**112,815**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**285,552**	
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. INTERNATIONAL				**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				**35,411**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**35,411**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**320,963**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**128,437**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**449,400**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**449,400**	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME
Daniel Fletcher

ORG. REP. NAME*
Sharon Louie

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Date Checked	Date Of Rate Sheet	Initials - ORG

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

NSF Subaward Budget Justification

(Subaward from UCSF)

UC Berkeley PI: Daniel Fletcher, Ph.D.
Project Title: Center for Cellular Construction
Project Period: 10/01/2021 – 09/30/2026

A. SENIOR/KEY PERSONNEL:

A.1. **Co-Principal Investigator:** Daniel Fletcher, PhD (no salary requested). Dr. Fletcher will be responsible for guiding the project and oversight of the research. He will also be responsible for coordination with UCSF, participating in CCC activities, and ensuring that the project is carried out in compliance with all NSF and UC Berkeley rules and regulations.

B. OTHER PERSONNEL:

B.1. **Graduate Student Researcher:** To be named (effort = 4.5 / 1.5 calendar months per year in years 1-3; 4.5 calendar months in year 4; 2.25 / 0.75 calendar months in year 5). He/she will be responsible for carrying out the proposed research on engineering cell-cell interactions. He/she will also be responsible for participating in CCC activities and disseminating the results of this project through talks and publications.

Salaries are based on current actual salaries and are projected to include a 3% annual cost-of-living adjustment (and merit, if applicable) effective each year. GSR salaries are based on experience level.

For the purposes of determining NSF's 2-month annual effort limit on senior personnel compensation, UC Berkeley defines a "year" as the organization's fiscal year that spans from July 1 – June 30.

C. FRINGE BENEFITS:

The University of California, Berkeley Composite Fringe Benefit Rates (CFBR) have been reviewed and federally approved by the Department of Health and Human Services (DHHS) for use by all fund sources for FY20. Rates beyond June 30, 2020 are estimates and are provided for planning purposes only. Future CFBR rates are subject to review and approval by DHHS on an annual or bi-annual basis. Fringe benefits are assessed as a percentage of the respective employee's salary. The benefit rates are as follows:

	Approved	Projections for Planning Purposes ->			
CBR Rate Group	FY20	FY21	FY22	FY23	FY24
Academic	36.5%	36.5%	36.5%	36.5%	36.5%
Staff	45.5%	45.5%	45.5%	45.5%	45.5%
Limited	17.4%	17.4%	17.4%	17.4%	17.4%
Employees with No Benefit Eligibility	5.6%	5.6%	5.6%	5.6%	5.6%
Students	2.4%	2.4%	2.4%	2.4%	2.4%

For more information, please see: http://www.spo.berkeley.edu/policy/benefits/benefits.html

The University of California provides full remission of tuition, fees, and graduate student health insurance to all graduate students who are employed on-campus 45% time or greater during the academic year. The rate for in-state remission is $9,833.25 per semester, which is escalated annually in the budget at a rate of 5% per year. The rate for out-of-state remission is $17,384.25 per semester, which is escalated annually in the budget at a rate of 5% per year. Additional information regarding the fee remission program can be found at: http://grad.berkeley.edu/financial/fee-remissions/

D. OTHER DIRECT COSTS:

D.1. **Materials and Supplies:** A total materials and supplies budget of $35,411 ($8,433 in year 1, $7,820 in year 2, $7,177 in year 3, $6,314 in year 4 and $5,667 in year 5) is requested for the project. Funds are requested for cell culture reagents, laboratory disposables, and other costs related to pursuit of the project goals.

E. INDIRECT COSTS:

Indirect costs are based on University negotiated rates with the cognizant federal authority and are applied at a rate of 57% for the period from 7/1/2019 – 6/30/2020; increasing to 59% from 7/1/2020 – 6/30/21; and increasing to 60.5% from 7/1/2021 – 6/30/22. Indirect costs are applied using the Modified Total Direct Cost (MTDC) formula, per rate agreement dated October 24, 2019. Modified total direct costs exclude equipment, capital expenditures, charges for patient care, student tuition remission, rental costs of off-site facilities, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000.. The rates after July 1, 2022 are provisional and subject to change based upon our updated federally negotiated indirect cost rate agreement. For more information, please see: http://www.spo.berkeley.edu/policy/fa.html

WALLACE MARSHALL
Other Support- Current and Pending

Ongoing Research Support

R35 GM130327 (PI: Marshall) 02/01/19 – 01/31/24
NIH (NIGMS) Total award: $3,168,526 Effort: 6.0 calendar
Origins of Cell Geometry
The goal of this NIH R35 (MIRA) proposal is to use *Chlamydomonas* flagellar length control, yeast organelle size control, and whole-cell regeneration in Stentor to explore the fundamental "design rules" by which cells are able to build precise structures, a key open question in basic cell biology. The currently active R01 grant GM097017 will be ended this April and from that point on all NIGMS funded work in the Marshall lab will be supported by this single R35 MIRA grant.
Role on project: PI

DBI1548297 (PI: Marshall, Gartner) 10/01/16 – 09/30/22
NSF Total award: $24,000,000 Effort: 3.0 calendar
Center for Cellular Construction
The goal of this Science & Technology Center is to develop cell biology as an engineering discipline through a series of integrated research, education, outreach, and industrial knowledge transfer activities. Specifically, we are developing CAD software for re-designing the internal structure of cells and using this approach to develop novel cell-based applications including cross-species hybrid bioreactors for production of biofuels and other value chemicals. This is a multi-institutional Center that includes UCSF, San Francisco State University, UC Berkeley, Stanford, IBM Almaden Research Center and the Exploratorium. Funding supports eighteen research investigators plus a large educational program.
Role on project: Lead PI.

Pending Support

I2Cell (PI: Marshall) 10/1/19 – 09/30/22
Fondation Fourmentin-Guilbert Total award: $281,921 Effort: 0.5 calendar
The Cell as a Finite State Machine
The goal of this project is to apply concepts from theoretical computer science to understand cell motility, by inferring finite-state machine models for the walking gait of Euplotes, a giant ciliate that walks using an array of cirri on its ventral surface.
Role on project: PI

P0541102 (PI: Suliana Manley) 02/01/20 – 01/31/23
Human Frontiers Science Program Total award: $300,000 Effort: 0.5 calendar
Maintenance, homeostasis and heredity of mitochondria and their genomes
The goal of this collaborative project is to learn how the network morphology and dynamics of mitochondria affect mitochondrial propagation and genome maintenance.
Role of project: co-investigator

9765058632 (PI: Marshall) 03/01/20 – 02/28/23
Gordon and Betty Moore Foundation Total award: $746,322 Effort 1.0 calendar
Stentor pyriformis: Developing a Cell Biological Model System to Uncover Molecular Pathways of Secondary Plastid Endosymbiosis

The goal of this project is to develop the symbiotic ciliate Stentor pyriformis as a novel model system in which to investigate symbiosis among unicellular organisms, by developing methods for transgenics and genomics in both the host cell (*Stentor pyriformis*) and the endosymbiotic green algae contained within it.
Role on project: PI

20191118 (PI: Tingting Xiang, UNC Charlotte) 03/01/20 – 02/28/23
Gordon and Betty More Foundation Total award: $ 396,366 Effort: 0.12 Calendar
Ciliates as a New Model for Marine Symbiosis
The goal of this project is to develop methods for analyzing symbiosis between the ciliate *Euplotes uncinatus* and the dinoflagellates *Symbiodinium*. The focus is on developing methods for high throughput phenotypic screening and RNAi perturbation of gene expression.
Role on project: co-investigator

MCB-1938102 (PI: Tang, Marshall) 01/01/20 – 12/31/22
NSF Total award: $228,207 Effort: 1.0 Calendar
Collaborative Research: Uncovering the Biophysical Mechanisms of Single-cell Wound-healing
The goal of this project is to determine the cellular mechanisms by which cells heal wounds in the plasma membrane, using the giant cell *Stentor* as a model system combined with novel microfluidic devices for creating wounds of defined size.
Role on project: co-PI

MCB- (PI: Marshall) 07/01/20 – 06/30/23
NSF Total award: $677,366 Effort: 1.0 Calendar
Quantitative Analysis of Single Cell Learning
The goal of this project is to analyze the ability of a single cell to show a simple form of learning, using the habituation response of *Stentor coeruleus*. The project will combine mathematical modeling, quantitative measurement of stimulus-response relations, and molecular analysis of signaling pathways underlying the learning process.
Role of project: PI

ZEV J. GARTNER
Other Support - Current and Pending

Ongoing Research Support

DBI-1548297 (PI: Marshall) 10/01/16—09/30/22
NSF Total award: $1,339,325 Effort: 1.2 calendar
(Gartner lab only)
Center for Cellular Construction *$24,0000 overall total*
The goal of this Science & Technology Center is to develop cell biology as an engineering discipline through a series of integrated research, education, outreach, and industrial knowledge transfer activities. Specifically, we are developing CAD software for re-designing the internal structure of cells and using this approach to develop novel cell-based applications including cross-species hybrid bioreactors for production of biofuels and other value chemicals. This is a multi-institutional Center that includes UCSF, San Francisco State University, UC Berkeley, Stanford, IBM Almaden Research Center and the Exploratorium. Funding supports eighteen research investigators plus a large educational program.
Role: Co-PI

1R01GM135462-01 (PI: Gartner) 9/20/19—06/30/23
NIH (NIGMS) Total Award: $1,273,877 Effort: 1.2 calendar
MULTIseq: multiplexing massively parallel single cell transcriptional analysis across time, space, and conditions
The major goals of this project is to develop new methods for encoding spatial, temporal, and perturbational information into single cells sequencing experiments using lipid-modified oligonucleotides.
Role: PI

U01-DK103147 (PI: Klein) 7/1/19-6/30/24
NIH/NIDDK Total Award: $107,535 Effort: 0.60 calendar
(Salary Support only)
Regulation of distinct pools of intestinal stem cells The major goal is to study how the interaction between signaling pathways regulates behavior of adult stem cells.
Role: Co-Investigator

Pending Support

1 U01 CA244109-01A1 (Gartner, PI) 02/2020-02/2025
NIH Natl Cancer Institute (NIH-NCI) 2.4 calendar
Understanding breast cancer progression as a defect in the mechanics of tissue self-organization
This proposal aims to provide a physical and molecular explanation for why some breast cancers progress and others do not. The major goals of the project include: (1) to identify the physical mechanism for how luminal epithelial cells push past myoepithelial cells to invade, and (2) to identify the molecular mechanism for how PIK3CA activation alters tissue self-organization during breast cancer progression.
Role: Co-PI

1R01DK126376-01 (Gartner, PI) 07/2020-06/2025
NIH-NIDDK 2.4 calendar
The physical and molecular mechanisms of intestinal villus morphogenesis and repair
The major goal of this is to (1) identify the physical mechanism of intestinal villus morphogenesis, and (2) identify the molecular mechanism of intestinal villus morphogenesis.
Role: Co-PI

Facilities, Equipment, and Other Resources

UCSF has an exceptional atmosphere for scientific collaboration and intellectual development and is committed to making its resources accessible to all Center members. Specialized shared resources include core facilities for high throughput DNA sequencing, FACS sorting, peptide synthesis, gene expression mapping, mass spectrometry. The **Center for Advanced Technology** contains high throughput instrumentation for sample preparation and liquid handling, next generation sequencing, array fabrication and analysis, spectrophotometric analysis, proteomics, antibody generation, cell analysis, and microscopy. This facility houses a Bioforce Nano eNabler providing micron resolution printing capabilities relevant to this project. The **CAT 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** uses modern robotic instrumentation for high-throughput biochemical and cell biology assays. The **Ab Core** generates recombinant antibody fragments and nanobodies for use in protein assays and imaging, and the CCC will leverage this resource to build antibody based linkers for cells. **QB3 computing cluster** is equipped with 4346 Xeon and Opteron cores and more than 20 Tb of storage. The **Teaching Laboratory**, a dedicated open-floorplan space with moveable lab benches, white boards, and lab equipment such as centrifuges and electrophoresis equipment. UCSF is also a center for cutting edge cryo-electron tomography for both molecular and cellular studies.

The CCC owns and operates as a shared facility a GE InCell 6000, housed at UCSF. The InCell 6000 is a high-end, automated microscopy imaging platform specifically designed for high-content imaging-based assays and screens. The InCell 6000 provides CCC researchers with the ability to rapidly analyze large numbers of constructs and parameter variations. A shared computational space in Genentech Hall at UCSF is designated for processing images. It includes a Dell Image Workstation containing the InCell Developer, Priism Fiji, ImageJ and Imaris software.

The UCSF **Science and Health Education Partnership (SEP)** is recognized for supporting of high quality science education for K-12 students. SEP's Resource Center houses more than 3,000 educational materials available to teachers, 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 by the CCC are posted on this website for national dissemination.

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, and the Electron Microscopy Facility (EMF). These resources are used not only for research purposes but also in support of the CCC Summer Course.

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.

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 have complete access to IBM Research spectrum of computational resources (IBM software suites, local server time, Accelerate Discovery Lab cluster time, wireless access, etc.)

UC Berkeley. 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 Data Management Coordinator will aid in managing all the datasets created by investigators working on each Project described in the Research Objectives. At the time that research is in progress, all CCC affiliates have access to the UCSF Box application that allows unlimited storage. After publication of each major paper, the Data Management Coordinator will work with each PI to assemble a dataset with full documentation linked to each publication. Data will be provided to a public repository such as Dryad that can be downloaded freely from the site. 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.

The CCC InCell image acquisition system is equipped with a 120 TB Synology Diskstation Raid 5 for storage of In Cell raw and processed image data.

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 Dryad. Dryad is an open-source, research data curation and publication platform. UCSF is a proud partner of Dryad and offers Dryad as a free service for all UCSF researchers to publish and archive their data. Researchers at other CCC institutions will have access to this service through affiliate status at UCSF. Datasets published in Dryad receive a citation and can be versioned at any time. Dryad is integrated with hundreds of journals and is an easy way to both publish data and comply with funder and publisher mandates. 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.

Curriculum Materials Sharing Plan

Lecture Bricks, Ethics Modules, and instructional modules from the High School Cellular Construction Workshop (refer to section c Education and Human Resource Development) will be disseminated through the Center's web site. Exhibits and demonstration projects developed at The Exploratorium will be disseminated through their extensive network of interactions with science museums around the world.

3D Printing Data Sharing

One of the advantage of rapid prototyping methods such as 3D printing is that the specification of the parts being printed can be shared in electronic form. Within the CCC we make extensive use of 3D printing to develop custom components for research and educational programs. We will make the .stl files for each 3D design publically and freely available via thingiverse.com.

Lab Data Archiving Plan

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 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 sections.

Software Distribution Plan

Our approach to software distribution and IP protection is discussed in Section e. Knowledge Transfer. In many cases this approach is based on free distribution of software source code. In these cases, we will distribute software through Github. In the specific case of Matlab programs, we will distribute the software through Matlab File Exchange, a free, publically accessible, portal for Matlab code.

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, this approach gives CCC postdocs a truly inter-disciplinary training that is extremely difficult to acquire under the normal one advisor - one postdoc mentoring model. Advising meetings are also 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 are 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 write the majority of publications associated with this proposal, guided by their respective advisor. All postdocs 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), UC Berkeley QB3-Berkeley Graduate and Postdoc Career Development, and Stanford University Office of Postdoctoral Affairs all offer 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 CCC at include Ethics and the Responsible Conduct of Science offered at all institutions. Postdocs will present their work once every two years to the entire CCC community at the weekly Research in Progress series, presented by students and postdocs, and at the annual CCC Retreat. Through local talks, presentations at national meetings, and presentation in lab meetings, the postdocs gain experience presenting their research that will benefit them in their 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 give 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 not only design and supervise the experimental projects used as the centerpiece of the course for hands-on learning, but they will present lectures within the course, 1-2 lectures per postdoc per course session. PIs 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.

Project Summary

Overview

The Center for Cellular Construction (CCC) is an NSF Science and Technology Center whose vision is to develop an engineering discipline based on cell biology that will allow us to design and build cells and tissues with specific three-dimensional structures. These structures will serve as living factories and parts for better and more sustainable products, materials, therapeutics, and devices to benefit humankind.

The long-term vision of the Center for Cellular Construction is to turn cell biology into an engineering discipline. In this vision of the future, we will routinely design, build, test, and deploy 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. We will realize this vision through four subgoals, including (i) building the tools and concepts to implement a full design-build-test cycle in cell biology; (ii) educating a new breed of scientist/engineer; (iii) broadening awareness and participation; and (iv) driving innovation through applications. 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 biological structure at the cell and tissue level. This will allow improved use of the interconnected pathways and processes operating in many cellular compartments, between many cell types, and 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 biophysical and biochemical principles that underlie cell biological phenomena. Success will rely on learning the core concepts and mastering the tools of self-organization. By learning how cells build themselves, the Center for Cellular Construction will develop the concepts and tools 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

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. The unique physics of biology at the spatial scale of the cell poses deep conceptual challenges for basic science. Cells are highly complex, exhibit emergent behaviors, and operate far from chemical equilibrium. Moreover, they also exhibit considerable cell-to-cell variability in molecular and morphological states. Thus, they can best be described as existing within an ensemble of molecular and structural states. While we acknowledge these as challenges, they also provide unique opportunities for innovation and motivate the development of new concepts and technologies. If we can learn to understand and 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).

Even though cells are the basic building blocks for life, we 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 or specify tissue structures? The question of how cells specify structures was identified as a key question for the new millennium (Kirschner, Gerhart and Mitchison, 2000) but has remained largely

unanswered, in part because it spans multiple scientific disciplines and spatial scales. To tackle this challenge the Center has assembled a team of experts from the multiple disciplines necessary to engineer cellular properties: physics, chemistry, engineering, computation, synthetic biology, and cell biology. The Center's research efforts will span the ***multiple spatial scales*** at which cells operate: organelle level, whole-cell level, and cell-collective level. Organelle scale research focuses on the pathways regulating organelle size and shape, and the relation of organelle geometry with biochemical function. 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. One intellectual merit of our approach is that basic research will be driven, at least in part, by potential real-world applications, providing a novel source of new ideas and target goals, while creating synergy between the research goals and broader impact goals.

Broader Impacts

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 an engineering discipline requires scientists from multiple fields working across multiple spatial scales. We are focusing on interdisciplinary training in cellular engineering through two innovative educational programs, both of which employ project-based learning in small teams as a way to train students in collaborative approaches. The CCC Summer Course is a two week research project-based course for undergraduate and graduate students, in which participants learn experimental and computational approaches of quantitative cell biology by working in small groups on novel research projects derived from CCC research. This approach leverages the proven efficacy of project-based learning to help students from different fields learn to work together and speak a common "language" of concepts and terms (Vale 2012) as well as the strength of learning biology in a team setting (Wright 2002). The other educational program is the High School Student/Teacher Cellular Engineering Workshop. This workshop is a two week immersive experience where teachers and their students co-learn engineering concepts in a biological context by learning how to build LEGO robots that emulate cell behavior. This workshop helps biology teachers integrate engineering concepts into their classrooms, while exposing technology-oriented students to the interesting problems that exist in cell biology. Part of the challenge to fostering cellular engineering as a field, is creating awareness among the general public that such a field even exists. To this end, the CCC is working with the Exploratorium, one of the world's leading science museums, to create exhibits and demonstrations that create awareness of the cell as a machine that can be engineered.

Developing methods for engineering the cell will not only provide new insights into the basic biology of cells, but has the potential to revolutionize biotechnology. The second broader impact area will be ***knowledge transfer with industry***. The IBM Almaden Research Center is a key research institution within the CCC, such that virtually all CCC activities are implemented as a partnership between academia and industry. This partnership will be complemented and extended by collaborations with other industrial partners, internships for Center trainees, and our early-stage internal seed funding for incubating research ideas with commercial potential within CCC labs until they reach the stage to pursue outside funding.

Developing a new interdisciplinary field will require the maximum possible diversity of viewpoints and backgrounds. Our third broader impact is to ***increase diversity and inclusivity in cellular engineering***, primarily at three levels: graduate and postdoc training, mentorship, and strengthening research infrastructure resources for faculty training minority students. During the first project period, we have forged a genuine collaboration between faculty at San Francisco State University and the large research-intensive institutions of the CCC. This collaboration has enabled students from SFSU to be fully included in Center activities, and we will further build on this collaboration in the next project period.

The **potential legacy and global impact** of the Center for Cell Construction will be nothing less than to spawn an entirely new branch of engineering. Success will have a national and global impact, particularly if the Center can disseminate the approach into an industrial setting.

4.a. Problem Description and Rationale for Center Approach

Cells represent the scale of organization at which life emerges from non-living matter. Although cells are sometimes viewed merely as amorphous bags of enzymes, cells have highly complex and intricate structures. Cells are full of internal compartments (organelles) that serve the role of reaction vessels, analogous to the reactors inside a chemical factory. Cells are bristling with sensors for both the external world and internal conditions, and these sensors feed into a network of control systems. Vessels, sensors, and control systems are arranged into specific structures that allow living cells to function as intelligent nanofactories. How can we harness the capabilities of the living cell for our own purposes? Much effort has gone into engineering the biochemistry of the cell, but the physical structure of the cell has mostly been ignored. We believe that this is a big mistake. In chemical engineering, the physical design of the factory is at least as important as the chemistry itself, and cannot be disregarded. We believe that the same is true of the cell.

The vision of the Center for Cellular Construction is to develop an engineering discipline that will allow us to design and build cells and tissue with specific and dynamic three-dimensional structures. These structures will serve as living factories and building blocks for better and more sustainable products, materials, and devices to benefit humankind. Our long-term goal is to contribute to the development of Cellular Engineering as an emerging engineering discipline in which the engineering medium is the structure of a living cell. This is a highly interdisciplinary goal that is far beyond the scope of what a research group, or even a set of independent research groups, can accomplish. Rather, it requires by its very nature a collaborative interaction between groups with distinct expertise and perspectives. Moreover, it will not be enough to focus purely on research-related goals to make the vision a reality. Because this interdisciplinary project crosses traditional academic boundaries between fields, it will be necessary to educate and train a new generation of highly diverse scientists and engineers who will bring a range of different perspectives and backgrounds together under the umbrella of "cellular engineering" in order to tackle this interdisciplinary goal. If we succeed in building such an intellectually rigorous and inclusive community, we believe that learning how to engineer cells and subcellular structures can have a large impact on solving real world problems, particularly in biotechnology. We further believe that a center based on engineering principles (as opposed to purely hypothesis-driven research) is the right way to maximize our impact. Indeed, we draw inspiration from the long tradition in engineering where fundamental research insights have been driven by the attempt to address real-world applications. The framework of the STC program allows us to integrate these activities via a highly connected network of collaborations.

During the first funding period (Phase 1), the CCC has established collaboration as the central mechanism for accelerating research progress, and has leveraged these collaborations to make major strides in learning how to manipulate and probe cell structure and function. Our progress to date has led us in several unexpected directions, most notably the pervasive role of machine learning as a core tool. During the next funding period (Phase 2), we will focus on integrating modeling and machine learning approaches for cell design with molecular methods for re-engineering cellular pathways and for probing cell state. As these approaches become increasingly standardized within the center, we will work to expand our footprint in academia and industry. Our educational program will build on approaches that we have developed during the first project period to produce a carefully documented program that will transition to independence over the next five years. In the context of knowledge transfer, we have designed a pipeline to take ideas from the lab to the real world by harnessing existing programs and providing support at key stages of translating ideas to startups, for which current support mechanisms do not exist.

4.b. Research Objectives of the Center

In the first project period (Phase 1) of the Center for Cellular Construction (CCC), we began efforts to engineer the structure of organelles, cells, and tissues as part of a broader effort to turn Cell Biology into an engineering discipline. Our research objectives had two main goals: to establish the tools, technologies, and basic science insights necessary to implement a design-build-test cycle; and to motivate our efforts with real world applications of our work. We pursued five research objectives: (i) develop the tools necessary for Cell Engineering (*Cellular Machine Shop*); (ii) develop the modeling and design tools necessary for Cell Engineering (*CellCad*); (iii) engineer subcellular structure to facilitate the production of real world products (*Cellular Bioreactor*); (iv) engineer multicellular structure to enable new applications of Cell Engineering (*Cell Legos);* and (v) to understand the relationship between cell structure and transcriptional state to allow inferences of microenvironment from morphology (*Cell State Inference*).

Moving into the second project period (Phase 2) of the Center, we propose to maintain the same goals of implementing a design/build/test cycle for engineering cell and tissue structure motivated by real world applications. Based on our experience and feedback from site visits, we propose to streamline our efforts and integrate our efforts more fully among projects. Motivating our decisions in terms of how to focus our efforts were the following questions: how can we integrate data types to understand how molecules determine structural *ensembles* at the cell and tissue level? What are the best platforms for subcellular engineering and what are the most fruitful applications of these platforms? Where can cell engineering at the multicellular level make an impact, both in the next decade and beyond? How can we move from inference to design when proposing to engineer a specific aspect of cell or tissue structure? How can we provide a more scientifically inclusive organization structure to Center research allowing all members to more fully contribute their expertise to our major goals?

In order to position ourselves to answer these questions, we have condensed our five original research objectives into four streamlined "themes." In theme 1, *CellProbes*, we develop experimental and analytical tools to control and measure structure, and place a new emphasis on linking the molecular and morphological states of a cell together. In theme 2, *Living Bioreactor,* we continue our efforts to engineer organelle structure, with a new emphasis on modifying the biochemistry of organelles such as peroxisomes as a new engineering chassis for a variety of applications. In theme 3, *Cell Legos*, we continue our efforts to understand and engineer multicellular self-organization with a focus on near and long-term applications of these technologies. In theme 4, *CellCad*, we aim to integrate information from all other themes to generate predictive models and design tools that will enable our long-term goal of building cell and tissue structures to meet the demands of specific applications. We now place a new emphasis on statistical models that accurately reflect the sometimes rapidly interconverting ensemble of structures observed in cell and tissue biology. Together, these research themes amplify the strengths of our research programs and have greater synergy. The reorganized structure emphasizes research directions that we find particularly important, deemphasizes research areas where we see less impact, and provides a more inclusive organization to the Center which will maximize collaboration.

Importantly, these revised research themes are highly synergistic. In the CellProbes theme we generate tools to enable the Living Bioreactor and Cellular Legos themes, and the massive data sets that provide the foundation to the data driven approach of the CellCad theme. The Living Bioreactor theme will provide data for CellCad, motivate the development of new tools in CellProbes, and provide control over the cellular structures that mediate interactions among cells in Cellular Legos. Efforts within the Cellular Legos theme will motivate the development of new tools relevant to CellProbe, the engineering of new subcellular structures in Living Bioreactors, and will develop new observations, data sets, and models for CellCad. Finally, the CellCad theme feeds off the data and models generated by the other themes.

Below, we summarize in broad strokes the proposed approaches to achieve our research objectives, noting that some projects leverage achievements from the first project period, while others will take CCC into

new territory. We also note that each of these research themes provides wide-ranging opportunities for integration with our other CCC activities, for example by generating project ideas for our projects-based CCC Summer Course.

1. CellProbe: Tools for probing and measuring cell state and structure

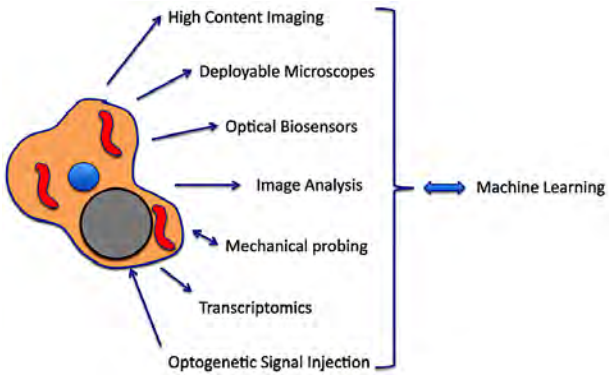

Figure 1. CellProbe develops the tools necessary to perturb, measure, and analyze cellular structure and function.

Vision: In order to engineer the structure of organelles, cells, and tissues, we must first understand how the molecular and mechanical state of the cell maps to its structure. This requires the development of new tools to image and quantify cell structure, as well as new tools to perturb and measure the molecular and mechanical state of cells and tissues (**Figure 1**). Using these tools, we aim to illuminate a mapping from molecular state to cell structure, as well as from cell structure back to molecular state. Completion of this work will allow forward design and engineering of cell structure (conducted in themes 2-4), as well as the potentially transformational ability to predict the internal molecular state of a cell from a snapshot of its structure.

Objective 1.1: Build and integrate tools to perturb the mechanical, morphological, and molecular state of cells and tissues. When cells are perturbed, they respond actively. This is true for mechanical, morphological, or molecular perturbations. Understanding how perturbations to cellular state affect their morphological response reveals the underlying physical and molecular regulatory mechanisms that determine cellular morphology. We will therefore continue to develop a comprehensive suite of perturbational tools that can be applied across the subcellular, cellular, and multicellular length scales. A first focus area will be molecular perturbations that can be controlled with high temporal and spatial precision using optogenetics. We have made tremendous strides in this area including optogenetic control of Ras and Rho GTPases (subcellular; Toettcher 2013), as well as immune cell synapse formation and gap junctional signaling (intercellular; Tischer 2019). We will continue to focus our efforts on tools that enable control of the mechanical machinery of the cell as well as organelle biogenesis. For example, linking optogenetic control of the cell leading edge (e.g. through Rac1) with optogenetic control of cortical contractility (e.g. through RhoA) would provide effective control over multiple aspects of cell structure and tissue self-organization. A second area of focus is on mechanical perturbations. We have made important strides applying mechanical perturbations to the cell surface using magnetic nanoparticles (Seo 2016), and to the mitotic spindle using calibrated microneedles (Suresh 2019). These same tools can now be applied at the cellular and tissue scales. We plan to couple these and other tools with methods to alter the morphological and mechanical microenvironment of cells, for example by defining their shape and substrate viscoelasticity on patterned polyacrylamide (or other materials) gels. These tools will provide unique insight into how cells measure their shape and mechanical microenvironment and couple it to their molecular state and organelle organization.

Objective 1.2: Build tools to measure cell state and structure. Critical for our efforts to engineer cell and tissue structure is the ability to quantitatively measure multiple aspects of cell/tissue state and structure. During the first phase of the CCC, center researchers made enormous strides in the integration of high content imaging with machine learning tools to extract quantitative morphological features of cells from microscopy images. We have used these data to inform efforts in all other major projects of the Center. Our future efforts will require continued development and optimization of these methods. A first area we will work to improve is the acquisition and analysis of high resolution, isotropic, *3D images* of cells and tissues. Quantitative analysis of these images remains a major challenge, and it must be solved

in an automated manner since virtually all of our planned experiments will need to be done in a high throughput fashion. However, the denoising, segmentation, and quantitative analysis of large high-throughput 3D data sets is an unsolved problem in the field. This challenge is one where we feel our combined expertise in microscopy, machine learning, and image analysis is already making a major impact (**Figure 2**). As an example, we will implement a robust pipeline for segmenting 3D confocal time-series images that involves machine-learning based automated image denoising and human-in-the-loop machine learning (Hughes 2018a). A second area where we will innovate is in new approaches for linking cell state with morphology at scale. We will build an experimental and analytical pipeline capable of capturing dynamic and high dimensional morphological measurements, then link these to transcriptional or epigenetic measurements. We propose to accomplish this using the InCell6000 high content imaging system, live cell reporters, and multiplexed single cell molecular analysis (e.g. scRNAseq, scATACseq, etc.). To enable highly multiplexed single cell measurements (across many genetic or chemical perturbations), we will implement the MULTIseq platform recently developed in the CCC (McGinnis 2019) in conjunction with the live imaging platform. Using this platform we will map the distribution of dynamical morphological behavior of the cells back to the specific epigenetic or transcriptional program that drives it. New tools developed by Center members will also provide means of localizing measured transcriptional states back to specific locations of a culture using high resolution tissue choppers and barcoding techniques.

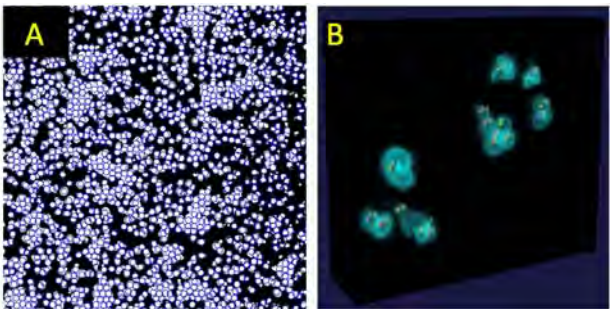

Figure 2. Examples of two image analysis tools developed in the CCC. (A) Fully automated segmentation of yeast cells using convolutional neural networks. (B) 3D recognition of complex organelle morphology in the yeast vacuole.

Objective 1.3: Generate large datasets linking perturbations to the molecular and morphological state of cells. The relationship between the molecular state of a cell and its structure is likely to be non-linear and is thus ideally suited to machine learning approaches such as those we are beginning to develop. Such approaches have the potential to provide a predictive engine for designing new cell and tissue structures. Machine learning approaches will require very large data sets linking quantitative metrics of a cell's molecular and morphological state. Generating these data sets will be enabled by Objectives 1.1. and 1.2 but, in this case, we will scale the tools created in the context of these objectives to generate massive data sets that will serve as raw material for data analytics. Working with specific cellular chassis (e.g. cell lines or yeast strains expressing multiple organelle markers), we will begin with libraries (knockout or promoter swap libraries for yeast, CRISPRi and CRISPRa libraries for mammalian cells) and grow single clones in multiwell plates. We will perform live imaging on plates using the InCell6000 and use machine learning pipelines to cluster single cells and conditions according to their morphological dynamics. We will subset these data to identify clones that deviate from controls, then barcode them using MULTIseq reagents for single cell RNAseq (McGinnis 2019). The resulting data will include matched single cell morphological dynamics and transcriptional states useful for CellCad.

Impact. This theme will build perturbational and analysis tools that will assist in our larger goal of understanding how the molecular state of a cell (which we can control directly) affects the morphology of a cell (which we can only control indirectly). We currently lack methods for generating this type of data, as well as analytical tools for processing and analyzing these data. This theme will generate the necessary tools and data. These will in turn facilitate the other CCC themes, and culminate in a one of kind data set to drive the "data-driven" processes proposed in the CellCad theme, while providing a new basic view into the multi-scale nature of the cell.

2. Living Bioreactor: Engineering cell structure to optimize cell function

Vision: The Living Bioreactor theme builds on the concept of a cell as a chemical factory. In a chemical factory, the structure of reaction vessels and pipelines are designed so as to optimize the synthesis of a specific chemical compound or process (e.g. distillation). In a cell, the structure of organelles has similarly evolved to optimize a subset of biochemical reactions or processes, but may not be optimal for others. If organelles can be engineered to have larger volumes or surface areas, this is predicted to allow them to store more intermediates, handle higher quantities of toxic intermediates (**Figure 3**), or support greater flux in and out of the compartment. Metabolic engineers do not currently emphasize the importance of cell or organelle structure in their design processes, and therefore are limited in the extent to which they can optimize production or processing of value chemicals. We will evaluate the extent to which organelle and cell structure can be designed and altered, and how the resulting structures optimize the production of useful chemicals, materials and useful cellular functions.

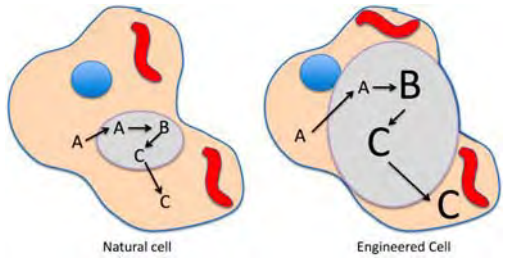

Figure 3. Living Bioreactor. Prior to organelle engineering, a cell produces a valuable product **C** via a rate limiting and toxic intermediate, **B**, which limits yield. Increasing organelle size allows more intermediate **B** to be stored, leading to increased production of **C**.

Objective 2.1: Engineering organelle structure. Reaction vessels, pipes, and storage containers in chemical factories are defined by their surface area, surface chemistry, and volume (among other properties). Analogously, we hypothesize that the organelles, transport pathways, and their surface chemistries are equally important for optimizing the production of useful products in synthetic biology. We will engineer organelle size and shape, together with their biochemical and mechanical properties, with the goal of turning organelles into highly flexible bioreactors for production of value compounds at levels far beyond what is currently achievable in existing cells.

In one area, we will engineer the peroxisome as a reactor for handling toxic biochemical reactions. The peroxisome is unique in several respects that make it ideal for such biochemical repurposing (DeLoache 2016). First, it is not essential for growth, meaning we can alter its structure and function without affecting cell viability and biomass production. Second, it can concentrate enzymes to near crystalline densities while sequestering the enzymes away from the cytoplasm, allowing toxic enzymes to be used without affecting cell viability. Third, peroxisomal membranes allow substrate and product molecules to enter and exit. In order to maximize the usefulness of the peroxisome, we will implement several engineering modifications. First, we will implement molecular systems to alter peroxisome size, drawing on comparative genomics studies in industrial yeast species that have extremely large peroxisomes, combined with knowledge of the organelle dynamics underlying peroxisome biogenesis. We anticipate that increasing the size of the peroxisome in budding yeast will greatly increase the biochemical capacity of reactions targeted to this organelle. To make the peroxisome a truly flexible platform for organelle engineering, other key goals will be to engineer a way to purify peroxisomes using scalable physical principles (bubble binding, bubble nucleation, precipitate inside of them, flocculation among two flavors of peroxisomes in two organisms, split calmodulin, etc.), and to alter and tune the internal chemical environment of the peroxisome, with respect to pH and redox state. With a view towards biotechnology applications, we propose to engineer fusion of peroxisomes with the plasma membrane, allowing their biochemical contents to be shed into the media.

In a second area, we will develop the axoneme (the protein core of cilia and flagella) as a self-assembling protein array. The organelle biogenesis of cilia and axonemes uses a combination of motors and chaperones that allows the system to assemble even hard to fold proteins in their functional form into linear arrays on the micron length scale. One important feature of flagella is that they protrude from the surface of the cell and can be easily induced to pop off simply by a transient drop in pH (Quarmby 2004).

This “self-shedding” property of flagella in green algae mean that the linear arrays can be cleanly isolated from the living cells in a single purification step with almost complete recovery of biomass. During the first project period, we identified axonemal proteins that can act as scaffolds to mediate incorporation of enzymes and biosensors into the axoneme (Ishikawa 2019). Moving forward, the CCC will focus on further developing this system for solving real world applications.

Objective 2.2: Engineering cell structure. Given a set of optimized pipes, reaction vessels, and storage depots, chemical engineers must design strategies to link these components together, or control their spatial arrangement, so as to optimize a complex chemical process. Similarly, cells must position their organelles appropriately so as to provide building blocks to the correct location, and at the correct time. We hypothesize that engineering the overall structure of the cell, together with organelles, will be dramatically enabling for synthetic biology applications. CCC researchers have found that cell size and membrane integrity are amenable to engineering as a way to overcome traditional limitations on harvesting cellular products. Improvements in harvesting and processing have proven critical to the success of modern agriculture (e.g. Calrose rice is easy to harvest and process, Flavr Savr tomatoes are easy to transport, etc.). Perhaps surprisingly, synthetic biologists have largely ignored isolation and processing as areas to engineer. During the current project period, we found that optogenetic relocalization of the budding machinery in yeast allows cells to grow many times their normal size, and that these enlarged yeast cells become remarkably sensitive to osmotic lysis. Lysis of fungal microbes is challenging, and is therefore a major contributor to the cost of high molecular weight or low permeability fermented products (e.g. polymers, proteins, charged/polar molecules, etc.). In the next project period we will develop an industrial yeast platform that will allow rapid induction of cell lysis using inexpensive input signals (several degrees of temperature or light).

Objective 2.3: Optimize cell function by engineering organelle and cell structure. Biotechnology and metabolic engineering attempts to improve or alter biochemical function of living cells to produce chemical products of value. As we begin to gain engineering control over cell and organelle structure, our goal is to enhance biochemical production by changing the physical structure of the cell, thus creating an analogy to reactor design in chemical engineering. We will therefore implement strains that combine novel enzyme pathways with mutations that alter organelle or cell morphology. In one area, we will continue to develop methods to increase bioproduction of methyl halides by engineering the yeast vacuole. Methyl halides are a class of industrial chemicals used as precursors for many organic reactions, including the production of silicone, quaternary amines, methyl cellulose, and butyl rubber. The U.S. produces roughly 500-1000 million pounds of methyl halides per year, mainly methyl chloride. Methyl chloride is produced through a toxic and corrosive reaction process requiring special containment, but these dangers can be circumvented by producing the chemical in yeast. When a bacterial halide methyl-transferase is targeted to the yeast vacuole, it results in production of methyl halides (Bayer 2009). Mutants that reduce vacuole size lead to a large drop in yield, suggesting that the vacuole plays a role, either in sequestering toxic intermediates or as a storage site for SAM, a key precursor substance. Based on data provided by Brenda Andrews (U of Toronto), CCC researchers have assembled a collection of mutants that alter vacuole shape, and quantified their effects on vacuole surface and volume (**Figure 4**). We will use these mutants to test the relation between vacuole geometry and biochemical output. In a second area, we will engineer peroxisomes to enable

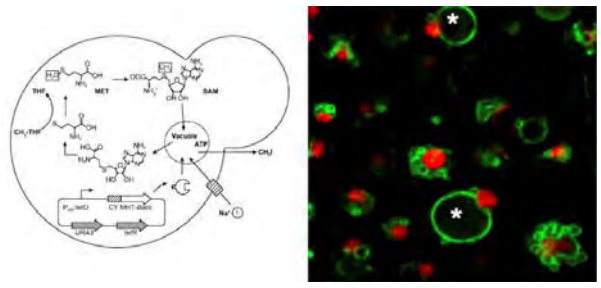

Figure 4. Improving methyl halide bioproduction by increasing vacuole size. Diagram illustrates synthetic pathway, with intermediates inside the vacuole. Image shows yeast fab1 mutant cells expressing a vacuole membrane marker (green). In this mutant, the vacuole becomes so large that the nucleus (red) is pushed to the side. Testing how such mutants affect biochemical output is a key goal of the Living Bioreactor theme.

compartmentalization of toxic enzymes while maintaining the ability to perform metabolism, and then test how alteration of peroxisome surface or volume affects biochemical output. Our initial experiments will focus on production of (S)-reticuline, a valuable product important for the synthesis of many alkaloids, but whose bioproduction is normally limited by toxic effects (Minami 2008). By combining engineered protein import systems with mutations to increase peroxisome size and number, we seek to vastly increase titer of the desired product.

Impact: We believe that by gaining full engineering control over the structure of organelles and of cells, we can harness the cell as a living chemical factory. At the same time, we will have gained an unprecedented level of understanding about the fundamental mechanisms that determine cellular structure, and the possible influence of this structure on endogenous biochemical pathways. Such an understanding could provide a key piece of missing information about the evolution of eukaryotic life by revealing how sub-cellular compartmentalization (a hallmark of eukaryotic cells) affects cell function.

3. Cellular Legos: Self-organizing multicellular structures

Vision: The variety of structures and functions available to multicellular organisms is vastly larger than that accessible to unicellular organisms. Multicellular organisms have evolved to execute more complex functions than are achievable by unicellular organisms because different cells can specialize to better perform subsets of a more complex task, for example, manufacturing different components of a more complex chemical product or material in different cell types. This process is analogous to supply chain management issues confronted by multinational corporations, where different components of a product are sourced from a variety of specialized factories before being assembled together. Multicellular structures form through programs of self-organization—a hallmark of living systems. Understanding and controlling the engineering principles underlying self-organization is therefore a requirement for building multicellular structures (**Figure 5**). However, these principles are incompletely understood, and have not yet been extensively exploited in traditional tissue engineering which tends to focus on artificially fabricated scaffolds. We therefore aim to reveal core principles of tissue self-organization in existing living systems—including their mechanics, information processing, information flow—and to place them under engineering control to build consortia of interacting cells. These consortia will ultimately be applied to produce a new generation of living devices and materials with applications in chemical production, materials science, therapeutics, and nanotechnology.

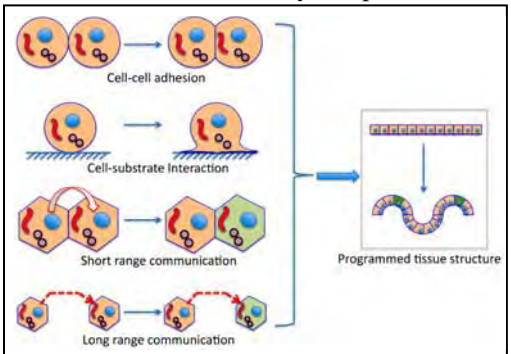

Figure 5. Cellular Legos. By engineering control over cell adhesion, cell mechanics, and information flow, it will be possible to create self-organizing multicellular structures.

Objective 3.1: Reveal new principles of multicellular self-organization and information flow by analyzing living systems using the principles and tools of engineering. The diversity of multicellular structures we observe in the natural world arise through a palette of self-organization programs applied to tissue in a step-wise and hierarchical fashion. While some of these principles are becoming better understood, many remain opaque or shrouded in mystery. We propose to investigate several novel mechanisms of self-organization using a quantitative, engineering approach while simultaneously attempting to reconstitute these systems in vitro. In one area, we aim to better understand how cell and tissue mechanics contribute to tissue-scale patterning events. For example, we are interested in the forces and cell behaviors that drive the self-organization of villi—the finger like projections on the intestinal surface that increase its surface area by 100-fold. Recent work from CCC members suggest that this patterning event can best be understood as a mechanochemical patterning system: cell mechanics and mobilities, coupled to a diversity of initial boundary conditions, can give rise to complex architectures. We will take advantage of the ability to image the morphogenesis of villi in tissue explants, coupled with

an ability to perturb the mechanics of the system through a variety of genetic, molecular, and physical perturbations, to understand how initial conditions contribute to the formation of a diversity of patterns. We further anticipate that the lessons learned in this system, and others, will form the foundation of engineering efforts in other parts of this theme. In a second area, we aim to understand how Calcium signaling (and other paracrine factors) among a population of coupled cells can lead to coordinate changes in the physical properties of a cell population, for example driving transitions between a jammed (non-motile) and unjammed (motile) state or a well-mixed and phase-separated state. These are important questions because the ability to rapidly fluidize, jam, or segregate the cells of a tissue is critical for controlling the kinetics and stability of structural changes at the tissue scale (Mongera 2018).

Objective 3.2: Develop new tools for controlling information flow and self-organization at the tissue level. Cells exchange information to set their collective molecular and physical states. The physical state of cells (e.g. elasticity, motility, protrusivity, adhesivity, and secretory program) then determines the specific programs of self-organization that they engage. Redirecting these programs requires developing new tools for regulating the flow of information between cells in addition to the ability to control the specific physical property of cells. However, a key aspect of self-organizing systems is that information flow among individual elements is a direct function of the element's local structure. For example, protrusivity would be induced by contact with a specific cell type or the local concentration of a morphogen. Thus, we need tools that link information flow to the local structure of a tissue. We therefore developed synthetic receptors (SynNotch) that allow cells to exchange information only upon direct cell-cell contact – the most explicit aspect of local tissue structure (Toda 2018). By linking these local information exchanges to internal genetic programs to trigger expression of cell adhesion proteins, we were able to create self-organizing structures that spontaneously differentiated into distinct cell layers (**Figure 6**). Thus, cellular decisions that affect self-organization become directly linked to the local tissue structure experienced by the cell. We propose to build on these successes. In one area, we aim to reprogram cell adhesion to allow cells to effectively couple changes in the mechanics of interfacial interactions (e.g. tractions and interfacial tensions) with any other surface by making chimeric adhesion receptors that couple different extracellular domains to distinct intracellular domains. For example, we will engineer cells to direct traction toward specific cellular interfaces by engineering the extracellular domains of integrins with single chain antibodies directed to specific chemical species. Using analogous approaches, we will engineer cells to wet specific chemical interfaces by engineering the extracellular domains of cadherins with single chain antibodies. In another area, we aim to reprogram cell-cell interactions at a distance. We propose to re-engineer long range signaling platforms such as those that derive from diffusible molecules or that ride along the tips of specialized signaling filopodia. Many additional areas are available for innovation: our recent studies of gap junctional communication by Center members suggest that these signaling conduits may represent an additionally fertile area for engineering, for example, by designing signaling logic into their conductance for different small molecules and cations. Other work by CCC members suggests that filopodia length can be engineered to sculpt patterning.

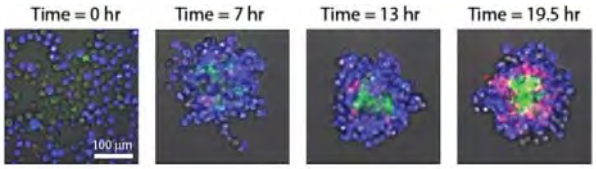

Figure 6. Self-organization of a three-layer structure using the SynNotch system. Sequential images show how cell adhesion and communication allows self-assembly of a multi layer system in which cells can enter three different states depending on position in the aggregate (Toda 2018).

Core to our efforts in engineering information flow and self-organization are modular and bio-orthogonal (no cross-reactivity with other cellular components) tools for linking a molecular binding event to a cellular process. We envision creating these modular tools by selecting binding domains from phage-based libraries of antibody fragments which can then be converted to single chain antibodies and fused to cellular proteins of interest (e.g. cadherins, integrins, Notch, etc.). Center members have extensive

experience with these tools and we will work in the next period to make this resource available across the Center to advance efforts in Cell Legos and other themes.

Objective 3.3: Engineer self-organization and information flow to build new multicellular structures and enable new applications. The ultimate goal of our efforts in Cell Legos is to leverage our understanding of multicellular self-organization to program the formation of new types of multicellular structures and to enable classes of applications that fundamentally rely upon interactions among different cell types. We foresee several exciting and rapidly developing areas where our efforts will find immediate applications, as well as emerging areas where the techniques and technologies we develop will be foundational for future progress.

In one rapidly developing area, engineering of the immune system will be an exciting test bed for innovation. Engineered immune systems have potential to answer basic questions about the evolution and logic of pathogen detection and elimination, as well as application in emerging areas like cell-based immune therapies. At their core, immune cells make decisions by self-organizing then exchanging and processing information among many different cell types. Thus the tools developed in Cell Legos to program self-organization and facilitate the exchange and processing of information can enable entirely new forms of immune cell behaviors. On the side of self-organization, we propose to program immune cells to partition into tissue types that they normally would avoid by using chimeric adhesion receptors (see objective 3.2) to manipulate their interfacial energies. Similarly, we propose to program immune cells to self-organize into specific multicellular structures once they arrive at a specific target site in the body—for example assembling into a barrier or reconstituting a "forward deployed" artificial lymph node for information exchange.

In another area, we will leverage our understanding of self-organization that we develop in Objective 3.1 and CellCad to engineer more reproducible *in vitro* tissues for basic science research and industrial applications. For example, more reproducible and richly structured organoids would have numerous applications as models and screening platforms in the drug development industry.

Impact: Beyond the basic science impact of an engineering-level understanding of multicellular self-organization, the near and long term applications of this work will impact several areas. In the near term, better control over cellular interactions in the immune system will have an outsized impact on the emerging immunotherapy industry. In the long-term, engineering collaboration among unicellular organisms will have an important impact in materials research. For example, engineering the self-organization of multiple types of rapidly growing bacteria or fungi could provide new light-weight packaging materials to reduce waste in e-commerce. Cell consortia could also be engineered to collaborate in order to facilitate harvesting of fermented products – either by selectively increasing or decreasing their buoyancy.

4. CellCad: A modeling and design framework for cell and tissue structure

Vision: Changing cell or tissue structures requires manipulating the pathways that regulate organelle and tissue biogenesis. However, in most cases we do not know what molecular programs to alter, or how to alter them in order to create a particular cell or tissue structure. We propose to take two complementary approaches towards solving this problem (**Figure 7**): we will build mathematical models from first principles and identify the key parameters in these models that are amenable to programming (model driven approach); and we will train machine learning algorithms to recognize non-linear correlations between molecular state and physical structure that can be exploited for design (data driven approach).

Objective 4.1 Implement a model-driven approach for CellCAD. Our first strategy is to develop a model-driven CellCAD system in which mathematical models are used as design tools, in much the same way that mathematical models of transistors and diodes are used to implement computer aided design of electronic circuits (Bianco 2020). This strategy is based on coarse-grained mathematical models, in which

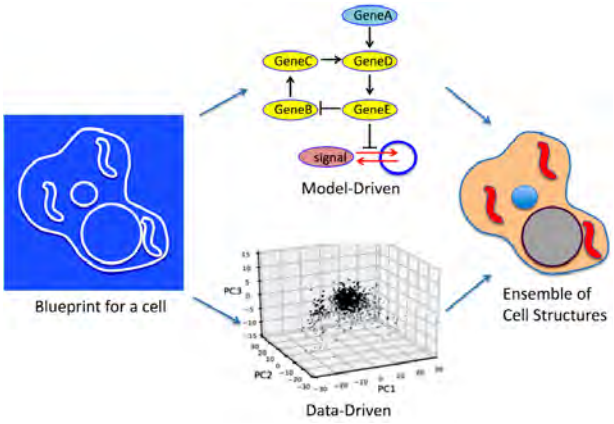

Figure 7. CellCAD. Starting with a design target for a desired cellular structure, perturbations are predicted that will achieve the desired design, using either model-driven or data-driven approaches.

the size and shapes of organelles, cells, and tissues are described by real variables and the processes of organelle and cell dynamics are represented by differential equations. Each model is characterized by a number of adjustable parameters, such as rate constants or diffusion constants. Given a particular set of values for these parameters, the differential equations are typically solved (usually numerically) to produce a simulation or prediction of how the cell or tissue geometry will change over time. In the context of cell biology, a unique challenge is that structure is not specified exactly, but rather as a statistical ensemble centered around a mean. This is a major and fundamental finding of Center Members over the last project period. For design purposes, an additional challenge is to start with the desired end-point – a statistical ensemble of organelle, cell, or tissue morphologies – and work backwards to infer what parameter values will yield the desired result. This model inference problem is extensively studied in the context of engineering and control systems, and a number of mathematical methods are being developed for solving this problem in complex biological systems (Babtie and Stumpf 2017). The result will be a range of parameter values that are predicted to result in a cell or tissue with a desired structure.

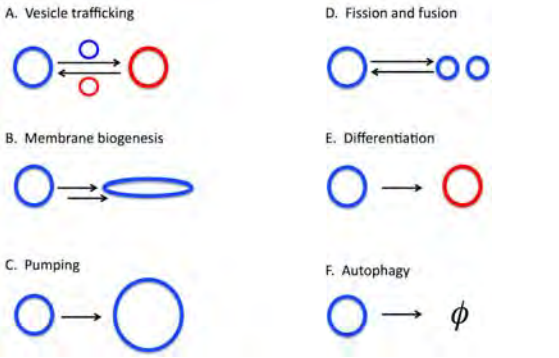

Figure 8. A framework for building models of organelle dynamics from a palette of conserved processes.

In a first area, we will develop predictive models for the full range of organelle and cellular processes of potential interest for cellular engineering. This includes building new models for organelle size control of peroxisomes, vacuoles, filopodia, leading edge, and cell-cell junctions. During the first project period, we began to recognize that many of these models employ similar processes, such as organelle fusion or membrane growth (**Figure 8**). We will therefore be developing a computational framework for rapidly building new mathematical models by taking advantage of the intrinsic modularity of these cell biological processes.

In a second area, we will develop methods for implementing design choices in actual cells. In a computational model, each parameter can be arbitrarily changed to whatever number we want, but this is not the case inside an actual living cell. Some aspects of biology are easy to manipulate with modern molecular approaches, but others are far more difficult because they are constrained by the laws of physics or available biological "parts." For the most part, the easiest changes to implement are tuning of gene expression by replacing promoters. An important goal in the next project period will be to investigate which parameters of organelle and tissue dynamical models can be tuned by promoter engineering while also identifying opportunities in protein engineering to extend these efforts.

Objective 4.2 Implement a data-driven approach for CellCAD. In an alternative to the model driven approach for CellCAD, we will apply machine learning and data analytic methods to large datasets in which the ensemble of organelle, cell, or tissue morphology have been measured under many different

molecular perturbations. Neural networks will be trained using this empirical data to predict molecular changes that can be combined to achieve a particular design goal. A major advantage of this "data-driven" approach is that it starts with defined molecular perturbations, allowing us to implement any design choices in terms of those defined perturbations. A major challenge of this approach is the need for large datasets in which cell structure is measured in a large number of cells and also across a large number of experiments perturbing different genes in a variety of ways. These are exactly the types of datasets that will be generated by the CellProbe theme (see Objective 1.3) and deployed in the Living Bioreactor and Cell Legos themes. These themes are not only collecting raw data, but also building automated analytical tools to extract organelle size and shape descriptors, thus producing an extensive database that maps an ensemble molecular space onto an ensemble morphology space, precisely as required as the starting point for data-driven CellCAD. Only through a large collaborative center like the CCC would such data become available. We have already been able to show in the first project period that individual perturbations usually affect multiple organelles, generate large scale changes to the statistical ensemble of cell and tissue morphologies, and give non-linear effects when combined. It is thus not enough to simply add together two or more defined perturbations: instead, a method is required for predicting the non-linear relationships that determine how two or more perturbations interact to produce a final statistical distribution of phenotypes. This is precisely the type of challenge that machine learning methods are designed to handle. In the next project period, we will build on the extensive expertise of CCC members in machine learning to build a predictive system that first learns relations within the data, and then uses these nonlinear relationships to infer combinations of molecular perturbations that will steer the cell or tissue structural ensemble towards a particular region of morphology space. We will also develop methods to "unpack" the neural networks to produce a description of the data in human-understandable terms, thus leading to new basic insights.

Objective 4.3 Conceive and execute a design framework for programming cell and tissue structure. In order to integrate the design tools into a fully usable CAD tool, we need a way to specify the desired structure of a cell. How exactly to do this is still an open question (Bianco 2020). One could draw a cell, like a blueprint. However any such drawing might only represent one exemplar of a range of cells that would, for a given purpose, still be considered to have equivalent shapes. An alternative would be to specify the volume, surface, or other morphological parameters for each organelle, without necessarily specifying their exact shapes or arrangements. Such an approach is more aligned with the ultimate purpose of the design, but may be harder for the user to visualize. Moreover, because of the dynamic and stochastic nature of living cells, the Center has learned to think about a design target not as a single structure but as an ensemble of structures, such that the goal of design is to specify a statistical distribution across the space of cellular architectures. We propose to build visual tools such as employed in parametric design, whereby the user will adjust organelle size and shape parameters using interactive sliders, with graphical renderings of consistent cell structures generated on the fly. Once a design is settled, the software will produce a specification in a formal language that can be handed off to software modules that compute parameter changes using either the model-driven or data-driven strategies.

Impact: In the long term, success of the CellCAD theme will take the design of cellular structure out of the realm of tinkering or random screening, and place it on a rational and predictable footing. This would mean that researchers in academia or industry would be able to specify the internal design of a cell or tissue, run the software, and obtain a list of molecular perturbations to create in their lab, without having to be an expert in the mechanistic biology of every organelle. This would go a long way towards making cellular engineering a routine feature of biotechnology, while also taking our basic understanding of the origins of biological structure to a new, quantitatively predictive level.

4.c. Education and Human Resource Development Objectives of the Center

4.c.1 Introduction

In Phase 2, the CCC will build on and expand educational efforts, hone programs based on strong evaluation programs, disseminate educational resources more widely, and work to ensure sustainability so those educational initiatives with evidence of effectiveness continue beyond NSF STC funding.

4.c.2 Framework for cellular engineering education

In the current project period, the CCC developed a Framework for Cellular Engineering Education, which articulates the "big ideas" of cellular engineering and delineates the educational goals of the Center. The three core components of the Framework are described below.

- ***Cells are machines that can be engineered*** – A central tenet of the CCC is that cells are biological machines that can be engineered to solve important problems. *Educational efforts include*: build awareness of the cell as an engineering platform; develop trainees' fluency with the novel approaches and tools used to examine and manipulate cellular structure and function; and prepare trainees to use interdisciplinary approaches to design approaches to engineer new functionalities into cells.
- ***Applying an engineering approach to biological problems is essential*** – Building the discipline of cellular engineering relies on drawing from other disciplines to develop novel quantitative methods for use in biology. *Educational efforts include*: work with trainees to develop an engineering mindset that shapes their approach to problems and transcends the platform they are using; build trainees' comfort and fluency with convergence research, a type of cross-discipline research to addresses specific and compelling problems; prepare trainees to work effectively on interdisciplinary, inclusive teams; and prepare trainees to apply their knowledge and skills across disciplines to develop new tools and approaches for solving problems.
- ***Engineering complex systems requires working across interfaces –*** Because biology is highly nonlinear, dynamic, and noisy, cellular engineers need to think differently about how to design biological machines, selecting from many possible designs using high throughput methods and machine learning. *Educational efforts include:* build trainees' knowledge and skills in developing quantitative, predictive models of biological phenomena that can help inform approaches to problems; prepare trainees to leverage approaches such as machine learning to facilitate using high throughput approaches in the engineering design cycle; and introduce trainees to control systems and other approaches to minimize the variability inherent in biological systems.

4.c.3 Key individuals overseeing this work

Please see the Management Plan (4.f) for a description of the roles and experience of the individuals overseeing our educational and human resource development activities.

4.c.4 CCC wide educational and mentoring offerings

Cellular Engineering Summer Research Course at SFSU – Our Cellular Engineering Summer Research Course is a cross-institutional course that brings together undergraduate, Master's and PhD students, postdocs, and faculty from all CCC institutions to work collaboratively on research projects that simultaneously promote Center research goals and address the three components in the Framework. The course's cross-institutional nature coupled with its intensity (meeting daily from 9 am-5 pm for two weeks) forges strong bonds among participants and faculty, strengthening the Center community. Among many reported benefits of these types of experiences (Corwin *et al*, 2017), the research literature provides evidence that course-based research experiences can make scientific research more inclusive (Bangera & Brownell, 2014) and increase students' sense of ownership of their research projects and increase students' persistence in science (Hanauer *et al*, 2012).

The course was piloted for the first time in 2019 (fund year 3); renewal funding will support this course in years six through eight and will allow the Center to collect evidence to document effective course structures and outcomes, with the ultimate goal being institutionalization of the course by year nine (thus allowing the course to continue beyond STC funding).

The course is refined each year based on evaluation and reflection on the prior year's offering. CCC faculty will select three to four research projects for the course each year. These projects will 1) be designed so that small groups of students can make tangible progress in a short time period, 2) highlight techniques, skills, and habits of mind of cellular engineering, and 3) further CCC research goals. Leadership of the course will rotate among the CCC faculty providing opportunities for faculty at each of our institutions to gain experience leading a project-based course. Senior graduate students and postdocs from the Center will serve as Project Leads (teaching assistants); thus, this course also builds capacity for teaching and mentoring among CCC trainees. Project teams will be intentionally diverse – including students from across undergraduate – PhD student spectrum, allowing for near peer mentoring of more junior Center students.

Students will be selected from all Center institutions in each of years six through eight of the grant. In years seven and eight, we will also open enrollment to students from outside the Center and will pilot charging tuition for non-Center students. In years nine and ten, we expect the course to be fully supported through tuition fees, similar to other courses (e.g., Woods Hole courses). Opening the course to non-Center students expands the number of students who learn about cellular engineering and builds knowledge and capacity of the interdisciplinary practices that are a part of Cellular Engineering research.

Cellular Engineering Techniques Workshops – Building on the popular *Techniques Bazaar* currently offered at the Center Annual Retreat, we will support regular student-organized Techniques Workshops. These cross-Center workshops will allow trainees to identify and organize workshops on emerging techniques to facilitate innovative research. The workshops will strengthen the Center community, nucleate collaborations, and develop communication and laboratory leadership skills among the trainee organizers while simultaneously providing opportunities for cross-disciplinary learning among participants. Specific workshop locations will rotate based on the host's location as well as the location of key equipment required for use during the workshop. Workshops will be announced via the Center's listserv and Slack channel, and a template for workshop organization will be provided to the organizers.

Ethics – Center-wide Ethics education in years six through ten will continue, in dedicating time for discussions about ethics and Responsible Research Innovation at the Center Annual Retreat and Quarterly Meetings. Topics for these meetings will be informed by baseline data from Center-wide ethics surveys, interviews of CCC faculty completed by the Center Lead Ethics Investigator and emerging developments in the fields of engineering living systems. Sessions will be active to encourage participation of all in attendance and will include case studies, panel discussions, and discussions of articles that raise ethical, questions. In all sessions, participant discussions will relate to CCC research goals, policies, how we communicate about our work.

4.c.5 Integrating the framework for cellular engineering education into teaching and learning at member institutions Significant efforts have been made to incorporate the Cellular Engineering Framework into new and existing courses at all Center-affiliated institutions. We will continue refining our new courses in years six through ten, and ensure sustainability of these courses beyond NSF STC funding, working closely with our program evaluator. Evaluation data will also be used to provide justification for institutionalization of these courses at CCC-affiliated institutions. In addition, we will document several of the courses and produce course modules that will be disseminated via the CCC website. These modules will allow faculty from other Center institutions as well as from outside the CCC to adopt and refine the course for use in their own settings.

4.c.6 Resources for cellular engineering education

Content and technique "Lecture Bricks" – To facilitate inclusion of Cellular Engineering content and techniques in courses and seminars both inside and outside of the Center, CCC faculty will create and share "Lecture Bricks." Individual bricks will be short slide decks, along with literature reading lists, that convey core CCC ideas, describe novel tools and techniques developed in the Center, and highlight research findings. This format allows bricks to be easily slotted into a course lecture or seminar. All bricks will be publicly available on the CCC website.

Ethics modules –To integrate ethics into all courses taught by CCC faculty, we will produce a series of ethics vignettes, based on interviews with CCC faculty and Center-wide research surveys. Each vignette presents a short narrative description of an ethical issue that may arise in the CCC along with discussion questions. Vignettes will be designed so that faculty may easily include individual vignettes within a course session or journal club meeting. Vignettes will be piloted and refined in the Cellular Engineering Summer Research Course, then disseminated via the CCC website.

4.c.7 Evaluation of education work

Evaluation questions and approach – Evaluation of educational offerings are guided by a logic model (Peyton & Scicchitano, 2017; Knowlton & Phillips, 2013). In the model, the educational framework for cellular engineering is based on: **Inputs**, in the form of CCC resources; **Activities**, such as course development; and **Outputs**, in the form of ongoing courses, workshops, and modules. Within this logic model, developmental and formative evaluation (Patton, 2011) focus on activities and outputs while summative evaluation focuses on outcomes. The overall question guiding the evaluation is: To what extent and in what ways do the CCC's educational offerings (i.e. courses, minicourses, internships, student technique workshops, and ethics training) contribute to and advance the three goals stated in the education framework? In addition to the questions directly tied to the three goals in the framework, the evaluation will address: To what extent and how are offerings addressing issues of Responsible Innovation and ethics in Cellular Engineering? To what extent and how are offerings promoting connectivity and inclusion across disciplines and campuses? To what extent and how are the Center and affiliated institutions developing capacity to sustain these offerings? And what is the evidence of summative contributions of the CCC's educational offerings for participating individuals, groups, and institutions?

Methods – The mixed-method evaluation (Creswell & Plano Clark, 2011) will consist of formative elements to guide continuous improvement (Bryk, 2009; Englebart, 2003) and summative elements to document the CCC's contributions. The **quantitative** measures used in the evaluation of the education components include an assessment of content goals relevant for cellular engineering as an emerging discipline and a retrospective pre-post- survey of affective dimensions associated with participants' involvement in CCC education offerings, such as their identities as scientists and their sense of inclusion in the CCC. While there will be some free-response questions on the content assessment and surveys, the primary source of **qualitative** data will be interviews with a sample of faculty and students, focused on their learning, their perspectives on the CCC's approaches to addressing issues of connectivity and inclusion, and how CCC offerings can be improved (Gubrium et. al, 2012; Desimone & leFloch, 2004). Mini-case studies (Yin, 2018) of focal students in the CCC will illuminate trajectories of students who started at different levels in the Center and who may have taken different professional paths (e.g. academic versus industry). These cases studies or vignettes will serve as educational examples for other cross-institutional Centers that seek to provide pathways for students in innovative, cross-disciplinary fields within STEM.

The evaluation will employ constant comparative methods to establish validity of insights, through data triangulation, external review, and member checking (Miles et. al, 2014). Evaluation reports will be provided to CCC leadership on a continual basis, as education components are offered, and data is collected and analyzed.

4.c.8 Outreach

Exploratorium – The Exploratorium will continue to play a key role in the Center's outreach activities, providing a portal for the public to engage with research done in the Center. Concepts from the Center's Framework for Cellular Engineering Education will be embedded in ongoing exhibitions and programming platforms at the Exploratorium. Over the next project period, three exhibits and twenty programs will be created in collaboration with the CCC. Because Cellular Engineering involves concepts and tools that are unfamiliar to most museum visitors, public programs provide an in-depth experience of fifteen to thirty minutes, where visitors can be introduced to foundational concepts and then explore concepts from the Center's framework. The programs will cover the breadth of the CCC's research,

including new discoveries, tools, and approaches that highlight key themes from the Center's educational framework. For example, CCC faculty member, Dr. Orion Weiner, will present on how optogenetics are used to study cells in the Exploratorium's annual program "Glow" (Framework Concept: Cells are Machines that Can Be Engineered), while a Spanish speaking postdoc from Dr. Manu Prakash's group will share their visualizations of cell flow and talk about the role of computation in biology on Latino Engineering Day (Framework Concept: Engineering Complex Systems Requires Working Across Interfaces). The three exhibits produced will be more technically intensive, focused on the technological approaches used in cellular engineering, such as computational modeling and machine learning, highlighting concepts in Convergence Research.

The Exploratorium will train CCC members in science communication, by providing seminars on current topics in science communication open to all CCC members, such as inclusive science communication and how to communicate controversial topics. In addition, the Exploratorium will host two interns per year; these interns facilitate collaboration between the Exploratorium and CCC researchers and enable the public to directly interact with Center students through weekly demonstrations on the museum floor. Evaluation of the Exploratorium work will be completed by the Exploratorium's in-house evaluation team, which has a team of three Ph.D. Learning Scientists and four evaluators.

Cellular Construction Workshop – The Cellular Construction Workshop (CCW) brings together high school students and teachers as co-learners in a novel two-week long workshop. The CCW provides an opportunity for the Center to 1) introduce high school students, the majority from backgrounds underrepresented in science, to Cellular Engineering and careers in STEM, while also 2) providing high school science teachers an opportunity to learn how to integrate engineering content and practices into their discipline-based curricula (e.g. biology or chemistry). The CCW design is informed by best practices in teacher professional development (Darling-Hammond *et al*, 2017) as well as research-based recommendations for how to broaden participation in science (including: Barron & Bell, 2015; Bell, 2017; Carlone & Johnson 2007; National Academies, 2011; NRC 2012) The workshop has been tremendously successful – all participating teachers bring CCW lessons to their classrooms, with the majority also integrating robotics to model cellular behaviors into their syllabi. As evidence of our impact, student alumni are also pursuing STEM majors at increased rates.

In the next project period, we will transition of the workshop to a fully independent program that can be sustained beyond NSF STC funding. We have already piloted a sliding scale registration fee so that the workshop can be self-funded while remaining accessible to students from low-income backgrounds. We will also focus on rigorously documenting outcomes; on making workshop materials publicly available on the Center website; and disseminating our work through sessions and workshops at practitioner focused conferences and publications focused on science teaching and learning.

4.c.9 Student recruitment and retention – We believe our unique collection of innovative research and educational activities greatly contribute to our ability to attract and retain a diverse cadre of high quality students. For example, as word of CCC students gaining experience at the Exploratorium has spread, students from non-CCC labs have been approaching CCC leadership asking how they can get involved. A summary of degrees awarded to CCC students is below (**Table 4.c.1**).

Table 4.c.1. Summary of degrees awarded to CCC funded students.

	Total	Avg years to complete degree	Women/ Men	Hispanic	Asian	African American	Native American	Native Hawaiian/ Pacific Islander	Multiracial
Bachelors	33	5*	15/18	14	8 (1 SEA)	6	2	2	1
Masters	22	2.02	9/13	11	2 (1 SEA)	7			
Doctoral	12	6.00	4/8		3	1			

*Many of the UG students spent the first years at community colleges before transfer to SFSU. After transferring to SFSU with a structured science major, research opportunity, and better faculty advising, most finished their transfer degrees within 2 years.

4.d. Broadening Participation Objectives of the Center

4.d.1. Goals, Progress, and Future Plans

Through its partnerships and diversity activities, the CCC promotes inclusion and retention of diverse scientists at all career stages (from undergraduate to faculty/scientist). Our programs are specifically targeted at several key career stages where a loss of inclusion in STEM fields can take place: The progression of undergraduates to pursue graduate education, the pursuit of postdoctoral training by Ph.D. students after graduation, and the progression of underrepresented groups, including women, into faculty and scientist careers. We have selected these stages because they are points at which diversity tends to drop, and because they are stages for which the CCC resources and partnerships can effectively be brought to bear to improve the degree of diversity and inclusion.

Research inclusivity through true partnership with SFSU – The centerpiece of our approach to Broadening Participation is a true partnership with faculty and students at San Francisco State University (SFSU). SFSU is a minority and Hispanic serving institution with a highly diverse faculty and student body. Over the past 30 years SFSU has significantly increased the numbers of URM students entering top PhD programs in STEM. In 2019, 35 SFSU URM students majoring in Biology, Biochemistry and Chemistry were placed into STEM PhD degree programs. Rather than exploiting SFSU as a source of students to be recruited by other research universities, the CCC takes an approach based on inclusivity, by including SFSU faculty as research partners and by facilitating access to resources to support their research activities. Specifically, access has been arranged for SFSU faculty and students to shared resources at UCSF such as the Nikon Imaging Center and the Center for Advanced Technology. This arrangement has given SFSU trainees and researchers access to the most cutting-edge technologies, accelerating the pace of research for SFSU faculty. This partnership has resulted in a significant and sustained increase in the number of publications and presentations from SFSU faculty and students since joining the Center, with almost all of this increase involving authorship and presentation by URM students. We believe these numbers strongly confirm our concept of making SFSU a bona fide research partner in the center, rather than simply feeding the pipeline of students to work at other institutions.

Increasing diversity of center students at undergraduate and graduate levels – Two academic stages at which diversity is known to drop are (1) during undergraduate training when students make the decision to pursue STEM field majors, and (2) during the transition to MS and PhD studies. The CCC will promote diversity at the first step by maintaining an exciting and inclusive environment in which URM undergraduate students are welcomed as participants in all center activities, including quarterly meetings, annual retreats, and the CCC Summer Course. For the second step, the CCC has put in place a Masters program that funds students for two years after their undergraduate training to conduct research in CCC labs located at SFSU. As part of the program, these students have full access to all CCC activities. The training allows students to gain additional research experience, making them more competitive for PhD programs. In the past few years, there has been a significant increase in the number of SFSU URM students joining PhD programs at UCSF; we believe this is driven in part by UCSF-SFSU partnerships like the one fostered CCC. An important goal for the next project period will be to extend this partnership to UCB and Stanford, as addressed below.

Success of these programs requires that the CCC foster an inclusive environment. To achieve this, we have made training in diversity and inclusion an ongoing element in all of our center-wide meetings. The annual retreat always includes an interactive session on such topics as stereotype threat or implicit bias. All center members, from faculty to students, are required to take part in these sessions. These sessions are taught by diverse faculty members who have participated in training at the National Mentoring Research Network (NRMN) program.

Increasing diversity at the postdoc level – There are currently 13 postdocs supported by the Center, of whom 2 are URM. This represents 15% URM among our postdocs. For comparison, a recent analysis of diversity among postdoctoral fellows (Meyers *et al.,* 2018) estimates that approximately 11% of postdocs

who earned PhD degrees in the US are URM. In the next project period we seek to increase diversity in additional new postdoc hires by changing our postdoc recruitment process.

The CCC will leverage our community of collaborators to improve the diversity of the postdocs by pooling applicants and coordinating center-wide postdoc interviews. This approach greatly increases the total number of URM postdoctoral candidates exposed to each faculty member and increases the likelihood of identifying a good fit between candidate and mentor. In conjunction with this policy, we will direct recruiting efforts through participation at meetings for the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) and Annual Biomedical Research Conference for Minority Students (ABRCMS), and at the Minorities Affairs Committee poster session of the American Society for Cell Biology (ASCB) annual meeting.

A second approach we will take is to leverage the group recruiting events hosted by the UCSF Institutional Research and Career Development Award (IRACDA) program – specifically their annual group interview of 20-30 URM postdoc candidates each year and their Path to Postdoc program, which brings potential URM postdoc applicants to UCSF for 3 nights to meet with UCSF faculty of interest. CCC faculty will take part in these events, creating the opportunity to recruit URM postdocs with interests related to the CCC, who we will then fund and train within the Center.

To help ensure that the center is an environment that nurtures success in all its postdoctoral fellows, all center postdocs, regardless of their minority status, are trained in broadening participation issues as part of the annual retreat as discussed above.

4.d.2. The Role of other CCC Partner Institutions in Broadening Participation
Our planned activities for Diversity and Inclusion extend beyond SFSU to include all CCC institutions.

UCSF – UCSF has seen a large increase in the diversity of its graduate student population, due in part to efforts of CCC faculty involved in graduate admissions committees. CCC Director Marshall is a member of the Diversity Admissions Committee for the Tetrad graduate program at UCSF, where he personally reads 100% of all applications each year from URM students in order to avoid applying arbitrary triage based on GPA or standardized testing, both of which are known to be biased in their outcomes. Since the launch of the CCC, we have seen a steady increase in the number of URM students from SFSU who are moving on to PhD programs at UCSF, and we believe that this is due in part to the inclusion of these students in CCC activities where they are able to get to know UCSF students and faculty, and vice versa. In this way, the CCC is helping to further strengthen the links between SFSU and UCSF, allowing us to promote diversity at the graduate level, but even more importantly, these pre-existing interactions help to promote inclusivity since CCC undergraduates from SFSU who join UCSF for their Ph.D. studies will have a social network, in the form of their colleagues in the CCC, in place from their first day in graduate school. At the undergraduate level, we will leverage support from the UCSF Summer Research Training Program (SRTP; co-directed by CCC Director Marshall) by working to recruit diverse participants from that program into CCC labs.

UC Berkeley – As a direct result of discussions between the CCC Diversity Coordinator and CCC faculty member Dan Fletcher, Chair of UCB Bioengineering (BioE), the UCB/UCSF joint PhD program in BioEngineering began to embrace the efforts by SFSU to increase URM PhD students in their program. Prior to the CCC, no URM students from SFSU had been accepted in the joint BioE program, but in the past two years three SFSU students have joined this program. We will continue to build on this track record by creating more opportunities for SFSU undergraduate and MS students to take part in CCC meetings and events, which always include UCB faculty and students within the CCC.

Stanford – We have established a track record of placing SFSU students from CCC labs in the Biosciences PhD program at Stanford. In 2018, we placed Cecilia Brown and in 2019 we placed Austin Murchison, both from CCC labs at SFSU. As we have done with our growing connection, catalyzed by

the CCC, between SFSU and UCSF, we will continue to create opportunities for SFSU students to interact with students and faculty at Stanford through our CCC Center-wide meetings.

IBM-ARC **–** IBM supports a diverse and inclusive hiring practice and has hired several students from Center partners to work on government research grants including Postdoc Sara Capponi and interns Cecelia Brown, Amanda Paulson, Ryan Winstead, and visiting student Sita Chandrasekaran. IBM faculty are proactive by attending various Diversity Conferences and on-campus recruiting events and conferences. IBM's global research ecosystem is grounded in acknowledging that our strength is in our diversity. Different perspectives, identities, and experiences lead to greater innovation and more effective technology. Because talent shortages exist in Science, Technology, Engineering, and Mathematics (STEM), IBM's intern programs and partnerships with colleges, universities, K-12 schools, and non-profit organizations aims to strengthen their diverse pipeline of researchers. Partnership with the CCC fits with this strategy. Recruitment of women and minorities into STEM at institutions of higher education is a key contributor in growing IBM's talented and diverse workforce.

Exploratorium **–** Each year, the Exploratorium hosts Latino Engineering Day / Día de la Ingeniería in collaboration with the Society of Hispanic Professional Engineers. This event combines panel discussions, presentations on the science and engineering heritage of Latinos, and playful activities such as making Nature Bots. This annual program is conducted primarily in Spanish and provides opportunities to meet with prominent engineers in the Latino community. Starting in 2019 with a presentation in Spanish by a CCC postdoc on physics in biology, CCC members will continue to take part in this event by developing new Spanish language presentations focused on cellular engineering.

4.d.3. Center Demographics and Measuring Progress

The demographics of CCC participants are provided in **Table 4.d.1.**

Table 4.d.1. Current demographics of CCC participants

	Total	Women/Men	Hispanic	African American	Native American	Native Hawaiian/ Pacific Islander	Asian or SEA	Multiracial
High School*	31	15/16	11	2	1		11	2
Undergraduate	44	19/25	24	3	1	1		
Graduate	76	37/39	19	7				
Post Doctoral	13	5/8	2				2	
Other Researchers	17	6/11	2				3	
Funded Faculty	22	6/16	3	1	1		6	
Administration	6	6	3					
EAB	10	5/5	1				3	

*High school students are considered CCC affiliates, as time spent in CCC workshops is less than 160 hours/year. Participants are defined in accord with NSF STC Annual Report directions as individuals contributing 160 hours or more per year to CCC efforts.

4.e. Knowledge Transfer Objectives of the Integrated Center

4.e.1 Overall goals/objective

The CCC's goals for knowledge transfer are to: (1) catalyze the transfer of center-developed ideas and results into the real world, so as to have a positive impact on the economy and society; and (2) draw on the expertise of partner institutions and companies to gain insights into methods, ideas, and approaches that will help us achieve our research and educational goals. By collaborating with our partners, we can direct our research activities towards problems that are of relevance in industry, while preparing our students to employ cellular engineering approaches in an industrial setting.

4.e.2. Industrial collaborations

The CCC was established with an intended focus on developing productive collaborations with industry. To this end, a key objective for the center is to fully leverage the local innovation and entrepreneurship ecosystem of the Bay Area to advance Center cell engineering discoveries towards product development and commercialization. Resources and paths that will support the commercialization of Center research includes venture capital, incubators, accelerators, and law and bioengineering firms. The bidirectional bridging of academia with industry is a central theme of our knowledge transfer objectives and is demonstrated by including IBM-ARC as a funded Center member institution. IBM has partnered with the CCC in two distinct ways. First, the IBM computational biology team led by Dr. Bianco is a major research participant in all CCC themes. By involving IBM as an integral partner in the Center, the CCC benefits from the tremendous expertise of IBM in computational methods and questions. At the same time, the CCC provides IBM with new research areas in which to apply deep learning and other computational methods, helping them to expand the reach of their own programs. Second, IBM is playing a key role as a knowledge-transfer interface to the rest of the industrial world. A major element in the business strategy at the IBM Almaden Research Center is licensing intellectual property, and a major motivation for IBM to take part in the CCC is precisely because they believe that by investing in IP development from Center research, the work will eventually help create both a new industry, yielding licensable IP, and create the essential knowledge base to train a new workforce for this industry. Our joint IP management plan coordinates IP center-wide including both IBM and academic institutions.

In addition to the IBM partnership, the Center is actively pursuing collaborations with other companies to support the bi-directional transfer of knowledge. These collaborations enable the CCC to potentially influence the company to move in directions related to our long-term goals, while also giving CCC personnel access to the companies' research and resources. For example, Zymergen is a strain engineering company located in the Bay Area that focuses on industrial fungi. Discussions with Zymergen experts have helped shape our goals for the CellCAD theme, and a CCC student completed an internship at Zymergen. Building these industrial connections allows the CCC to adjust our research goals to be responsive to real problems and challenges present in industry, while simultaneously providing opportunities and career perspectives for Center trainees.

We have also established partnerships with existing startups and small companies. By collaborating with companies in their earliest phases, the CCC can often influence the company and collaboration to maximize the benefit to the CCC. During the first project period, the CCC worked with Serotiny, a local startup that invents proteins for novel cell therapies. Through this collaboration, the CCC gained efficient access to state-of-the-art tools for cellular research and bioengineering know-how, as well as contributing to the Public repository of useful genetic tools. The Center also gained experience interacting with small business partners. Serotiny gained access to pilot funding for promising projects, access to the Center's bioengineering know-how, and benefited from the validation that association with a large NSF funded Center brings, as well as the Center's entrepreneurship network and ecosystem.

4.e.3. Educational roles and opportunities in Knowledge Transfer

To promote student, postdoc, and faculty engagement in the CCC's knowledge transfer activities, we will create an internship program that will be integrated into the ongoing internship program coordinated by

the UCSF Catalyst Program. The Catalyst Program shares the CCC's goals in promoting the advancement of academic discoveries along the translational path to healthcare product development and commercialization. The Center's internship program will expose CCC trainees to both real-world entrepreneurial activities as well as seminars and discussion groups. Presenters will include both entrepreneurs who have developed products from discoveries in their labs and experts in ancillary fields that facilitate the entrepreneurial journey (e.g. regulatory affairs, financing, intellectual property, business development, project management, quality systems, artificial intelligence, incubators, accelerators).

4.e.4. Pipeline for moving ideas to startup stage

In cases where a partner company does not already exist in a research area critical to the CCC, we will establish startup companies with Center-generated ideas. The Bay Area is a hotbed of startup and venture capital activity, and we plan to leverage those opportunities to take our ideas into the real world. Our primary philosophy is to leverage those opportunities and resources that exist, and use center funding to patch holes in the pipeline. We will do so through the following specific activities:

- **Catalyst Funding**. The UCSF Catalyst Program is UCSF's translational accelerator focused on facilitating the advancement of UCSF healthcare inventions to product development and patient benefit. The Catalyst Program centerpiece are Catalyst Awards, where selected projects receive seed funding and guidance and mentorship of ~100 expert industry, venture capital, and legal advisors. A Catalyst Award provides seed funding for commercialization of new ideas along with mentorship from local experts in industry and venture capital. In past years, Catalyst had a strictly medical focus (therapeutics, diagnostics, medical devices, and digital health product opportunities). During the current project period, the Center Knowledge Transfer Coordinator (Dr. Charles Craik) was able to negotiate with Catalyst leadership to expand their thinking to non-medical applications. As a result, the Catalyst Program now has a formal Biological Engineering track. Two CCC projects are now funded by Catalyst. Programs similar to Catalyst exist at UCB and at Stanford. Our key approach is to leverage Catalyst and similar programs to provide funding and mentorship for launching startups.
- **Pre-catalyst seed funding**. Many innovative ideas in Center labs may be too preliminary to successfully compete for funding by Catalyst and similar programs, which are highly selective. To help our ideas advance to the Catalyst stage, we will initiate a seed funding program within the CCC with the goal of funding small projects in Center labs to solidify potentially commercializable ideas to a mature enough stage to be competitive at Catalyst. Twice per year an RFA will be issued. Applications will be evaluated by a committee assembled by the Knowledge Transfer Director to assess the promise of the project in terms of product opportunity, market potential, competitive landscape, intellectual property, scientific rationale, engineering soundness, and technical feasibility. Prioritized projects are then reviewed by the Leadership Committee to assess their alignment with CCC intellectual goals. Funding will provide financial support to perform a key experiment that will help de-risk the idea and show feasibility, making for a stronger application to Catalyst or other early stage funding programs.
- **Promote filing of patents and disclosures**. During the current project period, we realized that many faculty were unclear on how to go about patenting their ideas, or even how to disclose potential inventions to their institutional technology transfer officials. As an element of our annual retreat, we now include talks and brainstorming sessions led by CCC Innovation and Entrepreneurship experts, including IBM Master Inventor Tom Zimmerman, to educate our faculty and trainees about this process and encourage them to think about ideas that might have commercial or real-world potential. Talks will also include training for faculty, students, and fellows in the processes by which intellectual property is handled by the individual campuses.
- **Licensing**. While a project is receiving Catalyst Award support, assigned industry mentors work with funded projects to develop a Target Product Profile (TPP), which includes an analysis of commercial potential. In instances where licensing is a promising option, the CCC will assist the inventors by harnessing the large network of industrial contacts that the full faculty membership of the CCC has in place. IBM-ARC has a robust program for seeking industrial partners for licensing, by which industrial

representatives visiting the lab meet with IBM scientists for confidential discussions about patentable results of potential interest for development and licensing. Dr. Bianco has been involved in many of these discussions, in many cases together with CCC faculty from other institutions.

- **Startup Launch**. If the Catalyst TPP indicates a startup would be potentially viable, the CCC will use Knowledge Transfer funds to cover the basic costs of incorporation. Facilitation of Center startup company formation, for example with the California Institute for Quantitative Biosciences' (QB3) 'Startup-in-a-Box' or similar programs, will also be encouraged. In years eight through ten we plan to issue fewer seed funds and provide more funding for startup launch.
- **Supporting SBIR applications**. Once a startup has launched, funding is needed to rent space and support initial proof of concept experiments necessary to pursue venture capital funding. The federal SBIR program is designed for this purpose, and we will leverage this program to the maximum possible extent. We are also pursuing the NSF Partners for Innovation (PFI) program.
- **Pre-SBIR Grants**. During the course of Catalyst funding and the TPP process, it may become clear that certain fundamental basic science questions still exist, and that answering those questions would make for a stronger SBIR proposal while providing new research results for the Center. In this case, the CCC will work with faculty to secure additional funds. For example, the NSF CBE (Cellular and Biochemical Engineering) program funds basic research into the engineering of cellular components.

4.e.5. Software Dissemination

Many of the activities in the Center will result in useful software. The Center will make all open source software publicly available to the scientific community through an existing centralized GitHub repository, currently managed by the Bianco group at IBM.

4.e.6. Dissemination of CCC concepts and approaches to the Scientific Community

A major focus of the next project period will be to maximize the CCC's impact by spreading our ideas among researchers and engineers. In addition to the usual routes of publication and presentations at meetings, we propose two approaches. First, we will aggressively expand our local footprint within the Bay Area by using our Research Seed Funding to recruit new faculty as center affiliates. These faculty will receive small seed funds ($25K) for one year to work on center-related projects in their labs, after which they will continue to take part in the Center's quarterly meetings and retreats. We will use this mechanism to bring in at least five additional faculty, spread across center institutions. Second, in the last two years we will host Symposia on Cellular Engineering that will bring Center researchers together with interested researchers from around the country, with a focus not just on presenting ideas but on catalyzing new collaborations. These meetings are part of our general plan for continuing the CCC scientific legacy after the NSF funding has sunsetted, as discussed further in the Management Plan.

4.e.7. Dissemination of CCC Concepts to the Public

Another aspect of Knowledge Transfer is communicating Center concepts and results to the public. We are pursuing this objective with a variety of outreaches: (1) Our website (https://ccc.ucsf.edu/) is designed to inform both the professional and lay audiences. During the next project period we will be rolling out a newly designed web site with greatly enhanced graphics. (2) Our social/professional media Twitter feed (@C3STC) and LinkedIn posts are focused on informing both professional and lay audience. During the first project period, most of the social media posting was done by a small number of CCC faculty. During the next project period we will be working to increase participation in social media by CCC trainees, with a particular focus on disseminating their own scientific work and ideas.

4.f. Management Plan

Overall center structure. The CCC is an interconnected network of participants at UCSF, UC Berkeley, San Francisco State University, Stanford University, IBM Almaden Research Center and the Exploratorium. Our team combines experts in cell biology, tissue engineering, biophysics, mathematics, bioengineering, and industrial design, including both research and education experts. Industrial internship programs strengthen interactions between the Center and industry, but also represent a way non-academic educational programs can be intimately linked with the work of the center. The management structure of the CCC is shown in **Figure 4.f.1**.

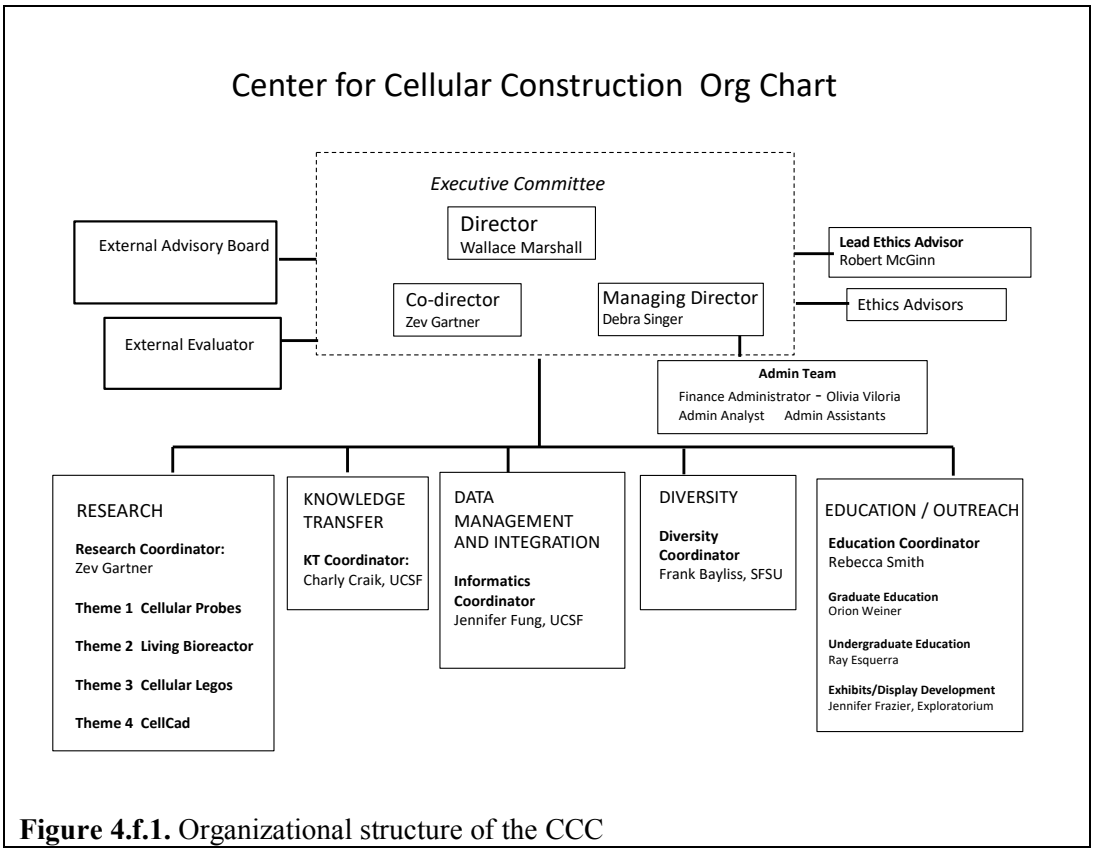

Figure 4.f.1. Organizational structure of the CCC

Leadership Team. Faculty and staff with vision, leadership and management experience, and deep commitment to improving and sustaining Center programs occupy key positions at all levels of the center. The Executive Committee, consisting of the Center Director, Co-Director, and Managing Director, is charged with communicating with the EAC and NSF, organizing key center activities, coordinating and overseeing Center participants to advance Center goals, and revising Center strategies towards achieving those goals. An internal Managing Committee comprised of the Executive Committee plus the Objective Coordinators is responsible for research, education, knowledge transfer, broadening participation and convening internal focus groups to work on specific initiatives, comprised of members of the full CCC community. These focus groups allow especially engaged students, postdocs, faculty, staff, and educators to share perspectives.

The CCC *Executive Committee*, which includes Director (Marshall), Co-Director (Gartner) and Managing Director (Singer), leads the center in consultation with a larger *Managing Committee*. The Executive Committee and center administration is based at UCSF; the Managing Committee combines researchers and educators from partner organizations.

Wallace Marshall (Director) conceived the idea for the CCC and has been directing the Center since its inception, providing executive oversight of the integration of research, teaching, outreach, and knowledge transfer components. He has prior experience serving as PI on three multi-PI collaborative grants at UCSF. Over the past five years he has organized a series of thirteen workshops and meetings funded by the NSF to promote quantitative cell biology, as well as five international conferences.

Zev Gartner, (Co-Director, Research Coordinator) has played a lead role with Wallace Marshall in formulating the vision for the center, articulating conceptual research frameworks, designing multi-disciplinary research themes that draw from strengths of CCC faculty and recruiting new key collaborators. He has overseen Center research programs from inception to present, and as Research Coordinator, he will continue to oversee all CCC research activities.

Debra Singer (Managing Director) has >20 years experience as a grants specialist and program manager, coordinating large collaborative research programs, including consortium and financial management for shared beamlines at the Advanced Light Source, LBNL. She has been involved with the CCC from application phase through start up, and oversees overall budgets, reporting, events, logistics, and contributes to strategic planning.

The CCC *Management Committee* is comprised of the following:

Frank Bayliss (Diversity Coordinator) has >25 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 at SFSU– and obtained extensive extramural funding to support its programs. He will continue coordinating efforts to broaden the diversity of participation at all levels and phases of the center.

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. She will oversee the execution of our Education and Human Resources plan as described in section 4.c, working with other lead education faculty and in concert with Exploratorium Site Director to integrate Exploratorium activities with the overall education plan.

Charles Craik (Knowledge Transfer 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. He will oversee the knowledge transfer activities of the center, as detailed in section 4.e.

Robert McGinn (Lead Ethics Investigator and Advisor) has > 47 years experience researching, writing, consulting, and creating and teaching courses on ethical issues raised in contemporary engineering and science and technology, He served > 10 years as Lead Ethics Investigator for the National Nanotechnology Infrastructure Network (a consortium of 13 nanotechnology research labs). He has taught several faculty-development courses in ethics, science, and technology for NSF and NEH.

Michelle Phillips (Center Evaluator) was formally trained in evaluation at Stanford University and SRI, and has 20 years of experience leading and collaborating on evaluations of large-scale STEM initiatives. With Inverness Research, she helped develop driver diagrams and frameworks for leading and evaluating 11 NSF-funded Centers. She is well- acquainted with the mission, goals, and strategies of the CCC.

External Advisory Committee. Our external advisory committee (EAC) members have combined experience in managing diversity, education, basic research, and academic-industry partnerships. The EAC will aid the CCC in identifying opportunities and improving outcomes on all of its goals. Current members of the EAC are: ***Radhika Nagpal (Chair*)**, Dept. of Computer Science, Harvard University; ***Neda Bagheri,*** Dept. of Biology & Chemical Engineering, U. of Washington; ***Tom Daniel***, Dept. of

Biology, U. of Washington; ***Erin Dolan***, Dept. of Biochemistry & Molecular Biology, U. of Georgia; ***Carlos Guttierrez***, Dept. of Chemistry and Biochemistry, CSU Los Angeles; ***Jennifer Lippincott-Schwartz***, HHMI Janelia Farm Campus; ***Wenying Shou***, Fred Hutchinson Cancer Research Center; ***Brian von Herzen***, Climate Foundation; ***Kinkead Reiling***, Co-founder of Amyris, Inc.; ***Dan Widmeier***, Co-founder, Bolt Threads, Inc. In the next project period (Phase 2), EAC personnel will be changed to provide new perspectives and increase diversity of representation. A new role for the EAC will be to help the CCC formulate plans for continuation of center activities beyond NSF funding.

Institutional Partnerships. Each Institution's Site Director provides oversight of the research, education, outreach, and knowledge transfer activities of the groups at their respective institution, and reports progress to the Managing Committee.

Research Management. Individual Center Investigators will meet monthly with theme leaders to discuss progress and coordinate future directions. Theme leaders will submit progress reports biannually 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. In the first project year, theme leaders will be Jennifer Fung (Cellular Probe), Mark Chan (Living Bioreactor), Zev Gartner (Cellular Lego), and Simone Bianco (CellCAD).

Center Research Faculty. Center research will be carried out by the following individuals: Wallace Marshall (UCSF, Cell Biology), Zev Gartner (UCSF, Chemical Biology), Hana El-Samad (UCSF, Systems Biology), Wendell Lim (UCSF, Synthetic Biology), Orion Weiner (UCSF, Cell Biology), Jennifer Fung (UCSF, Genomics and Microscopy), Sophie Dumont (UCSF, Systems Biology), Shawn Douglas (UCSF, Computer Science), Dan Fletcher (UCB, Bioengineering), John Dueber (UCB, Bioengineering), Sindy Tang (Stanford, Microfluidics), Manu Prakash (Stanford, Physical Biology), Mark Chan (SFSU, Cell Biology), Laura Burrus (SFSU, Developmental Biology), Blake Riggs (SFSU, Developmental Biology), Diana Chu (SFSU, Cell Biology), Ray Esquerra (SFSU, Biochemistry), Wilfred Denetclaw (SFSU, Developmental Biology), Simone Bianco (IBM, Computational Biology)

Administrative Management
The CCC will coordinate its activities by facilitating planned and ad hoc meetings between CCC members and advisors.

Executive Committee (weekly)
- Purpose: Discuss progress, evaluate programs and projects, review proposals for new initiatives

Managing Committee (quarterly in person)
- Purpose: Evaluate research projects, educational and broadening participation initiatives, define future directions, troubleshooting, administrative business

Membership Meeting (monthly phone call)
- All CCC-funded investigators
- Purpose: forum for updates on research progress and center activities

Scientific Meeting (Center-wide quarterly Meetings, including a 2-day Annual Retreat)
- All CCC-funded members (including trainees)
- Purpose: Share research results and techniques being developed by the CCC, integrate research with educational and outreach programs; integrate new members into center programs, provide opportunities for collaboration and mentoring as a community.

Fiscal Management. Budgetary allocations are approximately 53% for Research, 10% for Education and Outreach, 10% for Broadening Participation overall, 7% for Knowledge Transfer, and 21% for Administration (leadership, administrative personnel, communications and conferences).

The budget for the Renewal period was designed to retain key expertise for the most important components of the Center, yet provide for active management to invest resources and personnel into developing the most transformative directions. The Executive Committee will allocate funds based on yearly evaluation of plans, performance and progress. Strategic reserve funds within the broader research,

knowledge transfer, diversity, education and outreach budgets will provide flexibility to fund new directions and initiatives, including key symposia / science communication workshops. Seed funds for research will fund the most important emerging ideas, as described in the knowledge transfer section.

Changes Management. The Center Director will lead the CCC through the next funding period, limiting other commitments to ensure adequate effort over the funding period. Should Dr. Marshall not be able to carry out his assigned role, the CCC Co-Director Dr. Gartner will assume leadership of the CCC. A succession plan is in place to ensure permanent leadership of the CCC in a seamless manner. Proposed leadership changes will be presented to the EAC and NSF for comment and approval, and will be put into place as quickly as possible. If other key leadership positions become vacant, the Center Director will stand in while a general search is coordinated by the members of the Managing Committee and the EAC.

Ethics and Conflict Resolution. The Executive Committee will oversee ethics training and policies as outlined in the Ethics Plan. The Site Directors will ensure that 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 third impartial senior leader mutually agreed upon by both co-directors. No members of the arbitration committee will be directly involved in the research grant or disagreement.

Sustainability Planning. The Executive Committee is aware of the importance of building a diverse funding portfolio and will dedicate effort in the next funding period to work with CCC members to identify and secure other sources of funding. Planned activities include meetings with research theme groups to discuss potential funding opportunities and collaborations (annual); strategic planning meeting with the Managing Committee and research and education leads to develop sustainability plans for activities currently funded by the CCC (annual); presubmission review of all research proposals led by a CCC member and related to CCC activities (ongoing); partner with the UCSF Research Development Office to identify sources of funding and develop other research proposals (ongoing).

Evaluation of Center Activities. The efficacy of research, education, knowledge transfer and broadening participation programs will be assessed through several approaches to strengthen the most promising activities and directions, identify emerging opportunities and partnerships and determine phase out of ineffective programs. With advice from the Managing Committee, the Center Director has overall responsibility and final jurisdiction for the evaluation and evolution of activities in the CCC. The Managing Director collates internal and external evaluations that are used to guide the progress and evolution of the CCC. Center Evaluator Michelle Phillips will evaluate integrated research, education, knowledge transfer, and diversity outcomes.

Internal Evaluations: The Center Director will receive updates on center activities in the form of written progress reports, quarterly Managing Committee and scientific meetings, annual meetings of the EAC, consultations with individual advisors and with focus groups of Center members.

External Evaluations. The EAC will convene annually to review the progress of the CCC. A summary of activities for each center objective are distributed to the EAC prior to the meeting. The EAC will offer feedback, including recommendations for future directions and sources of funding.

Remediation Plan. Should a milestone not be met or be significantly delayed, the Executive Committee will develop a remediation plan to ensure project success. This will be context-specific and allow for adaptability in the research plan to the extent that it ensures overall project success. Potential remediation plans include increasing or decreasing resources and/or personnel devoted to a particular milestone or recruiting and/or incorporating additional expertise, technology, or investigators to overcome any unexpected challenges or roadblocks that are encountered.

Prior Accomplishments

During the first project period, CCC research activities were organized into five research projects (Cell Machine Shop, CellCAD, Cellular Legos, Living Bioreactor, and Sentinel). However, we are reorganizing research activities for the next project period into four research themes: CellProbes, Living Bioreactor, Cell Legos, and CellCad. For consistently across this proposal, the past accomplishments summarized below are organized by the new structure.

Research Accomplishment Highlights in Cell Probe Theme

Summary: We have made tremendous progress towards our goals of building new tools to perturb, measure, and analyze cell and tissue structure. Achievements include powerful deep-learning algorithms that are being applied across Center projects, new genomics tools that allow us to link the molecular state of cells to their morphological state, innovative perturbational tools for manipulating the mechanical and molecular state of cells and tissues, and new field-deployable microscopy tools for remote sensing. We summarize some of these successes below.

Deep-learning based organelle and cell segmentation: Because of our focus on cellular structure, it is essential to have rapid and effective ways to quantify the size and shape of cellular components. Image analysis tools exist for microscopy data but tend to be focused on ad hoc identification of cells, and in some cases nuclei, but not other cellular sub-structures. A systematic approach based on a general set of algorithms to annotate cellular images, detect, segment and track cells and cellular structures was missing before our project started. During the initial project period, CCC investigators have put together a suite of image analysis tools for a variety of organelles relevant to the Center, including but not limited to tools for segmenting and measuring vacuoles, mitochondria, cilia, spindles, endoplasmic reticulum, and filopodia, as well as tools for automatically segmenting yeast cells in dense layers and for the annotation of large cellular datasets. These algorithms represent an important accomplishment of the first project period, and already are enabling us to greatly increase the scale of our cell biological analyses. However, such painstakingly designed custom image analysis algorithms are time-consuming to develop, and while our existing tools will be applicable in many other cases, we recognized that modern advances in machine learning could provide a solution for new structures in the future. A second major outcome of the CCC thus far, in terms of image analysis, has been to successfully harness advanced machine learning algorithms, particularly deep learning methods, to segment cells and organelles from high-throughput microscopy images. Our extensive collaborations within the center have made use of both supervised learning, that is, requiring large sets of pre-annotated images, and unsupervised learning, that is, not requiring any pre-annotation, to produce high quality, reliable, unbiased and standardized quantitative data from cellular images. Given the amount of data the CCC is capable of producing, deep learning represents the de facto standard to achieve such results. The CCC has developed several deep architectures, many times in concert with other machine learning methods to increase performance, that have been used to reconstruct cellular images from noisy data; detect, segment and classify organelles within cells; and track the movements of cells and cellular structures from live imaging experiments, achieving performance beyond the current state of the art.

Front-end software for rapid and quantitative crowd-sourced image annotation for machine learning applications: We developed Quanti.us, a crowd-sourced image analysis tool that uses micropayments through the Amazon Mechanical Turk interface to rapidly obtain large numbers of high quality human annotations of a variety of imaging data types. We provide quantitative validation of the methods, analysis of best-practices, and a variety of pre- and post-processing tools to help the Turkers annotate data and the Quanti.us user to aggregate data and remove outliers (**Figure 1**). We showed that groups of 3 or more Turkers can generate annotations equivalent in quality to that of an expert, and also showed integration with machine learning pipelines. We have launched a website (Quanti.us) that makes this tool available to researchers anywhere, and released the code for the system as an open source tool for improvement by the community. Quanti.us is now being used by scientists across the globe.

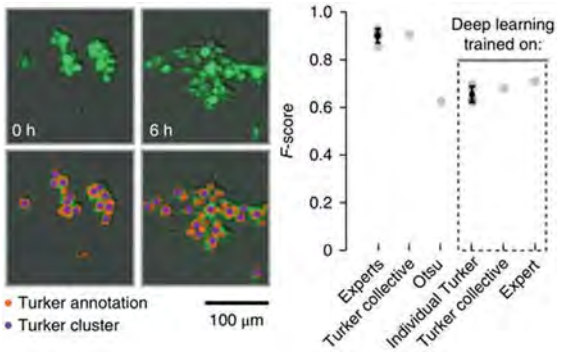

Figure 1: *Left, raw example images (top) and corresponding overlays (bottom) of Turker annotations and clustered annotations for 2 of 48 frames from a movie of mammary epithelial cell spreading (ten Turkers per frame). Right, F-score plotted for five experts; the Turker collective; automated Otsu segmentation; and convolutional neural networks trained on annotations from five randomly chosen Turkers, clustered Turker annotations, or expert annotations. Data are shown as mean ± s.d. and are representative of at least two experimental replicates*

Physical probes of mechanics in the mitotic spindle: We have developed methods to use glass microneedles to move and deform cellular structures inside vertebrate cells, and to computationally extract the resulting deformation map of cellular structures under force to infer their mechanical properties. We are currently using these tools to define the mechanical properties of the mammalian spindle but with the goal of providing a more general approach for mechanical manipulation and testing of cells.

Microviscosity: Viscosity is a key physical property of cells that affects the structure at both the molecular, organelle, cell, and tissue length scales. While a variety of methods are available for measuring macroviscosity, fewer are available for measuring microviscosity. Macroviscosity (or bulk viscosity) is determined by the translational diffusion of large probes. In contrast, microviscosity is determined by measuring rotational or translational diffusion over nanometer to micrometer spatial scales. We developed Time Resolved Linear Dichroism (TRLD) to allow microviscosity measurements in live cells. These studies (1) provide a measurement of myoglobin mobility in the cytoplasm, (2) taken together with *in vitro* TRLD studies yield new insights into the nature of the cytoplasmic environment in cells, and (3) demonstrate the feasibility of TRLD as a probe of intracellular viscosity. We are now adapting this method to work inside organelles

Multiplexed method for probing transcriptional state in single cells: While the primary focus of the CCC is on cellular structure, we recognize and expect that alterations in structure will affect gene expression patterns, and vice versa. During the first project period we developed tools to allow hundreds to thousands of individual samples to be analyzed in parallel using single cell RNA sequencing platforms like Dropseq, SeqWell, or 10X (**Figure 2**). This information is critical for measuring the internal chemical state of a cell – which is necessary for building quantitative models for all center projects. We have now demonstrated nearly one thousand unique samples can be analyzed in a single run and efficiently demultiplexed. The method decreases the costs of analyzing multiple samples by 10-100 fold while simultaneously improving data quality and removing common artifacts. MULTIseq reagents have been shipped to over 200 scientists across the globe and the technology was recently licensed by a major reagent manufacturer who will make them broadly available.

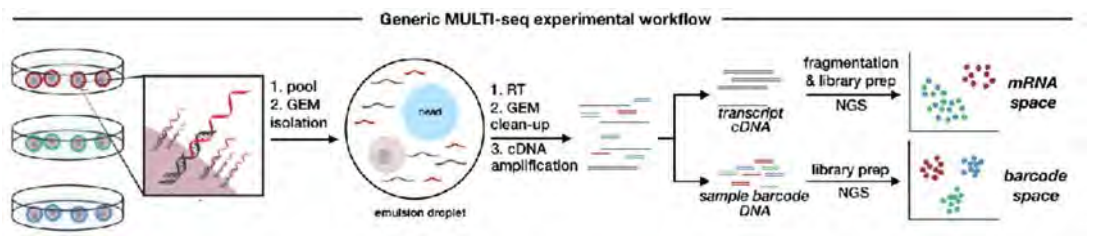

Figure 2*: General MULTIseq workflow allowing multiplexing of multiple samples in one single cell RNA sequencing run. The workflow generates two data sets: a cell x transcript_UMI matrix, and a cell x Sample UMI matrix.*

Looking forward, this tool will serve as the basis for our plans to link molecular state to cell morphology in the next project period.

Deployable AI-driven microscopes for plankton-based monitoring: A real-world application of the Cell Probe theme is to use analysis of cell morphology to infer changes in the environment. We envision a network of remote deployable microscopes that use machine learning to analyze the morphology and behavior of unicellular plankton in freshwater or marine environments. To this end we have developed a low-cost, robust, lens-less microscope that uses direct imaging of water near a CCD to obtain images without expensive objective lenses. To obtain 3D images, a new microscope has been developed that synergistically combines a stereo lens-less microscope with a digital in-line holographic microscope, producing low-resolution color images and high-resolution monochromatic image of plankton along with the 3D location. This provides a way to obtain three dimensional images in environmental water samples to analyze the cells present in the sample, and their morphology. To make use of the image data, we have implemented a plankton classifier algorithm comprising four modules: an image processor, a feature extractor, an unsupervised partitioning module and a classification module. Classification is achieved using anomaly detection, and it extends the unsupervised learning a step further, potentially enabling the design of a continuous end to end monitoring pipeline of the aquatic environment. The ability of this system to detect new cell shapes or movements means that it can potentially alert users to changes in the ecosystem that might result from previously unseen forms of pollution or other disasters. We confirmed the ability to detect novel species or cell forms using the WHOI database of plankton images (Pastore 2019)

Research Accomplishment Highlights in Living Bioreactor Theme

Summary: Towards our goals of engineering cellular and subcellular (organelle) structure to enable new applications we have made tremendous strides in the first project period. These include advancing our original proposals, such as improving methyl halide synthesis through organelle engineering, as well as entirely novel projects that emerged through unanticipated synergies among Center members. On this latter point, we highlight remarkable findings such as new tools to program microbial lysis to reduce fermentation costs, new tools for isolating recombinant proteins using axonemal arrays, and our findings that the Peroxisome is an ideal chassis for organelle engineering spawning a large variety of new projects and collaborations. These findings are already being translated into real world applications, for example as new heterologous protein expression systems for high-value and difficult-to-express proteins.

Programmed lysis of yeast cells: Microbial cells such as yeast are increasingly being used as cheap renewable sources for high-value chemicals and biopharmaceuticals. To isolate these products, yeast must either be lysed or the products must be secreted. However, existing mechanical and enzymatic methods for yeast lysis are inefficient and costly and can represent a significant proportion of the overall production cost of biologically-based chemicals. Thus, the industry has focused on secretion to bring down costs. Unfortunately, only a subset of biologically-based chemicals can be secreted, and many important products such as fatty acids, biofuels, biopolymers, and most recombinant proteins require cell lysis for their isolation. This provides strong motivation to engineer new autonomous (genetically encoded) methods for yeast cell lysis. We recently developed a system for light-based disruption of yeast that is simple, inducible, non-invasive, and highly efficient (**Figure 3**).

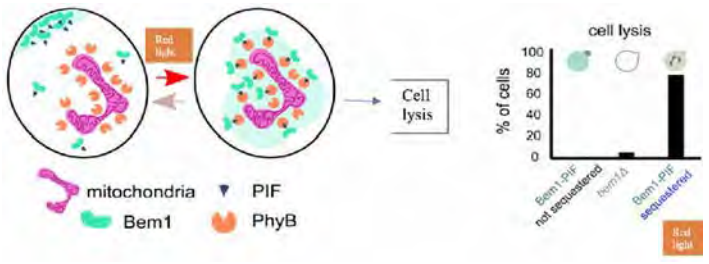

Figure 3*: Left, schematic of the optogenetic yeast lysis system. Right, representative data of system performance.*

One exciting aspect of this project that highlights the value added by the CCC is that the phenotype we observed – cell lysis – was originally interpreted as a problem by the research team. However, when the findings were

presented at a quarterly Center meeting, it was pointed out that inducible cell lysis would actually be an enormously valuable tool in the synthetic biology/manufacturing sector, thus setting in motion the current phase of this project.

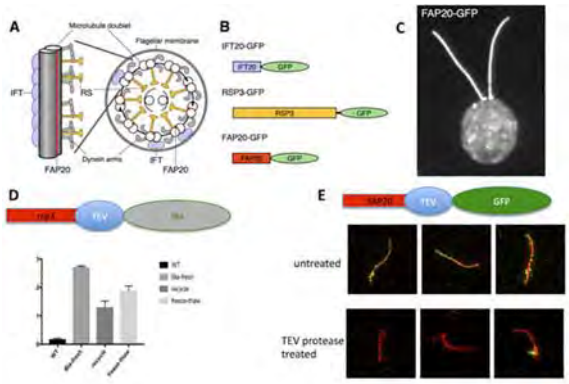

Figure 4: *Engineering the flagellar axoneme as a protein expression system. (A) diagram of axoneme. (B) constructs tested for expression as fusion proteins. (C) FAP20 shows strong uniform incorporation into the axoneme. (D) FAP20 targets beta lactamase to the axoneme in an active form, confirming the system can be used to express enzymes. (E) axoneme-tethered protein domains can be released by TEV protease cleavage.*

Engineering the axoneme as a self-organizing protein array: Another cellular structure that we have successfully engineered is the flagellar axoneme, a highly ordered structure that we hope to exploit as a scaffold for assembling proteins into dense arrays with highly uniform incorporation (**Figure 4**). This will serve as a platform for expressing hard to fold proteins and for assembling proteins into novel protein-based nanodevices. We have succeeded in expressing an enzyme (beta lactamase) targeted to the axoneme by fusion with axonemal proteins, and shown that it retains activity. Likewise we have successfully expressed protein biosensors in the axoneme, suggesting applications for protein sensor arrays. We also demonstrated the ability to cleave axoneme targeted proteins away from the axoneme anchoring site using TEV protease, as well as the ability to encapsulate axonemes within droplets in an aqueous oil emulsion (Ishikawa 2019).

Engineering methyl halide production in the yeast vacuole: We are testing the hypothesis that changing either the surface area or volume of the vacuole will increase methyl halide production in yeast that have been engineered to express a halide methyltransferase. This project encompasses the areas of 1) engineering organelles to make a specific product, and 2) high-throughput method for engineering/ screening organelle structure/function. As part of this project, CCC researchers have engineered linker sequences needed to target the methyltransferase enzyme to the vacuole and designed methods to prevent its degradation once it gets to the vacuole.

In addition, we have improved the chemistry of a high-throughput assay that can screen a large range of engineered organisms to test for improved methyl halide transferase (MHT) activity as a function of cellular structure. The assay employs a colorimetric indicator, 4-(4-nitrobenzyl)pyridine, an organic compound which changes from yellow to blue in the presence of methyl halides. We have also cloned and expressed MHT and MHT-mCherry fusions to calibrate the assay. We have measured essential parameters of the assay (i.e. compatibility and stability) and have shown that this method can be used to measure *in-situ* activity. With this assay in hand we are poised to massively expand our design/build/test efforts in the next project period.

Engineering the yeast peroxisome: The use of microbial cells as self-replicating factories often suffers from undesired interactions between the heterologously expressed proteins and native cellular factors. In many instances, the mechanism of resultant toxicity is not understood. One such example is the benzylisoquinoline alkaloid (BIA) pathway that comprises approximately 2,500 natural products with a broad range of bioactivities, including the analgesic opiates, potential anticancer therapeutics, antitussives, and anti-muscle spasm medications. Previous efforts by CCC researchers at engineering a BIA production pathway in *Saccharomyces cerevisiae* determined that the norcoclaurine synthase (NCS) enzymatic step is a bottleneck, rate-limiting step that severely limits titers. Accordingly, we have since isolated an engineered ortholog with considerably higher activity; however, this enzyme shows toxicity to the yeast production host. We have not been able to determine the mechanism of this toxicity. This

toxicity is alleviated through compartmentalization of NCS in the peroxisome, while the substrates and product can diffuse through the peroxisome membrane to allow production to continue. The current capacity of the peroxisome is limiting for production. Our aims in this project are to increase the peroxisome capacity for compartmentalization of enzyme cargo such as NCS.

Starting with a collection of genes expressed during oleic acid induction of peroxisome proliferation, we identified two genes capable of increasing the protein cargo capacity of the peroxisomes. We determined optimal expression levels of these two genes, verified improved cargo capacity of a model enzyme using an optical assay, and found that increased NCS localization improved the production rate of norcoclaurine. We have thus achieved proof of principle for the key idea of the Living Bioreactor project – that biochemical output can be improved through organelle engineering.

Research Accomplishment Highlights in Cellular Legos Theme

Summary: Towards our goals of understanding and engineering self-organization at the tissue scale, we have made tremendous advances. For example, we have developed strategies for engineering the folding of tissues and the sorting of cells within tissues. We have developed tools to engineer information flow and information processing among cells within tissues, and have developed new tools and paradigms for understanding how tissues manipulate fluid flow to communicate and modify their microenvironments. These findings are already being translated into new applications, for example in immune cell engineering and as living water treatment devices.

Tissue Origami: Fibroblasts are well known to compact tissue/ECM during fibrosis and wound healing, and this phenomenon can be recapitulated *in vitro* when they are reconstituted into collagen containing gels. We leveraged this process to engineer fields of directional strains into thick ECM gels (Hughes 2018). Patterns of strains resulted in corresponding patterns of curvature in the gels, allowing us to program their autonomous folding into complex three dimensional shapes that mimic structures seen in vivo and comprise entirely new structures designed from scratch (**Figure 5**). We built a predictive model as a CAD tool (see CellCAD Accomplishments, below).

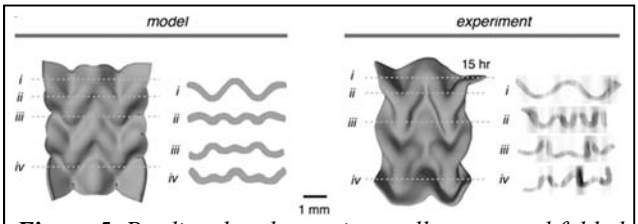

Figure 5: *Predicted and experimentally measured folded architecture for a Miura tissue origami fold*

Self-organizing structures with syn-notch: We have developed synthetic developmental programs that can be used to generate self-organizing multi-cellular tissues. We link synthetic cell-cell communication, via synNotch receptors, to the regulated expression of adhesion (cadherin) molecules that drive cell association or segregation. Using circuits of this type, we can flexibly program a diverse set of multicellular structures that mimic key properties of developing tissues: autonomous formation of complex multi compartment structures, increases in cell types (differentiation), formation of asymmetric structure, and the ability to self-repair when damaged. The resulting structures are highly robust and capable of healing and regeneration, which we have demonstrated by cutting multicellular structures in a custom microfluidic cutting device (Blauch 2017), and showing that the multi-layered organization was restored (Toda 2018). This work shows how minimal networks that link cell communication and morphology can drive self- organization and lays the groundwork for programmed assembly of customized tissues in the next project period.

The geometry of flow fields across arrays of multiciliated cells: An important challenge in Cellular Lego is programing long range order into self-organized tissues. Self-organization is known to occur in the biological context of multiciliated epithelia, where it appears that hydrodynamic interactions allow cilia to align to each other across distances much larger than a single cell. Mostly this has been studied in cell

culture, but the degree of ordering achievable is usually much less than seen *in vivo*. CCC researchers have developed methods to image ciliary flow in mouse tracheas, and are now using this method, combined with computational modeling, to understand how the sub-cellular and cellular scales of ordering affect the macroscopic ordering of long range mucus flows. Remarkably, we find that flow is optimal when cilia are less than perfectly oriented, suggesting a design principle for fluid flow (Ramirez-San Juan 2019). Eventually, we hope to use what we learn to build artificial flow fields in multicellular assemblies. Another example of coordination by long range hydrodynamics is our discovery that unicellular organisms can communicate with each other over very large distances, at high speed, using hydrodynamic trigger waves (Mathijssen 2019).

Research Accomplishment Highlights in Cell CAD Theme

Summary: Towards our goals of building models and predictive design tools for specifying cell and tissue structure we have made tremendous conceptual advances during the first project period. Our major conceptual advances occurred in three areas. First, we provided strong evidence that cell morphology can not be described within a linear vector space, providing strong motivation to more closely link our machine learning efforts in theme 1 with our modeling efforts in CellCad. In a second and related area, we realized that a data-driven approach to CellCad provides a powerful and complementary approach for designing cell and tissue structure combined with our originally proposed model-driven approach. Third and perhaps most profoundly, we have provided strong evidence at both the cellular and tissue scale that structure is best specified as a statistical ensemble, and that the design "target" should be a distribution of morphologies rather than a specific morphology. Interestingly, we find that simple equilibrium formalisms can effectively model dynamics in morphology space, at both the cell and tissue level. This result is a major research outcome for the CCC, and has profound implications for how we will propose to design structures across projects.

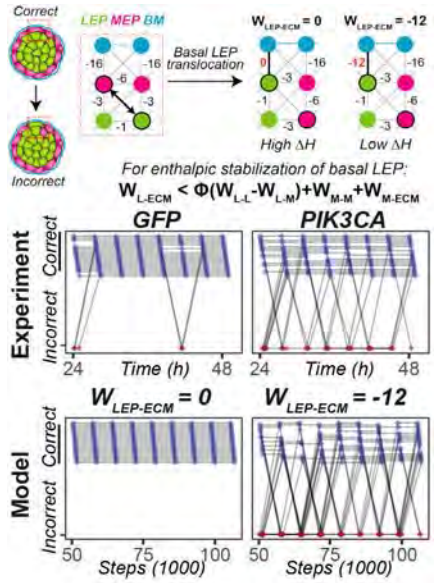

Figure 6: *Top, self-organizing tissues form a dynamic steady state between an ensemble of "correct" and "incorrect" tissue configurations. This process is simulated as a lattice-based Monte Carlo process using energy parameters measured directly in experiments. The model attempts to identify the configuration corresponding to the global energy minimum. Bottom, steady state trajectories for GFP and PIK3CA expressing tissues, in both the computational model and experiment show general concordance of overal organizational distributions and dynamics.*

A statistical mechanical model for tissue formation and breakdown: Self-organization is a dynamic process, with structures interconverting on a characteristic timescale. Whether considering structures at the cellular or tissue scale, one can often describe the observed distribution of forms as representing a steady state, akin to an equilibrium. We have been using concepts from statistical mechanics to understand what underlies observed steady state distributions of structure, as well as how the microscopic interactions among building blocks can alter the steady state.

In one example, we have been working to understand how the dynamics and microscopic forces linking cells in a model two-component tissue (the mammary gland) determine the distributions of three dimensional tissue structures we observed experimentally (**Figure 6, top**). Using a combination of theory and experiment, we developed a predictive model for how the forces linking the cellular building blocks, as well as their underlying dynamic rearrangement, determine the frequency of a particular tissue

structure. We applied these concepts to understand how dysregulation of genes during breast cancer affect the probability of the formation of structural intermediates that promote invasion. We found two key changes to the tissue promote formation of this structural intermediate: (i) more favorable interfacial energy between one cell type and the ECM, and (ii) a higher effective tissue "temperature" which is best interpreted as an increase in the rate of cellular neighbor exchanges. We found a frequently mutated gene in breast cancer, PIK3CA, increases the formation of this structural intermediate by making the cell-ECM interfacial energy more favorable. Strikingly, we show orthogonal molecular perturbations that restore a high cell-ECM interfacial energy or that decrease the effective "temperature" of the tissue restore tissue architecture, as predicted by the model (**Figure 6, bottom**).

State space representation of cell morphology: A central requirement for CellCad is to develop a representation for cell morphology that can be used to compare cells and to specify cell designs in formal terms. To this end, CCC researchers have implemented a way to construct a morphological state space for cells by imaging large numbers of cells, extracting shape features, and using data dimensionality reduction methods to create a state space (Chang 2019). We have performed cell state reconstruction using mouse embryonic fibroblasts. We find that all dimensions of the state space contain contributions from all organelles, suggesting that different organelles will not be independently addressable (**Figure 7**). Perturbations using drugs that target individual organelles affect other organelles, again confirming that organelles cannot be altered in isolation. To address whether the state space is linear, we compared position in morphology space for two single genetic perturbations as well as the combination of both perturbations. Results of this analysis clearly show that the perturbations do not combine linearly. These results suggest that morphology space cannot be treated as a linear vector space, and that nonlinear methods will be needed to predict the results of combined perturbations. We have taken initial steps in this direction using neural networks to accurately classify double versus single mutant cells. To start gaining insights from the network, we implemented a RxREN approach, a recursive approach that allows users to unbox the neural network, providing the range of input values that are responsible for shifting the classifier toward one of its output. Despite the complex nonlinear nature of the interactions between perturbations, we have found, by analyzing dynamics in morphology space, that cell behavior can be predicted by using an equilibrium "energy landscape" formalism. Thus, as with the modeling studies of tissue formation discussed above, we now believe that the key approach will be to think of design in terms of statistical ensembles.

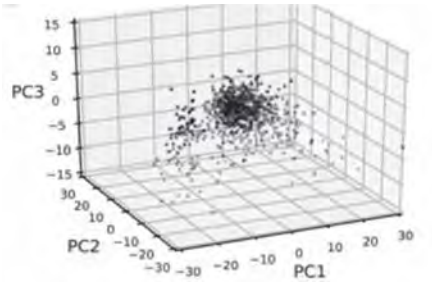

Figure 7: *Morphology space obtained by PCA analysis of over 200 morphological features measured in images of mouse embryonic fibroblasts*

CAD tool for tissue origami: Many tissues fold due to a mismatch of strain between two tightly conjoined tissue layers. Strains arise due to differences in cell growth and/or contractility between layers. In the mouse gut, existing evidence suggest that contractility in a population of cells immediately below the epithelium is tightly coupled to tissue folding, and we reasoned that this phenomenon was amenable to reconstitution in vitro, modeling, and engineering. Therefore, we parameterized a finite element model of tissue folding using quantitative measurements relating tissue strain and tissue geometry (**Figure 8A**). Our measurements demonstrated that contractile cell density along each axis of a tissue is linearly related to the degree of curvature along each axis of a tissue (Hughes 2018). We were therefore able to model the trajectory of tissue folding, and use it to prototype a variety of unusual tissue folds (**Figure 8B**).

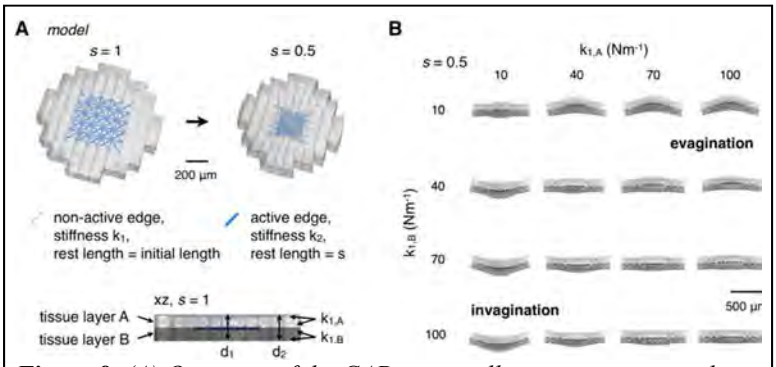

Figure 8: *(A) Overview of the CAD system illustrating active and passive edges in the FEM model. (B) Representative output of the CAD system for tissue origami demonstrating placode formation and two polarities of induced tissue curvature. See also Cell Legos project for representative tissue prepared using this tool.*

Rule-based modeling of branching tissue morphogenesis: Most natural organs have an underlying branching morphology, and controlled branching of self-organized cells is one of the ultimate goals of the Cellular Lego theme. We are thus developing computational tools to understand branching morphogenesis, in particular to predict (and therefore design) how final 3D patterning results from local branching directions (**Figure 9**).

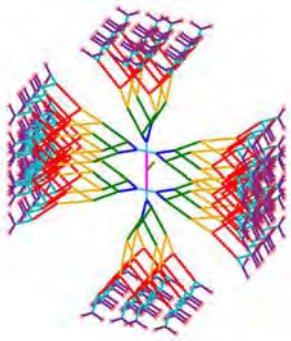

Figure 9*: An example of a computationally generated branching pattern*

We have developed a formalism known as Branching Tissue Specification Language (BTSL), which can be used to specify any branching pattern. Using this scheme, we have implemented an enumeration program that can generate all possible branching patterns in the specific case of orthogonal bifurcation. We have used this software to compare the actual branching pattern seen in the kidney – which among organs is unique in that it places the ends of all branches as the organ surface – with the complete set of possible branching patterns accessible during morphogenesis. Results indicated that the kidney branching pattern performs the best, compared to all other possible patterns. We believe this is a completely novel result that may explain why kidneys follow the developmental pattern that they do, and it represents an example of how an engineering approach, using generative models and figures of merit for design, can lead to new insights into basic biology.

Knowledge Transfer Accomplishments

Introduction of Biotools program within UCSF Catalyst program: One of our goals in the CCC was to leverage existing resources for bio-entrepreneurship in the Bay Area to help transition CCC developed ideas into the real world. In particular, our plan was to take advantage of the UCSF Catalyst program, a consortium of local industry and VC experts that administers a series of competitive awards that provide early stage funding and expert mentorship. However, we encountered a unique challenge: the Catalyst program traditionally had a strict focus on medical applications that were outside the scope of the CCC. A major accomplishment during the first project period has been the successful negotiation with Catalyst to add a "biotools" funding track that focuses specifically on engineering and biotechnology. With this new track in place, two CCC projects have already been able to obtain Catalyst support.

Partnership with Serotiny: Industrial partnership was part of our knowledge transfer vision from the outset of the CCC. One successful example has been our collaboration with Serotiny, a local startup

focused on protein engineering. Serotiny grew out of early efforts to formalize the research and knowledge transfer plan of the CCC. They provided the CCC with access to state-of-the-art tools for cellular research and bioengineering know-how, while the CCC contributed designs to Serotiny's Public repository of genetic tools. Interaction with CCC and the seed funding we provided helped Serotiny to gain visibility and validity, leading to their successful acquisition of Series A venture capital.

Faculty training in intellectual property and entrepreneurship: At the outset of the CCC, few participating faculty had any prior experience with filing invention disclosures, let alone patents. An important accomplishment of the first project period has been that all CCC faculty and trainees have received training in IP, including how to file invention disclosures. The upshot of this training has been a dramatic acceleration in the filing of disclosures and patent applications during the past year.

Broadening Participation Accomplishments

A paradigm for genuine collaboration between MSIs and large research-intensive universities: The major strategy for broadening participation in Cellular Engineering has been to focus not just on diversity, but inclusivity, by establishing true collaborations on research projects between the main minority serving institution of the CCC, San Francisco State University, and the large research-intensive institutions (UCSF, Berkeley and Stanford). The CCC was able to use its visibility with the UCSF administration to negotiate access to all of the shared core resources at UCSF for faculty and students at SFSU, thus helping to level the playing field for SFSU researchers in terms of research infrastructure. CCC funding supports research projects within labs at SFSU, which have led to 14 publications from SFSU labs thus far. Thus, by funding research of SFSU faculty and providing access to increased core resources, the CCC has been able to foster career success of diverse students and faculty in a direct way. SFSU students take part in all CCC meetings and activities, and as a result of this high degree of inclusion, there are now 18 active collaborations between SFSU labs and labs at other CCC institutions. In this way, our genuine partnership has had a much larger impact on broadening participation than if we had taken the more traditional approach of simply providing REU experiences for MSI students at the larger research partner institutions. We believe that our approach can serve as a paradigm for true partnerships with MSIs in other large centers.

Successful career transitions for under-represented trainees: Thus far 14 CCC MS students, all members of under-represented groups, have graduated. Nine of these MS students are now enrolled in PhD programs around the country. The other 5 are in research positions. Seven CCC undergraduate students, all members of under-represented minority groups, are now enrolled in PhD programs. Our first CCC URM postdoc to complete training, Dr. Guillermina Ramirez-San Juan, has obtained a faculty position at Brandeis University.

Trainee Success in the ASCB MAC poster competition: One notable accomplishment, that we believe attests to the strength of our approach based on genuine partnership and inclusion, was the strong showing by CCC trainees in the annual Minority Affairs Committee poster contest of the American Society of Cell Biology 2018 meeting. A number of students from the CCC attended this poster contest for URM students and postdocs that is judged based on the excellence of their presented research. Out of a total of 17 poster awards given, four of the prizes went to CCC trainees, including the undergraduate, graduate and postdoc categories. Given the large number of attendees at the ASCB meeting, the fact that the CCC was able to garner almost a third of the minority poster awards is a highly significant accomplishment and shows how our investment in research labs at SFSU is having an impact on the success of diverse trainees in our center.

Education and Outreach Accomplishments

CCC Summer course for undergraduate and graduate students: A key educational goal of the CCC is to train students to think about cells as machines, applying engineering concepts and techniques to the study of cell biology. To this end, we have launched a two week summer course for undergraduate and graduate students, in which students work in small groups on projects inspired by CCC research. This intensive hands-on course is based on approaches used in the famous summer courses at the Marine Biological laboratory in Woods Hole, MA. The first iteration of the summer course was held in July 2018. Several of the research projects begun in the course have now continued in the CCC, which illustrates the ability of such a course to catalyze new collaborations among the students in addition to providing a unique educational experience.

Cellular Engineering Workshop for High School students and teachers: When we first proposed the CCC, one of our main education goals was to create a mechanism for exposing high school students and teachers to the concept of cellular engineering, as a way to address the need for engineering concepts in biology education as part of the Next Generation Science Standard. We also hoped our efforts would serve to attract students to Cell Engineering who were interested in technology but who were not excited by biology as it was traditionally taught. Towards achieving these goals, we have implemented a two week summer program that brings together teachers and their students for an intense project-based learning experience that uses Lego robotics as a novel way to teach cell biology. Students and teachers work in small groups to build robots that solve challenges faced by actual cells, allowing them to learn concepts from engineering and computer science in parallel with concepts from cell biology. This curriculum is now fully established and has been running for three years. Thus far 55 students and 24 teachers have taken part in the summer course, and demand to participate continues to increase every year. This past year we ran the course twice. With such demand, we have developed a strategy to make the course self-sustaining by having some students, who pay to participate, cover the costs of other students who cannot afford to pay.

Opening of Cells to Self exhibit: A major goal of the CCC has been to promote public awareness of cell biology in general and cellular engineering in particular. In pursuit of this goal, the CCC has partnered with The Exploratorium to develop a new exhibit called Cells to Self, that introduces the public to cell biology through interactive exhibits and demonstrations. CCC faculty, as well as student interns, have interacted extensively with Exploratorium staff during the development of this new exhibit, which was funded in part by the CCC. On October 3, 2019, the Cells to Self exhibit officially opened at the Exploratorium, thus fulfilling one of our main goals for the first project period.

Selected CCC Publications

1. Blauch LR, Gai Y, Khor JW, Sood P, **Marshall WF**, **Tang SKY**. 2017. Microfluidic guillotine for single-cell wound repair studies. Proc Natl Acad Sci U S A. 114, 7283-88.

2. Hueschen CL, Kenny SJ, Xu K, **Dumont S**. 2017. NuMA recruits dynein activity to microtubule minus-ends at mitosis. eLife, 6:e29328

3. Hughes AJ, Miyazaki H, Coyle MC, Zhang J, Laurie MT, Chu D, Vavrusova Z, Schneider RA, Klein OD, **Gartner ZJ**. 2018. Engineered tissue folding by mechanical compaction of the mesenchyme. Dev. Cell. 44, 165-178.

4. Kimmel JC, Chang AY, Brack AS, **Marshall WF**. 2018. Inferring cell state by quantitative motility analysis reveals a dynamic state system and broken detailed balance. PLoS Computational Biology 2018 14(1): e1005927.

5. Liang SI, van Lengerich B, Eichel K, Cha M, Patterson DM, Yoon TY, von Zastrow M, Jura N, **Gartner ZJ**. 2018 Phosphorylated EGFR Dimers Are Not Sufficient to Activate Ras. Cell Rep. 22, 2593-2600

6. **King D**, Ma J, Armendariz A, Yu K. 2018. Developing interactive exhibits with Scientists: Three example collaborations from the Life Sciences collection at the Exploratorium. Integr. Comp. Biol. 58, 94-102.

7. Galli LM, Santana F, Apollon C, Szabo LA, Ngo K, **Burrus LW**. 2018. Direct visualization of the Wntless-induced redistribution of WNT1 in developing chick embryos. Dev Biol. 439, 53-64

8. Hughes AJ, Mornin JD, Biswas SK, Bauer DP, **Bianco S, Gartner ZJ**. 2018. Quanti.us: A tool for rapid, flexible, crowd-based annotation of images. Nature Methods 15, 587-590.

9. Toda S, Blauch LR, **Tang SKY**, Morsut L, **Lim WA**. 2018. Synthetic morphologies: Programming self-organizing multicellular structures using engineered cell-cell signaling cascades. Science 361, 156-162.

10. Chen E, **Esquerra RM**, Melendez PA, Chandrasekaran SS, Kliger DS. 2018. Microviscosity in E. coli cells from time-resolved linear dichroism measurements . J Phys Chem B. 122, 11381-11389

11. Hueschen CL, Galstyan V, Amouzgar M, Phillips R, **Dumont S**. 2019. Microtubule End-Clustering Maintains a Steady-State Spindle Shape. Curr. Biol. 29, 700-708.

12. Graziano BR, Town JP, Nagy TL, Fosnaric M, Penic C, Iglic A, KraljIglic V, Gov N, DIaz-Munoz A, **Weiner OD.** 2019. Cell confinement reveals a branched-actin independent circuit for neutrophil polarity. PLoS Biology

13. Tischer D, **Weiner OD**. 2019. Light-based tuning of ligand half-life supports kinetic proofreading model of T cell activation. Elife 8, e42498.

14. Mclaurin J, **Weiner OD**. 2019. Multiple sources of signal amplification within the B cell Ras/MAPK pathway. Mol Biol Cell. 30, 1610-1620.

15. Mathijssen A, Culver J, Bhamla MS, **Prakash M**. 2019. Collective intercellular communication

through ultra-fast hydrodynamic trigger waves. Nature 571, 560-564.

16. Ishikawa H, Yu JE, Tian J, **Tang SKY**, Qin H, **Marshall WF**. 2019. Cell-based biosynthesis of linear protein nanoarrays. Proc. SPIE 108930F

17. Kimmel JC, Brack A, **Marshall WF**. 2019. Deep convolutional and recurrent neural networks for cell motility discrimination and prediction. IEEE/ACM Trans. Comp. Biol. Bioinf. doi: 10.1109/TCBB.2019.2919307

18. McGinnis CS, Patterson DM, Winkler J, Conrad DN, Hein MY, Srivastava V, Murrow LM, Weissman JS, Werb Z, Chow ED, **Gartner ZJ**. 2019. MULTI-seq: Scalable sample multiplexing for single-cell RNA sequencing using lipid-tagged indices. Nature Methods 16, 6190-626

19. Bergman Z, Johnson B, Edington AR, de Cruz MA, **Marshall WF**, **Riggs B**. 2019. Microtubules are necessary for proper Reticulon localization during mitosis. PLoS One 14, e0226327

20. Yu W, **Marshall WF**, Metzger RJ, Brakeman PR, Morsut L, **Lim WA**, Mostov KE. 2019. Design rules for kidney branching morphogenesis. Cell Systems. 9, P221-P227,

21. Kuhn JA, **Dumont S**. 2019. Mammalian kinetochores count attached microtubules in a sensitive and switch-like manner to control cell cycle progression. J. Cell Biol. DOI: 10.1083/jcb.201902105 Diaz U,

22. Chang AY, **Marshall WF**. 2019. Dynamics of living cells in a cytomorphological state space. Proc. Natl. Acad. Sci. U.S.A. 116, 21556-21562

23. Ramirez-San Juan GR, Mathijssen AJTM, He M, Jan L, **Marshall WF, Prakash M**. 2019. Multi-scale spatial heterogeneity enhances particle clearance in ciliary arrays. *bioRxiv:* https://doi.org/10.1101/665125

24. **Bianco S**, **Chan YH**, **Marshall WF**. 2019. Towards computer aided design of cellular structure. Phys. Biol. *in press*

Selected CCC Disclosures and Patents

Patent applications filed

- Blauch LR, **Tang SKY** Microfluidic guillotine for splitting cellular structures
- **Zimmerman T, Bianco S**, McGillivary R, **Marshall W** Generating Three Dimensional Models of Microscopic Subject from a Sequence of Images
- Pastore V and **Bianco S** Semi-supervised Classification of Microorganism
- **Prakash M** Reconfigurable High-throughput Imaging Platform
- **Prakash M** MicroscopeBlocks: Modular microscopy platform
- **Gartner ZJ**, Chow E, McGinnis C, Weber R Lipid-modified oligonucleotides and methods of using the same.

Invention Disclosures

- **Weiner O** Optically induced autolysis of industrial fungi
- **Dueber J** Heterologous protein import into the peroxisome and purification
- H. Qin and **Marshall W** Living bioreactor for nanofabrication
- **El-Samad H** Caged-degron based molecular feedback circuits and methods
- **Zimmerman T** 3D microscope using front surface mirror
- **Fletcher D** Size-dependent modulation of cell-cell signaling

Ethics and Responsible Research and Innovation

As the Center aims to develop technologies in the new discipline of cellular engineering, intersecting cell biology and engineering, there is a need for deeper training in responsible conduct of science and responsible innovation, that addresses newly emerging ethical, legal, societal and other unknown issues associated with manipulating the structure of the cell and building novel structures inside living cells.

CCC ethics training comprises discussion of the complexities emerging in the field of cellular engineering, policy and governance analysis, leadership training and discussion of moral responsibilities needed as the pace of technologies supersede existing governance structures. We incorporate ethical discussions into center-wide quarterly meetings, annual retreat and in cellular engineering curriculum being developed (see Education Section).

One approach is to introduce all Center members to the field of ethics as a mode of inquiry and problem-solving, to prepare researchers in emerging fields to develop research design that is anticipatory, transparent and inclusive.

All students and researchers within the Center are required to be trained in Ethics and Responsible Conduct of Research at their respective institutions. Standard topics include:

- Scientific Misconduct (Plagiarism, Falsification and Fabrication of Data)
- Scientific Record Keeping and Data Management
- Animals and Human Subjects in Research
- Publication (Responsible Authorship and Peer Review Practices)
- Conflicts of Interest
- Mentoring and Being Mentored

However, as research and technology evolve, ethics training needs to be recalibrated. We are actively engaged with leaders in bioethics, synthetic biology, and responsible innovation fields to develop ethics training aligned with this framework. We have assembled an ELSI panel to advise us and help us develop center-wide training around ethics, legal, and societal implications of our work. This panel, led by Dr. Robert McGinn, the CCC Lead Ethics Investigator and Advisor, also includes Dr. Barbara Koenig, Director of the Bioethics program at UCSF; and Dr. Megan Palmer, Senior Research Scholar at the Center for International Security and Cooperation (CISAC) at Stanford University. We will be working with Dr. Koenig to pursue outside funding for a collaborative project to research ethical issues of cellular engineering using social science methodologies. We will also be encouraging our students and postdocs to attend conferences related to ELSI fields, such as the annual symposium of the National Science Policy Network

As lead Ethics Advisor, Dr. McGinn will co-develop ethics curriculum for workshops and mini-courses. He has systematically interviewed CCC research theme leaders and developed methodology to collect and classify promising RRI practices. These will be developed into a CCC Handbook of Cellular Engineering Ethics to be shared center-wide and disseminated outside the center.

Intellectual Property

Because this proposal involves the development of a new area of technology, novel intellectual property is an expected outcome. Training in topics such as ownership of research and ideas, and roles and responsibilities regarding intellectual property is critical. Training sessions in intellectual property, organized by Center Knowledge Transfer Coordinator Charles Craik, have been a key element of CCC meetings and retreats during the current project period. For example, Master Inventor Tom Zimmerman presented an introduction to Disclosures and Patents at the 2019 annual retreat. During the next project period, we will expand this training, utilizing the substantial resources available at UCSF in this area, such as the UCSF Clinical and Translational Science Institute (CTSI) and the UCSF Innovation, Technology and Alliances (ITA) Office.

New Shared Facilities

No new shared facilities are expected for the upcoming project period. The CCC membership will leverage existing facilities infrastructure at each participating institution, and has put into place mechanisms for providing access to such facilities to all CCC members as discussed elsewhere. The CCC Executive Committee and Site Directors will coordinate access to facilities as needed.