Introduction to Bioengineering
BIOE/ENGR.80
Stanford University

Spring 2020 Class Slides

Day 25
3 June 2020

Week 9 look ahead

CONCEPT
SKILL

Planet health

People health

Political health

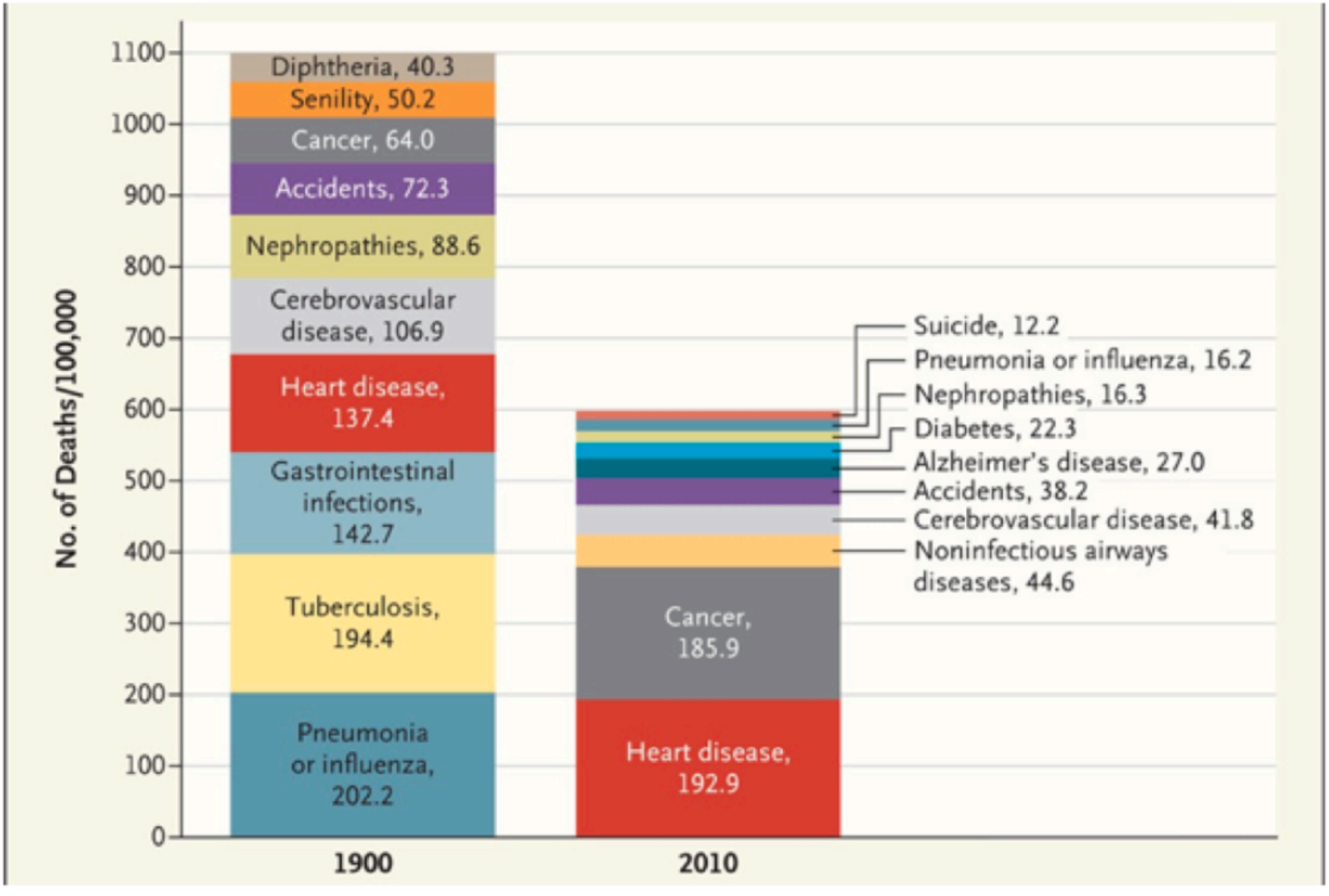
<Parsing & "Playing" Politics>

Introduction to Bioengineering
BIOE/ENGR.80
Stanford University

Spring 2020 Class Slides

Day 4
13 April 2020

Changes in Causes, 1900 to 2010



Jones DS et al. N Engl J Med 2012;366:2333-2338 (source)

"The Cuyahoga River Caught Fire at Least a Dozen Times, but No One Cared Until 1969"

https://www.smithsonianmag.com/history/cuyahoga-river-caught-fire-least-dozen-times-no-one-cared-until-1969-180972444/

Human Gene Editing Receives Science Panel's Support

By AMY HARMON FEB. 14, 2017

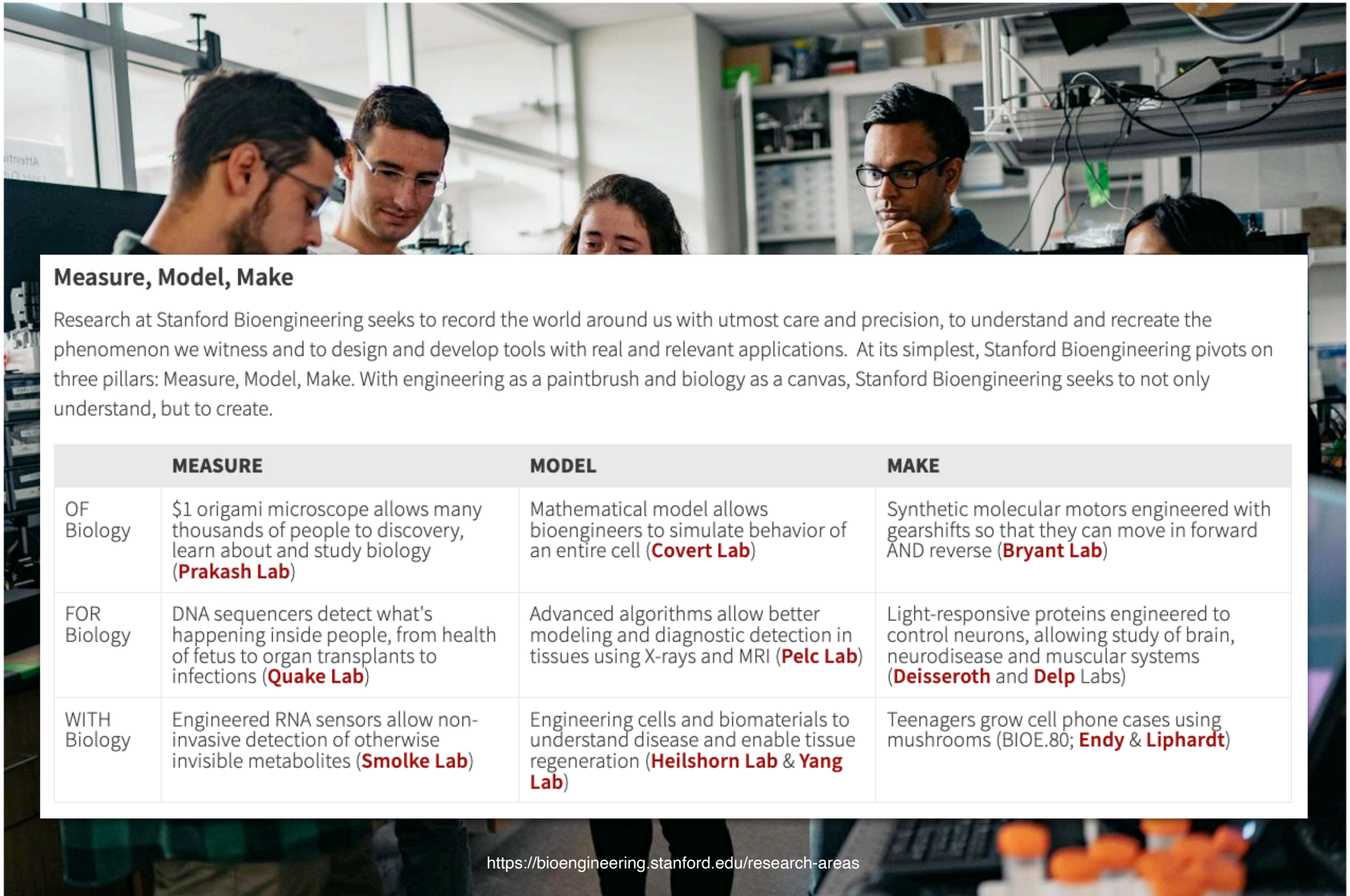
An influential science advisory group formed by the National Academy of Sciences and the National Academy of Medicine on Tuesday lent its support to a once-unthinkable proposition: the modification of human embryos to create genetic traits that can be passed down to future generations.

The advisory group endorsed only alterations designed to prevent babies from acquiring genes known to cause "serious diseases and disability," and only when there is no "reasonable alternative." The report provides an explicit rationale for genetic research that the federal government has avoided supporting until now, although the work is being pursued in countries like Sweden and China.

Embryos being removed from cryogenic storage. An advisory group has endorsed the engineering of human eggs, sperm and embryos only to prevent babies from being born with genes known to cause serious diseases and disability. Universal Images Group, via Getty Images

About Bioengineering Research

The study of bioengineering applies the principles of engineering to the complexities of biological systems in a fusion of studies that promotes scientific discovery, knowledge, and solutions through research and education. While our faculty and students already represent diverse areas of research, we are equally excited about expanding the frontiers of Bioengineering. We welcome those who wish to lead and pioneer.



Measure, Model, Make

Research at Stanford Bioengineering seeks to record the world around us with utmost care and precision, to understand and recreate the phenomenon we witness and to design and develop tools with real and relevant applications. At its simplest, Stanford Bioengineering pivots on three pillars: Measure, Model, Make. With engineering as a paintbrush and biology as a canvas, Stanford Bioengineering seeks to not only understand, but to create.

	MEASURE	MODEL	MAKE
OF Biology	$1 origami microscope allows many thousands of people to discovery, learn about and study biology (**Prakash Lab**)	Mathematical model allows bioengineers to simulate behavior of an entire cell (**Covert Lab**)	Synthetic molecular motors engineered with gearshifts so that they can move in forward AND reverse (**Bryant Lab**)
FOR Biology	DNA sequencers detect what's happening inside people, from health of fetus to organ transplants to infections (**Quake Lab**)	Advanced algorithms allow better modeling and diagnostic detection in tissues using X-rays and MRI (**Pelc Lab**)	Light-responsive proteins engineered to control neurons, allowing study of brain, neurodisease and muscular systems (**Deisseroth** and **Delp** Labs)
WITH Biology	Engineered RNA sensors allow non-invasive detection of otherwise invisible metabolites (**Smolke Lab**)	Engineering cells and biomaterials to understand disease and enable tissue regeneration (**Heilshorn Lab** & **Yang Lab**)	Teenagers grow cell phone cases using mushrooms (BIOE.80; **Endy** & **Liphardt**)

https://bioengineering.stanford.edu/research-areas

PRAKASH LAB

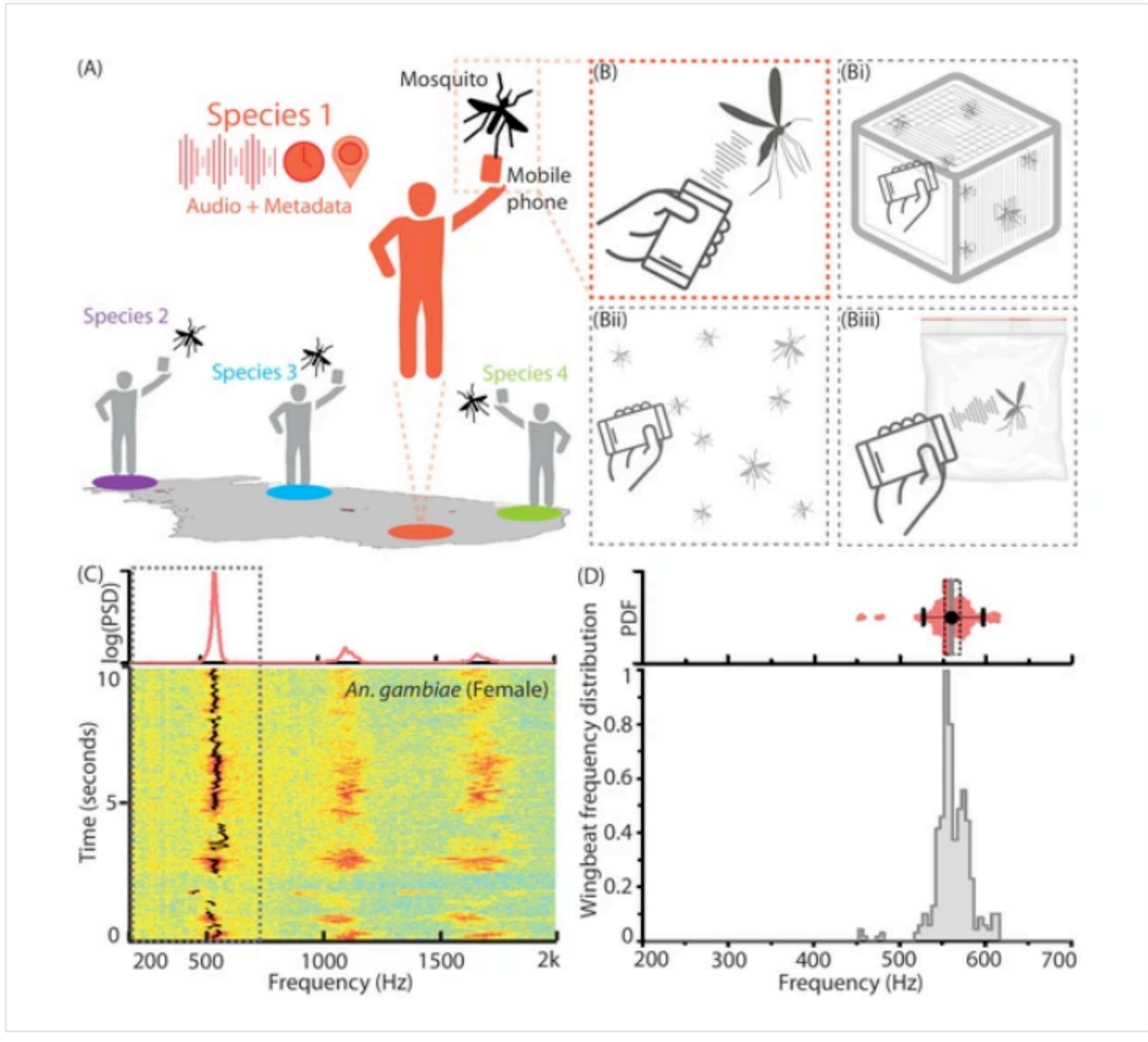
Curiosity-Driven Science

Using mobile phones as acoustic sensors for high-throughput mosquito surveillance

Haripriya Mukundarajan[1], Felix J H Hol[2], Erica A Castillo[1], Cooper Newby[1], Manu Prakash[2*]

[1]Department of Mechanical Engineering; University, Stanford, CA 94305, USA

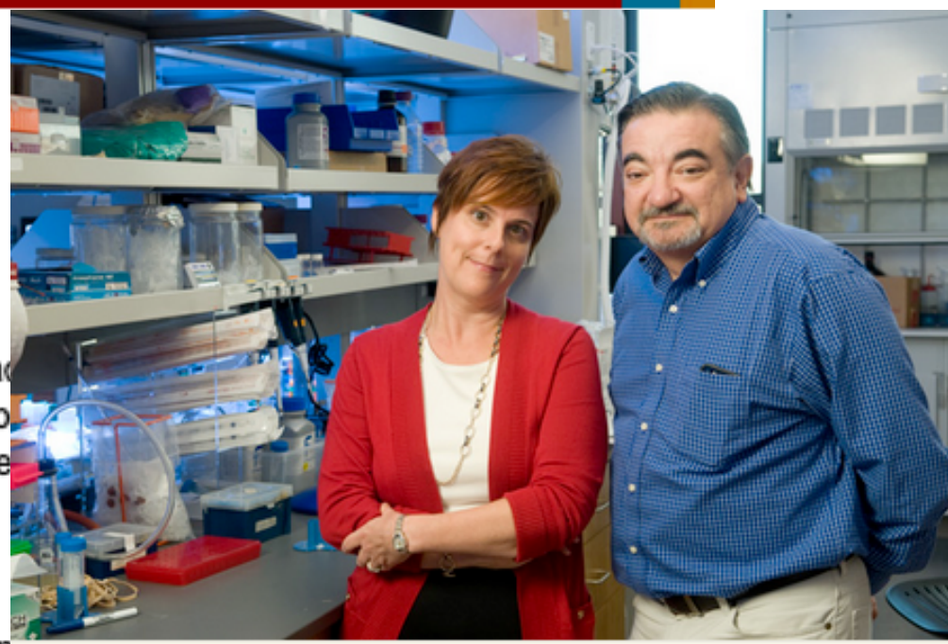
Abstract The direct monitoring of mosquitc shaping appropriate and timely control measu demonstrate that commercially available mob mapping mosquito species distributions worlc with very basic functionality are capable of ser mosquito wingbeat sounds, while simultaneou human-mosquito encounter. We survey a wid quantitatively demonstrate how acoustic reco enable rapid, non-invasive species identificatic demonstrations where minimally-trained user Thus, we establish a new paradigm for mosqu global mobile network infrastructure, to enabl resource-constrained areas.



Mobile phone users can collect acoustic data from mosquitoes characterized by the base frequency and harmonics.

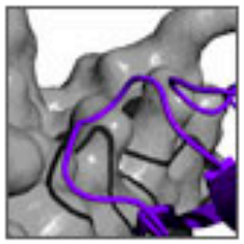
COCHRAN LAB

RESEARCH



Jennifer Cochran and Amato Giaccia are members of a team of researchers who have developed an experimental therapy to treat metastatic cancer.

RESEARCH OVERVIEW

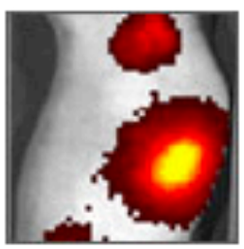


Engineering Growth Factor Ligand and Receptor Interactions

Our research group has much interest in engineering natural growth fa
tools for studying the relationship of protein sequence/structure to biolo
also have important clinical applications as therapeutics for the treatme
More...

Engineering Proteins that Bind to and Inhibit Multiple Receptors

There is great therapeutic potential for multi-specific proteins that can n
Our lab has a strong focus and interest in developing multi-specific pro
example of one project, we developed a novel platform for engineering
to and antagonize two different receptors involved in angiogenesis. We are currently evaluating the promise of these engineered proteins as cancer therapeutics and diagnostics. In addition, we are extending this platform to engineer dual-specific proteins against other important receptor combinations. More...



Engineering Proteins as Molecular Imaging Agents

In vivo molecular imaging enables non-invasive visualization of biological processes within living subjects, and holds great promise for diagnosis and monitoring of disease. The ability to create new agents that bind to molecular targets is critically important to further advance this field (1). Our research group has a strong interest in developing protein- and peptide-based molecular imaging probes that target and illuminate tumors for applications in cancer such as diagnosis, clinical staging and disease management, monitoring disease progression and response to therapy, and surgical guided resection. More...

Engineering Cystine Knot Peptides (Knottins) with Novel Molecular Recognition Properties

Our research group has a strong interest in developing peptide-based alternatives to monoclonal antibodies for tumor-targeting applications. Towards this goal, we engineered cystine knot (knottin) peptides for high affinity molecular recognition against tumor-associated receptors, and established them as a new class of molecular imaging agents in living animals. The knottin family of peptides contains a disulfide-bonded core that confers outstanding proteolytic resistance and thermal stability. Knottins, which naturally function as protease inhibitors, antimicrobials, and toxins, are composed of several loops that possess diverse sequences amongst family members. More...

nature chemical biology

ARTICLE

PUBLISHED ONLINE: 21 SEPTEMBER 2014 | DOI: 10.1038/NCHEMBIO.1636

An engineered Axl 'decoy receptor' effectively silences the Gas6-Axl signaling axis

Mihalis S Kariolis[1], Yu Rebecca Miao[2], Douglas S Jones II[1], Shiven Kapur[1], Irimpan I Mathews[3], Amato J Giaccia[2*] & Jennifer R Cochran[1,4*]

Aberrant signalin
notably metastati
rial approaches, w
alternative approa
caused structural a
When reformatted
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signaling. Moreov
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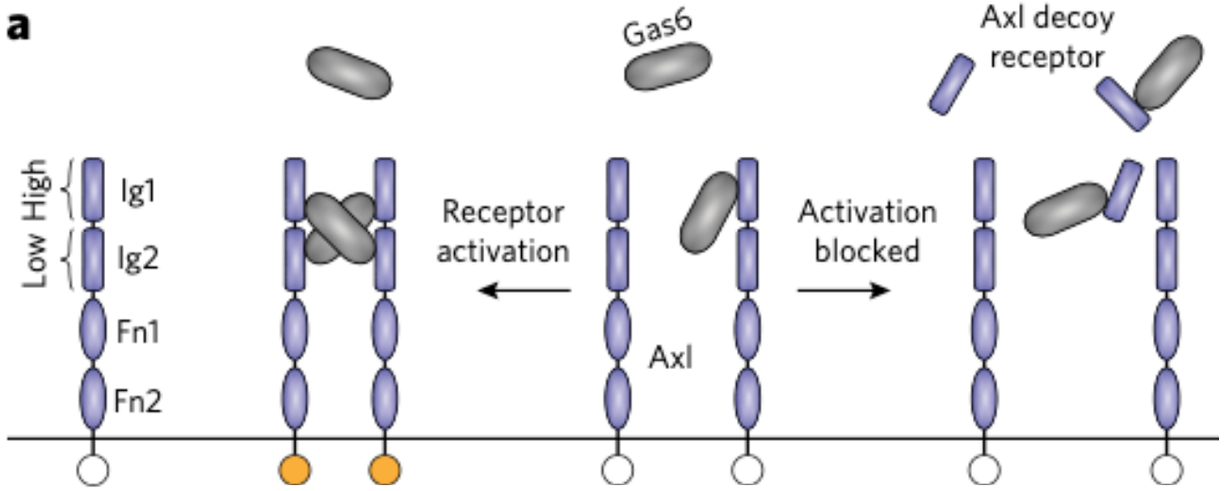
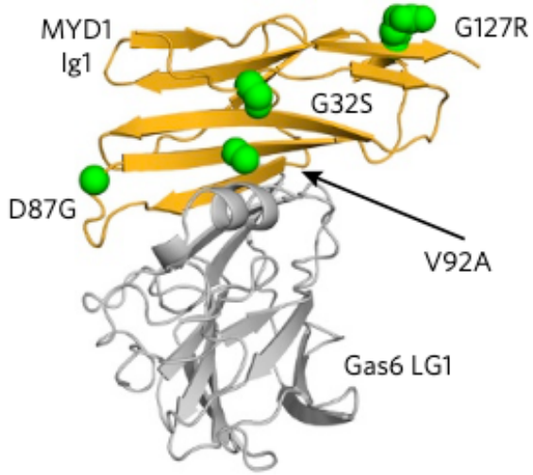
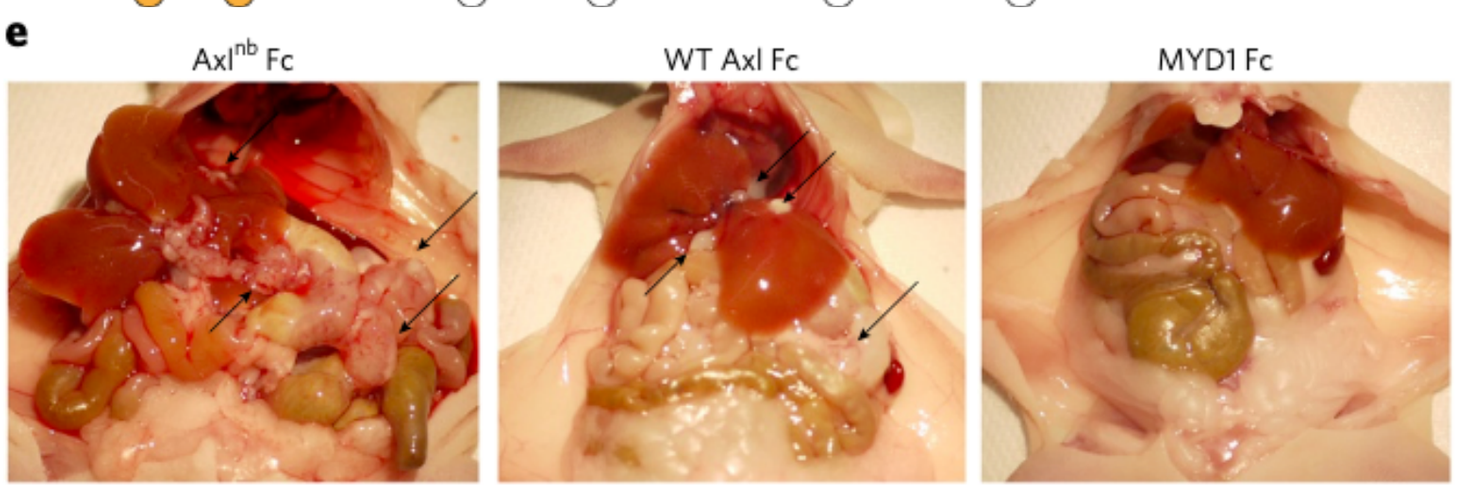
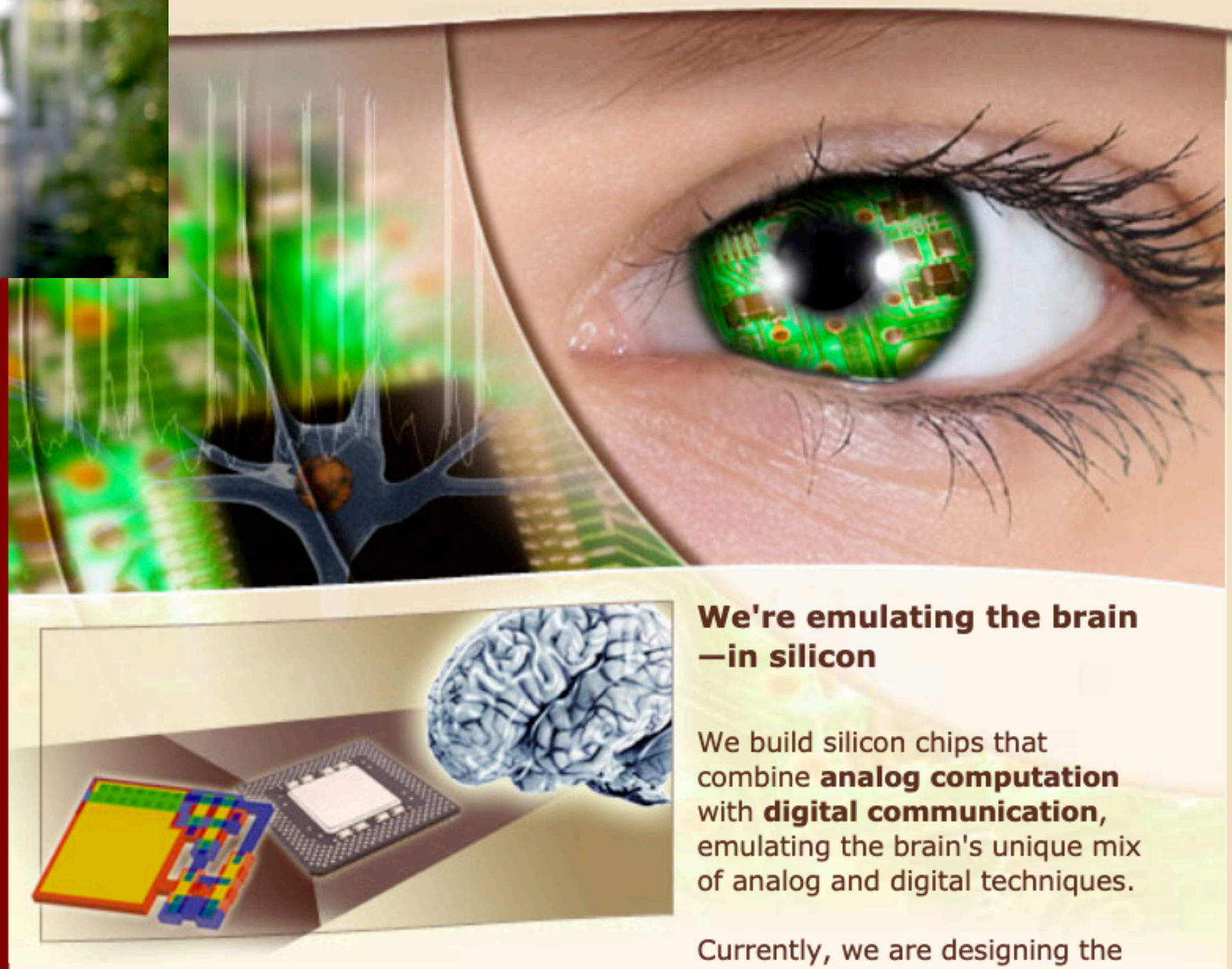
80-fold improve-
abrogation of Axl
eptors to potently







BRAINS IN SILICON
STANFORD UNIVERSITY



We're emulating the brain —in silicon

We build silicon chips that combine **analog computation** with **digital communication**, emulating the brain's unique mix of analog and digital techniques.

Currently, we are designing the first neuromorphic chip (**Brainstorm**) that implements spiking neural networks synthesized from a high-level description. We are also writing a software tool (**Neuromorph**) that performs this synthesis automatically.

We encourage you to browse to learn more about this project (**Neuromorphics**), as well as others we are pursuing (**Neuroprosthesis**, **Attention**); about the brains that work in **Brains in Silicon** (**People**); and about open positions that you could fill (**Lab Positions**).

A Brain-Machine Interface Operating with a Real-Time Spiking Neural Network Control Algorithm

Motor prostheses aim to restore function to disabled patients. Despite compelling proof of concept systems, barriers to clinical translation remain. One challenge is to develop a low-power, fully-implantable system that dissipates only minimal power so as not to damage tissue. To this end, we implemented a Kalman-filter based decoder via a spiking neural network (SNN) and tested it in brain-machine interface (BMI) experiments with a rhesus monkey. The Kalman filter was trained to predict the arm's velocity and mapped on to the SNN using the Neural Engineering Framework (NEF). A 2,000-neuron embedded Matlab SNN implementation runs in real-time and its closed-loop performance is quite comparable to that of the standard Kalman filter. The success of this closed-loop decoder holds promise for hardware SNN implementations of statistical signal processing algorithms on neuromorphic chips, which may offer power savings necessary to overcome a major obstacle to the successful clinical translation of neural motor prostheses.

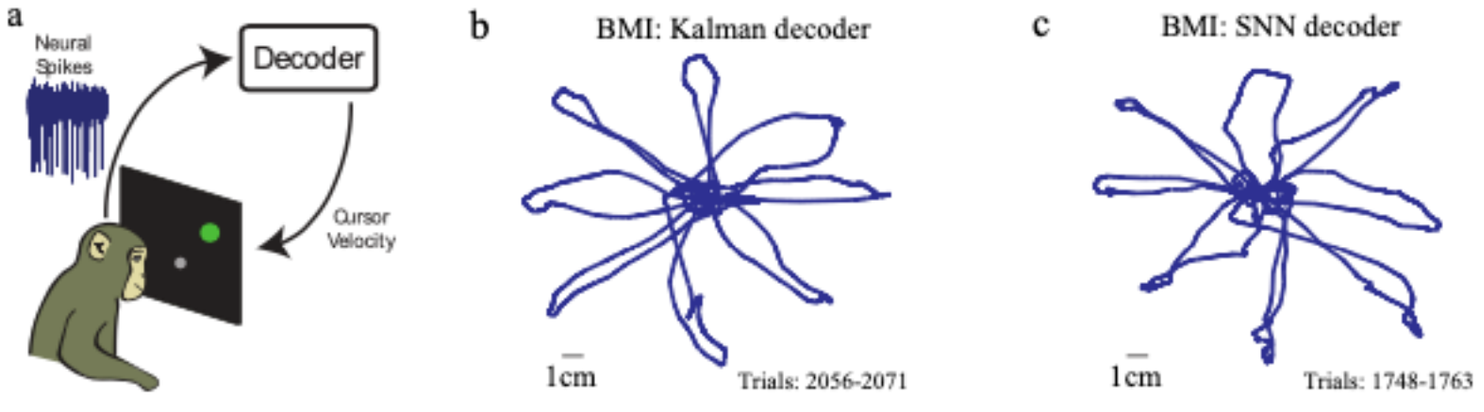
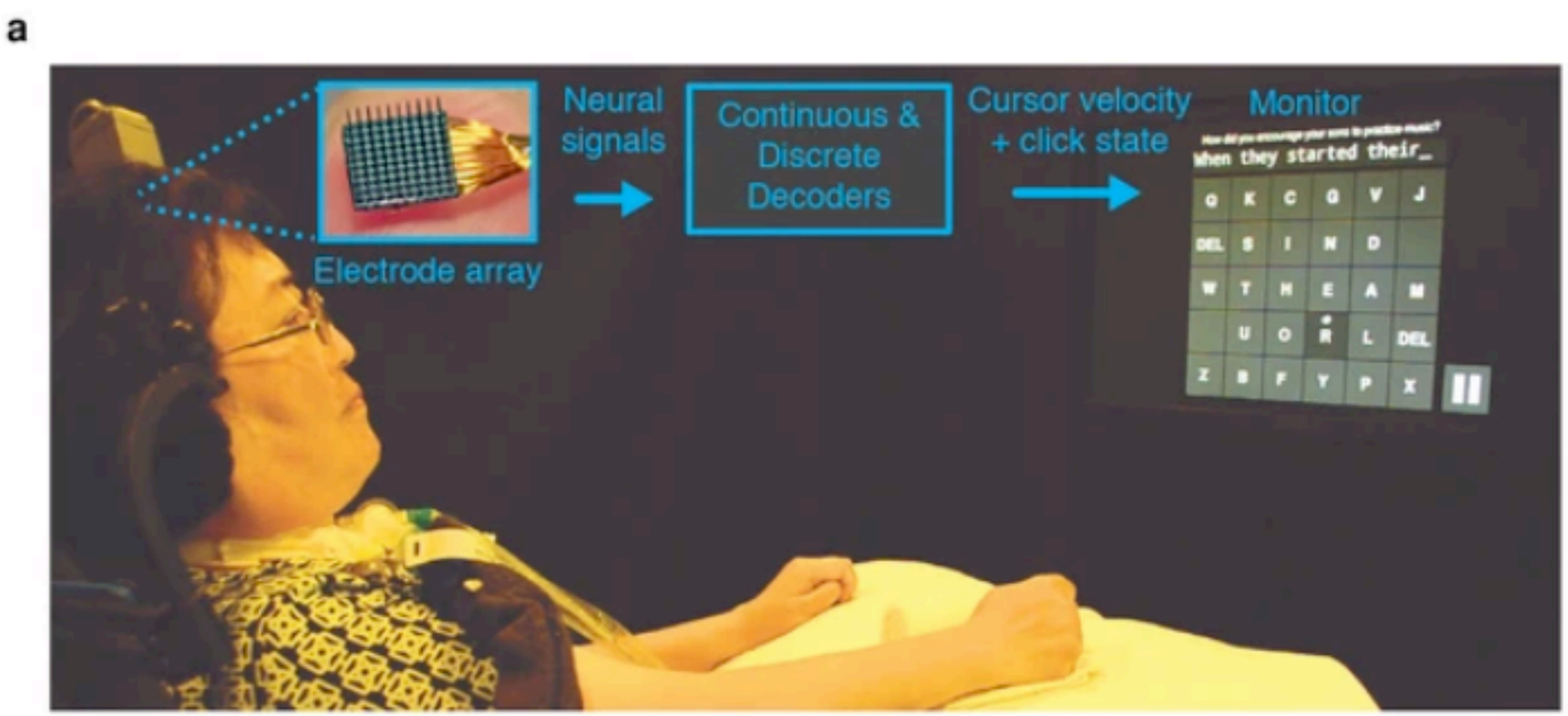


Figure 4: Experimental setup and results. **a.** Data are recorded from two 96-channel silicon electrode arrays implanted in dorsal pre-motor and motor cortex of an adult male monkey performing a center-out-and-back reach task for juice rewards to one of eight targets with a 500ms hold time. **b.** BMI position kinematics of 16 continuous trials for the standard Kalman filter implementation. **c.** BMI position kinematics of 16 continuous trials for the SNN implementation.

High performance communication by people with paralysis using an intracortical brain-computer interface

Chethan Pandarinath,
Paul Nuyujukian,
Christine H Blabe,
Brittany L Sorice,
Jad Saab,
Francis R Willett,
Leigh R Hochberg,
Krishna V Shenoy,
Jaimie M Henderson

Abstract



High performance communication by people with tetraplegia using an intracortical brain-computer interface

Pandarinath*, Nuyujukian*, Blabe, Sorice, Saab, Willett
Hochberg, Shenoy**, Henderson**

Free-paced typing using the OPTI-II keyboard

“How did you encourage your sons to practice music?”

Participant T6 / Trial Day 621 - Block 17

BrainGate2 Pilot Clinical Trial

Caution: Investigational Device. Limited by Federal Law to Investigational Use.

Stanford University
Brown University
Massachusetts General Hospital
Providence VA Medical Center

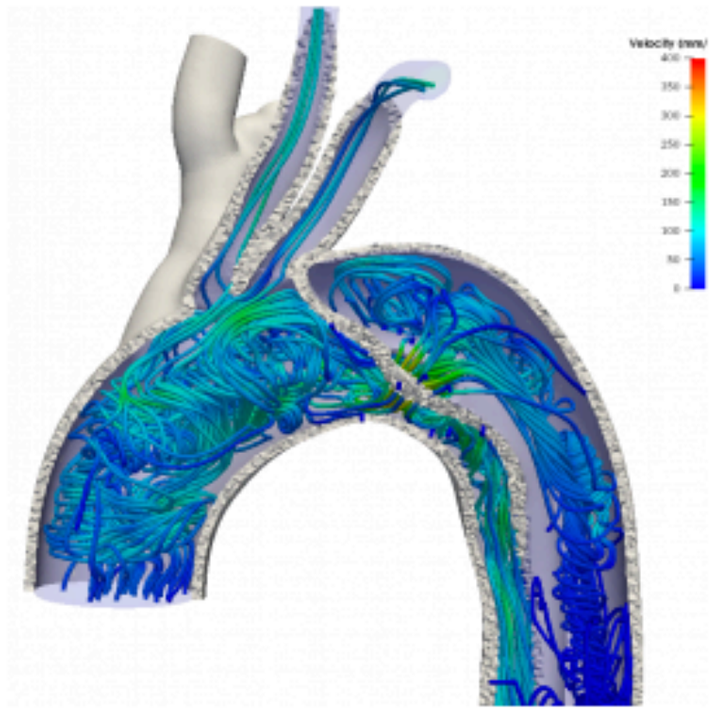
Stanford ENGINEERING | Cardiovascular Biomechanics Computation Lab

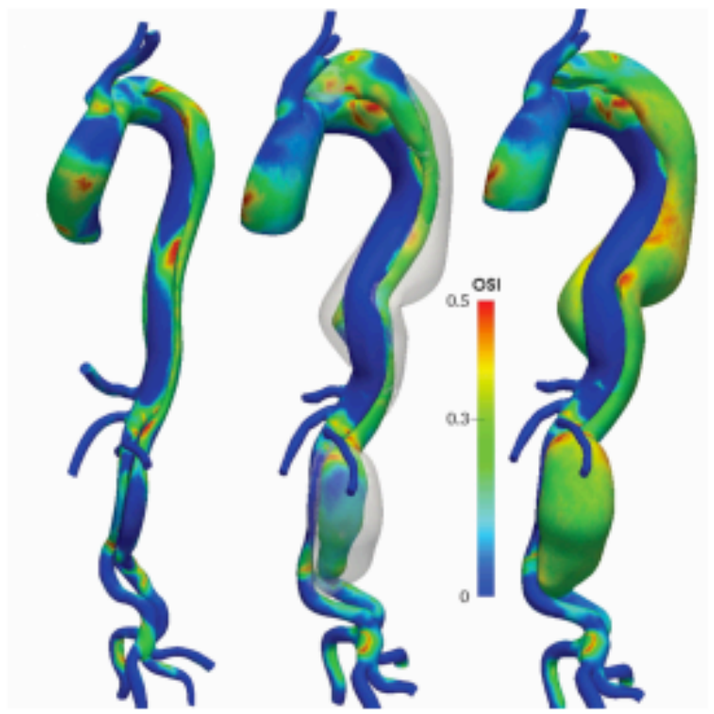
HOME ABOUT PEOPLE RESEARCH PUBLICATIONS NEWS EVENTS SIMVASCULAR

Marsden Lab

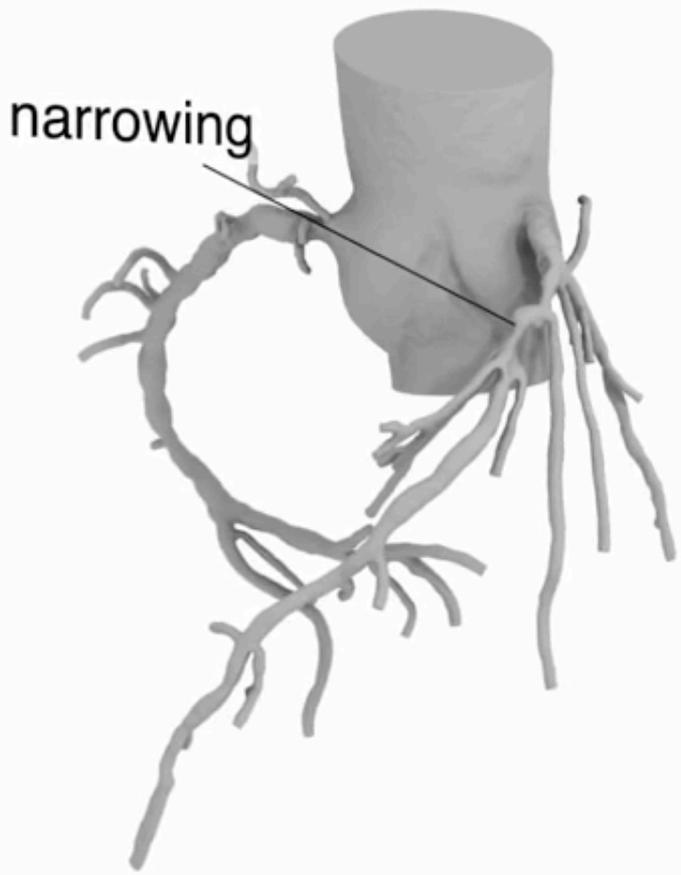
The Cardiovascular Biomechanics Computation Lab develops fundamental computational methods for the study of cardiovascular disease progression, surgical methods, treatment planning and medical devices. We focus on patient-specific modeling in pediatric and congenital heart disease, as well as adult cardiovascular disease. Our lab bridges engineering and medicine through the departments of Pediatrics, Bioengineering, and the Institute for Computational and Mathematical Engineering. We develop the **SimVascular** open source project.

More about us »

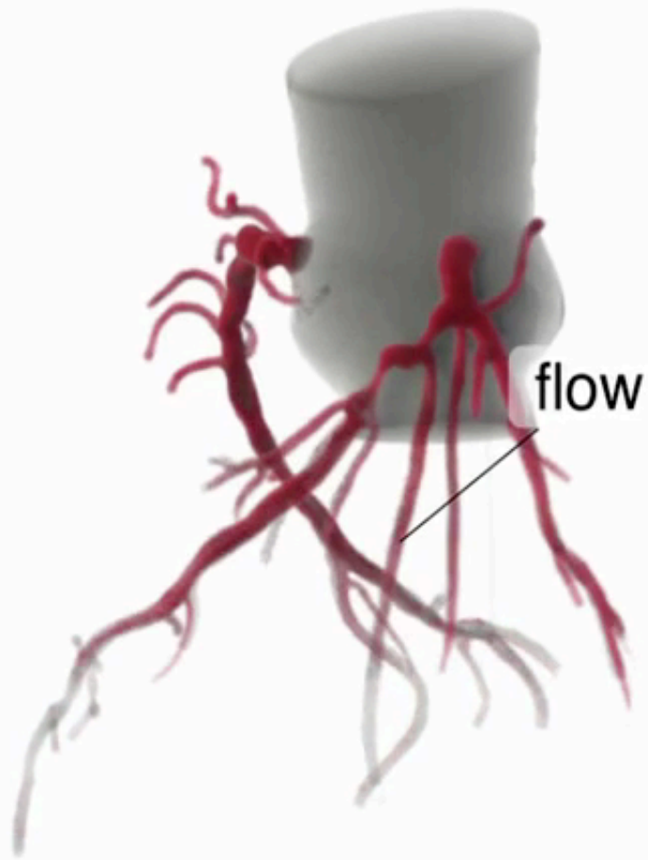




Anatomy



Function



http://heartflow.com/

Syst Synth Biol (2013) 7:67–72
DOI 10.1007/s11693-013-9117-3

RESEARCH ARTICLE

Synthetic biology as a source of global health innovation

Jenny Rooke

Abstract Synthetic biology has the potential to contribute breakthrough innovations to the pursuit of new global health solutions. Wishing to harness the emerging tools of synthetic biology for the goals of global health, in 2011 the Bill & Melinda Gates Foundation put out a call for grant applications to "Apply Synthetic Biology to Global Health Challenges" under its "Grand Challenges Explorations" program. A highly diverse pool of over 700 applications was received. Proposed applications of synthetic biology to global health needs included interventions such as therapeutics, vaccines, and diagnostics, as well as strategies for biomanufacturing, and the design of tools and platforms that could further global health research.

Table 1 List of projects funded under the Grand Challenges Explorations Program, "Apply Synthetic Biology to Global Health Challenges"

Project title	Principal investigator(s)	Institution	Summary
Diagnostics/biosensors			
A household yeast biosensor for cholera	Virginia Cornish, Nili Ostrov	Columbia University	Engineer baker's yeast to produce the red tomato pigment lycopene when exposed to the cholera pathogen in drinking water
Bacteriophage-based LAMP for pathogen detection	Héctor Morbidoni	Universidad Nacional de Rosario	Develop a biosensor to detect bacterial pathogens using modified bacteriophages and an isothermal DNA amplification process
Microbial biosensor for diagnosing leishmaniasis	Darren Zhu	Synbiosys, LLC	Engineer a bacterium with cell surface receptors that are activated and amplified by the presence of Leishmania proteases to produce a colorimetric readout that can rapidly diagnose leishmaniasis in field conditions
Multi-diagnostic platform derived from olfactory receptors	Sergio Botero	Rockefeller University	Build and test a library of yeast cells that express olfactory receptors encoded with a reporter gene that can react to various metabolic and infectious diseases, to be used in a diagnostics platform to detect multiple diseases at a time
Parasite protease biosensors	Paul Freemont	Imperial College London	Develop and test a self-replicating biosensor that can quickly detect proteases released by parasites
Pigment-based, low-cost, portable nutrition status tests	Mark Styczynski	Georgia Institute of Technology	Create portable, low-cost, bacteria-based genetic circuits to measure blood micronutrient levels without requiring sophisticated instrumentation to perform or read the test
Programmable genetic memory in bacteroides: diagnosis of diarrheal disease	Christopher Voigt, Michael Fischbach, Justin Sonnenburg	Massachusettes Institute of Technology, University of California San Francisco, Stanford	Engineer a strain of a common bacterial inhabitant of the human gut to contain genetic sensors that can report biomarkers for intestinal disorders in a stool sample
DNA nanodevice for pathogen detection	Eric Henderson	Iowa State University	Build an inexpensive and robust nanodevice that uses DNA as a scaffold to interact with proteins and nucleic acid markers of target pathogens. When this interaction occurs, the movement will be detected by a reader embedded in the device to create a visual readout of pathogen detection
Protein-based low-cost metabolite biosensors for pneumonia	Andriy Kovalenko, Nikolay Blinov, David Wishart	University of Alberta	Develop protein-based metabolite biosensors to create a simple, low-cost diagnostic test for pneumonia that is based on specific metabolite signatures found in urine
Nature-inspired nanoswitches for hiv antibodies detection	Francesco Ricci, Alexis Vallee-Belisle	University of Rome, Tor Vergata; University of California, Santa Barbara	Develop molecular nanoswitches that provide a visual cue when they bind to HIV antibodies for use in a rapid (1 min) diagnostic test to detect and quantify HIV antibodies in serum samples

Yeast receptors for a generic biomarker detection platform	Keith Tyo, Josh Leonard	Northwestern University	Engineer yeast-based biosensors that identify protein biomarkers in samples like blood and urine. An array of yeast strains could serve as a low-cost, in-home panel of diagnostics
Diagnostic/biosensor plus therapeutic			
A method to generate bacteriophages targeting enterobacteria	Mark van Raaij	Spanish National Research Council (CSIC)	Build a library of engineered bacteriophages that can recognize, infect, and kill a range of enterobacteria such as *Salmonella* and *E. coli*
Synthetic probiotic to identify and prevent cholera	James Collins, Ewen Cameron, Peter Belenky	Boston University, HHMI	Engineer the probiotic bacterium Lactobacillus gasseri to detect and kill Vibrio cholerae in the human intestine
Therapeutics			
Bacteriophage with programmable antibiotic activity	Feng Zhang	Broad Institute of MIT and Harvard	Engineer bacterial viruses to deliver enzymes that can be designed to degrade the genome of pathogenic bacteria
Discovering new anti-microbial peptides against mycobacteria	Erdogan Gulari	University of Michigan	Design and produce a large library of antimicrobial peptides (AMPS) that will be tested against Mycobacterium tuberculosis strains to identify potential new drugs that can damage the bacterial membrane and be less susceptible to evasion by the development of resistance
Synthetic signals to eliminate essential plasmodium proteins	Andreas Matouschek, Keith Tyo	Northwestern University	Develop synthetic compounds that target essential proteins in the Plasmodium parasite for destruction by its own protein degradation mechanisms
Transcription factor screening for *P. falciparum* therapy	David Segal	University of California, Davis	Develop a high-throughput screen to search for artificial transcription factors (ATF) that are candidates to treat *P. falciparum* infections
Vaccines			
A probiotic-based oral synthetic vaccine delivery system	Daniel González	University of Texas at San Antonio	Engineer a probiotic yeast into a strain that can deliver antigens directly to the intestinal mucosal immune system
Adenoviral HIV vaccine vector with CMV-Like immunogenicity	Matt Cottingham	The Jenner Institute, University of Oxford	Engineer an adenovirus vaccine vector that includes HIV antigens as well as the immune evasion genes of cytomegalovirus (CMV)
Bacterial nano-particles as oral vaccines against diarrhea	Garry Blakely	University of Edinburgh	Engineer a common gut bacterium to express antigens from pathogens that cause diarrhea onto nanoscale outer membrane vesicles, as the basis for a new generation of biocompatible oral vaccines
Plant-produced synthetic RNA vaccines	Alison McCormick	Touro University California	Test the ability of a low-cost plant-based synthetic biology method to produce a combined viral protein epitope with an antigen RNA expression system for use in an RNA

Biomanufacturing			
Design of pathways for biofabrication of global health drugs	Linda Broadbelt, Keith Tyo	Northwestern University	Use a computer-aided design (CAD) tool to identify new metabolic mechanisms of action in priority drugs for the developing world, to help optimize methods to produce low-cost versions of these therapeutics in microbes
Development of a microorganism to produce artemisinin	Jay Keasling	Zagaya	Explore the production by an endophytic fungus of artemisinin, a key ingredient in malaria treatments
Tools and platforms			
Genetically modified malaria parasites for human challenge	Christian Ockenhouse, Alan Cowman	Walter Reed Army Institute of Research, Walter and Eliza Hall Institute	Generate a transgenic *P. falciparum* malaria parasite that can be used to assess the efficacy of *P. vivax*-based circumsporozoite vaccines
A synthetic biosensor to find drugs targeting TB persistence	Robert Abramovitch	Michigan State University	Use a synthetic biosensor strain and high-throughput screening to discover compounds that inhibit tuberculosis persistence
Reconstitution of a synthetic mycobacterium tuberculosis system	Shaorong Chong	New England Biolabs, Inc.	Synthetically reconstruct essential biological processes of Mycobacterium tuberculosis and use this system as a drug-testing platform for the screening of small-molecule therapeutics against multi-drug resistant *M. tuberculosis*
A predictive model for vaccine testing based on aptamers	Alexander Douglas	Jenner Institute, University of Oxford	Use aptamers to develop a model that can be used to predict the success or failure of new vaccines in clinical trials
Wolbachia as a back door to synthetic entomology	Ichiro Matsumura	Emory University	Use synthetic DNA techniques to transform Wolbachia, a bacterial parasite that infects most insect species, in an effort to engineer mosquitoes to be immune to malaria parasites
A microbial platform for the biosynthesis of new drugs	Christina Smolke	Stanford University	Develop synthetic biology platforms to improve the scale and efficiency of microbial systems used to discover, develop, and produce drugs based on natural products
Agriculture			
Engineering plants that make their own fertilizer	Alvin Tamsir, Karsten Temme	Pivot Bio, Inc.	Transfer a nitrogen-fixing gene cluster from naturally occurring bacteria into agricultural crops. The engineered crops could capture and metabolize nitrogen from the atmosphere, reducing the need for petrochemical fertilizers and reducing the cost of farming in developing countries

iGEM ~ genetic engineering ‘olympics’

igem.org

2008

http://diyhpl.us/wiki/dna/projects/

- bacteria to eat polychlorinated biphenyls (a pollutant)
- cell density and buoyancy for lifting large deep sea objects
- in vivo directed evolution by targeting a specific gene with a genetic circuit
- pressure-sensitive gfp-expressing ecoli display screen
- production of vitamin A in human gut microbes
- BPA biosensor
- pulsed sustainable expression of recombinant proteins in yeast
- self-assembling biomaterials in response to patterns of light
- "Dr. Coli", a microbe to release drugs in the human body and then self-destruct when the disease is gone
- microbial phototaxis and transportation of heavy metals in water
- yeast sensor of ethanol
- UV sensor
- yeast production of resveratrol during beer formation
- PHB (polyhydroxybutyrate (bioplastic)) production and sensing
- lignin peroxidase to break down cell wall lignin, and ecoli synthesis of sorbitol for biofuel reasons
- ecoli random number generator
- bacterial counter based on light and fluorescence
- small intestine microbe to replace hemodialysis machines for kidney failure treatment
- self-assembling protien-based reaction comparment (encapsulin) to protect cell from toxic byproducts
- ecoli memory based on fluorescence, hydrogen peroxide and UV light
- ecoli production of the vitamin A precursor β-carotene
- ecoli chemotaxis and bacteriocide release
- ecoli thermometer that changes color
- thermogenin-expressing yeast strains to heat their own broth medium
- regulation of the synthesis of poly(3-hydroxybutyrate-co-4-hydroxybutryate) (bioplastic)
- cholera sensor
- oral hygiene yogurt
- conditional controlled gene transfer
- flagellar protein expression system

2016

https://twitter.com/kanzure/status/810643477692301312

- aptamers to tether chlorophyll to graphene plates, as a solar power device
- threshold sensor of plasmid production in cell culture, to kill off "slackers"
- ecoli cell surface display, using an N-terminal region ice nucleation protein anchor, for mercury remediation
- ecoli production of farnesol, a food flavor preservative
- cell-cell communication using autoinducer-2 (AI-2) signalling molecule production, autoinducer-2 sensor, and autoinducr-2 quorum sensing
- recycling carbon dioxide on spacecrafts using ecoli and formaldehyde
- carbon monoxide sensor, nitrogen oxide sensor
- ELISA plate to test for penicillin and antiobitics in meat products and other foods
- ethlyene sensor to measure fruit ripening
- biodegradable chitosan nanoparticles to deliver glutathione reductase (GSR) and 25-hydroxylase (CH25H) to counteract the accumulation of crystallin prote
- cell surface display of PET hydrolase (PETase) to degrade polyethylene terephthalate (PET) plastics
- protein dimerization for fluorescent proteins and regulation
- customizable outer membrane vesicles (OMVs), fluorescent protein display on OMV surfaces
- different gene expression in ecoli based on number of generations
- more PETase and polyethylene terephthalate (PET) degradation
- calcium ion channel to soften hard water
- various mosquito toxins like Cry and Cyt genes
- self-assembling peptides (SAPs), such as a ring of GFP proteins using disulfide bonds
- signal filter using regulatory gene expression elements
- ecoli production of spider silk protein Masp2 "We are targeting the mass production of spider silk protein Masp2 and a mechanism to extract it without the r
- photosynthesis in an oxygen-isolated system, using surface display and silicon encapsulation
- agricultural pesticide using "pantide" from spider toxins
- production of astaxanthin in rice
- biofilm for solar power production
- fast re-epithelialization of skin wounds using a fusion protein based on SDF1 (topical stromal cell-derived growth factor-1) and ELP (elastin-like peptides)
- coupling cell cycle to fluorescence and color, using recombinases, 'cell cycle rainbow'
- urine glucose sensor
- visual selection system based on visual phenotype of colonies
- ecoli degradation of antibiotics in waste water and rivers
- cell-free reprogrammable protein expression system using freeze-dried genetic circuits on filter paper
- microtubule + luciferase fusion protein
- fluorescent DNA nanostructures that look for specific microRNA/miRNA targets in vivo
- bacterial motility and colony shape patterning
- more PETase stuff
- hydrogen production from photosynthesis pathway and hydrogenase
- algae bloom control by down-regulation of GvpA gas vesicle protein which provides cyanobacteria with buoyancy
- magnetosome-based protein purification using Spytag and Spycatcher and Mms13 protein "Our team developed a novel protein purification approach that el of a magnetic bacterium AMB-1 that can produce magnet particles, also called Magnetosome, covered by a bilayer phospholipid membrane, in which Mms bacterial lysate. The Spycatcher-Mms13-linked Magnetosome can specifically and covalently conjugate to the Spytag-tagged protein in the bacterial lysate display and blue pigment protein)
- comparitive testing of different Cas9 proteins including Cpf1, for mammalian gene editing
- optimization of mesenchymal stem cells to target inflammation in human body
- reprogramming chemotaxis to respond to new ligands
- AHL signalng molecule sensor and M13 phage with sRNA casettes to kill pathogenic ecoli in food products
- T cell immune response stimulation via macrophage parasite to increase immune system inflammation response to specific antigens
- HHL1 protein to reduce light-induced damage to plants
- two-phase bioreactor where cells only begin producing protein once signalling says they have reached a certain concentration level
- in vivo production of star-like peptides in ecoli, as a method of enzyme co-localization in hydrogels
- optical control of tCas9 using CRY2 and CIBN to transcriptional activator VP64 and the catalytic domain of tCas9
- degradation of 3-phenoxybenzoate (3-PBA)
- microRNA detection using cas9 or something?
- hepatitis C biosensor using paper-based synthetic gene networks
- directed evolution to improve sound sensing CHO cells
- cystic fibrosis treatments using cas9, via inhalation into lungs, using cholera
- photothermal ablation of tumors using gold nanorods
- software for data storage in DNA
- genetic oscillators and quorum sensing autoinducrs, using fluorescence and gene circuits that switch out the currently active circuits based on optical input
- production of tanshinone to fight cardiovascular disease
- degradation of uric acid to urea using urate oxidase, allantoinase, and allantoicase
- bacterial production of cinnamaldehyde and phenylpyruvic acid to repel nematodes
- RNA inducible boolean-like output switches for better control over gene expression
- miRNA sensor of alzheimers disease, reporting by fluorescence
- ecoli surface capture of norovirus from human gut intestinal tract, and expulsion fro the human body
- ecoli surface display of alcohol oxidase to produce an electronic signal to determine blood alcohol content levels
- urine glucose sensor (again)
- secretion of exosomes with surface display of iRGD to target tumor cells
- protein polymer biomaterial for the capture of uranyl ions, also interaction with biotinylated magnetic beads
- freeze-dried yeast powder as a biosensor for glucose and epinephrine
- cationic antimicrobial peptides (cAMPs) to increase the shelf life of milk
- hydrogen production in green algae Chlamydomonas reinhardtii switched on and off by blue-light induced microRNA
- even more PETase stuff
- suvCas9 system (cas9, sgRNA, and a mRNA recognition system) in Saccharomyces cerevisiae to monitor for mutations in genomic sequence
- DNA vaccine backbone stuff
- ecoli production of hypotaurine
- endolysins (instead of antimicrobial peptides) to perform cell wall lysis of the pathogenic Acinetobacter baumannii
- V. fischeri bioluminescence lux genes, for a bioluminescent reading lamp
- degradation of lignin, using lignin proxidase, as a bleaching method for the paper industry
- an attempt at silk production in Chlamydomonas reinhardtii, and also a DIY centrifuge
- biofilm sensor and anti-infection wound patch
- bioremediation of estrogen
- Cas9 to detect a long non-coding RNA as a sensor for prostate cancer detection
- genome sequencing of a bacteria resistant to mercury from the Amazon forest
- Acidithiobacillus ferrooxidans and Chromobacterium violaceum, for recovering metals from the electronics waste ("e-waste")
- DNA clamps to reduce genetic interference from nearby active genes
- cas9 to deactivate the ArcAB-TolC efflux pump system in bacteria, disabling antibiotic resistance
- microfluidics + livestreamed microorganism battles from a microscope slide
- fluorimeter, optical density sensor, DNA concentration meter, incubator, refrigerated centrifuge, yeast dryer and oxytocin sensor and production of a more
- tardigrade proteins for bacterial resistance to desiccation
- protein degradation tags and protease, especially to fine-tune biosensors
- DARPins expressed on Lactobacillus brevis cell surface to bind and target tumors in the gastrointestinal cancer, and then using quorum sensing to trigger
- recombinases as a form of genetic memory, estrogen sensor, progesterone sensor, and receptors using synthetic promoters to detect endometriosis
- keratin degradation and kertinase stuff (again)
- photoacoustic imaging in the gut using ecoli expression of the bacterial pigment violacein and near-infrared fluorescent proteins iRFP670 and iRFP713
- genetic engineering of biomaterials for high-altitude weather balloons and space exploration
- harvesting the cellular penetration capabilities of toxin B from the Clostridium difficile bacteria (TcdB), which is capable of entering epithelial cells, for t
- in vivo production of fatty acid methyl esters in cyanobacteria utilizing the insect methyltransferase, DmJHAMT
- pathway to convert perchlorate into oxygen gas
- containment system based on a modified leucyl tRNA synthetase enzyme, using a modified leucine amino acid
- modulation of translation of different genetic circuits, using ribosome binding sites, promoters, etc.
- cell-cell communication, characterization of a variety of different quorum sensing systems based on N-acyl homoserine lactones (AHLs)
- using cas9 as a strong transcription regulator using catalytically-inactive dCas9-VPR complex
- ethanol bioremediation in runoff waste water
- ecoli production of 13 different bacteriocins to target common and historically significant mastitis-causing pathogens, to treat bovine mastitis
- taxol production for anti-cancer reasons
- production of mambalgin, production of lethal toxin-neutralizing factor LNTF-10 and LNTF-15, serum derivatives o Didelphis virginiana (North Americ
- investigation of pathogens in EMS vehicles using DNA sequencing
- aptapaper: aptamer-based proximity-dependent ligation (NASBA) and in vitro transcription and translation to produce enzymatic reporter protein providi
- increase cold resistance, freezing resistance and cold adaptation to cyanobacteria using lipid desaturase protein (desA) able to increase cold-growth tolera
- paper-based synthetic gene network to detect the presence of a metal, either lead or thallium
- detecting GPC1 through an identified binding partner Cripto-1 (CR-1), a membrane anchored protein co-receptor implicated in tumor cell, using exosoma
- yeast KaiABC oscillation and circadian rhythm system and control of gene expression
- color pigmentation using GAF domain of cyanobacteriochrome (CBCR) proteins as an alternative to artificial food dyes
- methane sequestration, and DIY -80 C freezer design, see freezer construction plans
- conotoxin sensor and response for bacteria in the respiratory system
- yeast culture control system based on color signals (violacein pathway) that cause computer system to release other chemicals into culture
- bacteriophage therapy to detect and kill Serratia marcescens, a coral reef pathogen, particularly looking for pathogens of the TolC protein "the goal being
- kombucha characterization and "designer kombucha"
- continuous flow microfluidics design tool
- quorum sensing and autoinducers to control cyanobacteria production in bioreactors
- Acinetobacter baylyi ADP1 and shuttle vectors during log phase for simple biobricks usage, "We will show that A. baylyi can be transformed with recom
- plastic sensing feedback device, to give indications as to where plastic exists in the ocean, including PETase to degrade the plastic
- ecoli production of blood clotting factors from Cerastes cerastes snake venom
- ecoli phosphorus remediation from water
- self-assembling protein cages capable of cleavage by thrombin proteases at blood clot sites, pre-loaded with anticoagulant drugs
- contact-dependent inhibition (CDI) systems as an alternative to antibiotics, explored through Lambda--red recombineering
- characterization of impact on protein expression by RNA sequences with known secondary structures
- ecoli production of aromatic aldehydes from toxic precursors using TOL pathway
- overexpression/overproduction of ATP
- plant biomass degradation, such as from large amounts of lignocellulose, using surface display of cellulases on Caulobacter crescentus
- ecoli production of ethanolamine utilization compartment (EUT), a simple bacterial microcompartment, which requires minimal genes and can assemble
- a tool to convert images of colonies into sound
- synthetic collagen scaffold infused with platelet drived growth factor (PDGF) and aprotinin to induce healing of chronic wounds
- Cas9 gene drive and recovery drive induced using tetracycline
- ecoli surface display of a copper binding protein, for copper remediation
- investigation of indigoidine tagging of nonribosomal peptides (NRPs) and investigation of nonribosomal peptide synthetases (NRPS)
- cyanobacterial production of tetrapyrrolic dye molecules such as heme, chlorophyll, and phycocyanobilin (PCB), and also BODIPY, a dipyrrin-containing
- gold sensor, and deep learning to find novel genes for gold biomineralization
- thallium bioremediation using an uptake system based on overexpression of the endogenous Trk protein complex (trkA, trkE, trkG and trkH)
- ribosomal binding site library
- software to replace metabolically-risky/mutationally-risky amino acid sequences with alternatives (such as to prevent a culture over time optimizing by re
- using cas9 to overexpress and knock-down prion protein expression, to better investigate prions
- reversible gene editing system using Cas9 to target RNA and avoiding homology-directed repair, using APOBEC1 and ADAR1/2 to enable CRISPR-targ
- yet another PETase project
- production of di-rhamnolipids (naturally produced by Pseudomonas aeruginosas) as a mosquito repellent
- mining porcupine feces for turpentine-degrading bacteria
- kill switch based on TetR repressor and colicin
- ecoli nitrogenous waste degradation using an ammonia oxidation pathway for waste water treatment and remediation
- bacteria to fight Pseudogymnoascus destructans, a fungal pathogen of bats, using ocimene, a volatile organic compound, and leupeptin, a protease inhibito
- outer membrane vesicles (OMVs) for the delivery of Cas9-complex for gene editing and delivery
- regulation of aerobic respiration in yeast by controlling the expression of mRPS12
- tuberculosis sensor using 1-mehtylnapthalene (1-MN) from lung breath output and indigo dye
- ecoli secretion of chitinase (a chitinase specific to Fusarium oxysporum, a major pathogenic fungi)
- ecoli production of erythritol, a food sweetener
- characterization of various new promoters
- radiation resistance for space exploration through a biotherapeutic transdermal patch to produce and deliver radioprotective peptide mBBI

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Micronutrients

VITAMIN A

VITAMIN B2

VITAMIN B12

IRON BIOAVAILABILITY

Because the law is not the only element we needed to consider for our project, we decided to build a survey on the food habits of Indian citizens, to understand what they eat the most and when, how they cook, how often the food varies, how they see our idea, would they try it, etc.

This survey take an important place in the Human practices, because collecting information on the field is essential, to understand people's acceptance toward our project, and to find ways of introducing this project into their daily life without disrupting their tradition and culture.

Alice's trip to India :

In order to get in touch with the Indian population, we shared our survey with an ex- iGEMer (Alice LEBOEDEC from the 2014 INSALyon team) who went to South India at the end of July. She helped us gather information by distributing the survey and assisting people with filling it out. This helped out team to shape our project according to people's preferences. Alice not only returned with the filled in surveys, but also a few samples of idli batter, curd (fermented milk), rice, lentils and condiments for us to analyze.

Among the farmers that filled out the survey, daily rice consumption was universal, being consumed with vegetables as a side dish, while fish and meat are eaten once or twice a week. The people she interviewed were really enthusiatic towards our project and said that they would try the modified microorganisms that make food more nutritious. You can see below the photos of the Idli preparation and the batter.



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Cobalamin (Vitamin B12)

Cobalamin is a vitamin involved in the metabolism of every cell in the human body. It is needed for development and maintenance of the nervous system and brain. Vitamin B12 is involved in DNA synthesis and regulation of the transcription. Neither humans nor animals are able to synthesize this vitamin. Foods of animal source are the only natural source of cobalamin in human diet and Coba
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microbial
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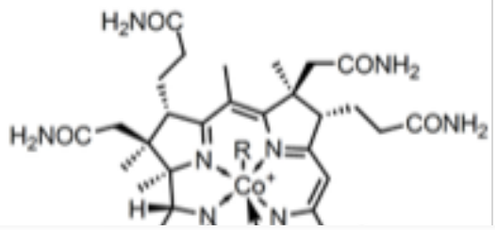


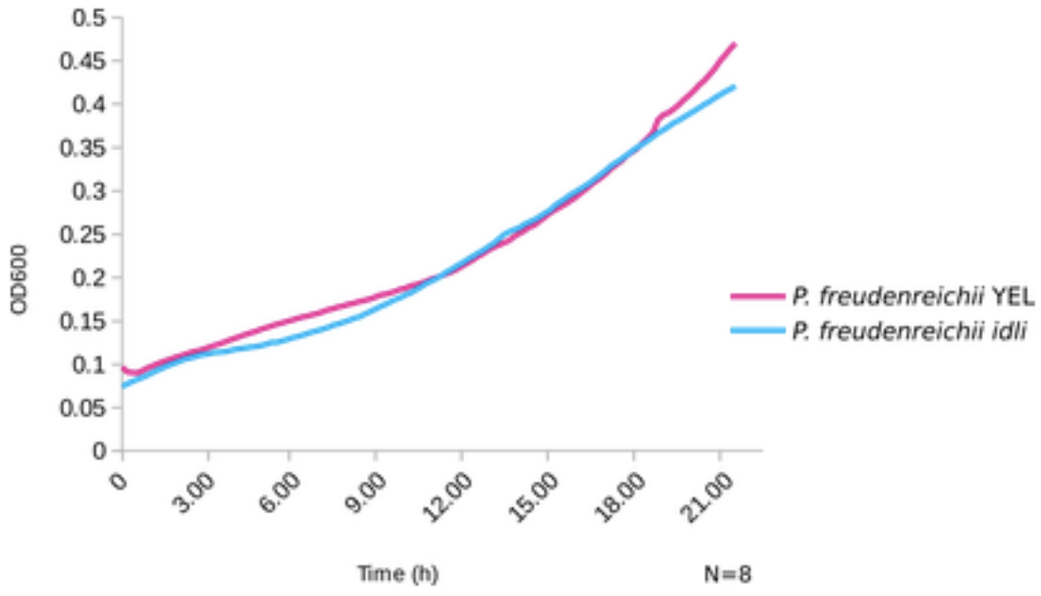
B12 daily requirement and toxicity

- **Children:** 0.4-1.8 µg/day
- **Pregnant Women:** 2.6 µg/day
- **Men:** 2.4 µg/day
- **Cobalamin** is not toxic even in doses well above the recommended daily allowance because it is a water soluble vitamin.

Propionibacterium freudenreichii grows in idli

Propionibacterium freudenreichii is a bacterium that has the Generally Recognized As Safe (GRAS) status, and is commonly found is cheese such as Emmental. It is a natural big producer of vitamin B12, conferring high amounts of this vitamin on cheese. Since the biosynthesis of vitamin B12 is a complex process, we decided to engineer the microbiome of idli by directly adding this bacterium to the batter, in the hope of increasing its vitamin B12 content.

As a matter of fact, *P. freudenreichii* was found to grow well in idli (see figure on the right).



Comparison of growth of *P. freudenreichii* in YEL (regular growth medium) and 100 times diluted idli batter.

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United Nation's SDGs

(adopted by all UN Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future)

https://sustainabledevelopment.un.org/sdgs