IN THE UNITED STATES DISTRICT COURT
FOR THE MIDDLE DISTRICT OF FLORIDA
FORT MYERS DIVISION

LEONARD G. HOROWITZ,
Plaintiff,

vs. Case No. 2:20-cv-00955-JLB-NPM

PFIZER INC., et al.,
Defendants.
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PLAINTIFF'S OPPOSITION TO DEFENDANT MODERNA's MOTION TO DISMISS

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OVERVIEW

This case pits the Plaintiff's damaged religious commerce in a claimed "vaccine and antibiotic alternative" (trademarked "OxySilver") against the Defendants' science and sales of a "novel" "genetic therapy" called the "COVID-19 vaccine". Both OxySilver and the Defendants' vaccines act therapeutically bioelectrically. Horowitz applies the "528 frequency" of sound and light, claimed to be therapeutic and the "key of the house of David" (Isaiah 22:22; Rev. 3:6-8). That frequency vibrates at the heart of sunshine and nature, and is evidenced by scientific studies to be an immune-boosting nerve-protecting antioxidant. Horowitz claims this 528 Solfeggio musical note is prophesied in the Bible to open doors to metaphysical protection and healing by the "Holy Spirit", impacting people bio-electrically and bio-spiritually (i.e., metaphysically) but not "supernaturally." Alternatively, Moderna and Pfizer manufacture their modified mRNA ("mmRNA") vaccines to supersede nature and natural immunity by directing DNA in cells to mass produce foreign proteins. These "Spike protein antigens" prompt antibody production and alleged protection by the immune system. Key in delivering Defendants' mmRNA "payload" is a "hydrogel" device that coats the genetic material and contains bioelectrically active copper (gold or silver) nano-electrodes in a lipid composite. Like OxySilver, the hydrogel is active bioelectrically, but unlike OxySilver the device can also be used to receive or transmit a wide array of bioelectrical data from within vaccinated people, a fact generally concealed from public discourse.

Horowitz claims his OxySilver is well-suited for people who distrust the Defendants' secular bioelectric drug commerce; are religious objectors; or are medically-compromised and cannot tolerate vaccines or their side effects.

Plaintiff also claims the Defendants are "state actors" that have partnerships or financial contracts with government officials, and have acted unlawfully as an "enterprise" to, inter alia, monopolize the health and therapeutic narrative, and force Plaintiff into bankruptcy in violation of the Florida Deceptive and Unfair Trade Act ("FDUTPA" as defined by Fla. Stat. § 501.204(1)); simultaneously depriving Horowitz's religious freedom and commerce secured by the Religious Freedom Restoration Act ["RFRA"] of 1993.

I. LEGAL STANDARD

A motion to dismiss under Rule 12(b)(6) must not be granted when the plaintiff is entitled to relief as a matter of law, assuming the truth of the factual allegations. *See Bell Atlantic Corp. v. Twombly*, 550 U.S. 544, 555 (2007); *Ashcroft v. Iqbal*, 556 U.S. 662, 678 (2009); *Ironworkers Local Union 68 v. Astrazeneca Pharm.*, 634 F.3d 1352, 1359 (11th Cir. 2011). Furthermore, if there is a "case or controversy" pursuant to Article III, a plaintiff stands properly, and the complaint must be adjudicated. 12(b)(1). *Fla. Family Policy Council v. Freeman*, 561 F.3d 1246, 1253 (11th Cir. 2009).

II. PLAINTIFF'S FDUTPA CLAIMS AGAINST MODERNA ARE NOT PRECLUDED BY THE STATUTE'S "SAFE HARBOR PROVISION"

Contrary to Moderna's main argument, the Plaintiff's § 501 unfair and deceptive trade claims are not precluded by the "safe harbor provision".[1] This Article III controversy lies in damage done to Plaintiff's personal, professional, commercial, and religious interests by a claimed anti-competitive "civil conspiracy" committed by Moderna as a state actor with the Department of Defense's "DARPA" (as evidenced in **Exhibits 1, 2** and **11**) securing Defendants' monopolisitic "enterprise." Justification for this action arises from Moderna and Pfizer having:

(1) converted Plaintiff's bio-electric (a.k.a., 'bio-spiritual') intellectual property (commercialized between 2006 and 2008 under the trademark " 'OxySilver™' with 528" (hereafter "OxySilver") while advancing Defendants' unfair competition and monopoly over anti-

viral healthcare pursuant to modified messenger RNA ("mmRNA") and vaccines infused with nano-copper/silver/or gold crystalline composites that act as bioenergy transmitters and data-mining receivers within their hosts. This bioelectric function is accomplished by the vaccines' "hydrogel"—the genetic information delivery "device"—that is bio-electrically active, much like OxySilver is in the body. Defendants' vaccines function much like OxySilver does in the body to bring about immune protection and healing. There are many similarities and few differences. The main "unconscionable" difference, discerned by well-informed religious persons, is that OxySilver works with and through the Holy Spirit that features 528 frequency resonance, whereas Defendants' bioelectronics interferes with these natural healing modalities.

(2) Defendants acted under color of law with Moderna's financial steward—M.I.T.'s Robert Langer and the DOD's DARPA—that also partnered with Defendant Hearst (Hearst Healthcare/FirstData Bank or "FDB") and the McKesson Corp.[1] Together, the Defendants interests lie in profitable data-mining and analyzing bio-data wirelessly accessed through the hydrogel's bioelectronics in order to purportedly diagnose and treat patients' abnormal biochemistry, related illnesses, and even record recipients vaccine history and brain activity according to Defendants' publications and techno-promotions; and

(3) Defendants' enterprise relies on Hearst, and its other partners in advertising Moderna/Pfizer's "novel" bioelectric technology, in disparaging Plaintiff's academic and scientific reputation; twisting Plaintiff's religious beliefs and writings in propaganda-like

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[1] According to Court documents, Hearst and co-conspirator McKesson "engaged in a racketeering enterprise". (**Exhibit 5**) Both McKesson and Hearst (FDB) agreed to pay millions for conspiring to overcharge Medicaid *inter alia*. McKesson manages a huge pharmaceutical and medical supply conglomerate in the U.S., and is one of the largest distributors of vaccines in the US and Europe, including both Moderna and Pfizer's vaccines, respectively. (**Exhibit 6**)

Mckesson's partner and co-conspirator "Hearst Ventures" is a key investor in Cogito—another DARPA-funded and inspired company—which is the leader in augmented "AI "—artificial intelligence. (**Exhibit 7**) In addition to kick-starting Moderna to develop its nano-gold/silver/copper hydrogel scaffolding, DARPA is also actively developing the other piece of the equation through Cogito/Tenancity, which will allow partners Hearst, Moderna, Schein and Pfizer to biosynthesize AI with human neurology. This appears to be the ultimate goal of all Defendants. Toward this end, Defendants activities (including their covert operations) coalesce at the Veteran Administration, which provides DARPA & it partner Defendants with an unquestioned steady stream of test subjects for its ongoing human trials. (**Exhibit 7**)

publications; undermining Plaintiff's scholarly affiliations and publications; demeaning the Plaintiff and the 528 frequency to damage Plaintiff's commercial markets; censoring and disparaging Plaintiff's popularity on the Internet; and undermining Plaintiff's religious and natural healing communities' support. This DARPA/Moderna/Hearst et. al 'enterprise' committed these acts because Plaintiff's 'alternative healing paradigm' competes directly and powerfully against Moderna's disease control narrative, their drug products, patented vaccines,[2] and antibiotics.

Accordingly, Plaintiff has plead an Article III case and controversy, because he has detailed his personal, professional, and ecclesiastical injury.

Furthermore, Moderna erroneously argues that the Plaintiff's FDUTPA claims are foreclosed because the U.S. Food and Drug Administration ("FDA") "issued an Emergency Use Authorization (EUA) to permit the emergency use of the ***unapproved product***, MODERNA COVID-19 VACCINE, . . ." (See: FDA's "Fact Sheet". Bold emphasis added.)

To the contrary, Fla. Stat. § 501.204(1) applies the "safe harbor" only to "[a]n act or practice required or specifically permitted by federal or state law." That "safe harbor" *does <u>not</u> apply to* Moderna's act and practice of converting, concealing and/or smearing Plaintiff's 528 intellectual and industrial property, nor obfuscating or concealing the company's nano-metal hydrogels' risks to society, public health and safety, juxtaposed against OxySilver's extreme safety. Horowitz reasonably objects to Moderna's: (a) vaccine hydrogel that competes against the Plaintiff's "OxySilver™ with 528"—an alternative bioelectrically-active nano-silver anti-microbial; and (b) lacking genetic safety and hydrogel testing protocols precluding necessary analyses by the FDA, encouraging unfair competition and monopolization of the COVID response by federal actors damaging the Plaintiff's OxySilver sales and benefits to society.

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[2] Moderna's patent number US 10,703,789 B2, inter alia, describes their invention as a "primary construct or mmRNA species [that] may be combined in an aqueous solution, in the presence or absence of copper [or more costly gold and silver] to form a new covalent linkage . . ." that purportedly increases immunity against COVID-19. Similarly, OxySilver™ covalently links silver to water forming the 'primary construct' in an 'aqueous solution' that boosts immunity when consumed orally against all infectious diseases. Accordingly, the two products and approaches to disease prevention compete directly in the healthcare industry, using biochemistry and bioelectronics; but OxySilver™ does so at far less cost, virtually no risk, and allegedly greater efficacy. These facts provide clear incentive for Moderna to act with its partners and commercial privies to maliciously target the Plaintiff to deprive his OxySilver™ therapeutic narrative and multiple markets.

Notwithstanding Moderna's diversionary case law, Plaintiff does not contest Moderna's "labeling" of its drug/vaccine bottle or package. Plaintiff contests Moderna's and Pfizer's alleged "tampering" with its mmRNA genetic drug.[3] 501.001(2)(a) precludes co-conspirators from tampering "with any consumer product" or "container for," any such product. The advertised product, called the "primary construct" (mmRNA genetic material) is contained within the mysterious hydrogel. This "device" has been, to date, generally concealed (i.e., "tampered with" according to 501.001(2)(a) definitions. The mmRNA, purportedly, provides "genetic therapy" with bioelectronic activity; with additional hydrogel options of generating, transmitting, and receiving electromagnetic and bioacoustic data wirelessly from within people's bodies, according to science published by Moderna's and DARPA's leading nano-bioelectronic data-mining experts. **Exhibits 11 and 16** evidence DARPA and Moderna's Harvard and M.I.T. lead scientists, Charles Lieber and Robert Langer, who collaborated and co-published science in this field.

Pursuant to concealed discovery in this case, and similarly in official proceedings at the FDA, Plaintiff alleges and contests risks posed by hydrogel fraudulent concealments that amount to "tampering" with Moderna's mmRNA drug. The product advertised is the "primary construct"—the mmRNA "payload". Any publicly-concealed alteration violates Florida's Anti-Tampering Act 501.001(2)(a), and voids Moderna's and Pfizer's "safe harbor." By concealing the hydrogel device, and its potential risks to vaccine recipients, Moderna and Pfizer have acted "with reckless disregard for the risk that another person will be placed in danger of death or bodily injury" *Id.* § 501. Knowledgeable intent to commit this wrongdoing is evidence by the Moderna/Pfizer protocols that admittedly omit genetic safety testing, and conceal the bioelectronic hydrogel device and its risks entirely.

The "safe harbor" does not exempt these violations of law, nor drug-makers from falsely and deceptively advertising or tampering with evidence under investigation by the FDA. See § 918.13(2.)(a)(b). During the emergency use authorization ("EUA") inquiry,

[3] According to jury instructions provided by the Florida Bar Association, "21.8 TAMPERING WITH OR FABRICATING PHYSICAL EVIDENCE (§ 918.13 Fla. Stat.)" includes concealing any record "with the purpose to impair its . . . availability, in the investigation proceeding."

Moderna knew, or should have known, that concealing the hydrogel device falsified safety claims in reckless disregard of Florida Statute § 918.13, inter alia. With no mainstream media news coverage revealing the nano-metal bioelectric vaccine device, Moderna, Pfizer, DARPA and their partners secured the bioelectric anti-viral market, excluding OxySilver—the industry and product the Plaintiff substantially pioneered.

Also, the "safe harbor" does not permit Moderna's violations of informed consent. The risks raised by such artificial intelligence injected into human bodies, including health, safety, and privacy concerns raised by such bioelectric nano-particle energy transducers of copper (gold, or silver) in the data-mining of human health status, chemistry, physiology and metabolism that this biotechnology affords, have been neglected. By concealing these facts, the Defendants have spurred their vaccine sales and diluted OxySilver sales.

Defendants' deceptive acts also include spreading the false narrative that Defendants' vaccines are more effective than Plaintiff's OxySilver, or even a placebo. This specious and presumptuous narrative outraged many experts, including the Associate Editor of the *British Medical Journal*, Peter Doshi.[4]

Defendants have also published to marginalize and discredit Horowitz as merely "a dentist" "conspiracy theorist," as Pfizer does in its motion to dismiss to bias the Court.

Accordingly, with Plaintiff's personal, commercial, and religious harm compounding, and federal actor DARPA partnered with Moderna/Hearst/FDB/McKesson officiating this unfair competition and deceptive trade, this Court has Article III subject matter jurisdiction in this state action in which injunctive relief from irreparable harm is requested.

III. PLAINTIFF HAS STANDING TO BRING CLAIMS AGAINST MODERNA FOR VIOLATING, INTER ALIA, PLAINTIFF'S RELIGIOUS FREEDOM

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[4] Doshi P. Peter Doshi: Pfizer and Moderna's "95% effective" vaccines—we need more details and the raw data. *The BMJ Opinion*. January 4, 2021. See also: Doshi P. Clarification: Pfizer and Moderna's "95% effective" vaccines—we need more details and the raw data. *The BMJ Opinion*. February 5, 2021.

Moderna's civil conspiracy defense falls and fails within the Defendants' bioelectronics enterprise that has transgressed its "safe harbor" and competes directly against Plaintiff's Judeo-Christian health science narrative and OxySilver. Moderna gains unjust enrichment by depriving Plaintiff's free and fair trade in competing religious commerce. Consequently, Moderna violates the Religious Freedom Restoration Act ["RFRA"] of 1993, codified at 42 U.S.C. § 2000bb through 42 U.S.C. § 2000bb-4. Evidence substantiating religious (anti-Semitic) animus directed against the Plaintiff and his 528 industry was filed in exhibits attached to Plaintiff's opposition to Defendant Schein's motion to dismiss.

Suffice it to say that the Defendants' state actions leverage Hearst's and DARPA's abusive media to compete unfairly and deceptively against the Plaintiff's OxySilver and "528 industry"—religious and commercial interests that herald the '528—key of the house of David' as intellectual property based on Bible code revelations prophesied in Isaiah 22:22 and Revelation 3:6-8. The Defendants (as co-conspirators) have smeared Horowitz to deprive the Plaintiff's religious knowledge from becoming widely known, and restricted his freedom to advance his ministry, companies, markets, products and services.

IV. PLAINTIFF HAS STATED COGNIZABLE CLAIMS AGAINST MODERNA AND ITS PRIVIES-IN-INTEREST FOR COMPETING UNFAIRLY, DECEPTIVE, AND WITH RELIGIOUS AND RETALIATORY ANIMOUS TO DEPRIVE PLAINTIFF'S FREE AND FAIR COMMERCE.

A. MODERNA, DARPA, and HYDROGEL BIOELECTRONICS vs. PLAINTIFF'S BIOSPIRITUALITY AND 528 FREQUENCY

It is public knowledge that Moderna received substantial financial support for the development of mmRNA vaccines through the Department of Defense ("DoD"). (**Exhibits 1 and 2**) Beginning in the 1980s to the present, the DoD and its contractors began work on what is described as the "most dauting obstacle"—bridging the gap between biology and electronics. For decades, the scientific consensus was that this gap was insurmountable, given the "stark disparities between the two realms." Then (at an undisclosed time) DARPA's contractors at Harvard and M.I.T. "hit" upon the idea of using metalized

"nanogels" to conduct electricity through biologic tissue. This science provided renewed hope to a languishing "bioelectronic" industry, that a solution to bridge the gap between biology and robotics was indeed possible.[5],[6] (**Exhibits 1 and 2**)

With DARPA seed financing assured, University researchers and transnational corporations began work to develop the "hydrogel" industry. The World Economic Forum (WEF), as cheerleader, began publishing videos and white papers heralding the imminent integration of humans with intelligent machines, made possible by the emergence of DARPA's hydrogels well-suited for distribution via vaccines.

Proponents and critics agreed, being "human" would no longer be scientifically definable. This controversial biosynthesis was termed "transhumanism." The movement depended on the Defendants' three intertwined industries: (1) pharmaceutical developments in nano-bioelectronics such as Moderna's and Pfizer's "game changing" hydrogels enabled via vaccines; (2) bioelectronic data mining and *in vivo* (real-time) data processing and analysis for drug commerce or patient/population management; and (3) public persuasion by media partners for social acceptance.

All three of these requirements were largely met by Moderna's alliance with DARPA's partners—Hearst Healthcare, McKesson, and FirstData Bank ("FDB"). This evidences an enterprise that originally "consummated a merger that monopolized the integrated drug information database market," according to a Federal Trade Commission's ("FTC") *injunction*. (**Exhibit 3**) This alleged "racketeering enterprise," instantly "disgorged $19 million in profits" when the Moderna/Hearst/FDB/DARPA consortium was formed (according to the FTC's **Exhibit 3**). This enterprise sold government officials and society on the benefits of this bioelectronic

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[5] Judicial Notice is brought to the fact that electricity is conducted by electrons vibrating and spinning at certain frequencies of sound and light measured in cycles-per-second in Hertz (Hz) or nanometers (nm), respectively. Bioelectricity, likewise, conducts electrons to, through, and from cells mediated by water. This hydrodynamic bioenergetic activity best describes the function of Defendants Moderna and Pfizer's nano-metal hydrogel device, as well as the Holy Spiritual dynamics fundamental to Christian Science, natural healing, and the Plaintiff's 528 silver-hydrosol infectious disease remedy.

[6] This hydro-nano-biotechnology reflects DARPA's/Defendants' most advanced bioelectronic devices enabling health status, physiological, chemical, and metabolic "data-mining" within each human being as promptly as a Google search accesses millions of files directing intelligence through the Cloud in favor of those who developed and financed the Defendants as privies-in-interest.

pharmaceutical movement. Injured war veterans who required cyborg limb replacements were sure to benefit, officials predicted.[7] (**Exhibit 2**)

Extending said enterprise's aforementioned pattern and practice of concealing important facts, on September 18, 2020, DARPA issued its first public notice confirming that the agency was investigating Moderna for "alleged failure to disclose DARPA funding support in its patented inventions." (**Exhibit 1**)

Plaintiff became aware of Defendants' transhumanist agenda in 2019, but his focus stayed on "Oxysilver™ with 528" for the benefit of humanity. Though Plaintiff became a target for vaccine industry invective, as a religious leader, a recognized expert on emerging diseases, and an outspoken critic on the misuse of vaccinations, it was not until late 2019 that Plaintiff began to understand the nature and the reason for Defendants' specific attacks on his products, his 528 frequency especially, and his Judeo-Christian ministry.

Plaintiff had published at length for years on the use and abuse of bioelectronic/ biospiritual frequencies. His videos and books decrypted and resurrected ancient mystery-school mathematics, alchemy, and the Solfeggio (musical) arts and sciences.

But it was not until 2019-2021 that Plaintiff realized Defendants were not only intending to disparage his Bible code revelations, frequency research, and commercial developments, but substantially the 528 frequency that is a "key" energy in organic/natural bioelectronics and "intelligent design". It became most obvious from witnessing a pattern of Defendants' libel and censorship that the Defendants intended to deceive consumer markets, by generally concealing, misrepresenting, or demeaning Horowitz and his 528 frequency therapeutics.

By studying Moderna's little-known emerging science, Horowitz witnessed a pattern. The Defendants repeatedly evaded their public duty to inform society about their hydrogel technology and its risks. Otherwise, similarities to OxySilver with 528 bioelectricity could be compared. Such concealment to restrain trade could only be discovered by reading

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[7] **Exhibits 1** thru **4** evidence Moderna's start-up financing by DARPA agented by MIT's leading bioelectronics entrepreneur, Robert Langer, Moderna's most influential governing board member.

Moderna's patents that far exceeds lay comprehension. Therein, activating the hydrogel's data-processing and frequency-transmitting precious metals using 'modified water' is described as Horowitz had pioneered with his colleagues in 2006 through 2008 with OxySilver™. The Plaintiff had advanced this healing technology featuring 528 frequency based on his partner's 1998 Bible code revelations and related discoveries in "intelligent design," and Moderna and Pfizer appeared to be converting Horowitz's religious intelligence for secular enrichment.[8]

1. PLAINTIFF'S BIOELECTRIC/BIOSPIRITUAL "528" RELIGIOUS COMMERCE

Beginning in the 1980s to the present, Plaintiff has written extensively, and lectured nationally and internationally on bioelectric therapies and their synergistic effects with "structured water" ("sH_2O") and nano-silver.

By 2008, this work led to Plaintiff's invention, manufacture, and worldwide distribution of "OxySilver™ with 528" that pioneered a new paradigm in clinical care and religious commerce.

OxySilver™ with 528 featured modified (structurally-engineered) water that was 'wetter' than most waters, meaning the water would carry and transmit to human cells more micronutrients, such as anti-microbial silver, as well as more electro-dynamic energy rejuvenating DNA.[9] Drug delivery was also enhanced, if and when desired, by structured micro-clustered water—a scientifically-proven fact that may be used to reduce drug intake, drug dependence, and drug side-effects.

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[8] These alleged torts now trigger Plaintiff's prophetic warning of what will occur if this case is dismissed. Defendant Moderna and Pfizer's genetic-bioelectric technology will eventually risk human sustainability and free natural (i.e., Divine) spiritual sovereignty.

Therefore, this lawsuit is Plaintiff's best effort to inform the Court how Defendants' actions have specifically injured his religious ministry, his commercial interests, as well as to warn the world how Defendants' godless approach to biosynthesis and electro-genetics, if not curtailed, will have dire consequences for everyone, beyond those imposed with COVID-19.

[9] K. Liu, J.D. Cruzan, and R.J. Saykally, *"Water Clusters,"* *Science* ***271***, 929 (1996) –Invited Paper. *Cover Article. For Saykally's list of 435 published articles in this field, see: http://www.cchem.berkeley.edu/rjsgrp/publications.php

This knowledge was used by Horowitz to develop OxySilver as an alternative to pharmaceuticals. He encouraged energizing structured-water ("sH_2O") with expressly the 528Hz/nm frequency of sound and light to bio-energetically empower myriad remedies. Horowitz helped pioneer with James Karnstadt the alkalized water movement. These outcomes of the Plaintiff's research and developments merged water chemistry with medicine, religion and biophysics, modern biochemistry and ancient alchemy.

Plaintiff's 528 frequency products and services arose from a millennial-long tradition of religious teaching and are proffered by Plaintiff (who is a Levitical Priest), based on his deep understanding of religious doctrine and the concomitant insight that understanding provides with respect to health products and services. The centrality of these religious teachings involve 'intelligent design,' nature's inherent (musical-mathematical matrix) structuring life through biophysics, organic chemistry, and molecular biology. This fact is confirmed textually in the Plaintiff's publications, and in the Tanakh, comprised of the Pentateuch (Torah), the Nevi'im (the Prophets), the Ketuvim (Writings), and in the Plaintiff's many published books.

Dozens of Plaintiff's scientific peer-reviewed publications have reached international audiences and several of his books have become best-sellers that have been quoted widely by such luminaries as President Obama's minister, Reverend Jeremiah Wright. Plaintiff's businesses, personal practices, and popularity in the international religious community have received substantial numbers of advocates. Plaintiff's "528 Radio Network" broadcasts more than a dozen stations offering different genres of music transposed into the frequency of 528Hz. This music is enjoyed for free by a large and growing international audience. The complimentary service (at 528Radio.com) is claimed to be "therapeutic" and advertises "OxySilver™ with 528" as a "Holy Water." From Horowitz's intertwined Bible and scientific studies, the Plaintiff claims "528" is the "key" to which King David tuned his "healing harp." Horowitz's achievements in 'frequency therapeutics' advanced nearly a decade before similar research and developments were announced by Defendants' officials.

2. MODERNA'S NANO-BIOELECTRICITY vs. HOROWITZ's BIOSPIRITUALITY

The Defendants' research and developments (such as hydrogels) compete directly against the Plaintiff's religious commercial interests that utilize the same, similar, or related science. (See: **Exhibits 8 - 11**.)

As made known in Plaintiff's filing to oppose Defendant Schein's Motion to Dismiss, the Defendants have been well-aware of Plaintiff's competing theology and biotechnology. It is Plaintiff's contention that Defendants' interference with Plaintiff's religious commerce was not primarily due to Plaintiff's opposition to traditional vaccine platforms (as Plaintiff initially surmised), but for the purpose of marginalizing Plaintiff's alternative health science narrative proven by the success of Plaintiff's silver-hydrosol bio-resonating 528 therapeutic technology. The benefits of using antimicrobial bioelectric silver-hydrosol technology versus the Defendants' pharmaceuticals are many.

For this reason, opposing competition, Defendants are alleged to have conspired to minimize Plaintiff's visibility, reputability, and ability to impact their carefully constructed pharmaceutical-bioelectronic narrative. Extra protection was required to advance Defendants' market for "novel" mmRNA electro-biologics—the genetic gateway to transhumanism. Defendants knew their future markets and monopolies were secured by their conversion, obfuscation, and smearing of Plaintiff's 528-resonating silver-hydrosol biotechnology and educational outreach. This interference with the Plaintiff's commercial viability and Christian Science narrative was vitally important for Moderna and Pfizer's roll-out of their competing bioelectric products.

The main difference between OxySilver and Defendants' hydrogels is not only the extensive and long-lasting reach and integration into people's bodies, minds, and souls. OxySilver does not administer data-mining, data analysis, and real time physico-chemical wireless administration/modulation of the patients' *in vivo* "health status." OxySilver does not monitor physiology, metabolism, vaccine history, nor anti-microbial chemistry foundationally and freely regulated by natural 'electro-genetics,' water science, the susceptibility of microbes to anti-oxidants, and the Holy Spirit.

The Defendants use nano-metal hydrogels to bioelectrically transmit frequencies of sound and light energy. Defendants advertised this as a remedy for myriad diseases. (See **Exhibits 8-11**.) **Exhibit 11** evidences Moderna's expert investor in this field, MIT's Robert Langer, co-publishing exceptional science in this field with Harvard's Charles Lieber.

While Defendant Moderna wishes to characterize the focus of this lawsuit as limited to COVID-19 vaccines, RFRA, 42 USC 1983 and FUDPTA questions arise from Plaintiff's 2000 copyright on the text *Healing Codes for the Biological Apocalypse* (TX0005256671/ 2000-08-09; **Exhibit 12**). That national best-selling book is largely responsible for Defendants' alleged anti-competitive activities as it delves into bioelectronics' versus Holy Spiritual dynamics.

Though Plaintiff admits that at this time Plaintiff's market share presents little concern to Defendants, the growing popularity of Plaintiff's characterization of Defendants' mis-guided approach to bioelectronic therapies constitutes an imminent and material threat to Defendants. The Plaintiff's large and growing international outreach threatens Defendants' Pandemic Supply Chain Network's plan for bioelectric medicines (**Exhibits 13**) and DARPA's promised 'early treatment' determined by "injectable biosensor technology." (**Exhibit 14**)

Given DARPA's and partnering Defendants' investments, their officials envisioned a usurpation of their profits damaging stockholders in the field of wireless bioelectronics and data-mining. This required hydrogels.

The Plaintiff made known that receiving and transmitting data wirelessly to and from cells in the brain, nerves, and immune system, purportedly to supplement "genetic therapy", is precluded by Bible law that commands the Plaintiff's alternative religious narrative, to secure the body 'temple'—home of the soul.[10] To impose upon any person's soul, religious or not, the Defendants' wireless genetic electro-dynamic biotechnologies is arguably *unconscionable*. It is

[10] 1 Corinthians 6:19 "[K]now ye not that your body is the temple of the Holy Ghost *which is* in you, which ye have of God, and ye are not your own?" Leviticus 19:19 "'You shall keep My statutes. You shall not let your livestock breed with another kind. You shall not sow your field with mixed seed. Nor shall a garment of mixed linen and wool come upon you."

surely incompatible with Bible laws that herald the supreme healing power of the Holy Spirit that is administered piezo-electrically, like all energy universally.[9] The general consensus still favors such theology, and the Constitutional imperative securing religious freedoms.

B. PLAINTIFF'S CIVIL CONSPIRACY CLAIM IS JUSTIFIED BY THE FBI'S INDICTMENT OF MODERNA'S LEADING SOURCE OF HYDROGEL INTEL.

Moderna and Pfizer's mmRNA religiously-juxtaposed vaccines draw substantially on classified research conducted by Harvard's Charles Lieber and M.I.T.'s Robert Langer, who appear to have converted Horowitz's OxySilver™ bioelectric 528-frequency nano-technology to the Defendants' similarly-functioning hydrogel applications.

Obviously, with Moderna and Pfizer's chief benefactors being DARPA, the Defendants' bioelectronic drug enterprise operates largely covertly, due to concerns for "National Security." Though attacks by Defendants' competing enterprise against Plaintiff and his products began in "FY2016," it was not until 2019 that Horowitz gained solid evidence of the civil conspiracy depriving his commercial and religious rights. DARPA announced its funding of Profusa's hydrogel biosensors to detect disease outbreaks two months before the revealing "Event 201" coronavirus predictive-programming conference at Johns Hopkins. (**Exhibit 14**) That August 8, 2019 notice prompted Plaintiff to consider covert operations stemming from the National Biodefense Strategy Act (NBSA) of 2016's connections to Moderna's and Pfizer's key hydrogel bioelectronics expert, Charles Lieber, and his co-author, Robert Langer. (**Exhibit 11**) Langer is Moderna's chief financial agent and M.I.T.'s leading scientist in this field.

The Defendants' pattern and practice of fraudulently concealing vital intelligence is compounded by Lieber, who "knowingly and willfully made materially false, fictitious and fraudulent statements to DoD [and similarly to the NIH] in violation of 18 U.S.C. § 1001(a)(2)" according to his federal indictment. (See: Criminal Complaint in **Exhibit 15. Exhibits 8 thru 11** evidence Lieber's main area of Chinese espionage, according to facts under seal in *U.S. v. Charles Lieber*. (**Exhibit 15**) Lieber is considered the world's best

informed researcher and developer of biotechnologies called "nanoscale field effect transistors (nanoFETs)." "Field effect" means electromagnetic or bioacoustic wave energy transmitted in this instance through body water affected by the Defendants' injected hydrogels.

The first step in nanoFETs' developement includes "metalization" using gold, copper, or silver. These are the best energy-conducting elements. (**Exhibit 16**). One outcome is the development of drugs capable of "electronic signaling."[11] Lieber played a key role in developing silver, copper, or gold-infused hydrogels made to "***meld tiny electronics with the brain***," explained *NPR*. (**Exhibit 17**; emphasis added)

To neutralize the Plaintiff's bio-spiritual religious narrative (and competing interests in 528 religious commerce) thus secure the Defendants' scientific, secular, transhumanist/cyborg narrative, Lieber et. al. literally claimed his devices provided the "Holy Grail in intracellular electrophysiology." Lieber's devices promised the "exciting future application of these nanoFET probes . . . measuring membrane potentials directly from cellular organelles." This is the Defendants' "Holy Grail." (**Exhibit 16**, p. 9).

The government contracted with Lieber at Harvard and his co-author, Robert Langer at M.I.T., to partner with Moderna and other corporations to not only initiate lab endeavors to advance and secure the bioelectronics market, but also to administer media campaigns targeting religious group leaders threatening the Defendants' cyborg industry, as shown in **Exhibits 18** thru **20**. By competing against this public/private enterprise, Horowitz became an "enemy of state."

The Plaintiff and his religious community espousing alternatives to pharmaceutical narratives and "vaccination hesitancy" became targeted by the National Security State controlling DARPA, biodefense, and the Defendants' media enterprise. Aside from

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[11] In science-speak, the objective is to build "3D macroporous biomaterials as extracellular matrices . . . [that] allow for studies of cell/tissue development in the presence of spatiotemporal biochemical stimulants(119,120), and (ii) the understanding of pharmacological response of cells within synthetic tissues." Said "stimulants" include drugs and electronic signals mediated through the water-lipid interface, superconducted by copper, gold, or silver, generating electromagnetic or bioacoustic fields that are conducted wirelessly or by "nano-wires". (**Exhibit 16**)

competing against the Defendants' hydrogel technology and vaccines, Horowitz was, and still is, considered a leading risk associated with "major biological incidents." (See: National Biodefense Strategy Act of 2016, **Exhibit 18**; religious "vaccination hesitancy" in **Exhibit 19**; and DARPA's financing of media counter-intelligence. (**Exhibit 20**)

National Security is purportedly threatened by religious evangelists, conspiracy theorists, and the politically-oppressed-and-distressed untrusting public. (**Exhibit 19**) Such enemies of state were prioritized to be neutralized, as exemplified by Horowitz's persecution. Hearst collaborator and alleged secret government agent, Colin McRoberts, fortified by his McChrystal Group cohorts, led the propaganda campaign to discredit Horowitz, according to the Plaintiff's knowledge, belief, and solid proof.

Accordingly, Plaintiff alleges the Defendants have acted to disparage and bankrupt Plaintiff by maligning his religiously-informed and bio-spiritually oriented publications and health products, reflecting the Defendants' complicity in an ongoing retaliatory state action against the Plaintiff evidencing Defendants' religious and competitive animus, and civil conspiracy to deprive Plaintiff's rights in commerce in violation of 42 USC §§ 1981 and 1983.

C. MODERNA, PFIZER AND ALLEGED CO-CONSPIRATOR/PUBLISHER HEARST, SUBSTANTIALLY BURDENED PLAINTIFF'S FREE EXERCISE

Plaintiff has alleged the existence of a civil-conspiracy involving state actors DARPA, Moderna, Pfizer, governmental vaccine distributors Schein and McKesson, and their advertising partner and biodata administrator, Hearst (Healthcare/FDB). Together Defendants' enterprise deprived Plaintiff's civil right to fair trade in religious commerce.

"In order to prevail on a conspiracy claim under § 1983, a Plaintiff also asserts that persons acting under color of state law conspired to deprive him of a federally protected right."; *Marchese v. Umstead*, 110 F. Supp. 2d 361, 371 (E.D. Pa. 2000) ("To state a section 1983 conspiracy claim, a plaintiff must allege: (1) the existence of a conspiracy involving state action; and (2) a depravation [sic] of civil rights in furtherance of the conspiracy by a party to the conspiracy."); see also *Avery, Rudovsky & Blum*,7 Instructions 12:31, 12:32, 17

12:33, & 12:43 (providing suggested instructions regarding a Section 1983 conspiracy claim). According to the RFRA, the "[g]overnment shall not substantially burden a person's exercise of religion even if the burden results from a rule of general applicability," unless the government demonstrates a "compelling governmental interest" and uses the "least restrictive means" of furthering that interest. 42 U.S.C. § 2000bb-1(a),(b); *Holy Land Found. for Relief and Dev. v. 9 Ashcroft*, 333 F.3d 156, 166-68 (D.C. Cir. 2003).

Horowitz's central religious belief is that the Holy Spirit administers healing by, most importantly, vibrating in the 528Hz/nm frequency of sound and light. To establish a prima facie case under RFRA, a plaintiff must show that the government action "has placed a substantial burden on the observation of a central religious belief or practice." *Henderson v. Kennedy*, 253 F.3d 12, 17 (D.C. Cir. 2001) The Moderna/Pfizer/DARPA/ Hearst/Schein et. al. enterprise cannot prove their actions to smear Horowitz and his 528 products to restrict his religious commerce and burden his "central religious belief" is the "least restrictive means" to serve the public's health or biodefense.

Furthermore, Defendant Moderna cannot demonstrate any compelling state interest in converting the Plaintiff's Bible-based Christian Science-backed discoveries and intellectual property into Defendants' pharmaceutical-bioelectronic hydrogel narrative.

Horowitz has stated a claim under 42 U.S.C. § 1983, and established the two essential elements: (1) The HearstHealth/FDB/DARPA/Moderna defamation and religious freedom deprivation was committed by state actors under color of state law; and (2) the conduct deprived Plaintiff's rights, privileges, and immunities secured by the Constitution or laws of the United States. *Blanton v. Griel Mem'l Psychiatric Hosp*., 758 F.2d 1540, (11th Cir. 1985).

V. FEDERAL SUBJECT MATTER JURISDICTION

The subject matter of this case involves federal questions per 28 USC 1331, as Defendant Moderna and its privies-in-interest, including DARPA, under color of law, overstepped their "safe harbor" protection, interfered with Plaintiff's religious commerce,

disparaged Plaintiff's Judeo-Christian identity and 528 industry, smeared Plaintiff's bioelectric/biospiritual products competing against Moderna's and Pfizer's hydrogel devices, and deprived Horowitz of his free and fair trade. These acts violate the First Amendment of the Constitution, the Religious Freedom Restoration Act of 1993 (codified at 42 U.S.C. § 2000bb through 42 U.S.C. § 2000bb-4; and civil rights statutes 42 U.S.C. §§ 1981 and 1983.

Though this matter raises both state and federal issues, Plaintiff contends the hybrid law issue should be resolved in favor of federal jurisdiction, given Defendants' violations of Plaintiff's constitutional rights supersede Plaintiff's state claims. Additionally, the weight of federal authority is that when fairness dictates claims against federal actors, such as evidenced in this case with DARPA substantially financing and administratively furthering Moderna's hydrogel and vaccine commerce, they should be adjudicated in federal court.

The court may dismiss a complaint for lack of subject-matter jurisdiction only if "'it appears beyond doubt that the plaintiff can prove no set of facts in support of his claim which would entitle him to relief.'" *Empagran S.A. v. F. Hoffman-Laroche, Ltd.*, 315 F.3d 338, 343 (D.C. Cir. 2003) (quoting *Conley v. Gibson*, 355 U.S. 41, 45-46 (1957)).

VI. PLAINTIFF HAS ADEQUATELY STATED COGNIZABLE CLAIMS AGAINST MODERNA TO SATISFY FED. R. CIV. P. 8(a)(2) OR OTHERWISE PERMIT AMENDING THE COMPLAINT

The Supreme Court has explained that a complaint need only "give the defendant fair notice of what the plaintiff's claim is and the grounds upon which it rests." *Swierkiewicz v. Sorema* N.A., 534 U.S. 506, 512 (2002); accord *Atchison, Topeka & Santa Fe Ry. v. Buell*, 480 U.S. 557, 568 n.15 (1987) (under Federal Rule 8, claimant has "no duty to set out all of the relevant facts in his complaint"). "Specific facts are not necessary in a Complaint; instead, the statement need only 'give the defendant fair notice of what the . . . claim is and the grounds upon which it rests.'" *Epos Tech.*, 636 F. Supp.2d 57, 63 (D.D.C. 2009) (quoting *Bell Atlantic v. Twombly*, 550 U.S. 544, 555 (2007)).

As Florida courts have consistently held, *Twombly* and *Iqbal* do not change the fundamental analysis that a district court engages in, when ruling on a motion to dismiss, i.e.,

accepting all plausible allegations as true and determining whether the complaint contains a short and plain statement of the claim showing that the pleader is entitled to relief. *Smith v. Wm. Wrigley Jr. Co*., 663 F.Supp.2d 1336, 1341 n. 3 (S.D. Fla. 2009).

The issue for consideration on a motion to dismiss is not whether the plaintiff will ultimately prevail, but "whether the claimant is entitled to offer evidence to support the claims." *Little v. City of North Miami*, 805 F.2d 962, 965 (11th Cir. 1986). If a defect can be cured by amendment, leave to amend should be freely granted. *Forman v. Davis*, 371 U.S. 178, 182 (1962); *Ferrell Law, P.A. v. Crescent Miami Center, LLP*, 313 Fed. Appx. 182, 186 (11th Cir. 2008); Fed. R. Civ. P. 15(a)(2) Thus, the Federal Rules embody "notice pleading" and require only a concise statement of the claim, rather than evidentiary facts. Accordingly, Defendant's Motion would be properly filed only "where a plaintiff's complaint is 'unintelligab[le] (sic),' not where a complaint suffers for 'lack of detail.'" *Epos Tech*., 636 F. Supp. 2d at 63 (citations omitted).

A. PLAINTIFF CLAIMS STATE ACTOR MODERNA, UNDER COLOR OF LAW, DEPRIVED PLAINTIFF OF HIS RELIGIOUS FREEDOM IN COMMERCE

Plaintiff claims Moderna's enterprise with federal agents and agencies, especially DARPA, and private companies, including Hearst Healthcare/ FDB/McKesson and others, acted to deprive Horowitz of his civil rights to commercialize OxySilver and 528 healing technologies. 42 U.S.C. § 1983 (2000) imposes liability on every person who, under the color of a statute, ordinance, or regulation, causes the deprivation of another's federally protected right. Moderna acted with the "authority of [the] state." In this case, governmental entities and private parties together acted to deprive the Plaintiff of his constitutionally guaranteed liberty. See 14 C.J.S. Civil Rights § 30 (2007).

The Supreme Court noted that the determination of whether conduct is private or amounts to "state action" is not an easy question and there is no singular fact that is a "necessary condition.., for finding state action." The important inquiry, therefore, is the interplay of the government and private actions in light of the particular facts of a case.

Gilmore v. City of Montgomery, 417 U.S. 556, 573 (1974) (citing *Burton v. Wilmington Parking Auth*., 365 U.S. 715, 725 (1961)).

Here, Defendant Moderna is a state actor for satisfying the 'three exceptions' to the 'State Action Doctrine.' Those exceptions are *public function*, *entanglement*, and *entwinement*. (*Milner v. Plukerbert*, Supreme Court of the United States, No. 17-874, Brief for Respondent, January 31, 2020.) The facts, corroborated by **Exhibits 1 thru 3,** trigger the three exceptions, and justify treating Moderna as the government itself. Indeed, in this instance, the U.S. Government is entangled and entwined with Moderna as a "public function" in bio-preparedness and remedial response to infectious diseases. Here, as the facts and exhibits show, federal officials take credit for financing and stewarding Moderna's and Pfizer's nano-bioelectronic vaccine hydrogels as disease therapies and more.

In addition, DARPA has heralded its exploitation of Big Tech's media messaging capabilities to influence public opinion and acceptance of Moderna/Pfizer's "novel" bioelectric technologies. DARPA's media influence also compounds evidence of the Defendants' anti-religious vaccine hesitancy campaign damaging the Plaintiff and many others in many ways, including depriving Horowitz of his constitutional right to the free exercise of his religious commerce in the bio-electric, bio-spiritual, and bio-defense field. (**Exhibits 19 and 20**)

B. IRREPARABLE HARM TO PLAINTIFF

Plaintiff seeks relief to enjoin compounding irreparable harm to Horowitz, his businesses, his reputation, and his free exercise of religion, caused by Moderna's complicity with the other Defendants, by and through continuing disparagement, censorship, and propaganda campaigns, causing said damage.

In fairness, Plaintiff pleads that this Court not reward Defendants for their inequity, by dismissing this Complaint and denying Plaintiff's due process for the harm he has suffered.

Respectfully submitted.

DATED: April 12, 2021

/s Leonard G. Horowitz
Plaintiff, pro se

Leonard G. Horowitz

DECLARATION OF LEONARD G. HOROWITZ

I, LEONARD G. HOROWITZ, under pain of perjury of law, do hereby state and declare as follows:

1) I am an individual over the age of twenty-one (21) years, a resident of Lee County in the State of Florida.
2) I declare that the facts and dates stated in this Opposition filing to Defendant Moderna's Motion to Dismiss are accurate to the best of my knowledge and belief; and if called to testify before this Court on these matters, I shall do so competently.
3) I also declare that the attached evidentiary Exhibits 1 thru 20 are true and correct copies of the original documents in my possession.

Respectfully submitted.

DATED: April 12, 2021

/s Leonard G. Horowitz
Plaintiff, pro se

ADDENDUM

According to a DARPA press release, beginning in 2011, the DoD's "ADEPT" program (i.e., Autonomous Diagnostics to Enable Prevention and Therapeutics) "began investing in nucleic acid vaccines." (**Exhibit 2**) This effort included "rapidly manufacturing new types of vaccines . . . novel tools to engineer mammalian cells for targeted drug delivery and . . . novel methods to impart near-immediate immunity to an individual using antibodies."

Then Moderna, by direction of Moderna's co-founder, co-owner, and secretive CEO billionaire Stéphane Bancel, and his business advisor and senior board member, M.I.T. scientist Robert Langer, (**Exhibit 11**) along with Langer's counterpart at Harvard, Charles M. Lieber, (**Exhibits 10 and 16**) began receiving generally secreted financing from the U.S Government (**Exhibits 1, 2 and 22**) and private investors including vaccine and wireless neuroscience cheerleader, Bill Gates.[12]

A year later, in 2012, Langer and Lieber's team published a ground-breaking paper in *Nature Materials* describing their breakthrough in technology enabling "merging tissue with electronics in a way that it becomes difficult to determine where the tissue ends and the electronics begin."[13]

M.I.T.'s Media Lab is publicly known for administering this extraordinary bioelectric technology. Their "Nano-implants for energy harvesting and wireless sensing" advances as evidenced in **Exhibit 22**, intertwine with Moderna's nano-bioelectric vaccine hydrogels.

Defendant Moderna thus competes against OxySilver™ with 528 energy bioresonance (See: **Exhibit 11**.); does so under color of law; and while doing so deprives Plaintiff of his constitutional right to the free exercise of his religious commerce in the bio-electric, bio-spiritual, and bio-defense fields.

---

[12] Tracy M and Hsu T. Director of M.I.T.'s Media Lab Resigns After Taking Money From Jeffrey Epstein, *New York Times*, September 7, 2019. "[I]ncluding a $2 million gift from the Microsoft co-founder Bill Gates. . . 'directed by Jeffrey Epstein.'"

[13] Tian B, Langer R and Lieber CM, et. al. Macroporous nanowire nanoelectronic scaffolds for synthetic tissues. *Nature Materials*, August 26, 2012; with quotes from Lieber reported in *ScienceDaily*. See **Exhibits 16 and 22**.

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that on this 12th day of April 2021, I filed a true and correct copy of the foregoing "Plaintiff's Opposition to Moderna's Motion to Dismiss" including Exhibits 1 thru 20, with the Court's Clerk for customary E-filing. I further certify that I served by E-Mail a copy of the filed document to the following participant(s):

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HONORABLE JUDGE JOHN BADALAMENTI
HONORABLE MAGISTRATE NICHOLAS MIZELL
United States District Court
for the Middle District of Florida
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2110 First St, Fort Myers, FL 33901
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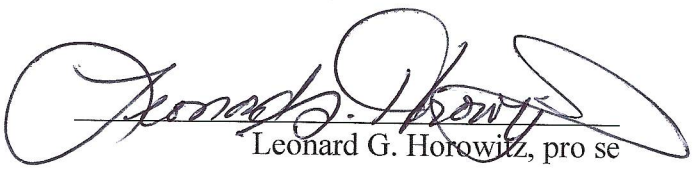

Leonard G. Horowitz, pro se

IN THE UNITED STATES DISTRICT COURT
FOR THE MIDDLE DISTRICT OF FLORIDA
FORT MYERS DIVISION

LEONARD G. HOROWITZ,
Plaintiff,

vs. Case No. 2:20-cv-00955-JLB-NPM

PFIZER INC., et al.,
Defendants.
_____/

EXHIBITS LIST FOR PLAINTIFF'S OPPOSITION TO DEFENDANT MODERNA's MOTION TO DISMISS

EXHIBIT 1 –DARPA's public notice of Moderna Therapeutics investigation of "alleged failure to disclose DARPA funding support in its patented inventions," dated September 18, 2020; with attached corroborating news article.

EXHIBIT 2 –DARPA press release evidencing federal financing of bioelectronic hydrogels in health science, including mmRNA vaccine developments by Moderna and Pfizer, published Feb. 6, 2019.

EXHIBIT 3 –US Federal contracts awarded to Hearst's First Databank, Inc.; and Department of Defense financing of parent Defendant Hearst Corporation for developing "MedKnowledge"—live (in vivo) data mining, data analysis, and drug prescriptions based on emerging field of nano-bioelectronics.

EXHIBIT 4 –Federal Trade Commission (FTC) injunction updated December 14, 2001 against Hearst Trust, The Hearst Corporation, and First DataBank, Inc. for concealing federal funding upon premerger notification that "consummated a merger that monopolized the integrated drug information database market" instantly disgorging $19 million in profits.

EXHIBIT 5 –Memorandum and Order Approving Class Settlement in New England Carpenters Health Benefits Fund, et. al. v. [Hearst]First Databank, Inc and McKesson Corp. Doc. 810, filed 08/03/09 in case 1:05-cv-11148-PBS (US District, Massachusetts).

EXHIBIT 6 –McKesson Fills Initial Government Orders for Moderna's COVID-19 Vaccine. McKesson press release, Dec. 20, 2020.

EXHIBIT 7 –Lawrence S. VA contracts with DARPA-backed startup for real-time behavioral analytics, mental health app. *Fierce Biotech*. Dec. 16, 2015.

EXHIBIT 8 –Ohm Y, et. al. An electrically conductive silver-polyacrylamide-alginate hydrogel composite for soft electronics. *Nature Electronics* 4: March 2021, 185-192.

EXHIBIT 9 –Harvard-led group, Korevaar, et. al. Non-equilibrium signal integration in hydrogels. *Nature Communications*, March 2020. (Explains similar nano-bioelectric functionality between hydrogels and OxySilver™ with 528 frequency.)

EXHIBIT 10 –Harvard bioelectronics expert, Dr. Charles Lieber, identified by his protégé, Dr. Jiang, "with a focus on the design and application of nanoscale materials and nanoelectronic devices." Dated Nov. 15, 2019.

EXHIBIT 11 –Moderna Company History Timeline supplemented by science paper from *Nature*, identifying "Robert Langer, an MIT professor, Moderna board member, and founder of dozens of biotech companies" is evidenced co-authoring a "nanoelectonic" science article with Harvard's DOJ-indicted chemistry professor, Charles Lieber.

EXHIBIT 12 –Plaintiff's Copyright on *Healing Codes for the Biological Apocalypse*, August 9, 2000; Registration No. TX0005256671.

EXHIBIT 13–United Nations World Food Program article heralding Henry Schein's key activity in "Innovative Supply Chain Information Platform [to] Help Prepare for the Next Pandemic." News Release, March 28, 2021.

EXHIBIT 14–Press Release by Profusa, Inc. Profusa and partners receive DARPA award to speed detection of disease outbreaks. Aug. 8, 2019.

EXHIBIT 15 –*U.S. v Charles Lieber*, sealed Criminal Complaint by Affidavit of Robert Plumb, FBI Special Agent. Case No. 20-mj-2158-MBB; filed January 27, 2020, concealing bioelectric hydrogel nano-silver/water neuroscience technology transferred to China's Wuhan Lab officials.

EXHIBIT 16 –Tian B and Lieber CM. Synthetic nanoelectronic probes for biological cells and tissue. *Annu Rev Anal Chem* (Palo Alto Calif.) 2013; 6:31-51.

EXHIBIT 17 – Brumfiel G. Harvard Professor's Arrest Raises Questions About Scientific Openness. *NPR*, February 19, 2020.

EXHIBIT 18 – National Biodefense Strategy Act of 2016; S.2967. Committee on Homeland Security and Governmental Affairs. Ordered to be reported with amendments favorably. 05/25/2016.

EXHIBIT 19 – Dias E and Graham R. White evangelical resistance is obstacle in vaccination effort. *New York Times*, April 6, 2021.

EXHIBIT 20 – Hinchliffe T. DARPA to 'exploit social media, messaging and blog data' to track geopolitical influence campaigns. *The Sociable*, Oct. 30, 2020.

EXHIBIT 21 – Jenkins A. DARPA's Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT). Not dated. Available at https://www.darpa.mil/program/autonomous-diagnostics-to-enable-prevention-and-therapeutics

EXHIBIT 22 –MIT Media Labs. Nano-implants for energy harvesting and wireless sensing. Available online at: https://www.media.mit.edu/projects/wireless-sensing/overview/.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
675 NORTH RANDOLPH STREET
ARLINGTON, VA 22203-2114

September 18, 2020

Via Electronic Mail

James Love
Knowledge Ecology International
1621 Connecticut Avenue, NW, Suite 500
Washington, D.C. 20009

Dear Mr. Love:

I am responding to your letter of August 27, 2020, to Dr. Amy Jenkins at the Defense Advanced Research Projects Agency (DARPA) requesting the Department of Defense investigate Moderna Therapeutics' (Moderna) alleged failure to disclose DARPA funding support in its patented inventions. DARPA is reviewing agreements it has awarded to Moderna and U.S. patents and published patent applications for Moderna and ModernaTx, since March 2013.

Thank you for bringing this matter to our attention. Should you have any questions, please contact DARPA Deputy General Counsel, Geraldine Chanel, at 571-218-4609 or geraldine.chanel@darpa.mil.

Sincerely,

D. Peter Donaghue
Contracting Officer-Division Director
Contracts Management Office

Exhibit 1

How the U.S. government bolstered Moderna's COVID-19 vaccine candidate

By Brian Buntz | November 23, 2020

Until recently, the most rapidly developed vaccine was for mumps, which took four years. Now, Pfizer (NYSE:PFE) and Moderna (NSDQ:MRNA) appear to be on the cusp of commercializing COVID-19 vaccines under emergency use authorization.

[Image courtesy of Wikipedia]

It was only a year ago that physicians in China identified unusual pneumonia cases that would later be associated with the novel coronavirus.

As impressive as the rapid pace of COVID-19 vaccine development has been, researchers have drawn on foundational work that stretches back almost two decades, said Barry Bloom, a research professor at Harvard University, in the recent webinar titled the "Race for the COVID-19 Vaccine: Latest Updates."

And the Moderna vaccine candidate, in particular, has benefited from U.S. government support.

A marathon as well as a sprint

The race to develop COVID vaccines has roots stretching back to the terrorist attacks on September 11 and the anthrax attacks that followed in the subsequent weeks. The events led the National Academy of Sciences to convene a set of committees to examine the twin threats of terrorism and pandemics. The committees "concluded that we were enormously vulnerable and we had to do a lot of different things [to] protect the country," said Bloom, who co-chaired a bioterrorism panel for the National Academy of Sciences at the time.

In 2002, severe acute respiratory syndrome (SARS) first appeared in China and took hold internationally within months. Effective public health interventions prevented SARS from becoming a pandemic.

The pandemic plan stressed the importance of antiviral drugs and vaccines. “It is a wonderful plan,” Bloom noted. But before COVID-19 hit, the report had “disappeared in a drawer somewhere in Washington,” he added.

But the U.S. government’s focus on vaccines to combat pandemics likely played a role in spurring further research into novel vaccine platforms.

DARPA and BARDA make vaccine investments

Government agencies such as the Defense Advanced Research Projects Agency (DARPA) and the Biomedical Advanced Research and Development Authority (BARDA) would play a role in vaccine development. DARPA “invests in very long term science and technology [projects] that will pay off in 20 years,” Bloom said.

The National Institute of Allergy and Infectious Diseases (NIAID) developed a stabilized SARS-CoV-2 spike immunogen (S-2P) that Moderna would later use in its messenger RNA platform.

DARPA was instrumental in the development of RNA vaccines and provided $25 million in financial support to Moderna in 2013 to pursue messenger RNA–based antibody drugs and vaccines. DARPA announced it was committing up to $56 million in additional funding to Moderna this October.

BARDA has committed another roughly $955 million to Moderna.

In all, the U.S. government vaccine contract with Moderna is worth roughly $1.5 billion. BARDA has also invested in producers of other COVID-19 vaccines.

BARDA was also instrumental in resetting researchers’ expectations for vaccine development, Bloom said. The organization set a goal of developing a vaccine 60 days after determining a pathogen’s DNA sequence. Moderna had a vaccine candidate 66 days after scientists identified its genetic sequence. “And that is a reflection of tremendous foresight by these technical agencies,” Bloom said. By identifying promising research and identifying companies to advance it, the government agencies have played a role in engineering COVID-19 vaccines. But the platform approach could also help fight future pandemics, given its ability to allow researchers to tweak antigens and genes to target a new pathogen.

The U.S. government’s support of the vaccine platform led to investigations into its use to treat infections from Middle East Respiratory Syndrome (MERS), influenza, Zika and HIV. “We had a background on these

Intelligent Healing for Complex Wounds

A bioelectronic interface could speed the body's natural healing processes to deliver faster recovery from wounds with fewer complications

OUTREACH@DARPA.MIL
2/6/2019

Blast injuries, burns, and other wounds experienced by warfighters often catastrophically damage their bones, skin, and nerves, resulting in months to years of recovery for the most severe injuries and often returning imperfect results. This long and limited healing process means prolonged pain and hardship for the patient, and a drop in readiness for the military. However, DARPA believes that recent advances in biosensors, actuators, and artificial intelligence could be extended and integrated to dramatically improve tissue regeneration. To achieve this, the new Bioelectronics for Tissue Regeneration (BETR) program asks researchers to develop bioelectronics that closely track the progress of the wound and then stimulate healing processes in real time to optimize tissue repair and regeneration.

Exhibit 2

Paul Sheehan, the BETR program manager, described his vision for the technology as “not just personalized medicine, but dynamic, adaptive, and precise human therapies” that adjust to the wound state moment by moment to provide greater resilience to wounded warfighters.

“Wounds are living environments and the conditions change quickly as cells and tissues communicate and attempt to repair,” Sheehan said. “An ideal treatment would sense, process, and respond to these changes in the wound state and intervene to correct and speed recovery. For example, we anticipate interventions that modulate immune response, recruit necessary cell types to the wound, or direct how stem cells differentiate to expedite healing.”

The envisioned BETR technology would represent a sharp break from traditional wound treatments, and even from other emerging technologies to facilitate recovery, most of which are passive in nature.

Under current medical practice, physicians provide the conditions and time for the body to either heal itself when tissues have regenerative capacity or to accept and heal around direct transplants. Most people are familiar with interventions that include casts to stabilize broken bones or transplants of healthy ligaments or organs from donors to replace tissues that do not regenerate.

Passive approaches often result in slow healing, incomplete healing with scarring, or, in some unfortunate cases, no healing at all. Blast injuries in particular seem to scramble the healing processes; 23 percent of them will not fully close. Moreover, research shows that in nearly two thirds of military trauma cases — a rate far higher than with civilian trauma injuries — these patients suffer abnormal bone growth in their soft tissue due to a condition known as heterotopic ossification, a painful experience that can greatly limit future mobility.

Although recent experimental treatments offer some hope for expedited recovery, many of these new approaches remain static in nature. For instance, some “smart” bandages emit a continuous weak electric field or locally deliver drugs. Alternatively, hydrogel scaffolds laced with a drug can recruit stem cells, while decellularized tissue re-seeded with donor cells from the patient help avoid rejection by the host’s immune system. These newer approaches may indeed encourage growth of otherwise non-regenerative tissue, but because they do not adapt to the changing state of a wound, their impact is limited.

“To understand the importance of adaptive treatments that respond to the wound state, consider the case of antibiotic ointments,” Sheehan explained. “People use antibiotics to treat simple cuts, and they help if the wound is infected. However, completely wiping out the natural microbiota can impair healing. Thus, without feedback, antibiotics can become counterproductive.”

Recent technologies have begun to close the loop between sensing and intervention, looking for signs of infection such as changes in pH level or temperature to trigger treatment. To date, however, these systems have been limited to monitoring changes induced by bacteria. For BETR, DARPA intends to use any available signal, be it optical, biochemical, bioelectronic, or mechanical, to directly monitor the body’s physiological processes and then to stimulate them to bring them under control, thereby speeding healing or avoiding scarring or other forms of abnormal healing.

By the conclusion of the four-year BETR program, DARPA expects researchers to demonstrate a closed-loop, adaptive system that includes sensors to assess wound state and track the body’s complex

responses to interventions; biological actuators that transmit appropriate biochemical and biophysical signals precisely over space and time to influence healing; and adaptive learning approaches to process data, build models, and determine interventions. To succeed, the BETR system must yield faster healing of recalcitrant wounds, superior scar-free healing, and/or the ability to redirect abnormally healing wounds toward a more salutary pathway.

DARPA anticipates that successful teams will include expertise in bioelectronics, artificial intelligence, biosensors, tissue engineering, and cellular regeneration. Further, DARPA encourages proposals that address healing following osseointegration surgery, which is often necessary to support the use of advanced prosthetics by wounded warfighters.

DARPA will host a Proposers Day on March 1, 2019 in Arlington, Virginia, to provide more information to researchers interested in submitting a proposal for funding. Additional information is available at https://go.usa.gov/xENCQ. A forthcoming Broad Agency Announcement, to be posted to the Federal Business Opportunities website, will include full details of the program.

TAGS

| Artificial Intelligence | Health | Injury | Med-Devices | Sensors |

SIMILARLY TAGGED CONTENT

New Generation of Intelligent Bio-Interfaces Could Overcome Aspects of Spinal Cord Injury
Bioelectronics for Tissue Regeneration
Biological Technologies
Detect It with Gene Editing Technologies (DIGET) Proposers Day
Gene Editors Could Find New Use as Rapid Detectors of Pathogenic Threats

IMAGES

BETR program

US Federal contracts awarded to First Databank, Inc. in United States Of America

Search 21 federal contracts awarded to First Databank, Inc. in United States Of America since fiscal year 2015.

Company Profile

Company name	First Databank, Inc.
D-U-N-S number	084259696
Address	500 E. 96th Street, Ste 500, Indianapolis, IN, 46240, United States Of America
Phone #	(317) 571-7200
Fax #	(317) 571-7253
Number of employees	17,000
Annual revenue	$250,000,000
Organizational type	CORPORATE NOT TAX EXEMPT
Alternate name	FIRST DATA BANK
Legal organization name	FIRST DATABANK, INC.
Parent Company	THE HEARST CORPORATION
Parent D-U-N-S number	001527241
Registration date	2001-11-14

Contract Description and awarding agency	Amount
"Option Period Two For Software License Renewal For Drug Database And Decision Support Tools For Va Pharmacy Reengineering Project. Period Of Performance Shall Be From January 18, 2016 Through January 17, 2017." awarded by Department Of Veterans Affairs on 2016-01-15	$3,471,431
"Software License Renewal For Drug Database And Decision Support Tools For Va Pharmacy Reengineering Project. Option Period One To Support Indian Health Services." awarded by Department Of Veterans Affairs on 2015-01-15	$3,387,091
"Pharmacy Drug Database Updates" awarded by Department Of Health And Human Services on 2015-09-29	$716,081
"Pharmacy Drug Database Updates" awarded by Department Of Health And Human Services on 2016-09-22	$358,040
"First Databank Medknowledge-opt 1" awarded by Department Of Defense on 2015-09-15	$31,200
"Medknowledge National Drug Data File-descriptive Data Package" awarded by Department Of Defense on 2016-03-31	$18,771
"Medknowledge" awarded by Department Of Defense on 2015-01-09	$18,323
"Licening Fees" awarded by Department Of Veterans Affairs on 2016-05-27	$13,200
"Knee Replacement" awarded by Department Of Veterans Affairs on 2016-08-13	$12,802
"First Databank Subscription" awarded by Office Of Personnel Management on 2016-06-21	$10,873
"Information Technology Software" awarded by Department Of Health And Human Services on 2015-10-23	$9,278
"Renewal Of License Agreement (acct#538218) (osppc/orm)" awarded by Department Of Health And Human Services on 2016-05-09	$8,951
"First Databank, Inc. Database Access For National Drug Codes For Nimh" awarded by Department Of Health And Human Services on 2015-09-16	$5,822
"Patient Solution" awarded by Department Of Defense on 2016-04-01	$3,588
"Patient Education Module" awarded by Department Of Defense on 2015-03-26	$3,500
"First Databank Medknowledge Software License" awarded by Department Of Defense on 2015-03-19	$0
"Patient Education Module" awarded by Department Of Defense on 2015-10-27	$0
"Medknowledge" awarded by Department Of Defense on 2016-04-19	$0
"Renewal Of License Agreement (acct#538218) (osppc/orm)" awarded by Department Of Health And Human Services on 2016-06-01	$0
"First Databank Medknowledge" awarded by Department Of Defense on 2015-04-01	$-12,733
"First Databank Medknowledge" awarded by Department Of Defense on 2015-03-19	$-15,280

Exhibit 3

Hearst Corp. To Disgorge $19 Million and Divest Business to Facts and Comparisons to Settle FTC Complaint

December 14, 2001

FOR RELEASE

TAGS: Health Care

The Federal Trade Commission today announced a proposed settlement with Hearst Corporation (Hearst) that would resolve charges that Hearst unlawfully acquired J.B. Laughery, Inc., which included the Medi-Span integratable drug information database business. Under the terms of the settlement, Hearst will divest the former Medi-Span business and pay $19 million as disgorgement of unlawful profits. The settlement will be presented to the federal district court for entry of a final judgment.

The settlement marks the first time the Commission has sought either divestiture or disgorgement of profits in a federal court action for a consummated merger. The Commission alleged that the merger violated Section 7A of the Clayton Act, Section 7 of the Clayton Act, and Section 5 of the FTC Act.

The Commission alleged that Hearst violated Section 7A of the Clayton Act when, in its requisite pre-merger filing with the antitrust agencies, it illegally omitted several high-level corporate documents prepared to evaluate the Medi-Span acquisition and its competitive effects. Hearst was required to provide those documents to the antitrust agencies to help them determine whether a full pre-merger antitrust review of the acquisition was necessary; its failure to submit those documents hindered the ability of the Commission to analyze the competitive effects of the acquisition prior to consummation. In its complaint, the Commission further alleged that this transaction substantially lessened competition in the integrated drug information database market, in violation of Section 7 of the Clayton Act and Section 5 of the FTC Act. The allegations are contained in the Commission's April 5, 2001, complaint. (*See* news release dated April 5, 2001; *Federal Trade Commission v. The Hearst Trust et al.*, Civil Action No. 1:01CV00734 (D.D.C) J. Jackson.)

Hearst will divest the Medi-Span business to Facts and Comparisons, a St. Louis based business unit owned by Wolters Kluwer, n.v., through its American subsidiary, Lippincott Williams & Wilkins, Inc., a Delaware corporation. Facts and Comparisons produces widely used print, Internet and CD ROM materials concerning pharmaceuticals. These publications are used as more in-depth reference materials by many of the customers of the integrated databases.

The integratable drug information database, formerly owned and maintained by Medi-Span, is one of the two databases that pharmacies, hospitals, doctors, third-party payers, and patients rely on to obtain information about drug prices, drug effects, drug interactions and the eligibility for drugs under various payment plans. The only other commonly used database is owned by Hearst's subsidiary, First DataBank. As a result, the January 1998 acquisition of Medi-Span by Hearst created a monopoly in the sale of integratable drug information databases. First DataBank used that monopoly power to substantially increase prices to all database customers.

The order also provides direct relief for those customers who were forced to pay monopoly prices for the database products. It requires Hearst to disgorge $19 million of profits obtained as a result of its unlawful acquisition of Medi-Span. According to a plan approved by the FTC, these funds will be distributed to injured customers as part of the settlement of a private class action suit alleging unlawful overcharges by Hearst.

The Hearst Corporation and The Hearst Trust are headquartered in New York City, and First DataBank, Inc. is headquartered in San Bruno, California. Facts and Comparisons, headquartered in St. Louis, Missouri, is an unincorporated division of Lippincott Williams & Wilkins, Inc., which is a Delaware corporation and subsidiary of Wolters Kluwer, n.v., a Dutch corporation.

The Commission vote to approve the settlement and direct staff to move entry of the final judgment before the Federal District Court was 5-0, with Commissioners Sheila Anthony and Mozelle Thompson issuing a joint separate statement, Commissioner Orson Swindle issuing a separate statement, and Commissioner Thomas B. Leary issuing a separate statement concurring in part and dissenting in part. Each is available on the FTC's Web site and is summarized below. The judgment will not become final until it is signed and entered by the District Judge.

The statement by Commissioners Anthony and Thompson noted that, while "the Commission should seek disgorgement as a remedy in competition cases only in exceptional circumstances . . . Hearst's conduct was sufficiently egregious to justify the extraordinary remedy of disgorgement" in this case. Anthony and Thompson said that "absent disgorgement, the divestiture of the Medi-Span assets alone might have allowed Hearst to profit from its unlawful behavior. Such a result would be untenable, not only because it would be insufficient to restore the competitive status quo, but also because it would deny a remedy to injured customers."

Hearst Trust, The, The Hearst Corporation, and First DataBank, Inc.

TAGS: Health Care | Prescription Drugs | Hart-Scott-Rodino Act (HSR) | Competition | Merger

LAST UPDATED: DECEMBER 14, 2001

FTC v. The Hearst Trust, The Hearst Corporation, and First DataBank, Inc.

FTC MATTER/FILE NUMBER: 9910323a

CIVIL ACTION NUMBER: 101CV00734

ENFORCEMENT TYPE: Federal Injunctions

CASE SUMMARY

The Commission negotiated an agreement with The Hearst Corporation (Hearst) to settle a permanent injunction action filed by the FTC alleging that Hearst failed to provide documents required by premerger notification law and then consummated a merger that monopolized the integrated drug information database market. Under the terms of the order, Hearst divested the Medi-Span business to Lippincott Williams & Wilkins, Inc. , a subsidiary of Wolters Kluwer, n.v., disgorged $19 million in profits, and to complied with certain other obligations.

CASE TIMELINE

December 14, 2001

- Stipulation For Entry of Final Order and Stipulated Permanent Injunction (8.59 KB)
- Final Order and Stipulated Permanent Injunction (60.15 KB)
- Exhibit F: Monitor Agreement Between Defendants And Richard Shermer (Dated November 2, 2001) (351.32 KB)
- Statement of Commissioners Sheila F. Anthony and Mozelle W. Thompson (4.67 KB)
- Statement of Commissioner Orson Swindle (4.13 KB)
- Statement of Commissioner Thomas B. Leary Concurring in Part and Dissenting in Part (4.96 KB)

PRESS RELEASE: Hearst Corp. To Disgorge $19 Million and Divest Business to Facts and Comparisons to Settle FTC Complaint

November 20, 2001

- Stipulation For Entry of Final Order and Stipulated Permanent Injunction (8.59 KB)
- Final Order and Stipulated Permanent Injunction (59.83 KB)
- Exhibit F: Monitor Agreement Between Defendants And Richard Shermer (Dated November 2, 2001) (351.32 KB)

PRESS RELEASE: Statement of Susan A. Creighton, Deputy Director, Bureau of Competition Regarding FTC Settlement with Hearst Corporation

April 4, 2001

- Complaint for Permanent Injunction and Other Equitable Relief Pursuant to 7A(g)(2) of the Clayton Act and Section 13(b) of the Federal Trade Commission Act (28.18 KB)
- Statement of Chairman Pitofsky and Commissioners Sheila F. Anthony and Mozelle W. Thompson (1.57 KB)
- Dissenting Statement of Commissioners Orson Swindle and Thomas B. Leary (2.36 KB)

PRESS RELEASE: FTC Charges Hearst Trust with Acquiring Monopoly in Vital Drug Information Market

Exhibit 4

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

NEW ENGLAND CARPENTERS HEALTH BENEFITS FUND, et al., Plaintiffs, v. FIRST DATABANK, INC. and McKESSON CORPORATION, Defendants.	CIVIL ACTION NO. 05-11148-PBS

MEMORANDUM AND ORDER APPROVING CLASS SETTLEMENT AND AWARDING ATTORNEY'S FEES AND EXPENSES

August 3, 2009

Saris, U.S.D.J.

After hearing on July 24, 2009, the Court allows the motion for final approval of the proposed nationwide class settlement of $350,000,000 as fair, reasonable, and adequate. See Fed. R. Civ. P. 23(e)(2).

As background, plaintiffs have asserted that defendants First DataBank, Inc. ("FDB"), a drug pricing publisher, and McKesson Corporation, a drug wholesaler, engaged in a racketeering enterprise to fraudulently increase the published "average wholesale price" ("AWP") of over four hundred branded drugs by five percent from late 2001 to 2005 in violation of 18 U.S.C. § 1962 and state law. The full factual background of the allegations are set forth in my Memorandum and Order, dated March

Exhibit 5

17, 2009 [Docket No. 720]. New England Carpenters Health Benefits Fund v. First Databank, Inc., 602 F. Supp. 2d 277 (D. Mass. 2009); see also New England Carpenters Health Benefits Fund v. First Databank, Inc., 244 F.R.D. 79 (D. Mass. 2007). Various objections were filed to the settlement. I find that the allocation among the cash, co-pay, and third-party classes is reasonable. I also find that notice to the classes was innovative, expansive and reasonable. I reject the objections to the allocation among the classes, the methodology for identification of class members, and notice for the reasons stated in court.

One remaining issue is the award of attorneys' fees and expenses. Class counsel seek an award of attorneys' fees and expenses in the amount of $84,000,000, which is 24 percent of the $350,000,000 settlement fund. The total lodestar accumulated by class counsel as of May 1, 2009 was in excess of $8,356,100. Plaintiffs report expenses accumulated in the amount of $4 million. If the lodestar of $8,356,100 (the attorneys' fees only) is divided into the requested fee award of $84 million, the multiplier is 10.05, which is at the highest end of multipliers imposed in comparable litigation. Objectors have challenged attorneys' fees and expenses as excessive and not supported by contemporaneous records.

In the First Circuit, "[t]he lodestar approach (reasonable hours spent times reasonable hourly rates, subject to a

multiplier or discount for special circumstances, plus reasonable disbursements) can be a check or validation of the appropriateness of the percentage of funds fee, but is not required." In re Compact Disc Minimum Advertised Price Antitrust Litig., 216 F.R.D. 197, 215-16 (D. Me. 2003); In re Thirteen Appeals Arising out of the San Juan Dupont Plaza Hotel Fire Litig, 56 F.3d 295, 307 (1st Cir. 1995); see also Manual for Complex Litigation (Fourth) § 14.122 (2004) ("the lodestar is . . . useful as a cross-check on the percentage method by estimating the number of hours spent on the litigation and the hourly rate, using affidavits and other information provided by the fee applicant. The total lodestar estimate is then divided into the proposed fee calculated under the percentage method. The resulting figure represents the lodestar multiplier to compare to multipliers in other cases.").

Several factors militate in favor of a significant multiplier. Plaintiffs point out that they successfully achieved a mega-amount of $350,000,000 plus future injunctive relief requiring First DataBank to roll back the prices of drugs subject to the conspiracy. There has been near-unanimous and "eye-popping" support for this settlement. (Aff. of Arthur R. Miller [Docket No. 794] ¶ 58.) Plaintiffs' counsel have been excellent in this complex, hard-fought litigation and innovative in its notice program and efforts to find class members. The expenses are included within the amount requested. Still, much of the

spade work in learning the arcane intricacies of drug pricing has been done in the related "Average Wholesale Price" litigation, which is separately compensated. See, e.g., In re Pharm. Indus. Average Wholesale Price Litig., 230 F.R.D. 61, 92 (D. Mass. 2005). The major new hurdle plaintiffs mounted here was the contentious battle over class certification, which was continued in the First Circuit. Balancing all the factors under the cross-check approach, I award the amount of $70,000,000, which represents a multiplier of about 8.3 times lodestar, and about 20 percent of the common fund. See Conley v. Sears, Roebuck & Co., 222 B.R. 181, 182 (D. Mass. 1998) (approving attorneys' fees that would constitute a lodestar multiplier of 8.9); In re Rite Aid Corp. Sec. Litig., 146 F. Supp. 2d 706, 736 n.44 (E.D. Pa. 2001) (concluding that, under the cross-check approach, a lodestar multiplier in the range of 4.5 to 8.5 was "unquestionably reasonable").

The Court allows compensation to the Named Consumer Representatives of $2,000 and the Third-Party Payor ("TPP") Plaintiffs for time spent on this case at $100 per hour. There were no objections to these amounts.

Finally, Skilstaf Inc., a TPP, has filed a motion for clarification of, or in the alternative, limited objection to the release by the class of the right to sue retailers separately. Specifically it objects to the release of "any other person" in Section 15 of the Settlement Agreement. McKesson argues that

this provision is important because it buys complete peace from having to contribute to judgments that might be entered against retailer pharmacies. This concern is hardly illusory. McKesson states that it has already received a demand letter for contribution in litigation filed in California by Skilstaf against retail pharmacies accused of being part of the price-rigging conspiracy. Mirabile dictu, class counsel (Hagens Berman) apparently is one of the law firms representing Skilstaf in that litigation. This was an issue which the parties did not flag to the Court during the preliminary approval proceedings or in the Notice, and the Court completely missed it. Confusingly, McKesson actually wrote Skilstaf an e-mail explaining that it did not intend the release to extend to claims against retail pharmacies. (Mot. for Clarification [Docket #779] Ex. B at 1.)

Because this is a proposed settlement, this Court would not have the authority to strike a material provision. At best it would be able to give a thumbs down to the entire agreement. To breach the impasse, McKesson has agreed to let Skilstaf opt out. While this approach raises some concerns that Skilstaf is being given special treatment, it is the pragmatic approach. No other TPP has objected to the provision, and indeed there has been no TPP objection to the settlement. Indeed, some TPPs filed a brief in support of the settlement. Moreover, any new suit against the pharmacies based on the allegations in this case is likely time barred. Accordingly, the Court declines to strike or clarify the

"any other person" language. Skilstaf has ten days from July 24, 2009 in which it may opt out of the settlement.

SO ORDERED.

S/PATTI B. SARIS
UNITED STATES DISTRICT JUDGE

McKesson Fills Initial Government Orders for Moderna's COVID-19 Vaccine

December 20, 2020

IRVING, Texas, Dec. 20 – As part of Operation Warp Speed, the U.S. government's public-private partnership to deliver COVID-19 vaccines to Americans, and under the direction of the Centers for Disease Control and Prevention (CDC), **McKesson** began distributing Moderna's COVID-19 vaccines and the ancillary supply kits needed to administer them. After months of preparation, which included establishing dedicated distribution centers and assembling supply kits, the company is primed to support the nation during this significant healthcare challenge.

Brian Tyler, CEO, McKesson said, "We are honored to be a partner with the U.S. government and other private-sector companies such as Moderna to support in the distribution of COVID-19 vaccines and the ancillary supply kits. In March, our world seemed to change overnight. But with a renewed sense of commitment and intensified focus, we've come together across industries and forged public and private partnerships to help restore and protect the health and well-being of people around the world. With our exceptional group of employees managing the effort, we stand ready as a company to meet this historical moment."

Key facts include:

- McKesson, a global leader in healthcare supply chain management, is managing two different aspects of the distribution efforts in coordination with the U.S. government. The company is distributing all supply kits for COVID-19 vaccines, as well as the distribution of frozen or refrigerated COVID-19 vaccines. McKesson is not distributing the Pfizer ultra-frozen vaccine.
- McKesson has a long history of managing the pharmaceutical and medical supply chain in the U.S., as well as handling the distribution of vaccines. The company has been the centralized distributor for the CDC's Vaccines for Children program for 13 years, including during the H1N1 public health crisis.
- The U.S. government is making all decisions related to where, when and how many doses McKesson will distribute. The company filled the first order from the CDC on Sunday, December 20. Our shipping partners should deliver initial vaccine orders at administration sites nationwide on Monday, Dec. 21, 2020.
- Maintaining the cold chain is a priority for the company. Upon arrival at a McKesson vaccine distribution center, McKesson will verify that the vaccines were maintained at the proper temperature while in transit and will place the vaccines inside a large-scale, pharmaceutical-grade freezer designed to maintain proper temperatures.
- The freezers are equipped with sophisticated controls, monitoring systems and alarms intended to ensure the vaccines remain within the appropriate temperature ranges.
- After receiving CDC orders, from inside the freezers the vaccine doses will be packed into insulated coolers with specialized cold packs and a temperature monitor so the administration site can verify that the vaccine doses stayed within the required temperature range during transit.
- For the Moderna COVID-19 vaccine, the ancillary supply kit normally will be sent at the same time as the vaccines. The kits include alcohol prep pads, face shields, surgical masks, needles and syringes, a vaccine administration sheet, and a vaccine record and reminder card.
- The company has partnered with FedEx and UPS, who will deliver the vaccines and ancillary supply kits to administration sites throughout the country.

Through Operation Warp Speed, McKesson partners closely with the U.S. Department of Health and Human Services (HHS) and the CDC. For the ancillary supply kit production and distribution, McKesson has partnered with the Strategic National Stockpile, which is part of the Office of the Assistant Secretary for Preparedness and Response within HHS.

About McKesson Corporation

McKesson Corporation is a global leader in healthcare supply chain management solutions, retail pharmacy, community oncology and specialty care, and healthcare information solutions. McKesson partners with pharmaceutical manufacturers, providers, pharmacies, governments and other organizations in healthcare to help provide the right medicines, medical products and healthcare services to the right patients at the right time, safely and cost-effectively. United by our ICARE shared principles, our employees work every day to innovate and deliver opportunities that make our customers and partners more successful – all for the better health of patients. McKesson has been named a "**Most Admired Company**" in the healthcare wholesaler category by FORTUNE, a "**Best Place to Work**" by the Human Rights Campaign Foundation, and a top **military-friendly company** by Military Friendly. For more information, visit **www.mckesson.com**.

PR Contact

Exhibit 6

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MedTech

VA contracts with DARPA-backed startup for real-time behavioral analytics, mental health app

by Stacy Lawrence | Dec 16, 2015 10:11am

The U.S. Department of Veterans Affairs has contracted with Boston-based startup Cogito for use of its real-time behavioral analytics mobile app that analyzes voice recordings and mobile phone usage to create clinically validated behavioral indicators of mental health. The agency said it will use the Cogito app to detect veterans in need of mental health care, including suicide prevention.

Cogito Companion app--Courtesy of Cogito

The VA use of the app is expected to enable healthcare managers to better assess veterans' mental health and then to implement outreach strategies for at-risk patients. The predictive behavioral model has been validated through research by agencies including the Defense Advanced Research Projects Agency (DARPA) and The National Institute of Mental Health (NIMH).

In fact, the NIMH is backing an ongoing **300-patient trial of the Cogito app** in patients within the age range of 18 and 70 and who have been referred to the South Huntington Clinic for behavioral health care. The app will offer real-time feedback on the patient's mental health based on its monitoring and analysis of voice interactions monitored by the smartphone.

The trial will assess treatment outcome and quality of life outcome as primary endpoints at 6 months; it will also measure other aspects such as self-care behavior and cost of care as secondary endpoints. It started in November and is slated to have final data in 2016.

"Improving the quality of life of the over 20 million veterans in the United States is a critical and important mission," said Joshua Feast, Cogito founder and CEO, in a statement. "The fact the VA is investing in novel behavioral analytics and mobile sensing technology to improve the mental health of veterans demonstrates their commitment to finding innovative solutions that will improve health outcomes."

Exhibit 7

The Cogito technology was developed in more than 15 years of research at the MIT Media Lab; the Companion app is intended to reveal unconscious signals in the human voice that disclose information about relationships and state of mind.

nature electronics

ARTICLES

https://doi.org/10.1038/s41928-021-00545-5

Check for updates

An electrically conductive silver–polyacrylamide–alginate hydrogel composite for soft electronics

Yunsik Ohm[1,2,5], Chengfeng Pan[1,2,5], Michael J. Ford[1,2], Xiaonan Huang[1,2], Jiahe Liao[1,3] and Carmel Majidi[1,2,3,4]✉

Hydrogels offer tissue-like compliance, stretchability, fracture toughness, ionic conductivity and compatibility with biological tissues. However, their electrical conductivity (<100 S cm^{-1}) is inadequate for digital circuits and applications in bioelectronics. Furthermore, efforts to increase conductivity by using hydrogel composites with conductive fillers have led to compromises in compliance and deformability. Here, we report a hydrogel composite that has a high electrical conductivity (>350 S cm^{-1}) and is capable of delivering direct current while maintaining soft compliance (Young's modulus < 1 kPa) and deformability. Micrometre-sized silver flakes are suspended in a polyacrylamide–alginate hydrogel matrix and, after going through a partial dehydration process, the flakes form percolating networks that are electrically conductive and robust to mechanical deformations. To illustrate the capabilities of our silver–hydrogel composite, we use the material in a stingray-inspired swimmer and a neuromuscular electrical stimulation electrode.

Soft electronics that exhibit high electrical conductivity and match the compliance of biological tissue are important in the development of wearable computing[1,2], soft sensors[3,4] and actuators[5], energy storage/generation devices[6,7] and stretchable displays[8,9]. A variety of material architectures have been used to create soft and stretchable electronics, including deterministic (such as wavy or serpentine) structures[10,11], soft microfluidic channels[12,13] and conductive composites or polymers[14–16]. However, these conductive materials have intrinsic limitations, such as relatively high Young's modulus (≫1 MPa in some cases) or limited deformability, and are not ideally suited for applications related to bioelectronic systems (such as those that require interfacing with biological tissues). Recently, researchers have demonstrated conductive elastomers with enhanced stretchability and compliance by incorporating microdroplets of liquid metal alloys such as eutectic gallium indium (EGaIn)[17,18]. In particular, a highly stretchable and conductive polymer composite has been developed using silver and EGaIn particles embedded in an ethylene vinyl acetate copolymer[18]. Although EGaIn-based polymer composites exhibit an encouraging combination of high conductivity, stretchability and compliance, they require a large volume fraction of metallic filler and their Young's modulus (~0.1–1 MPa) is greater than the modulus of soft gels and biological materials (roughly 1–10 kPa), such as adipose (body fat) tissue[19].

Hydrogels are a promising candidate for soft electronics since they have similar mechanical properties to a range of biological materials and soft tissues[20,21], including epidermal skin[22], brain[23], spinal cord[24] and cardiac tissue[25]. Recent research has highlighted various aspects of hydrogels, including high fracture toughness, tissue-like Young's modulus (<10^2 kPa), high water content (>75%), ionic conductivity, bioactivity and biocompatibility[21,26]. These properties enable unique applications in bioelectronics[27] and soft robotics[28], including soft-matter sensors[9,29] and actuators[30]. However, hydrogels have an intrinsic ionic conductivity (10^{-5} to 10^{-1} S cm^{-1}; refs. [31–33]) that is six to nine orders of magnitude lower than the conductivity of metals, and is inadequate for digital and power electronics[34].

To improve their electrical properties, hydrogel matrices have been filled with conductive materials such as metallic fillers (for example, nanowires or micro/nanoparticles)[35–38], carbon-based conductive materials (carbon nanotubes or graphene)[39,40] and intrinsically conducting polymers (for example, poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) or polyaniline)[3,34,41,42]. These composites demonstrate the potential for engineering hydrogels that are both electrically conductive (~10^{-5}–10^{1} S cm^{-1}) and have tissue-like mechanical compliance. However, there is a trade-off between improved electrical conductivity and lowered compliance and deformability in these conductive hydrogel composites. For example, a pure PEDOT:PSS hydrogel[34] has been developed with electrical conductivity of 40 S cm^{-1} but high Young's modulus (~2 MPa) and low maximum strain limit (<35% strain), while a soft graphene hydrogel[40] has been synthesized with favourable mechanical properties (Young's modulus of 50 kPa) but low electrical conductivity (~10^{-4} S cm^{-1}).

In this Article, we report an electrically conductive hydrogel composite that has high electrical conductivity (374 S cm^{-1}), a low Young's modulus (<10 kPa) matching that of soft biomaterials, such as adipose tissue[19], and high stretchability (250% strain). We use a polyacrylamide (PAAm)–alginate hydrogel that is embedded with a low concentration of silver (Ag) flakes. Electrical conductivity is created via a partial dehydration process[34] in which a moderate portion of water is removed to induce percolation and create electrically conductive pathways (Fig. 1a,b). Because the composite has a low concentration of metallic filler, it exhibits only modest hysteresis between loading and unloading cycles. The Ag–hydrogel composite's high conductivity, low Young's modulus, high electrical stability and high stretchability make it a suitable material for applications in soft robotics, bioelectronics and wearable electronics (Fig. 1c, Supplementary Fig. 1 and Supplementary Table 1). We demonstrate the potential applications of this soft conductor by using it in a light-emitting diode circuit that shows high mechanical compliance (Fig. 1d and Supplementary Fig. 2), a stingray-inspired

Exhibit 8

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Exhibits p. 18

nature COMMUNICATIONS

ARTICLE

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Non-equilibrium signal integration in hydrogels

Peter A. Korevaar[1,2]*, C. Nadir Kaplan[1,3,4]*, Alison Grinthal[1], Reanne M. Rust[5] & Joanna Aizenberg[1,3,5,6]*

Materials that perform complex chemical signal processing are ubiquitous in living systems. Their synthetic analogs would transform developments in biomedicine, catalysis, and many other areas. By drawing inspiration from biological signaling dynamics, we show how simple hydrogels have a previously untapped capacity for non-equilibrium chemical signal processing and integration. Using a common polyacrylic acid hydrogel, with divalent cations and acid as representative stimuli, we demonstrate the emergence of non-monotonic osmosis-driven spikes and waves of expansion/contraction, as well as traveling color waves. These distinct responses emerge from different combinations of rates and sequences of arriving stimuli. A non-equilibrium continuum theory we developed quantitatively captures the non-monotonic osmosis-driven deformation waves and determines the onset of their emergence in terms of the input parameters. These results suggest that simple hydrogels, already built into numerous systems, have a much larger sensing space than currently employed.

EXHIBIT 9

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ydrogels play a central role in a wide range of applications[1–11], from drug delivery[12] to microsensors[13] to smart optical[14] and homeostatic[15] materials. Much of the recent interest has focused on enabling hydrogels to deform rapidly in-phase with speci c inputs from the environment, such as pH[13,14], temperature[16,17] or chemical concentration[18,19]. In living systems, however, chemical signal transduction—from self-organizing amoebas navigating in elds of chemoattractant waves[20], to heartbeats adapting to ionic bursts and spikes[21], to membranes[22] and genetic material recon guring with changing metabolic states[23]—often involves coupling multiple chemical stimuli arriving at separate times and rates. This non-equilibrium integration is driven by materials that convert each incoming stimulus into a long-lived active chemical or mechanical response, often outlasting the duration of the stimulus and thereby enabling it to be coupled to a later one. We considered that even simple hydrogels intrinsically possess these same mechanistic elements. In this way, hydrogels may potentially act as complex chemical signal integrators and in turn exhibit a wide range of previously unexplored transient phenomena and sensing behaviors.

In current strategies, there is a tight, in-phase feedback between the hydrogel deformations, diffusion, and reversible chemical reactions, such as protonation/deprotonation[7,13,14], oxidation/reduction[24], or complexation/dissociation[10,18]. This means that as soon as the stimulus—e.g. protons, divalent ions or reagents—has been removed from the environment, the gel returns to its original state. Then, the gel s response to a subsequent stimulus is a new, separate, independent event. However, we hypothesized that introducing species that complex to the gel with variable, rather than uniformly fast, association/dissociation rates would enable common hydrogels to act as couplers of different stimuli separated across time and space. In particular, a slow dissociation rate should alter the traditional picture: By remaining complexed to the gel, a chemical stimulus would create a kinetically stable state with a characteristic lifetime. In such a case, the gel s deformation would be transiently maintained upon removal of the stimulus from the environment. A second chemical species introduced later could then compete for binding sites, and trigger decomplexation of the rst chemical species. As a result, the complexation, diffusion, and gel deformation rates associated with the rst stimulus become interlinked with those of the second. In this paper, we show how coupling the dynamics of otherwise separate stimuli in time and space creates speci c responses arising from the transient superposition of chemical species entering and exiting the gel.

We explore this concept with a widely used hydrogel, polyacrylic acid (PAA). Our system consists of a thin layer of hydrogel containing an array of embedded microplates, which enable real-time visualization of the gel s deformations at the microscale. The hybrid hydrogel-microplate con guration[25] has previously enabled a class of adaptive materials that catch and release biomolecules[26], switch chemical reactions on and off[27], or control wettability[28], homeostasis[15] and flow[29]. Under neutral or basic conditions, the carboxyl groups (COOH) of the PAA gel exist in a deprotonated form (COO), the gel is swelled, and the embedded microplates stand upright. Consistent with the traditional use of PAA gel as a direct pH sensor, exposure to acid protonates the COO groups, inducing nearly immediate contraction of the gel and the associated tilting of the microplates (Fig. 1a, yellow). Adding a base rapidly deprotonates the gel and restores the original state. To test our hypothesis, we apply as a rst stimulus divalent copper ions (Cu^{2}), which interacts with COO and contracts the gel. Cu^{2} and COO form a kinetically stable chelate complex, which has been reported to maintain localized gel deformation and blue color over months in the absence of external Cu^{2} (Fig. 1b, blue).[30] Our results demonstrate how this blue color, characteristic for COO -Cu^{2} -COO complexation, provides a complementary readout mechanism for the complex kinetic interplay between two stimuli. When acid (H) is delivered as a second stimulus to a system previously exposed to Cu^{2} , H competes for COO groups (Fig. 1b, gray box) and displaces Cu^{2} , releasing it into the fluid phase of the gel and then into the initially copper-free supernatant. Cu^{2} decomplexation will be dependent on the timescale of acid delivery $_{H}$. Varying $_{H}$ with respect to the timescales of Cu^{2} diffusion and hydrogel deformation leads to the emergence of a variety of competing non-equilibrium dynamics (Fig. 1, expanded gray box).

Through experiments, scaling laws and a non-equilibrium continuum theory that captures the time-dependent coupling of the two stimuli, we demonstrate how two different, previously unseen responses emerge. (i) Acid-induced Cu^{2} decomplexation inside the gel triggers transient water influx, driven by the osmosis caused by the Cu^{2} ions released into the fluid phase of the gel (dependent on the timescale of acid delivery $_{H}$). At the same time, acid itself contracts the gel (with the mechanical relaxation time $_{\perp}$). Counterintuitively, even though both Cu^{2} and H contract the gel upon complexation, the competition between Cu^{2} -induced osmosis and acid-induced contraction produces traveling osmotic swelling waves when $_{H} < _{\perp}$ (Fig. 1c). (ii) If copper is complexed locally in the hydrogel, acid releases Cu^{2} in region A to diffuse and recomplex to new COO groups in previously unoccupied neighboring regions B (Fig. 1d). At the same time, acid also competes with Cu^{2} and displaces it from these new sites. As a result, traveling color waves appear ahead of a slow-moving acid front when it progresses more slowly than Cu^{2} diffusion.

Results

Delivering the Cu^{2} stimulus to the hydrogel microplate system. Our hydrogel system comprises an array of surface-attached, slightly pretilted epoxy microplates embedded in a PAA hydrogel (Fig. 2a). The plates are 18 µm tall. The hydrogel has a height of H 10 µm measured from the confocal microscopy z-stack imaging (Supplementary Fig. 1). After deprotonating the PAA hydrogel by rinsing with a base, the hydrogel is swollen and the microplates are oriented nearly upright, 9° with the surface normal (see Methods for details). Upon addition of an aqueous copper(II)sulfate solution (0.8 M $CuSO_4$), the hydrogel turns blue, indicating the formation of COO -Cu^{2} -COO complexes in the hydrogel (Fig. 2b, c). Concurrently, the hydrogel contracts, and the embedded microplates tilt toward the substrate. This is evidenced by a progressive conversion from a rectangular to a square projection of the microplates in plain-view optical microscopy images. We note that the presence of the microplates and the blue color of the gel provide simple visual reporters on, respectively, (i) the deformation state of the gel, which is quanti ed by the microplate tilt angle, and (ii) Cu^{2} complexation, which is quanti ed by the red channel (r-) value in optical microscopy images (see Methods and Supplementary Fig. 1). Both the microplate tilting and the blue color are maintained after Cu^{2} is removed from the external solution, even after repeated rinsing with water, indicating a kinetically stable state that stores the Cu^{2} stimulus upon complexation. The vertical diffusion of Cu^{2} into the gel layer happens at a timescale $_{Cu2}$ H^2/D_{Cu2} 10 s, with a diffusion constant of D_{Cu2} 10^{-11} m^2 s^{-1}. Thus, we expect the local contraction and coloring responses upon Cu^{2} delivery to occur over a time $_{Cu2}$.

The Cu^{2} delivery can be localized and made directional by using a thin copper electrode wire (diameter approx. 100 µm) mounted directly on top of the substrate, covered with a thin

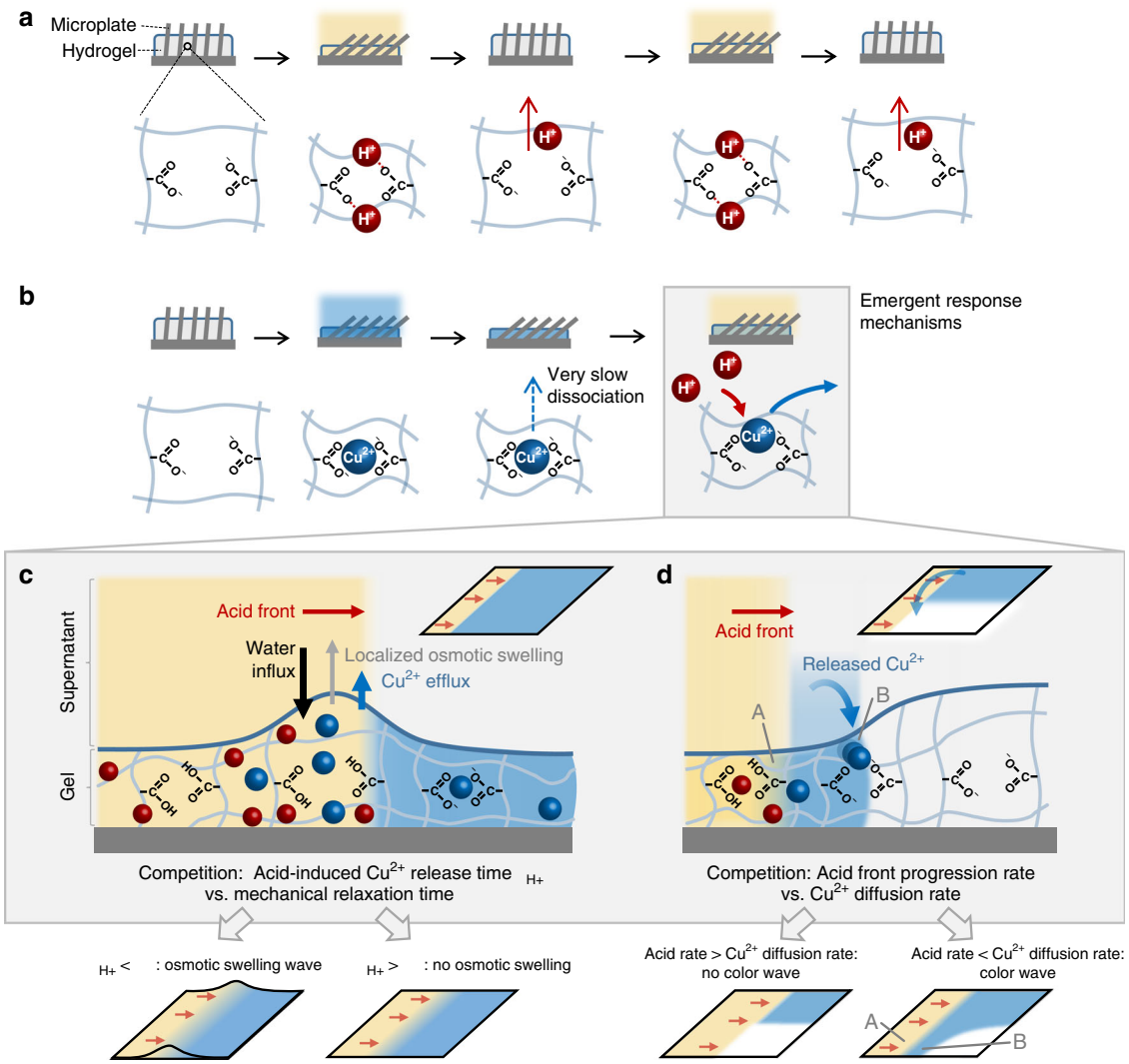

Fig. 1 Non equilibrium coupling of stimuli across time. a Traditionally, a responsive polyacrylic acid (PAA) hydrogel contracts and swells directly in-phase with the presence or absence of an acid stimulus (yellow). Here, hydrogel contraction tilts an array of embedded microplates (gray). **b** In contrast to this rapid reversibility, divalent cations (Cu^{2} , blue) contract the PAA gel by forming a kinetically stable complex with two carboxylate (COO) groups, remaining in the gel after removal of Cu^{2} from the environment. A subsequent acid stimulus then competes for COO groups and triggers dissociation of the Cu^{2} on a timescale determined by its delivery rate ($_{H}$). The ensuing dynamics of diffusion, complexation, and mechanical deformations in the presence of the entering and exiting stimuli can lead to scenarios depicted in c-d: **c** Competition between transient water in ux, induced by released Cu^{2} , and the mechanical relaxation time of the gel ($_{\perp}$) creates traveling osmotic swelling waves reporting the speed of an oncoming acid front when $_{H}$ < $_{\perp}$; **d** Competition between the diffusion and transient recomplexation of released Cu^{2} (top, curved blue arrow) and its re-release by oncoming acid creates rate-sensitive traveling color waves when the acid progression rate is smaller than the Cu^{2} diffusion rate (bottom right, narrow blue band).

layer of a sodium perchlorate electrolyte solution ($NaClO_4$, 0.05 M, see Scheme in Fig. 2d, Methods and Supplementary Fig. 2). When a voltage of approx. 1 V (current 0.1 mA) is applied, the microplates near the positive electrode begin to tilt as the corresponding region of the hydrogel contracts and turns blue. The region expands outward in time with a gradient of tilt angles and color intensity, consistent with Cu^{2} ions diffusing from the electrode through the electrolyte and binding to the hydrogel (Fig. 2e and Supplementary Movie 1). The slight initial pretilting of the microplates in one orientation results in a uniform tilting direction upon Cu^{2} -complexation. As we noticed a variability in the degree of gel contraction depending on the direction of electrochemical Cu^{2} delivery, all experiments were performed such that the pretilted plates were oriented towards the Cu^{2} source, as schematically represented in Fig. 2d. Both the tilted state and blue color are maintained after Cu^{2} is removed from the external solution by rinsing the substrate with water. Only a slow release of Cu^{2} occurs at the edge of the Cu^{2} -contracted region (Fig. 2f).

Osmotic pulses and waves selective to rapid Cu^{2} release. The kinetically stable complexation creates a unique condition where Cu^{2} is present inside the gel and absent from the external environment. Hence, rapid dissociation of Cu^{2} upon protonation of the carboxylates must yield a transient osmotic pressure within the gel (Fig. 3a): If the release rate of Cu^{2} is fast enough to induce water influx, this triggers an osmotic imbalance across the gel supernatant solution interface. Satisfying this condition requires the relaxation time of the hydrogel deformation $_{\perp}$ to be smaller than the diffusion timescale of Cu^{2} ($_{Cu2}$), *i e* $_{\perp}$ < $_{Cu2}$ ($\equiv \epsilon L$ $U^{(0)}$, where $\epsilon \sim$ h H is the ratio of the change in gel lm thickness h over its equilibrium thickness H, L is the horizontal length scale, and $U^{(0)}$ is the inlet speed of the acid).

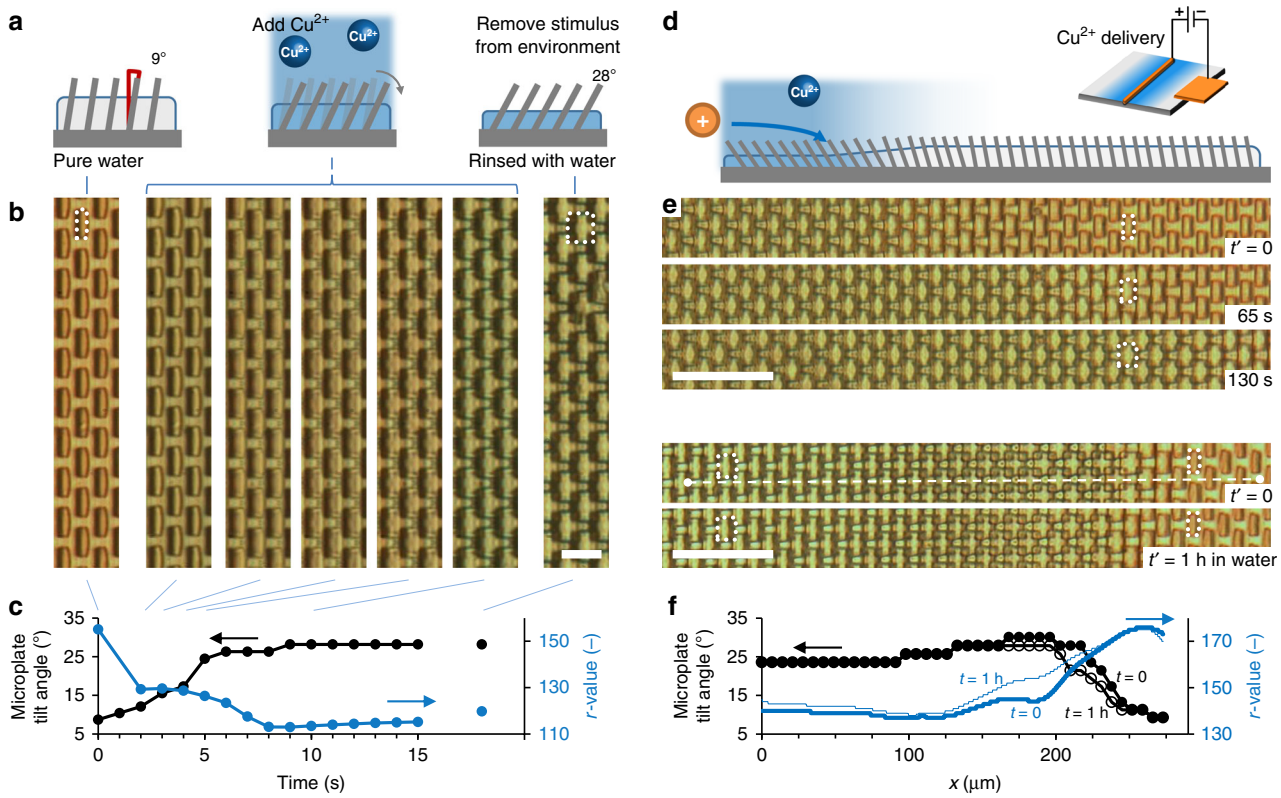

Fig. 2 Delivery and storage of a Cu^{2} stimulus. a Scheme of the Cu^{2} complexation, hydrogel contraction, and microplate tilting upon exposure to Cu^{2}, and the maintenance of this response upon the formation of kinetically stable complexes after the stimulus is removed from the external environment. **b** Optical microscopy images showing that the addition of copper(II) sulfate (see Methods) leads to progressive microplate tilting, concurrent with a progressive colorless-to-blue transition of the hydrogel, indicative of COO -Cu^{2} -COO complexation. The white dotted outlines indicate the change of the cross-sectional view of a single plate from rectangular (in the upright state) to nearly square (in the tilted state). Scale bar: 15 m. **c** Data corresponding to microscopy images of the microplate tilt angle (black, reported as the angle between microplate and normal to the substrate, see Methods), and Cu^{2} complexation (blue, reported as value, i.e. red-channel value of the optical micrographs). The tilt angles and blue color are maintained after rinsing the substrate with water (right image in b). **d** Scheme showing Cu^{2} ions electrochemically delivered from a positively charged copper electrode wire. **e** Upon applying a voltage of approx. 1 V across a copper wire (diameter approx. 100 m), Cu^{2} ions are released from the electrode (from the left side of the images), diffuse from left to right, and undergo complexation by the COO groups in the hydrogel, inducing blue color and microplate tilting. Scale bar: 50 m. **f** After electrochemical delivery, localized storage of Cu^{2} remains intact, with only a slow release of Cu^{2} at the boundary of the contracted region. The value and the microplate tilt angle vs. position *x*, shown in the graph, were acquired along the horizontal white dashed line shown in e. Scale bar: 50 m.

Then, a suf ciently low acid-induced Cu^{2} release timescale $_{H}$, such that $_{H} < _{\perp}$, is expected to produce an unusual transient gel swelling that would be selective only to fast onset-rates of the acid stimulus.

As an initial test of this scaling prediction, a concentrated acid solution (1 M HCl) was added to a hydrogel-microplate substrate containing complexed Cu^{2}. Directly after this delivery of a 'fast arriving acid stimulus, a rapid dissociation of Cu^{2} was observed, as indicated by the loss of blue color within $_{H}$ 2 s (Fig. 3b, d and Supplementary Movie 2). Concurrent with this color transition, the initially tilted microplates briefly stood upright at the onset of the acid stimulus, con rming that the system reports the fast acid flow with a transient swelling of the hydrogel when $_{H} < _{\perp}$, and then tilted back toward the substrate over $_{Cu2}$ 10 s. Corroborating that this unique transient swelling is indeed driven by an osmotic imbalance induced by Cu^{2} dissociation, we show that the inclusion of $CuSO_4$ (0.8 M) in the HCl solution—to reduce its hypotonic character—suppresses the swelling pulse (Supplementary Fig. 3).

To assess the selectivity of the swelling response for fast Cu^{2} release, the same amount of acid was added slowly via a series of progressively concentrated HCl solutions, from 0.01 to 1 M. As shown in Fig. 3c, e, Cu^{2} dissociates from the hydrogel during the addition step of 0.05 M HCl, over $_{H}$ 20 s. Since in this case the generation of free Cu^{2} inside the gel is slower than its diffusion out of the gel (i.e. $_{H} > _{Cu2}$ 10 s), the accumulation of free Cu^{2} in the gel is insuf cient to drive the osmotic swelling. As a result, the gel is observed to remain in its contracted state with the microstructures titled to the substrate, and simply changes color as protonation induces the release of Cu^{2}. We note that when calcium (Ca^{2}) is used as an alternative complexing agent to contract the PAA hydrogel, Ca^{2} release upon rapid addition of acid induces a transient swelling response as well (Supplementary Fig. 4), suggesting a general applicability of our approach.

The transient osmotic pressure due to rapid Cu^{2} dissociation can also take the form of traveling swelling waves that are sensitive to the progression rate and direction of an acid front spreading across the substrate. As schematically shown in Fig. 4a, an acid stimulus with a controllable progression rate can be initiated by delivering a drop of acid under one edge of a glass cover (Methods and Supplementary Fig. 5). Cu^{2} decomplexation at the acid front is indicated by a blue-to-colorless transition that progresses from left to right (Fig. 4b, c), and occurs over a length scale of L 100 μm, consistent with free diffusion within the stimulus front (D 10^{9} m^{2} s^{1}) over $_{Cu2}$ 10 s and $_{\perp}$ 10 s (see Supplementary Information). To meet the

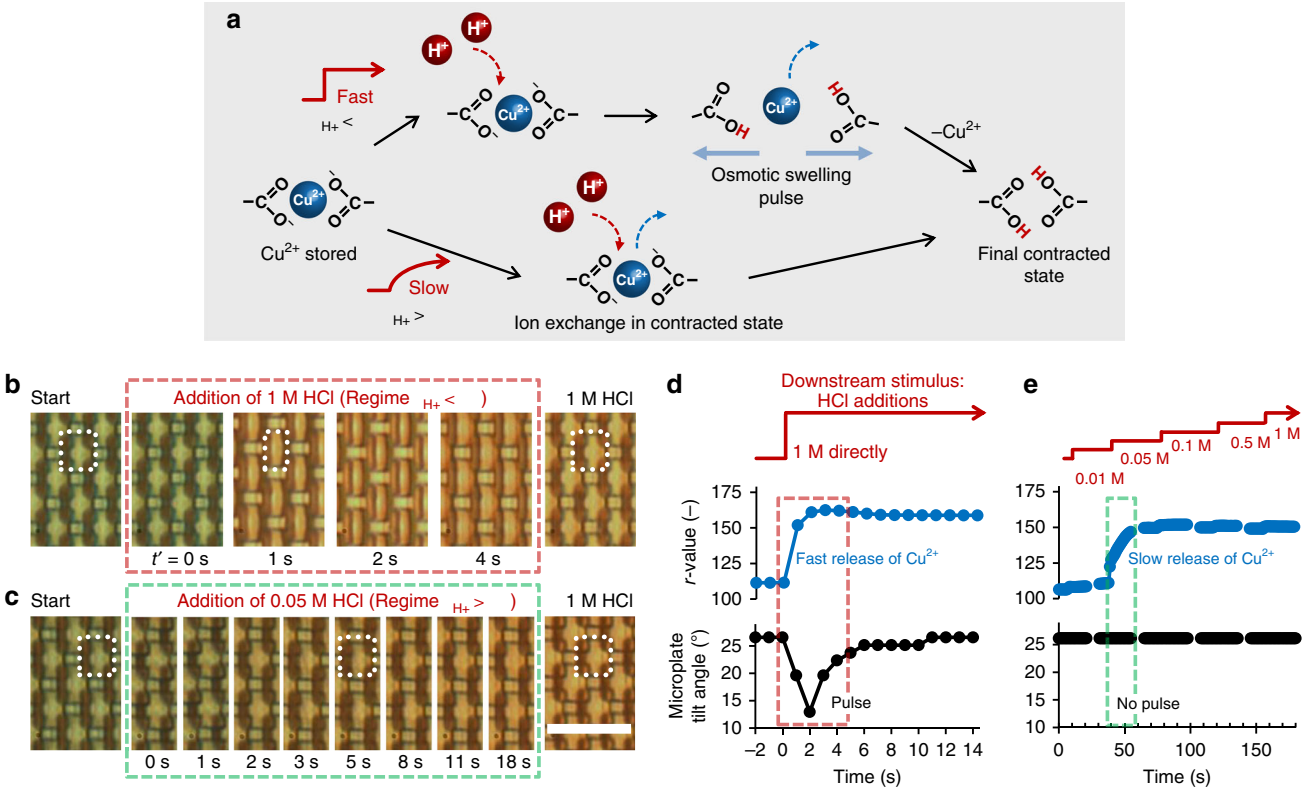

Fig. 3 Cu^{2} ions generate a transient osmotic swelling pulse upon rapid release by an acid stimulus. a Schematic presentation of the mechanism, showing how acid delivered after Cu^{2} has been removed from the external environment of the hydrogel protonates carboxylate groups and thereby releases the complexed Cu^{2} . Fast release would generate an osmotic swelling pulse (top) before acid contracts the hydrogel again, while slow addition of acid should lead to a slow Cu^{2} release without transient swelling (bottom). **b** Experimental demonstration of the fast Cu^{2} release (regime $_{H}$ < $_{\perp}$), triggered by direct addition of concentrated 1 M HCl, which results in rapid disappearance of the blue color and transient reorientation of the microplates to an upright position. The dotted outlines indicate the change of the cross-sectional view of a single plate from nearly square (in the tilted state) to rectangular (in the upright state), and back to nearly square. **c** Stepwise addition of acid leads to a slow release of Cu^{2} , such that the gel remains contracted without transient swelling (regime $_{H}$ > $_{\perp}$). Scale bar: 25 m. **d**, **e** Time-dependent microplate tilt angle and value (acid stimulus added at t = 0) for fast (**d**) and stepwise, slow (**e**) addition.

condition of $_{H}$ < $_{\perp}$ 10 s—the requirement for observing a transient swelling response as discussed above, where $_{H}$ L/v_C—the acid progression speed must be $v_C > 10\,\mu m\,s^{-1}$. Consistent with this prediction, a wave of weakly up-and-down moving microplates is experimentally observed to travel at the front of an acid stimulus moving with a minimum rate of $v_C = 8.6\,\mu m\,s^{-1}$ (Fig. 4c and Supplementary Movie 3). A slower progression yields no swelling pulse at the stimulus front (Supplementary Fig. 6), as exempli ed by the results in Fig. 4b acquired at $v_C = 0.76\,\mu m\,s^{-1}$. In contrast, fast progression ($v_C \geq 95\,\mu m\,s^{-1}$) yields a high-amplitude traveling pulse (Fig. 4d). The pressure that is required to establish a swelling wave spreading over L 100 µm within $_{H}$ 10 s determines the poroelastic diffusion constant of water inside the hydrogel, given by D_{water} $k_f p/\mu_f$ $10^{-10}\,m^2\,s^{-1}$, where k_f 10^{-19} $10^{-18}\,m^2$ is the hydraulic permeability of the hydrogel and $\mu_f = 10^{-3}\,Pa\,s$ is the dynamic viscosity of water. The required pressure p equals 1 10 MPa; a pressure that can be generated upon osmosis as the concentration of Cu^{2} ions is estimated to be 2.9 M (Supplementary Fig. 7 and Supplementary Information), implying a maximum osmotic pressure of ~7 MPa (p_{osm} [Cu^{2}]·$k_B T$). We note that the orientation of the microplates with respect to the acid stimulus progression does not have a major effect on the swelling response of the hydrogel.

To further assess the timescales and forces involved in the unique transient swelling responses and traveling waves that arise upon coupling of successive Cu^{2} and acid stimuli, we developed a continuum theory that gives the time-dependent height pro le of a thin hydrogel sheet, based on time- and position-dependent descriptions of (i) Cu^{2} and acid present in the supernatant fluid, in the hydrogel interior fluid, and complexed to PAA; (ii) the osmotic and contractile forces exerted on the gel due to free and complexed Cu^{2} and acid in the gel, and (iii) the mechanical deformation of the gel (see Supplementary Discussion). Simulations based on parameter values, which match experimentally assessed time- and pressure-scales, quantitatively reproduce the experimental vertical deformation waves of the hydrogel, as derived from the experimentally observed microplate tilting waves (Fig. 4e, Supplementary Figs. 8 and 9, and Supplementary Movies 4–6). The transient osmotic vertical flow for thin lm domains is given by Supplementary Eq. 14 and holds at the leading order $O(\delta^0, \epsilon^0)$, where δ is the aspect ratio of the thin lm; both ϵ and δ are very small. The mobility coef cient in Supplementary Eq. 14 scales with δ^{2} and is not a free parameter. This osmotic flow term quantitatively reproduces the osmosis-induced traveling waves (Fig. 4, Supplementary Movies 4–6). Thereby, our theory shows that, rst, species released within the hydrogel induce transient osmosis; second, this enables unique signaling routines that selectively report input stimuli occurring at fast rates; and, third, swelling pulses are displayed at timescales that cannot be established by solely breaking crosslinks in the hydrogel.

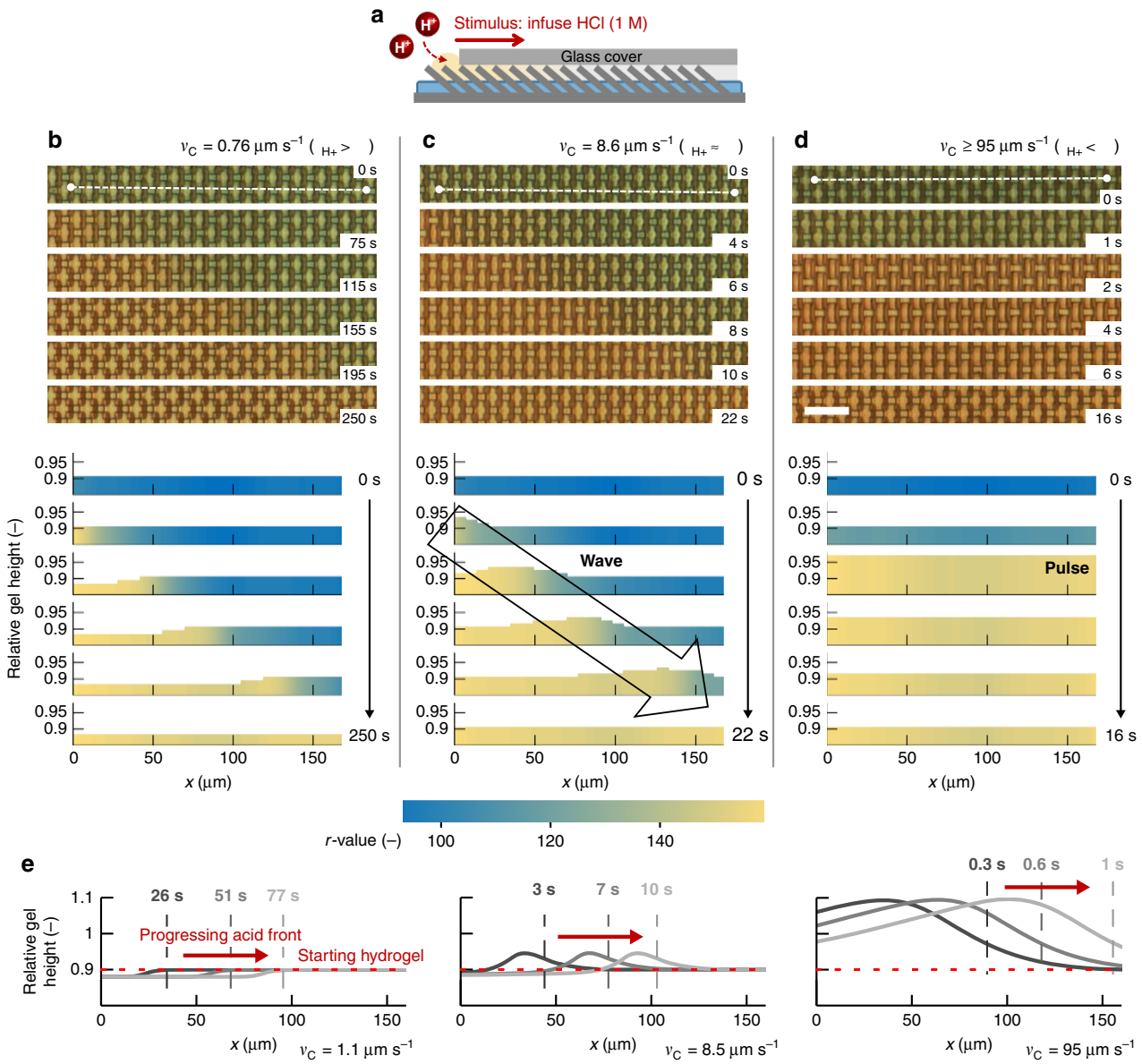

Fig. 4 Traveling swelling waves that are sensitive to the acid progression rate. a Schematic of the experimental design: HCl (1 M) is added from the left side of a Cu^{2} -contracted substrate covered with a thin water film and a glass cover (see Methods). **b d** (Top) Micrographs showing the progression of the acid stimulus at various rates, indicated by a blue-to-colorless transition. (Bottom) The height of the diagrams represents the evolution of the relative hydrogel height in time and space derived from the microplate tilt angle as described in Methods (Supplementary Fig. 1), along the white dashed line for the six micrographs from top to bottom; and the color of the diagrams represents the Cu^{2} release as characterized by the blue-to-colorless transition: **b** No swelling pulse is observed for the acid stimulus that travels from left to right over 190 m in 250 s ($v_C = 0.76$ m s ^{1}); **c**, **d** Faster progression of the acid within 22 s (**c** $v_C = 8.6$ m s ^{1}) and within 2 s (**d** $v_C \geq 95$ m s ^{1}) generates swelling/contraction waves that travel at the acid front. Scale bar: 25 m. **e** The results of our continuum theory show that traveling swelling/contraction waves are only obtained at $v_C \geq 8.5$ m s ^{1} for this set of experimental parameters, in excellent agreement with the experimental data. The red dashed lines indicate the starting height of the Cu^{2} -storing hydrogel; the vertical lines indicate the position of the progressing HCl front at three different times; the curves show the corresponding relative hydrogel height along the horizontal position *x*. The grayscale corresponds to three different times given in the legend of each plot.

Traveling color waves reporting slow acid fronts. Copper ions released by acid from the hydrogel into an otherwise Cu^{2} -free medium not only enable short-term osmotic pressure in the gel, but also give rise to localized patterns of recomplexation as the released Cu^{2} ions diffuse with the moving acid front. While swelling waves require a rapidly moving acid front to trigger a rapid release of Cu^{2} inside the gel, recomplexation of Cu^{2} should in contrast require the acid front to be moving slowly enough for the diffusing Cu^{2} ions to be able to compete with the oncoming protons for new binding sites. Assuming a graded acid concentration at the front, Cu^{2} comigrating with the front will potentially have a time window to recomplex to the gel in the presence of a low acid concentration, before saturating acid overtakes the recomplexed Cu^{2} and releases it again. Consistent with this possibility, flowing a solution containing 1 M HCl and 0.8 M $CuSO_4$ with a slow progression rate along a substrate with a deprotonated PAA hydrogel yields a transient band of Cu^{2} complexation at the solution front ($v_C = 3$ μm s ^{1}, Supplementary Fig. 10). For a system that is exposed rst to Cu^{2} and subsequently to progressing acid, initial release of Cu^{2} by acid at

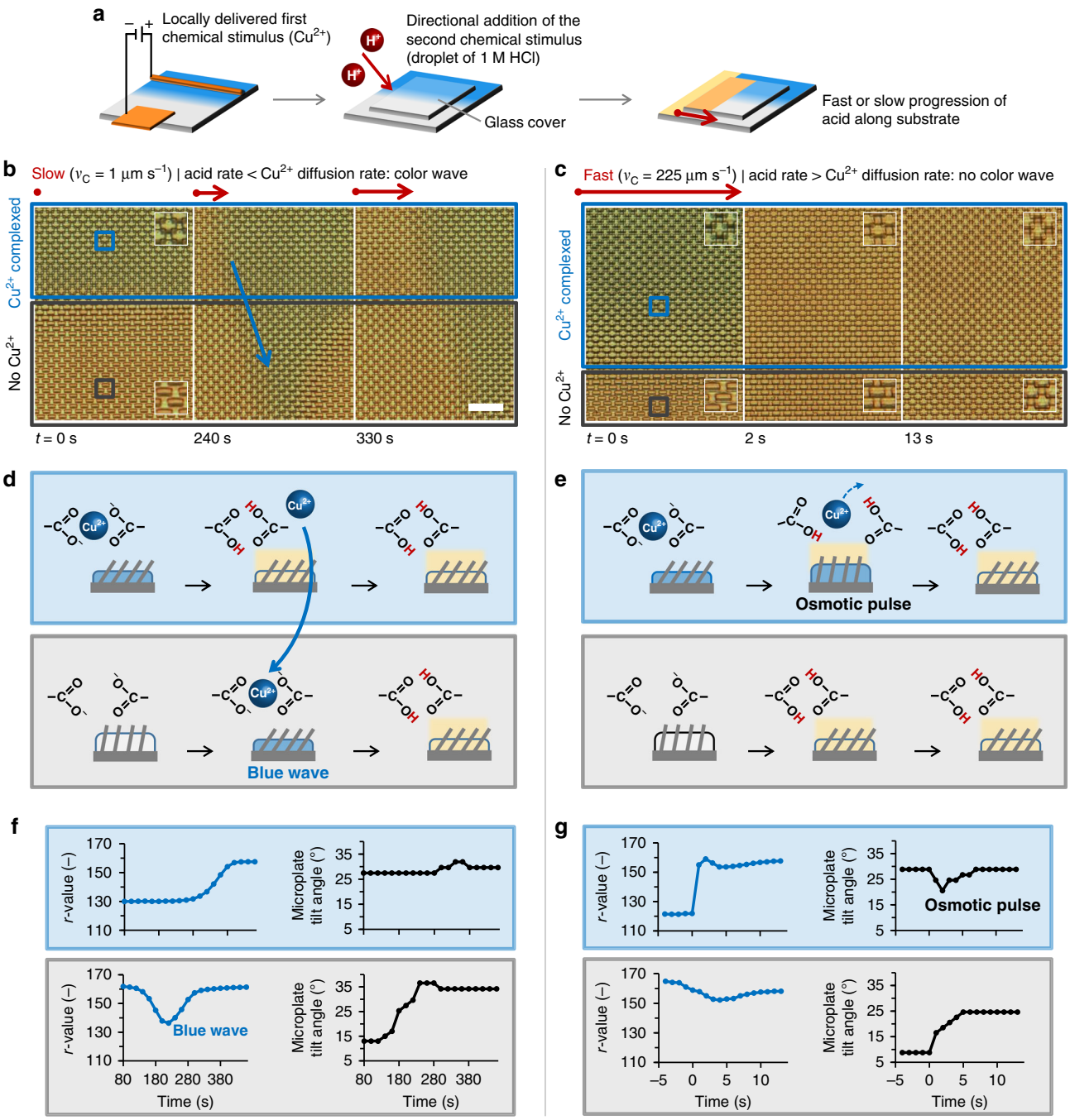

Fig. 5 Traveling color waves selectively reporting slowly progressing acid stimuli. a Schematic presentation showing the mechanism for the appearance of the travelling color waves: Cu^{2} is initially delivered electrochemically to one side of the substrate (blue region in diagram). A glass cover is then applied and the acid is added from the left and allowed to progress along the substrate. **b** Experimental demonstration of the slow acid progression: Cu^{2} is complexed in the region of the substrate where it was applied; slow progression of the acid (acid rate < Cu^{2} diffusion) allows Cu^{2}, released at the acid front in the Cu^{2}-complexing region (blue box), to migrate to the adjacent Cu^{2}-free region (blue arrow), generating a transient blue wave just ahead of the stimulus front (gray box). Scale bar: 50 m. **c** Fast progression of the acid from left to right (acid rate > Cu^{2} diffusion) induces a swelling/contraction wave in the Cu^{2}-complexing region (blue box) and a direct contraction of the hydrogel with no color wave in the region with no Cu^{2} (gray box). **d**, **e** Schematic representation of the subsequent stages for both regions in (**b**) and (**c**), respectively. **f**, **g** Time-dependent value and microplate tilt angle, acquired at the blue and gray squares in (**b**) and (**c**), respectively.

a region A, followed by diffusion of Cu^{2} through the supernatant solution and recomplexation to the gel at a region B, can result in a transient band of Cu^{2} complexation. This must only happen when acid migration from A to B is slower than the diffusion of Cu^{2} and its subsequent recomplexation at B: $L_x/v_C > L_x^2/D^{(a)}$ $_{Cu2}$, where $L_x \sim L$ 100 μm is the distance between A and B, and $D^{(a)}$ is the diffusivity in the supernatant solution.

To test this idea, we electrochemically delivered Cu^{2} across one half of a gel/microplate system, so that Cu^{2} is stored on one side while the other remains copper-free (blue and white sides in Fig. 5a, respectively). Acid is then flowed such that the front progresses over both halves in parallel (Fig. 5a, yellow). This con guration potentially allows some of the released Cu^{2} at the front to diffuse to and recomplex on the copper-free side, subject

to the acid-dependent competition and time window. Our experimental results at different progression speeds indeed indicate the ability of this mechanism to produce a distinctive slow-rate-sensitive response: a slow acid progression speed ($v_C = 1\ \mu m\ s^{-1}$) generates a wave of blue color that travels with the acid front through the initially copper-free side (Fig. 5b, d, f and Supplementary Movie 7), featuring the regime where the acid progression is slower than the Cu^{2+} diffusion. This response was further observed with an intermediate rate of $v_C = 3\ \mu m\ s^{-1}$ (Supplementary Fig. 11), and also with a hydrogel without embedded microplates (Supplementary Fig. 12). The inequality $L_x/v_C > L_x^2/D^{(a)}\ _{Cu2}$ only holds when $v_C < 5\ \mu m\ s^{-1}$, assuming $D^{(a)} = 10^{-9}\ m^2\ s^{-1}$ and $_{Cu2} = 10$ s. Indeed, at fast progression rates ($v_C = 225\ \mu m\ s^{-1}$, Fig. 5c, e, g), no blue color was observed on the copper-free side (acid progression rate > Cu^{2+} diffusion rate). Instead, a wave of osmotic pressure was generated on the copper-storing side, with the associated transient upright movement of the microplates, as discussed above.

Discussion

Our results provide a potentially transformative approach to chemical signal processing and, more generally, suggest that simple hydrogels have a much larger sensing space than is currently made use of. By integrating the complexation-transport-deformation dynamics induced in the gel by two chemical stimuli that occur separately in time and space, we show that a common hydrogel—traditionally used for direct stimulus tracking through nearly in-phase response to an applied stimulus—can produce previously unseen complexity. This is demonstrated by time-sensitive, nonmonotonic osmotic effects accompanied by spikes and waves of gel expansion and contraction, as well as traveling color waves of patterned migration and recomplexation. Our non-equilibrium continuum theory captures how the diverse responses depend on the coupling of diffusion, flow, complexation, and hydrogel deformation as successive chemical stimuli enter and exit the gel. The theory allows the parameter windows to be predicted for a range of phenomena based on the relative timescales involved in signal coupling. Combined with an extensive experimental and scaling analysis, the model provides insight into the competing processes underlying the response mechanisms and emergent behaviors. As exemplary cases, our theory reveals how traveling osmotic swelling waves can emerge in response to the rapid onset of a stimulus that would normally—on its own—contract the gel, if the timescale of acid propagation is smaller than the mechanical relaxation time of the hydrogel. The theory further implies that, when two H^+ signals approach from opposite directions, the accompanying swelling fronts would annihilate each other upon collision. This is because no available bidendate complexation sites would be left ahead of each front to be decomplexed and create osmotic imbalance. Further scaling laws elucidate how a slowly moving acid gradient can induce sequences of migration and recomplexation highly sensitive to the interdependent dynamics of the released and oncoming stimuli.

In conclusion, the framework presented here shows how a hydrogel can be used without specialized modi cations to perform complex chemical sensing tasks not previously achieved with electronics-free systems. The exemplary responses we demonstrate likely represent only a small sample of the dynamic phenomena that may emerge. Based on simple, reversible chemistry and trivial hydrogel composition and geometry, our scaling analyses and the theoretical model elucidate distinct outputs able to discriminate among many possible combinations and permutations of rates, times, sequences, and con gurations of multiple arriving stimuli. These concepts are potentially applicable to a wide range of hydrogels, stimuli and non-equilibrium molecular systems beyond the ions, acid, and PAA gel used in this study.[31–39] The non-equilibrium concepts and theory can be further applied to readout mechanisms beyond the microplates used in this study, such as via microparticles dispersed within the gel or via focussing and defocussing of light beams by the gel. Additionally, the concept of rate-selective recomplexation waves—exempli ed by the blue color waves in our system—can be expanded by selecting alternative pairs of complexing agents (such as Ca^{2+} and H^+), potentially in combination with fluorescent or other indicators. In particular, the non-equilibrium mechanisms revealed in this study may enable micron-scale synthetic soft actuators, analogous to the way Ca^{2+}-based biochemical reaction-transport pathways power the motion of some single-celled organisms, such as *D discoideum*[40] and the *Vorticella* ciliates[41]. Beyond reporting the gel s dynamics, microstructures embedded in the gel can themselves introduce feedback to the complexation-transport-deformation coupling[42], potentially opening another realm of non-equilibrium sensing. Further developing these capacities may bring about new possibilities for integrating complex chemical sensing and transduction, using simple soft materials, into areas such as soft robotics, catalytic materials, and agricultural and biomedical diagnostics.

Methods

Chemicals and materials. Polydimethylsiloxane (PDMS, Dow-Sylgard 184) was purchased from Dow Corning Corporation (Midland, MI, USA). Epoxy resin OG178 was purchased from Epoxy Technology (Billerica, MA, USA). Glycidyl methacrylate, acrylic acid, sodium acrylate, 2,2 -azobis(2-methylpropionamidine) dihydrochloride, *N-N* -methylenebisacrylamide, 1-butanol, ethylene glycol, copper (II)sulfate, sodium perchlorate, ethylenediaminetetraacetic acid, potassium hydroxide and hydrochloric acid were purchased from Sigma Aldrich. Irgacure 819 was purchased from BASF Corporation, Lumiprobe BDP FL NHS ester from Lumiprobe Corporation (Hallandale Beach, FL, USA), calcium chloride from J.T. Baker and copper(II)chloride from Fluorochem. All compounds and materials were used as received.

Fabrication of hydrogel embedded microplate substrates. To prepare the epoxy microplate substrates, rst a PDMS negative mold was obtained by curing a 10:1 wt./wt. mixture of base resin and hardener onto a silicon master with the microplates positioned in a staggered array, with a height of 18 µm, a width of 10 µm, a thickness of 2 µm and a spacing of 5 µm in both *x* and *y* directions. The silicon master was fabricated via the Bosch process and functionalized with (tridecafluoro-1,1,2,2-tetrahydrooctyl)trichlorosilane in a desiccator under vacuum at room temperature for at least 24 h, in order to facilitate demolding of the PDMS. The PDMS prepolymer mixture was mixed for 1 min, degassed under vacuum at room temperature, poured over the silicon master in a petri dish, put under vacuum at room temperature to remove bubbles, and then cured at 70 °C. After 2 h, the PDMS molds were cooled and peeled off from the silicon mold. To prepare an epoxy microplate substrate, 35 µL of a 9:1 (wt./wt.) prepolymer mixture of the OG178 epoxy resin and glycidyl methacrylate was added to the PDMS mold and covered with a glass slide (16 × 16 mm^2, pretreated in O_2-plasma for 2 min). UV curing was performed under a UV lamp (100 W, Blak-Ray with a 365 nm band-pass lter, approx. 10 mW cm^{-2} at 365 nm) for 30 min. The microplate substrate was then obtained by carefully removing the glass slide from the PDMS mold.

In order to embed the microplate structures in the hydrogel, 3 µL of a hydrogel precursor solution was added to the substrate. The hydrogel precursor solution was prepared by combining 400 µL of acrylic acid with 20 mg *N-N* -methylenebisacrylamide crosslinker in 1 mL of a 1:1 v/v mixture of ethylene glycol and 1-butanol. To introduce the Irgacure 819 photoinitiator, 10 µL of a 25 mg mL^{-1} solution in 1-butanol was added to 90 µL of the aforementioned solution to obtain the hydrogel precursor solution. After applying the hydrogel precursor solution to the microplate substrate, it was immediately covered with a thin glass cover slide (cleaned with isopropanol) and the hydrogel was subsequently cured for 5 min under UV, similarly to the epoxy curing. After curing, the hydrogel-microplate substrate was immersed in deionized water to allow the glass cover slide to detach and to exchange the ethylene glycol/1-butanol mixture in the hydrogel for water.

To assess the embedding of the microplates in the hydrogel, the hydrogel was dyed by combining a solution of Lumiprobe BDP FL NHS ester (2.5 mg mL^{-1}) in a 1:1 v/v 1-butanol/ethylene glycol mixture with an equal volume of a double concentrated hydrogel precursor solution (see above). Next, the obtained solution was applied to the microstructures and cured as described above. The dyed hydrogel-microplate substrates were then analyzed by confocal microscopy ($\lambda_{ex} = 488$ nm).

To prepare a hydrogel substrate with no microplates embedded, rst an epoxy substrate was prepared by photo curing a Norland 68 epoxy resin sandwiched between a flat PDMS support layer and a glass cover (prepared as described above, total exposure time under UV 10 min). Subsequently, 40 µL of a hydrogel precursor (113 mg mL 1 sodium acrylate, 11 mg mL 1 *N-N* -methylenebisacrylamide and 7.5 mg mL 1 2,2 -azobis(2-methylpropionamidine) dihydrochloride photoinitiator in water) was applied, and covered with a glass slide of 18 × 18 mm^2. Subsequently, the hydrogel was cured under UV (366 nm, 4 min) and the substrate was immersed in water to detach the glass cover. Then, the substrate was vertically immersed for 2 min in an aqueous $CuCl_2$ (0.8 M) solution, such that one half of the hydrogel was complexed to Cu^2 as evidenced by the appearance of blue color. The results in Supplementary Fig. 12 were acquired in analogy to the methodology applied for Fig. 5; the images were acquired on a Leica DM 2500 microscope equipped with a Leica DFC 7000T camera.

Assessing complexation of Cu^2 and tilting of microplates. All optical microscopy images were acquired with an Olympus IX71 dark eld inverted microscope equipped with a QImaging Retiga 2000R camera unless stated otherwise. All colored images were acquired with similar white balance settings and light intensity. Confocal microscopy was performed using a ZEISS LSM 700 microscope. SEM images were acquired on a JEOL JSM 639OLV scanning electron microscope, and the sample was sputter-coated with Au/Pd for imaging.

To quantify the tilting of the microplates, the microplate tilt angle was determined from the microplates projection in optical microscopy images. The projection of the microplates was measured in the images and, based on the ratio of this projection to the distance between n rows of microplates in the same image, which equals (n 1) × 7 µm, converted to the real dimensions p in µm. Based on the height of the microplates $h = 18$ µm and the thickness $t = 2$ µm, the microplate tilt angle α was determined as $\alpha = 90$ acos((p t)/h) (see Supplementary Fig. 1c). It is assumed that the plates do not curve upon actuation but maintain their straight form and only hinge at the connection to the substrate (see Supplementary Fig. 1b). The relative gel height was derived via $\cos(\alpha)/\cos(\alpha_{\text{gel completely swelled}})$.

The color pro les were acquired using ImageJ 1.50b software. To avoid the pro les being disturbed by the contours of the microplates, the images were blurred (Gaussian blur; Sigma radius 50) prior to acquiring the r value (red channel RGB value).

Absorption spectra were acquired on a Beckman Coulter DU 720 UV/Vis spectrometer, in a polymethyl methacrylate (PMMA) cuvette (optical path length 1 cm) at room temperature, and the background was acquired on a PMMA cuvette with water.

Complexation of Cu^2 in the hydrogel. Prior to the contraction of the hydrogel via Cu^2 complexation, the hydrogel-microplate substrate was sequentially rinsed with hydrochloric acid (HCl 1 M, 4× the same solution of 2 mL), water (5×), potassium hydroxide (KOH in a concentration of 0.1 M, 4× the same solution of 2 mL, repeated with a fresh solution of 2 mL), and water (5×). Thereafter, excess water was removed from the substrate with a tissue. For Fig. 2b, a thin layer of 50 µL water was applied to the substrate, and subsequently 10 µL $CuSO_4$ 0.8 M was added. To assess the storage of Cu^2 upon complexation to the hydrogel, the substrate was rinsed with water (4×).

Electrochemical delivery of Cu^2 . Cu^2 ions were delivered to the hydrogel-microplate substrate by mounting a copper wire (diameter approx. 100 µm) as a positive electrode and a copper mesh (hole and wire diameter approx. 100 µm) as a negative electrode on top of the substrate with scotch tape, with a distance between the ( ) and (–) electrodes of approx. 3 mm, as schematically represented in Fig. 2d. The scotch tape was applied such that it did not allow a short-circuit between the electrodes. One hundred microliters sodium perchlorate ($NaClO_4$) in water (0.05 M) was added as an electrolyte solution, forming a thin electrolyte layer that ensured contact with both the ( ) and (–) electrodes. The electrodes were connected via crocodile clips to a Keithley 2450 Sourcemeter power supply, and the current was set at 0.1 mA, resulting in a voltage of approx. 1 V.

Swelling and contraction pulses. To prepare the hydrogel for Cu^2 complexation, the hydrogel was rinsed with hydrochloric acid (HCl 1 M, 4× the same solution of 2 mL), water (5×), potassium hydroxide (KOH 0.1 M, 4× the same solution of 2 mL, repeated with a fresh solution of 2 mL), and water (5×). Subsequently, excess water was removed from the substrate with a tissue, 50 µL of a 0.8 M $CuSO_4$ solution was added, excess Cu^2 was removed by rinsing the substrate with water and excess water was removed with a tissue. To obtain the swelling/contraction pulse (Fig. 3b), 1 mL 1 M HCl was added. The stepwise addition of HCl solutions with increasing concentrations (Fig. 3c) was performed by adding volumes of 1 mL, with removal of excess HCl solution from the substrate prior to each subsequent addition.

Controlled progression of acid stimulus. Cu^2 was rst complexed to the hydrogel as described above (swelling and contraction pulses). The substrate was then dried with a tissue, 4 µL water was applied, and the substrate was covered with a 10 × 16 mm^2 glass cover of 1 mm thickness. To initiate the HCl stimulus, a droplet of 30 µL 1 M HCl was added at the edge of the glass cover as schematically shown in Fig. 4a. The color transition progression speed v_C in µm s 1 was determined via the time it took the blue-to-colorless front to progress from left to right over the eld of view (190 µm). Small-magni cation optical microscopy images in Supplementary Fig. 5 reveal a fast progression of the HCl front over the rst few millimeters, whereas further away from the edge of the glass cover the progression of the HCl front slows down, enabling variation of v_C for different experiments shown in Fig. 4 and Supplementary Fig. 6. Alternatively, a larger amount of water under the glass cover can be used to slow down the progression.

Spatial patterning of pulses and traveling waves. To obtain a localized Cu^2 complexation (Fig. 5), Cu^2 was electrochemically delivered via the same procedure as described above (electrochemical delivery of Cu^2). Here, the experiments started with a substrate that was rinsed with hydrochloric acid (HCl 1 M, 4× the same solution of 2 mL), water (5×), potassium hydroxide (KOH 0.05 M, 4× the same solution of 2 mL, repeated with a fresh solution of 2 mL), and water (5×). Subsequently, the electrodes were removed, and the substrate was rinsed with water, dried with a tissue, and covered with 4 µL water and a glass cover (10 × 16 mm^2, 1 mm thick). Similarly to the procedure described above (Controlled progression of acid stimulus), a droplet of 30 µL 1 M HCl was added at the edge of the glass cover to initiate the Cu^2 release, as schematically shown in Fig. 5a.

Determining the concentration of Cu^2 complexed to gel. The concentration of Cu^2 complexed to the COO groups in the hydrogel was determined upon extraction of Cu^2 from the hydrogel with an ethylenediethylaminetetraacetate (EDTA) solution, as shown in Supplementary Fig. 7. By comparing the optical density of the extract solutions to a calibration line (based on absorption spectra of aqueous EDTA solutions (0.27 M, 1 M KOH) with different $CuSO_4$ concentrations), the total amount of Cu^2 ions was determined. For the hydrogel-microplate substrate, we obtained a total Cu^2 -amount of 0.0038 mmol. Based on the ratio between the area of the blue region in Supplementary Fig. 7b and the printed squares of the paper background (0.634 × 0.634 cm^2), the hydrogel area in the sample is estimated to be 1.30 cm^2. Based on the estimated thickness of the contracted hydrogel of 10 µm (Supplementary Fig. 1), the volume of the hydrogel is 0.00130 cm^3. Therefore, the Cu^2 concentration inside the contracted hydrogel is estimated to be 0.0038 mmol/0.00130 cm^3 = 2.9 M (Supplementary Fig. 7). The concentration of carboxylic acid groups in the hydrogel is estimated from the precursor solution, which was prepared from a solution of 0.4 mL acrylic acid 0.5 mL ethylene glycol 0.5 mL 1-butanol, and was subsequently mixed in a 9:1 ratio with the initiator solution, resulting in an acrylic acid concentration of 3.74 M. After the application of the hydrogel precursor, we assume that the solution wets the plates, with a height of 18 µm, as well as the glass cover applied on top of it. Densi cation of this precursor solution with a thickness of 18 µm to a hydrogel with a nal thickness of 10 µm (see Supplementary Fig. 1) results in a nal carboxylic acid concentration of 6.7 M. This indicates that after exposing to a concentrated $CuSO_4$ solution, the Cu^2 to COO complexation in the hydrogel approaches a 1:2 ratio (Cu^2 /COO $_{max} = 43$).

Data availability

The data that support the ndings of this study are available within the article (and its Supplementary Information les) and from the corresponding authors on reasonable request.

Code availability

The computer code that was developed to perform the simulations with our model is freely available at Github: https://github.com/nadirkaplan/hydrogels_naturecomm.

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Author contributions

P.A.K., A.G. and J.A. conceived the research. P.A.K. and R.M.R. performed the experiments; C.N.K. developed the theoretical model; all authors analyzed the results; P.A.K., C.N.K., A.G. and J.A. wrote the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Living Electronics for Bio-interfacing

Speaker: Prof. Xiaocheng Jiang, Tufts University
Date: Nov 15, 2019; **Time:** 2:30pm **Location:** UTEB 175

Abstract: Electronic and biological systems represent two limiting thermodynamic models in terms of functioning and information processing. By converging the dynamic and self-adaptable features of bio-machinery and the rationally defined/programmed functionalities of electronic components, there is potential to evolve new capabilities to effectively interrogate and direct biologically significant processes, as well as novel bio-inspired systems/device concepts for a range of engineering applications. The intrinsic mismatches in physiochemical properties and signaling modality at biotic/abiotic interfaces, however, have made the seamless integration challenging. In this talk, I will present our recent effort in forging their structural and functional synergy through the design and development of: (1) bio-hybrid electronics, where living transducers, such as functional biomolecules, organelles, or cells, are integrated with electronic transducers using spatially-defined, biocompatible hydrogel as the interfacing material; and (2) biosynthetic electronics, where biogenic electron pathways are utilized to naturally bridge the gap between internal biological and external electrical circuits. Blurring the distinction between livings and non-livings, these efforts have the potential to facilitate the cross-system communication and broadly impact how complex structures/functions may be designed/engineered.

Biographical Sketch: Xiaocheng Jiang is an Assistant Professor in the Department of Biomedical Engineering at Tufts University. He received his Ph.D. in physical chemistry from Harvard University with Professor Charles Lieber, with a focus on the design and application of nanoscale materials and nanoelectronic devices. Prior to joining Tufts, he was an American Cancer Society postdoctoral fellow at Massachusetts General Hospital, where he worked with Prof. Mehmet Toner on functional microfluidics for early cancer diagnostics. His current research concentrates broadly at the interface of materials and biomedical science, with specific interests in bio-inspired/bio-integrable electronics. He is a recipient of NSF CAREER award (2017) and AFOSR young investigator award (2018).

EXHIBIT 10

moderna

MODERNA History

Zippia Score 4.3 ★★★★½

Claim This Company

Overview Salary History

MODERNA COMPANY HISTORY TIMELINE

2010 Since its founding in 2010, Moderna has raised more than 2.6 billion in equity financing.

2011 Bancel, who has been CEO since 2011 and previously worked at Eli Lilly Co.

The legal mess has its roots in Moderna's 2011 start, when Robert Langer, an MIT professor, Moderna board member and founder of dozens of biotech companies, told Bancel that Moderna was too underfunded and small to create its own delivery system.

2013 In 2013 the startup signed a deal with AstraZeneca that included a 240 million cash payment , followed by a 140 million investment this year.

2014 And a year before them, in 2014, Juno Therapeutics raised 264 million in its IPO, with a 2.2 billion market cap.

2015 Other top biotech IPOs included Axovant Sciences, which raised 315 million in 2015, giving it a 1.5 billion initial market cap, and Galapagos NV, which raised 275 million in an IPO in 2015, with an initial market cap of 1.7 billion.

2017 The company switched up its R D model from a venture-based one to a therapeutics area R D model in September 2017, bringing four separate units back under one umbrella.

EXHIBIT 11

nature materials

Published: 26 August 2012

Macroporous nanowire nanoelectronic scaffolds for synthetic tissues

Bozhi Tian, Jia Liu, Tal Dvir, Lihua Jin, Jonathan H. Tsui, Quan Qing, Zhigang Suo, Robert Langer, Daniel S. Kohane & Charles M. Lieber

Nature Materials **11**, 986–994(2012) | Cite this article

Abstract

The development of three-dimensional (3D) synthetic biomaterials as structural and bioactive scaffolds is central to fields ranging from cellular biophysics to regenerative medicine. As of yet, these scaffolds cannot electrically probe the physicochemical and biological microenvironments throughout their 3D and macroporous interior, although this capability could have a marked impact in both electronics and biomaterials. Here, we address this challenge using macroporous, flexible and free-standing nanowire nanoelectronic scaffolds (nanoES), and their hybrids with synthetic or natural biomaterials. 3D macroporous nanoES mimic the structure of natural tissue scaffolds, and they were formed by self-organization of coplanar reticular networks with built-in strain and by manipulation of 2D mesh matrices. NanoES exhibited robust electronic properties and have been used alone or combined with other biomaterials as biocompatible extracellular scaffolds for 3D culture of neurons, cardiomyocytes and smooth muscle cells. Furthermore, we show the integrated sensory capability of the nanoES by real-time monitoring of the local electrical activity within 3D nanoES/cardiomyocyte constructs, the response of 3D-nanoES-based neural and cardiac tissue models to drugs, and distinct pH changes inside and outside tubular vascular smooth muscle constructs.

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EXHIBIT 12

9 March 2017

Innovative Supply Chain Information Platform Will Help Prepare For The Next Pandemic

TOKYO - The United Nations World Food Programme (WFP) and NEC Corporation today announced their collaboration for the development of the first ever information platform to provide end-to-end visibility of supply chains for pandemic interventions, on behalf of the Global Pandemic Supply Chain (PSC) Network. The government of Japan has provided US$1 million for the PSC Network, which will be used as seed funding for the new information platform.

The Global Pandemic Supply Chain Network was formed in response to lessons learned from the 2014 West Africa Ebola outbreak and discussions that followed at the World Economic Forum in Davos in 2015, where the need for a collaborative, multi-stakeholder response became clear. The founding members of the Network, representing the public sector, include WFP, the World Health Organization (WHO), and the World Bank, and representing the private sector, Henry Schein, Inc., Becton, Dickinson & Co., and UPS Foundation.

The challenges faced during the West Africa Ebola outbreak included severe warehousing and distribution capacity constraints, limited visibility of the overall supply and demand of critical items, access constraints caused by border closures, and a lack of public-private sector coordination resulting in duplicate efforts and an inefficient

response.

These challenges are being answered by organizations including WFP, WHO, UNICEF, the Food and Agriculture Organization of the United Nations, the Office for the Coordination of Humanitarian Affairs, the World Bank, World Economic Forum, U.S. Agency for International Development, University of Minnesota, GS1, and Centers for Disease Control and Prevention, in collaboration with private sector companies, including Henry Schein, Inc., Johnson & Johnson, UPS Foundation, Becton, Dickinson & Co., and NEC. They have worked together in an unprecedented fashion to develop a framework for improving pandemic preparedness and response.

Supply chain logistics are fundamental to any emergency intervention. Inadequate preparedness and response capacity leads to critical delays, costs lives and wastes precious resources. By bringing together information on supplies and logistics and enabling analysis of supply chain inefficiencies, the new information platform, which will be part of the Global Pandemic Supply Chain Network, will promote timeliness and cost efficiency as well as aid in continuous improvement.

“In order to achieve any one of the Sustainable Development Goals (SDGs) by 2030, we must all do our part, lending our unique expertise and experiences to innovating solutions to global problems,” said Ertharin Cousin, Executive Director of WFP. “I am proud of the work being done by the PSC Network. The creation of this new platform is a prime example of the amazing endeavours that are possible when the public and private sectors work together.”

NEC was the first Asian company to join the PSC Network and remains the only

SAVING LIVES
CHANGING LIVES

can reach the world's most vulnerable people in times of crisis, NEC will focus on designing a logistics visualization system that will enable end-to-end tracking of pandemic response items, such as protective clothing and medical equipment within a country facing an outbreak, helping to ensure quick and appropriate delivery of supplies to people in need. Other key functions of the system include reporting, data integration with existing logistics systems and in-country warehouse management.

“We are honoured to collaborate with WFP and the other members of the PSC Network to strengthen the global supply chain for pandemic preparedness and response in order to more effectively fight the next disease outbreak,” said Dr. Nobuhiro Endo, Chairman of the Board, NEC. “This is a perfect example of our commitment to creating safe,

secure, efficient, and equal societies through the provision of innovative information and communications technologies such as Artificial Intelligence, which also contributes to the United Nations' SDGs."

As members of the PSC Network jointly advocated the need for more efficient pandemic supply chain, the Japanese government has since committed US$1 million to development of the Network, allowing NEC and WFP to begin work.

"It is widely recognized that the global health architecture could be reinforced with improved supply chain platform to enable better preparation and faster response time for pandemics," said Mr. Hideaki Chotoku, Director of Humanitarian Assistance and Emergency Relief Division, Ministry of Foreign Affairs of Japan. "The Japanese Government welcomes and is proud to support the PSC Network which also involves Japanese IT technology. We look forward to monitoring its progress in designing this innovative tool."

# # #

About the Global Pandemic Supply Chain Network
The Global Pandemic Supply Chain Network is a public-private initiative that seeks to increase supply chain and logistics capacities and develop an information platform to more equitably match supplies with demand. By focusing on supply chain logistics to support the response to large-scale health emergencies, the partnership complements other efforts that are underway to strengthen national and international systems that prevent and manage future pandemics.

About WFP
WFP is the world's largest humanitarian agency fighting hunger worldwide, delivering food assistance in emergencies and working with communities to improve nutrition and build resilience. Each year, WFP assists some 80 million people in around 80 countries. Because of its strong capacities in logistics WFP also serves as coordinator of the Humanitarian Logistics Cluster and as manager of the United Nations Humanitarian Air Service (UNHAS) and the United Nations Humanitarian Response Depots (UNHRD). Follow us on Twitter @WFP @WFP_Media @WFP_JP

About NEC Corporation
NEC Corporation is a leader in the integration of IT and network technologies that benefit businesses and people around the world. By providing a combination of

benefit businesses and people around the world. By providing a combination of products and solutions that cross utilize the company's experience and global resources, NEC's advanced technologies meet the complex and ever-changing needs of its customers. NEC brings more than 100 years of expertise in technological innovation to empower people, businesses and society. For more information, visit NEC at http://www.nec.com

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Seiichiro Toda/Shinya Hashizume, NEC Corporate Communications Division

Profusa and Partners Receive DARPA Award to Speed Detection of Disease Outbreaks

Profusa's Lumee Oxygen Platform Selected as Part of Comprehensive Monitoring Platform

NEWS PROVIDED BY
Profusa, Inc. →
Aug 08, 2019, 08:30 ET

SOUTH SAN FRANCISCO, Calif., Aug. 8, 2019 /PRNewswire/ -- Profusa, an empowered health company that is pioneering the next generation of personalized medicine, today announced in collaboration with RTI International and Duke University the award of a DARPA (Defense Advanced Research Projects Agency) award to develop an early identification system to detect disease outbreaks, biological attacks and pandemics up to three weeks earlier than current methods. The RTI DARPA SIGMA+ funded effort is based on evaluating monitoring platforms including Profusa's first-of-its-kind, minimally-invasive injectable biosensor technology, the Lumee™ Oxygen Platform, to measure tissue oxygen levels as a potential indicator of human response to infection or exposure.

Unlike current efforts, which among other methods track and predict outbreaks via public health network data of patients that seek medical care once already experiencing symptoms, this program will assess the ability to collect real-time physiological data including oxygen status through Profusa's injectable biosensor, and other measures to detect impending distress before symptoms are present.

"We believe that data collected by monitoring real-time changes in body chemistry will allow us to make an important shift towards preventative care and away from costly sick-care needed after a pandemic, like the flu, has taken hold," said Ben Hwang, Chairman and CEO of Profusa. "This could lead to advances like more effective vaccines and disease prevention plans that improve health outcomes and potentially reduce healthcare costs. We are honored to receive this DARPA grant and excited to work alongside our partners towards a healthcare ecosystem that is focused on true personalized care."

The data collected by this program will be used to develop new algorithms for the detection of respiratory infections using machine-learning techniques with the goal of optimizing predictive capabilities. The collaborative effort will monitor patients simultaneously, so the technology can provide real-time, geospatial information on the spread of an infectious disease in an urban environment, to derive more effective countermeasures and mitigation strategies.

The project is part of DARPA's SIGMA+ program in the Defense Sciences Office (DSO).

EXHIBIT 14

About Profusa

Founded in San Francisco, Calif., Profusa is an empowered health company led by visionary scientific founders, an experienced management team and a world-class board of directors who share the long-term goal of improving health and well-being for patients worldwide. With its long-lasting, injectable and affordable biosensors and its intelligent data platform, Profusa aims to provide people with a personalized biochemical signature rooted in data that clinicians trust and rely upon. These data may allow people to act as an active and educated participant alongside their care team and understand how their choices and decisions impact health and well-being, day-in and day-out. For more, visit https://profusa.com.

About the Lumee™ Oxygen Platform

Profusa's first clinical offering, the Lumee™ Oxygen Platform, which is CE marked for use in the European Union, is indicated for use in patients with potential acute and/or chronic changes in tissue oxygen levels who may benefit from monitoring. The sensors provide continuous and long-term monitoring of the oxygen in subcutaneous tissue. After a single injection, measurement thereafter are obtained non-invasively. In contrast to external pulse oximeters which measure oxygen bound to the hemoglobin in larger blood vessels, the Lumee™ platform measures dissolved oxygen at the tissue level in the fluid that bathes our cells.

About DARPA SIGMA +

The DARPA SIGMA+ program aims to expand SIGMA's advance capability to detect illicit radioactive and nuclear materials by developing new sensors and networks that would alert authorities to chemical, biological, and explosives threats as well.

SIGMA+ calls for the development of highly sensitive detectors and advanced intelligence analytics to detect minute traces of various substances related to weapons of mass destruction (WMD) threats. SIGMA+ will use a common network infrastructure and mobile sensing strategy, a concept that was proven effective in the SIGMA program. The SIGMA+ chemical, biological, radiological, nuclear and high-yield explosive (CBRNE) detection network would be scalable to cover a major metropolitan city and its surrounding region.

Planned execution of SIGMA+ will occur in two phases. Phase 1 will focus on developing novel sensors for chemicals, explosives, and biological agents while Phase 2 will focus on network development, analytics and integration.

Disclaimer

Funding from the Defense Advanced Research Projects Agency (DARPA). The views, opinions and/or findings expressed are those of the author and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.

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SOURCE Profusa, Inc.

Related Links

http://www.profusa.com

AO 91 (Rev. 11/11) Criminal Complaint

UNITED STATES DISTRICT COURT

for the

District of Massachusetts

United States of America v. CHARLES LIEBER	)	Case No. 20-mj-2158-MBB

Defendant(s)

CRIMINAL COMPLAINT

I, the complainant in this case, state that the following is true to the best of my knowledge and belief.

On or about the date(s) of April 28, 2018 & January 10, 2019 in the county of Middlesex in the _____ District of Massachusetts, the defendant(s) violated:

Code Section	*Offense Description*
18 U.S.C. § 1001(a)(2)	Making false statements to the agency of the United States Government

This criminal complaint is based on these facts:

See attached affidavit of FBI Special Agent Robert Plumb.

☑ Continued on the attached sheet.

Complainant's signature

Robert Plumb, FBI Special Agent

Printed name and title

Sworn to before me and signed in my presence.

Date: 01/27/2020

Judge's signature

City and state: Boston, MA

Hon. Marianne B. Bowler

Printed name and title

EXHIBIT 15

AFFIDAVIT IN SUPPORT OF APPLICATION FOR CRIMINAL COMPLAINT

I, Robert Plumb, being sworn, depose and state as follows:

1. I am a Special Agent with the Federal Bureau of Investigation ("FBI"), and have been so employed since June 2016. I am currently assigned to one of the FBI's Counterintelligence Squads in the Boston Field Office. My responsibilities include investigating violations of federal criminal laws relating to espionage and theft of trade secrets, the mishandling of classified and defense information, and export control laws. Previously, I was employed at the FBI as an Intelligence Analyst. I worked in this capacity for six years. I have participated in numerous investigations, during the course of which I have interviewed witnesses, conducted physical surveillance, executed search warrants, and used other investigative techniques to secure relevant information regarding various federal crimes.

2. I submit this affidavit in support of a Criminal Complaint charging Dr. Charles Lieber ("LIEBER") with making materially false, fictitious and fraudulent statements in a matter within the jurisdiction of the Executive Branch of the United States, in violation of Title 18, United States Code, Section 1001(a)(2). Specifically, based upon the evidence gathered thus far in this ongoing investigation, I have probable cause to believe and do, in fact, believe that LIEBER made materially false, fictitious and fraudulent statements regarding his participation in China's Thousand Talents Plan to the U.S. Department of Defense ("DoD") on or about April 24, 2018. I also have probable cause to believe and do, in fact, believe that, on or about January 10, 2019, LIEBER made and caused to be made a series of materially false, fictitious and fraudulent statements to the National Institutes of Health ("NIH") about his involvement in the Thousand Talents Plan and his affiliation with Wuhan University of Technology ("WUT") in China.

3. Based on the evidence gathered to date, LIEBER was a "Strategic Scientist" at WUT and a contractual participant in China's Thousand Talents Plan for significant periods between at least 2012 and 2017. The terms of LIEBER's Thousand Talents contract called for LIEBER to be paid up to $50,000 per month in salary and approximately $150,000 per year for living and personal expenses by WUT. LIEBER was also awarded more than $1.5 million by WUT and the Chinese government to establish a research lab and conduct research at WUT.

4. The information in this affidavit is based upon my training and experience, my personal knowledge of this investigation, information conveyed to me by other law enforcement agents and officials who assisted in the investigation, and the other sources of information described herein. This affidavit is submitted for the limited purpose of establishing probable cause to believe that LIEBER has committed the offenses described above. Accordingly, I have not included each and every fact known to me and other law enforcement officers involved in this investigation. I have set forth only those facts that I believe are necessary to establish the requisite probable cause.

FACTS SUPPORTING PROBABLE CAUSE

Background

5. LIEBER is a full-time faculty member and Chair of the Department of Chemistry and Chemical Biology at Harvard University in Cambridge, Massachusetts. He has been affiliated with Harvard since approximately 1991. According to LIEBER's biography on Harvard's website, LIEBER's primary area of expertise and research is nanoscience.

6. At all times relevant to this complaint, LIEBER served as the Principal Investigator of the Lieber Research Group at Harvard University. According to its website, the Lieber Research Group "is focused broadly on science and technology at the nanoscale, using novel synthesized

building blocks to push scientific boundaries in diverse areas from biology/medicine to energy and computing." The Lieber Research Group's website identifies its principal sponsors as NIH and DoD, including the Office of Naval Research ("ONR") and the Air Force Office of Scientific Research ("AFOSR"). Based upon records maintained by NIH, DoD, and Harvard University, I know that the Lieber Research Group has received more than $15,000,000 in grant funding from NIH and DoD since 2008.

7. A component of the United States Department of Health and Human Services, NIH is a government agency responsible for biomedical and public health research. The NIH conducts its own scientific research through an intramural research program, and also provides major biomedical research funding to non-NIH research facilities through an extramural research program. Many of the non-NIH research facilities that receive funding through NIH's extramural research program are colleges and universities, including Harvard University.

8. In order to receive NIH funding, non-NIH research institutions must submit a detailed application describing, among other things: (a) the purpose and scope of the proposed research; (b) the amount of funding requested; and (c) how the funding will be used. Both during the application process and periodically after an award is made, the institution must also disclose to NIH all foreign collaboration and foreign sources of research support, including, but not limited to, research grants, cooperative agreements, contracts and/or institutional awards. Additionally, NIH requires research institutions to identify and disclose to NIH significant (typically greater than $5,000) financial conflicts of interest by investigators (that is, the person or persons responsible for the design, conducting the research, and publishing or reporting the research performed pursuant to the grant), including those related to funds received from a foreign institution of higher education or the government of another country. Although it is the research institution itself that

submits the grant application and all other grant-related disclosures to NIH, the individual investigator(s) must certify to the institution and NIH that the information contained in grant applications, post-award submissions and all other grant-related filings is accurate and complete, and also acknowledge that any false, fictitious or fraudulent statements or claims made to NIH may subject the investigator to criminal, civil and/or administrative penalties.

9. WUT is a university located in Wuhan, China. It is considered a top-tier Chinese university recognized for its studies of science and technology.

10. The "Chinese Talent Programs" refer collectively to various plans designed by the Chinese Government to attract, recruit, and cultivate high-level scientific talent in furtherance of China's scientific development, economic prosperity, and national security. Implemented in 2008, the "Thousand Talents Plan" is the most prominent Chinese talent recruitment plan designed by the Chinese Government to incentivize individuals engaged in research and development in the United States to transmit the knowledge and research they gain here to China in exchange for salaries, research funding, lab space, honorary titles, and other incentives. The Thousand Talents Plan is designed to lure both Chinese overseas talent and foreign experts to bring their knowledge and experience to China. The so-called "World Recruitment Plan of Renowned Experts in China" is part of the Thousand Talents Plan. The Chinese Talent programs have rewarded individuals for stealing proprietary information and violating export controls.

Lieber's Affiliation with WUT and China's Thousand Talents Plan

11. According to records maintained by Harvard University, LIEBER traveled to WUT in mid-November 2011 ostensibly in order to participate in a Nano-Energy Materials Forum being hosted by WUT. Just days before LIEBER's trip, a professor at WUT (hereafter the "WUT Professor") emailed LIEBER a "Contract for Strategic Scientist's Appointment" (hereafter the

"Strategic Scientist Agreement"). He also informed LIEBER that LIEBER had been recommended for the "The Recruitment Program of Global Experts," which I know to be part of China's Thousand Talents Plan. In subsequent communications on or about November 11, 2011, both LIEBER and the WUT Professor acknowledged that LIEBER would sign the Strategic Scientist Agreement at WUT on November 15, 2011.

12. According to the agreement, which was written in both Chinese and English, LIEBER was appointed as a Strategic Scientist at WUT for five years from on or about November 15, 2011, until on or about November 14, 2016. LIEBER's objectives and tasks under the agreement were as follows:

> **Article Two Employment Objective and Tasks for Party B**
>
> 1. Make strategic, visionary and creative research proposals to guide the advancement of disciplines or scientific research institutes to become first class disciplines or scientific research institutes in China or the world, especially in frontier areas.
> 2. Supervise young teachers or receive them as visiting scholars, guiding or co-guiding postgraduate students (including post-doctoral students), leading them to the international forefront of related fields, jointly publishing academic papers in top international journals (in the name of WUT, and WUT faculty or students as the first author) or publishing high-level academic monographs and guiding young teachers to win national awards or influential international academic awards.
> 3. Build up a Discipline Innovative Team, introducing and cultivating high-level talents to be as qualified as those of China's 1000 Young Talents Plan, Distinguished Professors of Chang Jiang Scholars and winners of National Science Fund for Distinguished Young Scholars.
> 4. Conduct national important (key) projects or international cooperation projects that meet China's national strategic development requirements or stand at the forefront of international science and technology research field.
> 5. Carry out international exchanges and cooperation, and host or jointly host prominent international academic conferences in the name of WUT.

13. According to the contract, WUT agreed to pay LIEBER $50,000 U.S. Dollars ("USD") per month, prorated according to LIEBER's "actual work time" at WUT. WUT also

agreed to provide LIEBER with round-trip, business-class airfare to and from WUT. Finally, the agreement alluded to LIEBER's future involvement with China's Thousand Talents Plan, and allowed for seemingly greater monthly compensation to LIEBER in the future:

> **4. Once Party B gains a Chinese government-sponsored position through successful application for various Chinese talent-related projects, Party A shall adjust its payment terms to ensure that Party B enjoys more benefits on the principle of "taking the higher pay", but the same benefit terms will not be paid twice.**

14. LIEBER returned to Massachusetts from WUT on or about November 16, 2011. Two days later, in an email to the WUT Professor, LIEBER wrote, "I very much appreciate the effort that you put into making my visit a good one. I also agree that it would productive, and hope that we can push forward as per discussions to build up the joint laboratory to a truly world-level facility." Approximately one month later, on or about December 19, 2011, the WUT Professor emailed portions of a proposed website for the "WUT-Harvard Joint Nano Key Laboratory," which, according to the website, was established in 2009. The website prominently featured LIEBER's name, photograph and biographical information, and it identified him as the "Laboratory Director." In his email to LIEBER about the website, the WUT Professor noted that "the Chinese version [of the website] will be made after your approval for [sic] the English version."

15. On or about April 5, 2012, approximately five months after executing the Strategic Scientist Agreement with WUT, the WUT Professor wrote an email to LIEBER informing him that he had been selected to participate in China's Thousand Talents Plan. At that time, LIEBER's selection entailed awards by WUT and the Chinese Government of approximately $158,000 USD in "personal benefits" and nearly $800,000 USD in "research funding." Specifically, the WUT Professor wrote,

> I am very happy to let you know that, in the **World** Recruitment Plan of **renowned** experts in China (also called as one thousand plan of foreign experts), you have been approved and awarded as invited strategic foreign expert by Chinese government because of your **world-leading** achievements, the **good collaboration basis** between you and WUT, and your great **contribution** to national academic exchange between China and USA. You are provided with personal benefit of one million RMB (~158,800 USD), a research funding of 5 million RMB (~794,000 USD) for development of WUT-Harvard joint nano key lab and collaboration research This plan is the highest plan/program for famous foreign scientists in Chinese scientific field and only 40 famous experts from the world were awarded. (Emphasis original.)

16. Nearly three months later, on or about June 27, 2012, the WUT Professor shared with LIEBER a contract titled "Employment Contract of 'One Thousand Talent' High Level Foreign Expert" between LIEBER and WUT (hereafter the "Thousand Talents Agreement"). The WUT Professor asked for LIEBER's "ideas/comments/suggestions" within "one week when your schedule allows (of course, the sooner the better)." The first page of the agreement appeared as follows:

"千人计划" 高层次外国专家工作合同书

EMPLOYMENT CONTRACT of

"ONE THOUSAND TALENT" HIGH LEVEL FORTIGN EXPERT

聘任方：武汉理工大学（简称甲方）

受聘方："千人计划"高层次外国专家、美国哈佛大学教授

Charles M. Lieber 博士（简称乙方）

Employer (Party A): Wuhan University of Technology

Employee (Party B): "One Thousand Talent" high level foreign expert, professor **Charles M Lieber** from Harvard University, USA.

为保证"千人计划"高层次外国专家项目的顺利实施，保障甲乙双方的合法权益，根据中华人民共和国的有关文件精神和政策规定，经双方平等协商，订立本合同。

Both sides, in line with the principles of legality, fairness, equality, and mutual agreement, to ensure the implementation of "One Thousand Talent" high level foreign expert plan, and to guarantee the legal rights and obligations of both sides, on the basis of Chinese laws and rules concerned, agree to sign this contract.

第一条 聘期

"千人计划"高层次外国专家岗位首次聘期为三年，该合同自签订之日起生效。聘任期满，经双方协商后，报上级主管部门审批，可续签下一期合同。

1. Duration of the Contract

The term of this contract will be 3 years since the date of signature. Both parties can sign the new contract through consultation and mutual consent after the contract is upon expiration with the permission of superior authorities department.

17. The Thousand Talents Agreement was effective for three years "from the date of signature." Among other things, the agreement obligated LIEBER to conduct scientific research; to "publish high-level articles in the renowned and important international academic journals in the name of Wuhan University of Technology;" to assemble a research team with "strong ability of [sic] research and innovation" in LIEBER's field of expertise; to "guide 1-2 distinguished young scholars and 3-4 doctoral students … and help them publish systematic articles in the international

renowned journals;" to "organize 1-2 predominant influencing international conferences in his field in the name of Wuhan University of Technology;" and "invite 1-3 international top scientists to work in the lab as visiting scholars." The agreement also required LIEBER to work at or for WUT "not less than nine months a year" by "declaring international cooperation projects, cultivating young teachers and Ph.D. students, organizing international conference[s], applying for patents and publishing articles in the name of" WUT.

18. In exchange for his work for and on behalf of WUT, WUT agreed to pay LIEBER $50,000 USD per month, and living expenses of up to 1,000,000 Chinese Yuan (based on 2012 exchange rates, approximately $158,000 USD) to be paid over the three-year term of the contract. The contract also allocated 11,000,000 Chinese Yuan (or roughly $1.74 million USD based on 2012 exchange rates) for the joint Harvard-WUT Nano Key Lab and related research. The following portion of the contract documented those financial terms. WUT is referred to as "Party A," while LIEBER is referred to as "Party B."

二、甲方义务

1．依法维护乙方应享有的各项权利。

2．为乙方提供良好的工作和生活条件

(1)办公及实验室条件：甲方按乙方的要求为乙方提供办公及实验条件。

(2)科研配套经费：聘期内，甲方为乙方提供 1000 万元科研配套经费（其中包括国家拨款 500 万元），主要用于购置实验仪器设备、科研新方向和基础设施建设；此经费由甲方管理，乙方与甲方的合作教授共同商量支配。

(3)团队建设条件：甲方按乙方的要求为乙方组建学术团队，并每年投入 100 万元团队建设经费，主要用于开支团队成员的工资、安家补贴，团队及乙方本人的差旅等； 此经费由甲方管理，乙方支配。

(4)生活条件：薪酬标准为每月 5 万美元（税前标准），按实际到岗时间支付；另享受 100 万元人民币的生活补贴（免税），分三年用支付。

(5)为乙方指导博士、博士后工作人员和高级访问学者等创造条件，人员由甲方推荐、乙方考察并最终确定。

3．为乙方提供完成本合同规定的工作目标及任务所需要的校内相关政策和支持。

2. Party A's Obligations

(1). Party A shall respect Party B's legal rights

(2). Party A shall provide Party B with necessary working and living conditions

a. working and lab conditions: Party A shall provide Party B with working and lab conditions according to Party B's requirement

b. scientific research funding: Party A shall provide Party B ten million Chinese Yuan (10,000,000 RMB) including five million RMB from national fund during the term of this contract to the construction of new direction and infrastructure construction, equipments and instruments purchasing. This amount of money shall be managed by Party A, and Party B can use it after discussing with the co-professor from Party A.

c. talent team construction condition: Party A shall construct talent team according to Party B's requirement and provide one million Chinese Yuan (1,000,000 RMB) as the funds of talent team construction each year. The funds shall be mainly used as the payment, accommodation, and travel expense of Party B and the team members. This amount of money shall be managed by Party A, and Party B can use it.

d. payment and living conditions: Party A shall provide Party B with fifty thousand U.S. Dollars ($ 50,000) per month (before tax), paid according to his working time in Wuhan University of Technology. Party A shall provide Party B with one million Chinese Yuan (1,000,000RMB) (after tax) as living allowance which will be paid 1/3 a year for three years.

19. In a subsequent email to LIEBER dated July 10, 2012, the WUT Professor told LIEBER that WUT's president had signed the "1000 plan agreement" and that executed copies of the agreement had been mailed to LIEBER in Massachusetts for his signature. In an email dated on or about July 21, 2012, the WUT Professor informed LIEBER that WUT had received copies of the Thousand Talents Agreement signed by LIEBER.

20. After signing the Thousand Talents Agreement, LIEBER returned to WUT in November 2012. LIEBER's travel expenses to and from Wuhan were paid by WUT. Prior to this trip, arrangements were made to pay LIEBER his salary and living expenses as specified in the Thousand Talents Agreement. For example, in an email dated on or about October 26, 2012, a WUT employee (hereafter the "WUT Employee") wrote to LIEBER:

> Before your visit, I would like to talk about one detail in the implementation of the contract of "one thousand talent" high level foreign expert between you and our university. According to the article concerning the payment and living conditions, I want to know the way you prefer to be paid so that everything can be prepared before your coming. I would like to provide two options for you to choose if you do not mind. Option one. I help you open a new bank account in the Chinese Bank named [redacted]. The payment will be put into your account and you can get the payment from the branch of [redacted] in your country. Option Two. I can prepare the payment in cash.

21. Less than three months later, on or about January 10, 2013, the WUT Professor emailed LIEBER an agreement titled "Academic Cooperative Agreement between Harvard University, USA and Wuhan University of Technology, P.R. China." The stated purpose of the agreement, which had a five-year effective term, was to "carry out advanced research and development of nanowire-based lithium ion batteries with high performance for electric vehicles." Apart from its stated objective, the agreement provided for a "cooperative research program" whereby researchers from WUT would "visit Department of Chemistry and Chemical Biology of

Harvard University for two months each year." Without consulting any Harvard officials, LIEBER signed the agreement on Harvard's behalf and returned the executed copies to the WUT Professor on or about January 11, 2013. I understand from conversations with Harvard's representatives that LIEBER did not have the authority to execute this contract on behalf of Harvard.

22. One year later, LIEBER continued to work closely with — and continued to receive compensation from — WUT. For example, on or about January 18, 2014, LIEBER wrote to the WUT Professor and another person affiliated with WUT that he would accept a WUT graduate student (hereinafter the "Graduate Student") as a long-term "WUT-HU joint Ph.D. student" provided that WUT "support all of [the Graduate Student's] salary and research costs while working in my lab." In the same communication, LIEBER discussed an upcoming visit to WUT in February 2014, and he made specific demands regarding the payment of his salary:

> I would like to receive ~1/2 of salary (for the current period) in US dollars, with the remainder deposited into the bank account that was set-up. The ~00 that I promised to pay for the party following Lin Xu's Ph.D. defense in April, can be deduced from either 1/2.

23. In June of 2014, LIEBER continued to discuss his compensation under the Thousand Talents Agreement with WUT. In an email to the WUT Employee dated June 16, 2014, LIEBER asked to maintain his bank account "the way it has been for now" and he reiterated his earlier request that half of his salary be deposited into his Chinese bank account and the other half be paid to him in cash when he next visited WUT. LIEBER further stated, "I think this is close to what [we] have done in [the] past."

24. In late January 2015, LIEBER outlined his ongoing relationship with WUT, confirming that he intended to visit WUT "several" times per year or "perhaps slightly more in the next couple years as we try to build up the nano-bio part of the lab;" that he would be available for "electronic communication on a very regular basis with students (email, telephone, skype) so that

they obtain full input from me as an advisor;" and that "students visiting [from WUT] for periods at Harvard would have [the] same access as normal Harvard graduate students."

25. Around the same time, independent of LIEBER, Harvard administrators learned for the first time of the WUT-Harvard Joint Nano Key Laboratory at WUT, including the fact that LIEBER was the director of the lab. Harvard officials confronted LIEBER about the joint lab, and informed him that the improper use of Harvard's name and logo — orchestrated by LIEBER without Harvard's consent — violated University policy. In response, LIEBER falsely told Harvard officials that he was involved in collaborative research with WUT for "mutual scientific interaction," but that WUT was using Harvard's name and logo without his knowledge or consent.

26. On or about February 3, 2015, LIEBER emailed the WUT Professor and told him that WUT must cease using Harvard's name, stating, "Our agreement for research collaboration is between you/Wuhan University of Technology (WUT) and me, and **does not** constitute an agreement with Harvard University." (Emphasis original.) Subsequent emails suggest that LIEBER took additional steps to try and distance himself — at least publically — from WUT in the wake of Harvard's discovery of the joint Harvard-WUT nano lab. These included cancelling a trip to WUT in June 2015 and advising a postdoctoral fellow at the Lieber Research Group to continue her work in LIEBER's lab *rather* than starting a position at WUT.

27. Nevertheless, LIEBER's Thousand Talents Agreement and the earlier Strategic Scientist Agreement (which, according to their terms, expired in July 2015 and November 2016, respectively) appear to have remained in place well after January 2015. For example, in an email dated February 13, 2015, LIEBER told the WUT Professor that he would continue his review of a manuscript written by WUT researchers. In the same email, LIEBER also said that he "may be in touch with regards to several issues relating to my appointment/salary/funding @ WUT...."

Although it is unclear what precise "issues" LIEBER was referring to, at a minimum, this email shows that LIEBER continued to be paid by WUT after January 2015.

28. In an email dated November 26, 2015, the WUT Professor thanked LIEBER "for all you have done for our university and me!" The WUT Professor also told LIEBER that WUT had "put your salary in your … [bank] card and we will help you change the cash for you when you come to Wuhan." The fact that WUT continued to pay LIEBER's salary in late 2015 indicates to me that LIEBER, in fact, continued to work for, and with, WUT throughout 2015.

29. The payment of salary to LIEBER by WUT appears to have continued into 2017. In an email dated January 17, 2017, the WUT Professor sent the following message to LIEBER:

> During our last meeting you mentioned the tour of Bejing in the end of Feb. or early March. President [of WUT]…, I and all faculties and students in our Joint Nano Lab would like to invite you to visit WUT and our Joint Nano Lab. If your schedule is available, we would like to take this chance to express our everlasting gratitude to your great support for our university and me! Our university has put your salary in your … [bank] card and we will help you change the cash for you when you come to Wuhan. Our university will cover your first-class flight ticket and accomadation [sic] like before. We would like to know your idea. With my best regards and thank you very much for your strong support again.

By this point, according to their express terms, LIEBER's Strategic Scientist and Thousand Talents Agreements with WUT had expired. Insofar as it discusses the payment of additional salary to LIEBER in January 2017, this email is evidence that LIEBER may have executed a new agreement with WUT at some point in either late 2016 or early 2017.

Lieber's False Statements to DoD

30. Since 2009, LIEBER has been the principal investigator associated with at least six research grants funded by various DoD entities, including ONR and AFOSR. The total value of

these grants exceeded $8 million. As of April 2018, LIEBER was the principal investigator associated with three active DoD grants.

31. On April 24, 2018, DoD investigators interviewed LIEBER about his active grants and whether LIEBER had appropriately disclosed foreign research collaboration to DoD. During the interview, which took place at LIEBER's lab on the Harvard Campus, LIEBER said that he was familiar with China's Thousand Talent's Plan, but that he had never been asked to participate in the program. Although LIEBER stated that he was never asked to participate in the Thousand Talents Program, he also told DoD investigators that he "wasn't sure" how China categorized him. I believe these statements were false because, as described above, WUT expressly asked LIEBER on numerous occasions in 2012 to participate in the Thousand Talents Program and to sign a Thousand Talents Agreement with WUT. Moreover, based upon the email correspondence described above that I have reviewed, LIEBER *did* sign a three-year Thousand Talents Agreement with WUT on or about July 21, 2012, and was paid by WUT over the course of several years pursuant to that agreement. The agreement that LIEBER signed was titled "Employment Contract of 'One Thousand Talent' High Level Foreign Expert" and it referred to LIEBER as a "One Thousand Talent."

32. On April 26, 2018, two days after his interview with DoD, LIEBER emailed a research associate affiliated with the Lieber Research Group the following message:

> Can you also provide me with the link/info to CAS webpage where I am listed as directing (?) that lab at Wuhan? I lost a lot of sleep worrying about all of these things last night and want to start taking steps to correct sooner than later. I will be careful about what I discuss with Harvard University, and none of this will be shared with government investigators at this time.

I believe that "CAS" refers to the China Academy of Sciences, which I know to be a top Chinese research institute. According to Harvard University's website, LIEBER was elected to the CAS

in December 2015. At a minimum, this email demonstrates that LIEBER withheld information from "government investigators" about his relationship with WUT. Given the timing of this email — two days after his interview with DoD — I believe LIEBER was referring specifically to the DoD investigators.

Lieber's False Statements to NIH

33. I am aware that LIEBER was the principal investigator associated with at least three NIH-funded research grants awarded to Harvard University since 2008. The total value of those grants exceeded $10 million. Two of those grants were being actively funded by NIH as of November 2018.

34. On or about November 15, 2018, NIH inquired of Harvard about whether LIEBER and/or Harvard had failed to disclose LIEBER's then-suspected relationship with WUT and China's Thousand Talents Plan. In order to respond to NIH's inquiry, Harvard interviewed LIEBER about his foreign affiliations generally, and any connection he might have to WUT in particular. Based upon information provided by LIEBER during that interview, Harvard submitted a detailed written response to NIH on or about January 10, 2019. I believe that LIEBER caused Harvard to make materially false and misleading statements about his connection to WUT and the Thousand Talents Plan in that written submission.

35. Specifically, LIEBER caused Harvard to tell NIH that LIEBER "had no formal association with WUT" after 2012, but that "WUT continued to falsely exaggerate" LIEBER's involvement with WUT in subsequent years. This statement was false because, as described above, LIEBER maintained a formal, collaborative relationship with WUT between at least 2012 and 2017 that included the Visiting Scientist Agreement, the Thousand Talents Agreement, an Academic Cooperative Agreement between Harvard and WUT, and possibly other agreements.

36. LIEBER also caused Harvard to tell NIH that LIEBER "is not and has never been a participant in" China's Thousand Talents Plan. This statement was also false because LIEBER did, in fact, sign a three-year Thousand Talents Agreement with WUT on or about July 21, 2012.

CONCLUSION

37. Based on the forgoing facts, and on my experience, training and discussions with other individuals involved in this investigation, I believe that probable cause exists to conclude that on or about April 24, 2018, LIEBER knowingly and willfully made materially false, fictitious and fraudulent statements to DoD in violation of 18 U.S.C. § 1001(a)(2). In addition, I believe that probable cause exists to conclude that on or about January 10, 2019, LIEBER made and caused to be made a series of materially false, fictitious and fraudulent statements to NIH, also in violation in 18 U.S.C. § 1001(a)(2).

_____
Robert Plumb
Special Agent, FBI

Sworn and subscribed before me this _____ day of January 2020.

_____
MARIANNE B. BOWLER
UNITED STATES MAGISTRATE JUDGE

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

UNITED STATES OF AMERICA	)	Criminal No.
	)	
	)	Violations:
YANQING YE,	)	
	)	Count One: Visa Fraud
	)	(18 U.S.C. § 1546)
Defendant	)	
	)	Count Two: Making False Statements
	)	(18 U.S.C. § 1001(a)(2))
	)	
	)	Count Three: Acting as an Agent of a
	)	Foreign Government
	)	(18 U.S.C. § 951)
	)	
	)	Count Four: Conspiracy
	)	(18 U.S.C. § 371)

INDICTMENT

At all times relevant to this indictment:

General Allegations

A. The People's Republic of China and its Military

1. The People's Republic of China ("PRC") is a "foreign government" as that term is defined under 28 C.F.R. § 73.1(b). The People's Liberation Army ("PLA") is the military arm of the Chinese Communist Party ("CCP") and the armed forces of the PRC. The PLA is composed of six services and support forces: the PLA Army; PLA Navy; PLA Air Force; PLA Rocket Force; PLA Strategic Support Force; and the PLA Joint Logistics Support Force. The Central Military Commission ("CMC") controls the PLA. The PLA uses three schools (the Academy of Military Science, National Defense University, and National University of Defense Technology) to formulate military strategy, research and advance its military capabilities and

weapons systems, and train its armed forces. Professors at these schools also serve as military officers and leaders of the PLA.

2. National University of Defense Technology ("NUDT") is a top military academy directed by China's CMC. It was founded in 1953 by the Harbin's Military Engineering Institute PLA. NUDT is involved in national defense research for the PLA and responsible for modernizing the PRC's armed forces and designing advanced weapons. NUDT is also responsible for training advanced scientific and engineering personnel, commanding personnel, and senior leadership in the PLA.

B. The Defendant and Her Conspirators

3. YANQING YE ("YE") is a Chinese national, a female member of the PLA, and member of the CCP. At all times relevant to the Indictment, YE was a Lieutenant in the PLA and was being directed by senior leaders of the PLA while conducting research at Boston University pursuant to a J-1 non-immigrant visa.

4. Co-conspirator A was, at all relevant times, YE's supervisor as well as a Colonel in the PLA and full professor at NUDT.

5. Co-conspirator B was, at all relevant times, an Assistant Professor in Management Science and Engineering at NUDT and a member of the PLA who according to YE had the rank "of less than Colonel." YE was aware that Co-conspirator B had worked on military research projects regarding rocket launchers.

6. Co-conspirator C was, at all relevant times, an Assistant Professor in NUDT's College of Information Systems and Management.

C. YE Fraudulently Gained Entry into the United States

7. YE applied for, and obtained a, J-1 non-immigrant visa to conduct research in the Department of Physics, Chemistry, and Biomedical Engineering, Center of Polymer Studies, at Boston University. YE's research and studies in the United States at Boston University were funded by the Chinese Scholarship Council ("CSC"). The CSC was established in 1996 as a non-profit institution affiliated with the PRC's Ministry of Education. The CSC is responsible for the enrollment and administration of Chinese Government Scholarship programs and provides funding for both undergraduate and graduate students, as well as post-doctoral visiting scholars, to Chinese citizens wishing to study abroad and to foreign citizens wishing to study in China. CSC is financed mainly by the state's special appropriations or scholarship programs.

8. On or about August 4, 2017, YE electronically signed her visa application and certified that all of her answers on the form were true and correct when, in fact, she misrepresented her foreign military service to gain entry to the United States. In her visa application, YE described her foreign military service as follows:

> Name of Country/Region: CHINA
> Branch of Service: CIVIL SERVICE
> Rank/Position: STUDENT
> Military Specialty: NUDT [National University of Defense Technology]
> Date of Service
> From: 01 September 2009
> Date of Service
> To: 31 July 2017

This description was false as YE's foreign military service did not end on July 31, 2017, as she represented to the U.S. Government. Nor was her rank only that of a "student" in NUDT. To the contrary, YE was in fact a Lieutenant in the PLA and continued to work as a Lieutenant in

the PLA while studying and conducting research in the United States from in or about October 2017 to in or about April 2019. As described below, YE was tasked with numerous assignments from PLA officers while she was in the United States such as conducting research, assessing U.S. military websites, and sending U.S. documents and information to China, which YE completed by masking her affiliation to the PLA. YE also lied on her visa application when she answered "No" to the question: "Do you seek to engage in espionage, sabotage, export control violations, or any other illegal activity while in the United States?" Based upon YE's false representations, on or about September 5, 2017, the U.S. Department of State approved YE's DS-160 application. On or about October 14, 2017, YE gained entry into the United States using her visa that she knew had been procured through fraud and making false statements, in violation of 18 U.S.C. § 1546.

D. YE Makes False Statements to U.S. Law Enforcement

9. On or about April 20, 2019, officers of Customs and Border Protection along with a Special Agent of the FBI conducted an interview of YE at Boston Logan International Airport. During this interview, YE stated, among other things, that Co-conspirator A was her Chinese advisor and a "full professor" at NUDT and he held the military rank of "Colonel." YE falsely claimed that she had minimal contact with Co-conspirator A, and that Co-conspirator A did not provide much oversight of her research projects. She further falsely denied participating in any of Co-conspirator A's military projects. Yet, based upon records found on YE's electronic devices pursuant to a border search, at the instruction of Co-conspirator A, YE had accessed U.S. military websites, researched U.S. military projects, and compiled information for the PLA on two U.S. persons with expertise in robotics and computer science.

10. During the April 20, 2019 interview, YE also denied having any involvement in Co-conspirator B's research. YE described Co-conspirator B as an Assistant Professor of NUDT who held a military rank of "less than colonel." She also claimed that she had no recent communications with him when, in fact, she had numerous WeChat conversations with Co-conspirator B in 2018 and 2019. Indeed, according to a January 2019 WeChat conversation between YE and Co-conspirator B, they were collaborating on a research paper that was focused on a risk assessment model designed to assist the PLA in deciphering data for military applications. On or about April 11, 2019, Co-conspirator B sent YE a message in Chinese that has been translated into English that states: "See if [we can] find projects in risk analysis and policy sponsored by the US military by searching risk + US military directly." YE also provided Co-conspirator B her Boston University VPN login, including her username and password so Co-conspirator B could log into YE's account.

11. Lastly, during this interview, YE stated that she held the rank of Lieutenant in the PLA and admitted she was a member of the CCP. She planned to return to the PRC and complete her PhD at NUDT under the advisement of Co-conspirator A. YE indicated that part of her undergraduate studies at NUDT included classification training and students at NUDT worked on classified projects.

E. <u>YE Acted as an Agent of the PRC without Notification to the Attorney General</u>

12. In direct violation of the terms of her J-1 visa, while in the United States, YE had extensive communications with several senior PLA officers and she continued to work as a PLA Lieutenant. YE was tasked by senior PLA officers, completed those taskings, conducted research on the U.S. military for the PLA, collaborated with Co-conspirator B on research

projects that had potential military applications, and lied about her engagement with PLA officers when directly questioned about them. YE acted as an agent for the Chinese government, yet she never notified the Attorney General as required for agents working for a foreign government.

COUNT ONE
Visa Fraud
(18 U.S.C. § 1546(a))

The Grand Jury charges:

13. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

14. The conduct alleged in this Count occurred outside the jurisdiction of any particular State or district and within the venue of the United States District Court for the District of Massachusetts, as provided in 18 U.S.C. § 3238.

15. On or about August 4, 2017, in the People's Republic of China, the defendant

YANQING YE,

did knowingly subscribe as true, under penalty of perjury (28 U.S.C. § 1746), a false statement with respect to a material fact in an application, to wit, in response to the question: "Have you ever served in the military?" on the Form DS-160, Application for Immigrant Visa and Alien Registration, YE responded that she only had attained the rank of "student" at NUDT and her period of service to Chinese military ended on July 31, 2017, which statement the defendant then and there knew was false.

All in violation of Title 18, United States Code, Section 1546(a).

COUNT TWO
False Statements
(18 U.S.C. § 1001)

The Grand Jury further charges:

16. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

17. On or about April 20, 2019, in the District of Massachusetts, the defendant

YANQING YE,

in a matter within the jurisdiction of the executive branch of the Government of the United States, did knowingly and willfully make a materially false, fictitious and fraudulent statement and representation, which YE then knew to be false during an interview conducted by CBP officers and a FBI Special Agent.

All in violation of Title 18, United States Code, Section 1001(a)(2).

COUNT THREE
Acting in the United States as an Illegal Agent of a Foreign Government
(18 U.S.C. § 951)

The Grand Jury further charges:

18. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

19. Beginning on a date unknown to the Grand Jury, but no later than in or about October 2017, and continuing until in or about April 2019, in the District of Massachusetts and elsewhere,

YANQING YE,

defendant herein, did knowingly act in the United States as an agent of a foreign government, to wit: the People's Republic of China, without prior notification to the Attorney General of the United States as required by law.

All in violation of Title 18, United States Code, Section 951(a).

COUNT FOUR
Conspiracy
(18 U.S.C. § 371)

The Grand Jury further charges:

20. The allegations contained in paragraphs 1-12 are hereby re-alleged and incorporated by reference as if fully set forth herein.

21. Beginning on a date unknown to the Grand Jury, but no later than in or about October 2017, and continuing until in or about April 2019, in the District of Massachusetts and elsewhere, the defendant

YANQING YE,

did knowingly and willfully conspire with others known and unknown to the Grand Jury to commit an offense against the United States, to wit, 18 U.S.C. § 951, that is, to knowingly act in the United States as an agent of a foreign government, the PRC, without prior notification to the Attorney General as required by law, in violation of 18 U.S.C § 371.

OVERT ACTS

21. In furtherance of the conspiracy, and to effect its objects, the defendant and her co-conspirators committed overt acts, including but not limited to, the following:

a. On or about August 4, 2017, YE lied on the Form DS-160, Application for Immigrant Visa and Alien Registration, about her military rank in the PLA, position in the PLA, and the end date of her service. She made these statements to fraudulently obtain a J-1 visa so as to gain entry into the United States and operate within the United States under the direction and control of her senior leaders in the PLA.

b. On or about March 15, 2018, YE sent instructions to Co-conspirator B in Chinese via WeChat on how to access Boston University's document database using her Boston University VPN login information (username and password) thereby giving Co-Conspirator B the ability to log into Boston University posing as YE.

c. Beginning in or about January 2019, Co-conspirator B and YE collaborated on a research paper that was focused on a risk assessment model designed to assist in deciphering data for military applications. As part of this research project, among other things, on or about April 11, 2019, Co-conspirator B advised YE via WeChat: "See if [we can] find projects in risk analysis and policy research sponsored by the US military by searching risk + US military directly." In response, later on April 11, 2019, YE responded via WeChat that she would conduct this research.

d. On or about April 6, 2019, Co-conspirator A instructed YE via WeChat to research a U.S. professor at the Naval Postgraduate School at Monterey, California whose work focused on computer security, digital forensics, and computer and software engineering and prepare a summary of his biography for him. Co-conspirator A advised Ye: "Compile the information into a file, then send it to me please." YE responded: "Sure Teacher [Co-conspirator A]. Please go to bed now. I will start to work on it immediately." Approximately, six hours later, YE sent Co-conspirator A three documents: (1) a Word document that she prepared summarizing the professor's biography; (2) the professor's curriculum vitae from the school's website; and (3) a list of his published articles.

e. On or about April 11, 2019, Co-conspirator C requested YE via WeChat to download a pdf file from a U.S. navy website –

www.public.navy.mil/surfor/Documents/Surface_Forces_Strategy.pdf. YE did as she was instructed and sent Co-Conspirator C this document via WeChat. In response, Co-conspirator C stated: "Now a days, we can't connect to a link with *mil* top level domain from China… This is probably American taking precautions against us." YE agreed with these statements and revealed that when she has been searching for information recently, "sometimes I have to use the IP of the university to enter certain websites."

f. On or about April 15, 2019, Co-conspirator A sent YE requests via WeChat to access the U.S. navy website – **www.onr.navy.mil** and "check if it has a list of projects." Later that same day, Co-conspirator A also requested YE to access the U.S. army website – **www.arl.army.mil** and review the contents of that website for him.

g. On or about April 16, 2019, Co-conspirator A instructed YE via WeChat to conduct research and compile information on a Professor of Electrical and Computer Engineering at University of Texas at San Antonio. This professor's research focused on system of systems technology and intelligent robotics. As instructed, YE compiled the information Co-conspirator A requested and sent it to Co-conspirator A via WeChat on or about April 16, 2019.

All in violation of Title 18, United States Code, Section 371.

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

UNITED STATES OF AMERICA	)	Criminal No. 20CR10015
	)	
v.	)	Violations:
	)	
ZAOSONG ZHENG,	)	Count One: Smuggling Goods From the United States (18 U.S.C. § 554)
	)	
Defendant	)	
	)	Count Two: False Statements (18 U.S.C. § 1001(a)(2))

INDICTMENT

General Allegations:

A. The Defendant

1. ZAOSONG ZHENG ("ZHENG") is a Chinese national who entered the United States through the J-1 non-immigrant visa program ("J-1") on or about August 8, 2018. ZHENG's J-1 visa application was sponsored by Harvard University and granted by the State Department on or about July 17, 2018. While in the United States, ZHENG received a stipend of approximately $2,000 per month from the Chinese Scholarship Council. The Chinese Scholarship Council ("CSC") was established in 1996 as a non-profit institution affiliated with the PRC's Ministry of Education. The CSC is responsible for the enrollment and administration of Chinese Government Scholarship programs and provides funding for both undergraduate and graduate students, as well as post-doctoral visiting scholars, to Chinese citizens wishing to study abroad and to foreign citizens wishing to study in China. CSC is financed mainly by the state's special appropriations or scholarship programs.

2. ZHENG obtained medical degrees while living in the People's Republic of China

("PRC"). From in or about August 2018, and continuing until in or about December 2019, ZHENG conducted research in the area of biomedical sciences, specifically in cancer pathology, at the Beth Israel Deaconess Medical Center ("BIDMC").

B. Beth Israel Deaconess Medical Center and Wenyi Wei Laboratory

4. BIDMC is a teaching hospital and medical research facility of Harvard Medical School located in Boston, Massachusetts. BIDMC has numerous laboratories, including the Wenyi Wei laboratory. The focus of the Wei Laboratory is the study of cancer cells.

D. ZHENG Smuggles Vials Containing Biological Research and Specimens

5. Between on or about September 4, 2018, and on or about December 9, 2019, ZHENG worked at Wei's laboratory at BIDMC on cancer-cell research.

6. On or about Monday, December 9, 2019, ZHENG went to Boston Logan International Airport and attempted to leave the United States bound for Beijing, China on Hainan Airlines (HU) flight 482 with vials of biological materials and research he had stolen from Wei's laboratory.

7. Before ZHENG boarded HU flight 482, Customs and Border Protection ("CBP") officers located two checked bags in ZHENG's name and examined them. They discovered 21 vials wrapped in plastic and hidden in a sock. The vials were visually inspected and appeared to contain liquid. The officers suspected that the contents were biological in nature. As indicated below, the vials have been tested and analyzed and the results of this testing confirmed that the vials contained Deoxyribonucleic Acid ("DNA"), and therefore constitute biological specimens. Accordingly, ZHENG was required to package the vials in a heat sealed bag and label them with the words "[s]cientific research specimens, 49 CFR 173.4b applies." The vials were not

properly packaged or declared in accordance with U.S. transportation regulations.

8. CBP officers identified ZHENG and approached him before he boarded HU flight 482. CBP officers asked ZHENG multiple times if he was traveling with any biological items or research material in either his carry-on or checked luggage. ZHENG replied "no." ZHENG was then removed from the jetway and escorted to the baggage secondary area, where he acknowledged his ownership of the checked baggage containing the 21 vials.

E. ZHENG Admits He Stole Biological Research from BIDMC

9. On or about December 10, 2019, ZHENG returned to Logan Airport to board a flight destined for the PRC. When ZHENG arrived at the airport, he was met by Special Agents of the Federal Bureau of Investigation. With the aid of a Mandarin linguist, ZHENG was advised of his *Miranda* rights, which he waived, and was then interviewed. ZHENG explained that he worked at a laboratory at BIDMC, conducting research related to cancer. ZHENG admitted that he had stolen biological specimens from BIDMC and that he was planning to take the specimens to China so that he could conduct further research on the specimens in his own laboratory and publish the results under his own name.

10. On or about December 10, 2019, the vials found in ZHENG's luggage were sent to a government laboratory for testing. On or about January 17, 2020, the government received confirmation from the laboratory that the material in the vials contained DNA, and therefore constituted biological specimens for the purpose of Title 49, United State Code, Section 173.4b.

11. 49 C.F.R. § 173 sets forth the regulations for travel with hazardous materials. 49 C.F.R. § 173.4b regulates air travel with non-infectious biological specimens. In relevant part, it provides that:

Non-infectious specimens, such as specimens of mammals, birds, amphibians, reptiles, fish, insects and other invertebrates . . . are not subject to the requirements of this subchapter[1] provided the following packaging, marking and documentation provisions, as applicable, are met:
(1) The specimens are . . .
(ii) Placed in vials or other rigid containers with no more than 30 mL of alcohol or alcohol solution. The containers are placed in a plastic bag that is heat-sealed;
(2) The bagged specimens are placed in another plastic bag with sufficient absorbent material to absorb the entire liquid contents inside the primary receptacle. The outer plastic bag is then heat-sealed . . . and
(5) The outer package must be legibly marked "Scientific research specimens, 49 CFR 173.4b applies."

COUNT ONE
Smuggling Goods From the United States
(18 U.S.C. § 554)

The Grand Jury charges:

12. The allegations contained in paragraphs 1-11 are hereby re-alleged and incorporated by reference as if fully set forth herein.

13. On or about December 9, 2019, in the District of Massachusetts, the defendant,

ZAOSONG ZHENG,

did fraudulently and knowingly export and send, and attempt to export and send, from the United States, merchandise, articles, and objects, to wit: biological specimens, contrary to the laws and regulations of the United States, specifically, 49 C.F.R. § 173.4b.

All in violation of Title 18, United States Code, Section 554.

[1] Those requirements set forth further regulations that govern the transportation of hazardous materials including infectious biological specimens.

COUNT TWO
False Statements
(18 U.S.C. § 1001(a)(2))

The Grand Jury further charges:

14. The allegations contained in paragraphs 1-11 are hereby re-alleged and incorporated by reference as if fully set forth herein.

15. On or about December 9, 2019, in the District of Massachusetts, the defendant,

ZAOSONG ZHENG,

knowingly and willfully made a materially false, fictitious and fraudulent statement and representation in a matter within the jurisdiction of the executive branch of the Government of the United States, that is, when asked by Customs and Border Protection officers whether he was traveling with any biological items or research material, he answered "no," when in fact he had hidden 21 vials containing biological specimens in his luggage.

All in violation of Title 18, United States Code, Section 1001(a)(2).

A TRUE BILL

[redacted]

FOREPERSON

BENJAMIN TOKOFF
ASSISTANT UNITED STATES ATTORNEY
DISTRICT OF MASSACHUSETTS

District of Massachusetts: January 21, 2020
Returned into the District Court by the Grand Jurors and filed

DEPUTY CLERK

HAROLD G. PUTNAM
1.21.2020 @12:58pm

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Synthetic Nanoelectronic Probes for Biological Cells and Tissue

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Abstract

Research at the interface between nanoscience and biology has the potential to produce breakthroughs in fundamental science and lead to revolutionary technologies. In this review, we focus on nanoelectronic/biological interfaces. First, we discuss nanoscale field effect transistors (nanoFETs) as probes to study cellular systems, including the realization of nanoFET comparable in size to biological nanostructures involved in communication using synthesized nanowires. Second, we overview current progress in multiplexed extracellular sensing using planar nanoFET arrays. Third, we describe the design and implementation of three distinct nanoFETs used to realize the first intracellular electrical recording from single cells. Fourth, we present recent progress in merging electronic and biological systems at the 3D tissue level by using macroporous nanoelectronic scaffolds. Finally, we discuss future development in this research area, the unique challenges and opportunities, and the tremendous impact these nanoFET based technologies might have in advancing biology and medical sciences.

Keywords

Nanowire; field effect transistor; intracellular; extracellular; synthetic tissue

1. INTRODUCTION

Semiconductor science and technology is a driving force of the modern society due to the ever-increasing miniaturization of semiconductor processing and transistor devices(1–6). To continue the remarkable success of semiconductor technology and possibly produce new paradigms for logic, memory and sensor devices, many researchers have been investigating devices based on synthesized nanostructures(2,5,7–12) in which geometries, organizations and physical properties can be designed and controlled at the nanometer scale.

A wide spectrum of nanostructured materials have been designed and synthesized over the past several decades, including colloidal nanoparticles(13,14), semiconductor nanowires (NW)(3,4,15,16), and graphene(10,17–20), where properties distinct from their bulk counterparts have been discovered and exploited. For any class of nanostructured materials to become a platform for discovery and development, it is critical that new structures and

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DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

EXHIBIT 16

assemblies with tunable composition, morphology, and properties at different length scales be obtainable(3,10,18). In this regard, semiconductor nanowires have been recognized as one of the most successful platforms available today in nanoscience. First, it is now possible to design nanowire structures *de novo* and synthetically realize these structures with complex, yet controlled, modulations in composition(8,16,21–26), doping(16,23), defect(27–29) and even topography(30–32). Second, this high-level of synthetic control enables nanowire building blocks to be created that have predictable physical properties for testing fundamental limits of performance(5,16). Third, it is now possible to assemble hybrid or multicomponent functional materials in novel layout and configuration using these diverse nanowire building blocks(31,33–45), allowing for rational exploration of the possible applications of multi-component materials. With these characteristics and capabilities, nanowires are ideal building blocks for exploring what is possible in nanoscience and also creating new technologies. This has been the focus in nanoscience community over the past decade and continues to be so as it crosses over other disciplines, such as synthetic biology(46–51).

Research at the interface between nanoscience and biology has the potential to produce breakthroughs in fundamental sciences and lead to revolutionary technologies(52,53). In particular, the exploration and application of semiconductor nanowire materials and devices in cellular systems could produce unprecedented interactions down to the molecular level. Such interactions have been utilized to gain insights especially those relevant to human health by stimulating, recording from and delivering objects to single cells and tissues in controlled ways to induce desired physiological responses, while minimizing undesirable effects(52,53).

There are two types of nanowire-based platforms in biomedical sciences: *basic platforms* that can be readily adapted to address biomedical questions; and *advanced platforms* that are specifically designed to push the frontiers of what is possible by, for example, enabling a new measurement tool. The *basic platforms* use conventional nanowire material and device systems with well-exploited physical or chemical properties, and they also have wide-ranging applications in many other fields, such as energy scavenging systems(54–61) or components for integrated circuit(34,35). These *basic platforms*, such as planar nanowire field effect transistors(34,35,37,40,43) or vertical nanowire arrays(55–58,60,61), have been used in biomolecular sensing(52,53), extracellular recording(52,53), drug delivery(62–64) and localized cellular imaging(65). On the other side, the *advanced platforms* have been designed to address some intrinsic complexity in biology and medical sciences in way simply not possible previously. They allow new types or new scales of interact and measurements with their target systems(31,66–68), and in so doing, open up completely new opportunities in science and technology. Examples of *advanced platforms* include recent intracellular field effect transistor probes(31,67–69) and nanoelectronics-innervated synthetic tissues(66).

This review discusses the basic concepts of nanoscale field effect transistors (nanoFETs) and their applications in cellular electrophysiology. The first section highlights the motivation behind nanoFET probes to study cellular systems versus existing recording technologies, followed by the introduction of chemical synthesis to realize nanoFETs *de novo*. The second section gives an overview of the current progress in multiplexed extracellular sensing using planar nanoFET arrays. Electrical recordings at single cell, tissue and organ levels will be discussed, and their limits and promises will be delineated. The third section will detail the main designs and implementations of nanoFETs in intracellular electrical recording from single cells, the first paradigm change in intracellular electrophysiology since the 1950s. NanoFET based techniques will be compared with conventional micropipette and microelectrode probes, and the limits and future opportunities

of these new probes will be discussed. The fourth section will introduce very recent progress in merging electronic and biological systems at the 3D tissue level by introducing the new concept of macroporous nanoelectronic scaffolds. The first-ever nanoelectronics 'innervated' synthetic tissues will be reviewed and their applications will be discussed. The final section will present our perspectives on future development in this research area, the unique challenges and opportunities, and the tremendous impact these nanoFET based technologies might have in advancing biology and medical sciences.

2. FUNDAMENTALS OF NANOFET

2.1. Why and how are nanoFETs applied in biology and medicine?

The ability to make electrical measurements inside single cells or throughout the entire 3D space of the tissue can have many important impacts in electrophysiology and biomedical sciences. The patch clamp technique, in which a pulled glass micropipette filled with electrolyte is inserted into a cell, offers intracellular electrical measurements with high signal-to-noise ratio (S/N) and single ion channel recording capability(70). Ideally, the micropipette should be as small as possible to increase the spatial resolution and reduce the invasiveness of the measurement, and ideally, allow for recording from subcellular structures. However, the overall performance of the technique also depends on the impedance of the interface between the micropipette and the cell interior (*i.e.*, the smaller the probe tip size, the larger the junction impedance), which sets limits on the temporal resolution and S/N of the micropipette-based electrical probes(31,41). Advanced techniques that involve inserting metal or carbon microelectrodes or nanoelectrodes into cells or tissues could be subject to similar dilemma, because all these tools are single terminal devices and electrochemical thermodynamics and kinetics must be considered for device operation(71–78). We will discuss them in details in the subsequent sections.

In integrated circuits, the basic device element is a multi-terminal FET that uses either electrons or holes as the charge carriers(79) (Figure 1a). Although the charge carriers are ions in biological systems, there are many biophysical links that connect ions to electrons and holes in a FET. For example, the dynamic flow of ions in biological system can generate spatially defined field potential(80). The Poisson equation(81) links such potentials directly to the ionic current sources and sinks that produce them. The Goldman-Hodgkin-Katz voltage equation(81) has also been used in cell membrane physiology to determine the equilibrium potential across a cell's membrane, where it takes into account all of the ions that permeate through that membrane. The potentials, generated by ion flows and gradients, can function as the gate signals to modulate the electrical output in FET devices (Figure 1b and 1c). The sensitivity of a FET or how well the transistor can receive and amplify the gate signal is usually defined as transconductance (G_m)(6,52,53,79), which is inversely proportional to the dimension (L) of the active device(6). This fact implies that the use of nanoelectronics would have improved sensitivity compared to its bulk and planar counterparts. As shown in the following sections, nanoFETs have shown to be able to record electric potentials inside cells(31,67–69) and from the internal regions of synthetic tissues(66), and because their performance does not depend on impedance, they can be made much smaller than micropipettes and microelectrodes. Moreover, nanoFET arrays are better suited for multiplexed measurements(67,68).

2.2. Chemical synthesis of nanoFETs

Three distinct classes of *de novo* design and synthesis have been used to yield nanoFETs building blocks , covering structural motifs in one-dimension (1D), 2D and 3D (Figure 2). The basic semiconductor nanowire structure (Figure 2a, I) consists of a uniform composition, 1D structure with a diameter typically in the range of 3–500 nm. In the growth

process, which builds upon earlier work showing vapor-liquid-solid (VLS) growth of micrometer to millimeter diameter wires(82,83), the nanocluster catalyst (typically gold nanoparticles) forms a liquid solution with nanowire reactant component(s), and when supersaturated, acts as the nucleation site for crystallization and preferential 1D growth(84,85). Other growth mechanisms, such as vapor-solid-solid (VSS) and vapor-solid (VS)(15), can also be explored to yield high quality semiconductor nanowires. Within this framework, it is straightforward to synthesize nanowires with different compositions, such as groups III-V, IV and II-VI semiconductors(8,15,86,87), using the appropriate nanocluster catalysts and growth temperatures/pressures. Additionally, nanowire structures in which the composition, dopant and even growth mechanisms (*e.g.*, VLS, VSS) are modulated along axial(21,22,88–90) (Figure 2b) or radial directions(25,29,91)have also been widely exploited. These axial and radial nanowire heterostructures provide a number of advantages compared to homogeneous semiconductor nanowires, and they have proven exceptionally powerful for a broad range of electronic, photonic and optoelectronic device applications(16). For example, germanium/silicon core/shell nanowires have been chemically synthesized for high mobility nanowire FETs due to quantum confinement of carriers within the germanium core by the larger band-gap silicon shell(5,92–95).

The second structural motif was recently demonstrated by an approach in which topological centers are synthetically introduced in a controlled manner in linear 1D structures (Figure 2a, II)(31,32). In this area, we demonstrated that iterative control over nucleation and growth leads to kinked nanowires, in which the straight sections are separated by triangular joints and where doping can be varied at these topologically defined points (Figure 2c). Moreover, new work has shown that it is possible to control the stereochemistry of adjacent kinks in a manner that allows the synthesis of increasingly complex two- and three-dimensional structures akin to organic chemistry, thus opening up a great opportunity for the future in terms of designed synthesis(31).

A third basic motif involves the synthesis of branched or tree-like nanowire structures (Figure 2a, III)(24,26,96). To this end, we reported a rational, multistep approach toward the general synthesis of 3D branched nanowire heterostructures(24). Single-crystalline semiconductor, including groups IV, III–V, and II–VI, and metal branches have been selectively grown on core or core/shell nanowire backbones, with the composition, morphology, and doping of core (core/shell) nanowires and branch nanowireswell controlled during synthesis.

Although the first structural motif has been used most extensively as building blocks of *basic platforms*, the second and third motifs have much higher level of structural and functional complexity, and show great potential of bottom-up synthesis to yield increasingly powerful functional building blocks for *advanced platforms*.

3. MULTIPLEXED EXTRACELLULAR ELECTRICAL RECORDING

3.1. Why nanoFETs for multiplexed extracellular recording

Natural and synthetic cellular assemblies are usually organized into 2D or 3D hierarchical networks operating on spatial and temporal scales that span multiple orders of magnitude. Advances in microfabrication of high-density passive multielectrode arrays (MEAs) and active transistor arrays on silicon substrates enable direct electrical recording down to ca. 10 micrometer length scales, although it is important to recognize that signals recorded within ~100 μm are often correlated[4–6], and moreover, it has been difficult to to resolve the cellular signals at the single cell level. As mentioned above, simply reducing the size of individual metal electrodes to achieve more localized detection is not viable due to corresponding

increases in their impedance[7,8], which intrinsically limits the resolution of such passive recording devices.

Silicon nanowire nanoFET arrays have several features that make them unique for high-resolution multiplexed extracellular recording from cellular systems. First, previous studies have shown that nanowire nanoFETs can exhibit ultra-high sensitivity detection of charged biomolecules, including detection of single particles(53). Second, bottom-up fabrication of nanoFETs yields devices that have nanoscale protrusions from the substrate surface(53,97). This can reduce device to cell/tissue separation and promote enhanced cell-nanostructure interaction and has resulted in high S/N extracellular recording of field potentials from cultured cells and cardiac tissue with signals improved compared to planar FETs. Third, the bottom-up approach also enables high-performance nanoFET fabrication on transparent, flexible and stretchable substrates(34,38–40). The freedom to design device structures and arrays on substrates adapted to specific biological applications also opens up new possibilities for interfacing with living tissues, for example, bio-resorbable and implantable devices(98–101). This freedom also allows other measurements or manipulations to be performed in conjunction with nanoFET recordings, such as high-resolution optical imaging. Fourth, the active junction area of typical nanoFETs, 0.01~ 0.1μm^2, is much smaller and can provide better spatial resolution of signals compared to MEA and planar FETs that are 10^2 to 10^5 times larger in active area(41). Last, nanoFET detectors provide fast intrinsic response time which is critical for high temporal resolution recordings(95,102).

3.2. Electrical interfacing with cultured neurons

An early example of multiplexed nanoFET recording layout consists of a neonatal rat cortical neuron and four peripheral silicon nanoFETs that are arranged at the corners of a rectangle, where polylysine patterning was used to promote axon and dendrites growth across single nanoFETs(103) (Figure 3a). This multiplexed nanoFET/neurite hybrid was used to study spike propagation with NW1 as a local input to elicit action potential spikes. After stimulation with a biphasic pulse sequence, back propagation of the elicited action potential was detected in the two dendrites crossing elements NW2 and NW3. The lack of observed signal from NW4 demonstrates the absence of crosstalk in the hybrid device array, and thus the capability for multiplexed subcellular resolution detection.

3.3. Recording from cardiomyocyte monolayers

We also carried out multiplexed measurements using the nanoFET arrays interfaced with cultured embryonic chicken cardiomyocytes (Figure 3b)(33). The nanoFETs were patterned in a linear array with an average spacing of 300 μm so that signal propagation within cardiomyocyte monolayers could be characterized. Recording from multiple nanoFETs in contact with spontaneously beating monolayer yielded very stable and high S/N (>10) field potential spikes. In this experiment, the relative large signal magnitude confirmed that a good junction is formed between each of the nanoFETs and PDMS/cell substrate. Additionally, a cross-correlation method was used to determine robustly the time differences between the signals recorded by the devices. The time shifts between devices and device separations yielded propagation speeds of 0.07–0.21 m/s that are consistent with other measurement on cardiomyocyte monolayers. The variation in propagation speeds in these initial studies is not surprising given the monolayer inhomogeneity and suggests an important future direction. We suggest that high-resolution multiplexed nanoFET recording together with optical imaging will enable details of intercellular propagation to be characterized for well-defined cellular structures.

3.4. Recording from tissues and organs

Finally, nanoFETs have been used to probe electrical activities from tissues and organs(41,42). To this end, we have studied the activity patterns of layer II/III cells in the piriform cortex of acute rat brain slices by stimulating different sets of axon fibers in the lateral olfactory tract (LOT). In a representative experiment, eight devices within a four-by-four 2D array oriented under the pyramidal cell layer of an acute slice were simultaneously monitored following stimulation at eight different spots (*a–h*) in the LOT(41) (Figure 3c). Strong stimulation of all axons fibers in the LOT yielded similar response by nanoFETs *1–8* with clear population spike signals (postsynaptic activities) regardless of stimulation positions. Reduced stimulation intensity was also used so that at each spot only a subgroup of fibers was activated. Notably, visual inspection of 2D activity maps for each of the eight stimulation positions demonstrates clearly how heterogeneous activity can be resolved (Figure 3d), and thus define a complex functional connectivity in the piriform cortex.

3.5. Challenges and promises

Although great progress has been made in the extracellular electrical recordings using nanowire nanoFETs, many challenges remain. For example, there is still a pressing need to further enhance the nanoFET S/N so that very weak endogenous biological signals, with the amplitude of ~ 100 μV, can be readily resolved. We can potentially achieve this goal by (1) new chemical design and synthesis of high mobility nanowire building blocks for nanoFET, (2) nanoscale engineering of nanowire materials to reduce nanoFET noise by, for example, thermal annealing and/or surface passivation.

It is also important to note that the high input impedance of the nanoFETs circumvents the common challenges confronted by implanted microelectrodes, where gradual increases of single terminal device impedance due to, for example, absorption of proteins, leads to degraded S/N over time(41,104,105). This feature makes nanoFETs very promising for multiplexed, in vivo chronic recordings. This is particularly true considering the facts that (i) nanoscale device feature size allows integration of multiple nanoFETs on minimally invasive and movable electrophysiological probes(68), (ii) bottom-up fabrication makes it possible to choose biocompatible or even biodegradable materials as substrates to reduce mechanical mismatch and to minimize inflammatory tissue response(31,66,68,98–101), and (iii) the nanoscale topology could be arbitrarily designed *de novo* to promote better attachment of single cells or even intracellular contacts. Therefore, nanoFETs should bring many exciting opportunities to interfacing living tissue and organs with electronics for biomedical applications (*e.g.*, diagnostic devices for brain trauma and surgical tools for cardiac therapy), and even new cybernetic biosystems for hybrid information processing.

4. INTRACELLULAR ELECTRICAL RECORDING

4.1. Why intracellular?

As the key cellular component, lipid membranes represent important structural and protective elements of the cell that form a stable, self-healing, and virtually impenetrable barrier to the ions and small molecules(106). Since these membranes have resistance (R) and capacitance (C), the membrane RC circuit also behaves as an electrical barrier and would attenuate and even distort the intracellular signals as they are detected by extracellular sensors. More importantly, although cellular signal transduction often starts with an extracellular signaling molecules activating a cell surface receptor, it is the subsequent intracellular processing that eventually creates a cellular response. Deciphering of such intracellular signal transmission and amplification processes is critical to the understanding of cellular information flow and cell physiology. Therefore, it is highly desirable to deliver

nanoFETs into the cell and directly record intracellular electrical activities, which can provide much more detailed understanding of the inner workings of cells..

4.2. Why nanoFETs for intracellular recording?

Although nanoFETs have been exploited for ultrasensitive detection of biological markers and high-resolution extracellular recording from cells(53), localized and tunable intracellular sensing and recording had not been demonstrated prior to our work because all FET and nanoFET devices were created on planar substrates --- using the *basic nanoFET platform*. Ideally, rather than force the cell to conform to the substrate, a movable and 3D nanoFET with the necessary source (S) and drain (D) electrical connections could move into contact with the cell and probe within the cell membrane. However, minimally invasive insertion of a nanoFET into the confined 3D space of single cells, or even 3D cellular networks, was still a major challenge before year 2010 because the S and D typically dominated the overall device size and defined a planar and rigid structure, regardless of whether the nanoFET was on or suspended above a substrate. An *advanced nanoFET platform* that is designed specifically for intracellular measurement is needed to meet this requirement(32,67–69). Three distinct examples that we have recently introduced to address this central challenge are shown schematically in Figure 4a, and include (1) kinked nanowire nanoFET, (2) branched-intracellular nanotube nanoFET, and (3) active nanotube nanoFET devices.

Existing probes capable of intracellular sensing and recording include voltage-sensitive optical dyes or proteins(107–110), and single-terminal glass or carbon microelectrodes as mentioned briefly in prior section(70,72) (Figure 5). Voltage-sensitive dyes can readily be used to interrogate action potentials with high spatial resolution, but they still have limitations in terms of signal-to-noise (S/N) ratio, pharmacological side effects, phototoxicity, and difficulty in differentiating single spikes(108). For electrical probes (Figure 5), the single electrical connection facilitates design and mechanical insertion into cells, but the requirement of direct ionic and/or electrical junctions between probe tips and cytosol also introduce several limitations. First, the tip size of these probes (~0.2 to 5 μm) is a compromise between being small enough (<5 μm) to penetrate or rupture the cell membrane with minimum damage and large enough (>0.2 μm) to yield a junction impedance that is sufficiently low so that small cellular signals can be discerned from thermal noise. Second, direct exposure of intracellular species to extraneous probe surfaces or electrolytes in probe lumen, especially for larger glass micropipettes, might induce irreversible changes to cells and, thus, prevent long-term and noninvasive cellular recordings. Finally, these probe techniques are intrinsically passive and are not capable of built-in signal processing and facile integration with other circuitries, especially given the emerging need to enable a cell-machine communication(111–114).

NanoFETs can function in a sub–10-nm-size regime(2). In principle, their exceptionally small size enables them to function as mechanically noninvasive probes capable of entering cells through endocytic pathways, as can occur with nanoparticles(115–118). Moreover, when interfacing with cells, nanoFETs process input/output information without the need for direct exchange with cellular ions; thus, the issues of interfacial impedance and biochemical invasiveness to cells can be ignored or minimized (Figure 5). In addition, because signals are transduced by change in field/potential at well-isolated surfaces, nanoFETs can detect cellular potential, as well as biological macromolecules, and could be integrated for potential multiplexed intracellular measurements. Until recently, these advantages could not be exploited, although our recent work(31,67–69) (Figure 4a) has now shown three solutions that open up these exciting opportunities.

4.3. Designs and implementation of intracellular nanoFET probes

In 2010, the first nanoFET intracellular probes were designed and chemically synthesized without lithography to encode a ~ 100 nm FET device at the apex of a kinked nanowire(31) (Figure 4a,b). This was achieved through control over cis-/trans- conformations and modulation doping during the silicon nanowire synthesis(31,32). Subsequently, the free arms of such kinked nanowires were electrically contacted to free-standing and flexible electrodes. Electrical characterization of the 3D nanowire probes showed they were robust to mechanical deformation, recorded solution pH changes with high-resolution, and, when modified with phospholipid bilayers, recorded the intracellular potential of single cells. Significantly, electrical recordings of spontaneously beating cardiomyocytes demonstrated that the 3D nanoFET probes continuously monitored extra- to intracellular signals during cellular uptake for the first time. The nanometer size, biomimetic surface coating, and flexible 3D device geometry render these active semiconductor nanoprobes a new and powerful tool for intracellular electrophysiology.

The kinked nanoFET based intracellular recording represents the first example of interfacing semiconductor devices with cells intracellularly, but the kink configuration and device design also place certain limits on the probe size and the potential for multiplexing. To address these issues, we reported a new device platform in which a branched SiO_2 nanotube was synthetically integrated on top of a nanoFET (BIT-FET)(67)(Figure 4a,c). This branched nanotube penetrated the cell membrane, bringing the cell cytosol into contact with the extracellular FET, thus allowing intracellular recording of transmembrane potential. Studies of cardiomyocyte cells demonstrated that when phospholipid-modified BIT-FETs are brought close to cells, the nanotubes spontaneously penetrate the cell membrane and yield full-amplitude intracellular action potentials, thus showing that a stable and tight seal forms between the nanotube and cell membrane. Significantly, we also showed that multiple BIT-FETs can be used for multiplexed intracellular electrical recordings from both single cells and networks of cells.

Recently, we also demonstrated a conceptually new and practically simple nanoFET probe that consists of a single semiconductor nanotube(68)(Figure 4a,d). The fabrication of the active nanotube transistor (ANTT) intracellular probe involves the fabrication of S/D contacts to one end of a silicon or other semiconductor nanotube, and electrical isolation of these S/D contacts from surrounding medium. Then the solution filling the interior of the nanotube can gate the transistor and the variation of interior electrochemical potential is recorded as a change in device conductance. In experiments, the free end of ANTT probes were inserted into cardiomyocyte cells, and the time-dependent changes associated with action potential spikes were recorded by this nanoFET probe. As expected, if a similarly configured solid nanowire nanoFET was inserted into the cell, no signal was observed since it would not be possible to “gate” the nanoFET. Finally, the straightforward fabrication of ANTT devices was exploited to prepare multiple ANTTs at the end of single probes, which enabled multiplexed recording of full-amplitude intracellular action potentials from single cells, and multiplexed arrays of single ANTT device probes (Figure 4d).

4.4. Challenges and promises

Despite these advances, additional work remains to advance further the nanoFET-based intracellular measurement techniques (Figure 5). For example, the S/N is, at current stage, not better than that from glass micropipette recordings although spatial resolution is much higher. The current designs of nanoFETs only enable potential recordings, but measurement of ionic currents is also possible if other signal transduction mechanisms are combined with nanoFET. Moreover, the capability for cell stimulation in addition to recording is still lacking. Nevertheless, we believe that the advantages of the nanoFET intracellular probes

already demonstrated in our work, including the capability to realize sub-10 nm probes, ease of operations (*e.g.*, there is no need to compensate/calibrate the probe junction potential and capacitance, etc.), the biomimetic cellular entrance, minimal mechanical and biochemical invasiveness, and the potential for large-scale, high-density, multiplexed recording, make them very attractive new measurement tools that will extend substantially the scope of fundamental and applied electrophysiology studies to regimes hard to access by current methods. For example, an exciting future application of these nanoFET probes will be measuring membrane potentials directly from cellular organelles, a Holy Grail in intracellular electrophysiology.

5. NANOELECTRONICS INNERVATED SYNTHETIC TISSUES

The development of synthetic 3D macroporous biomaterials as extracellular matrices (ECMs) represents a key area because (i) functionalized 3D biomaterials allow for studies of cell/tissue development in the presence of spatiotemporal biochemical stimulants(119,120), and (ii) the understanding of pharmacological response of cells within synthetic tissues(121–123) is expected to provide a more robust link to *in vivo* disease treatment than that from 2D cell cultures. Advancing further such biomaterials requires capabilities for monitoring cells throughout the 3D microenvironment. While electrical sensors are attractive tools, it has not been possible to integrate such elements with porous 3D scaffolds for localized real-time monitoring of cellular activities and physicochemical changes.

Recent efforts in coupling electronics and tissues have focused on flexible, stretchable planar arrays that conform to tissue surfaces(10,42,53,98–101), or implantable microfabricated probes(124). These approaches have been used to probe electrical activities near surfaces of the heart, brain and skin, and they have shown translational potential. However, these new electronic tools are currently limited in merging electronics with tissues throughout 3D space while minimizing tissue disruption, because of the 2D support structures and the electronic sensors are generally much larger scale than the extracellular matrix (ECM) and cells. Our studies using nanoFETs have shown that electronic devices with nanoscopic features were able detect extra- and intracellular potentials from single cells but had also been limited to surface or near surface recording from tissue and organs(42,53). Merging electronics seamlessly throughout tissues (Figure 6a) had remained a major challenge. To address this challenge we recently set-forth the key constraints(66) include: (1) The electronic structures must be macroporous, not planar, to enable 3D interpenetration with biomaterials; (2) the electronic network should have nanometer to micrometer scale features comparable to biomaterial scaffolds; and (3) the electronic network must have 3D interconnectivity and mechanical properties similar to biomaterials (Figure 6b).

5.1. A new concept of merging electronics with cellular systems

Our fundamentally new approach integrates nanoelectronics into tissues in 3D, and the integrative synthetic approach involved stepwise incorporation of biomimetic and biological elements into nanoelectronic networks across nanometer to centimeter size scales(66) (Figure 6a). First, chemically synthesized kinked or uniform silicon nanowires were registered and electrically connected to yield FETs (step A, Figure 6a), forming the nanoelectronic sensor elements for hybrid biomaterials. Second, individual nanoFET devices were arranged and integrated into free-standing macroporous scaffolds (step B, Figure 6a), termed ‘nanoelectronic scaffolds’ (nanoES). The nanoES were tailored to be 3D, to have nanometer to micrometer features with high (>99 %) porosity, and to be highly flexible and biocompatible. NanoES could also be hybridized with biodegradable synthetic ECMs to enable suitable cellular microenvironments prior to tissue culture. Finally, cells were cultured inside nanoES or hybrid nanoES (step C, Figure 6a), with subsequent generation of biological species and the merging of cells with nanoelectronics in 3D. The entire

biomimetic process make a natural transition from electronic to biological systems by integrating the third component, nanoES, into the synthetic tissues (Figure 6c). Metal-electrode or carbon nanotube/nanofiber based passive detectors are not considered in our work because impedance limitations (*i.e.*, signal/noise and temporal resolution degrade as the area of the metal or carbon electrodes is decreased) make it difficult to reduce the size of individual electrodes to the subcellular level, a size regime necessary to achieve noninvasive 3D interface of electronics with cells in tissue.

5.2. Designs and preparation of synthetic tissues

In our experiments, we have designed two types of 3D macroporous nanoES (reticular- and mesh- nanoES) to mimic the structure of natural tissue scaffolds (Figure 7)(66). These nanoES were formed by self-organization of coplanar reticular networks with built-in strain (Figure 7a) and by manual manipulation of 2D mesh matrices (Figure 7b). We showed that nanoES exhibited robust electronic properties and could be used alone or seamlessly merged with other biomaterials as biocompatible extracellular scaffolds for efficient 3D culture of neurons, cardiomyocytes and smooth muscle cells (Figure 7c,d). Significantly, we have demonstrated multiplexed electrical recordings of extracellular field potentials from 3D nanoelectronic innervated cardiac patches, including the effects of drugs (Figure 7e,f). The results suggested the feasibility of continuous electrical monitoring of engineered tissue in 3D for *in vitro* therapeutic assays. Finally, we have used 3D distributed nanoelectronic devices for simultaneous monitoring of pH inside and outside an engineered tubular vascular construct that was developed from the nanoelectronic scaffold, suggesting the potential of a multifunctional prosthetics.

5.3. Challenges and promises

These results open up a new field whereby nanoelectronics are merged with biological systems in 3D, and as in any nascent area opportunities and challenges abound. For example, the sensing capabilities could be broadened to address various disease states, *in vitro* (organ-on-a-chip) or *in vivo*(125) by exploiting the diverse nanowire building blocks available from designed synthesis. Cell or tissue interactions with nanoES could be fine-tuned by modification with cell growth determinants(121). NanoES could be enhanced to provide electrical and mechanical stimulation to enhance cell culture; *in vivo* these properties could provide functionalities such as pacing, and moduli that match those of host tissues. Long-term *in vivo* biocompatibility of nanoES should be studied. One can envision nanoES-based tissues that are hard-wired to provide closed-loop systems that sense and treat, that enable telemetric monitoring of physiological processes, or that provide connections between engineered constructs with the host nervous system.

6. WHAT'S NEXT?

The challenges associated with nanotechnology applications in biomedical sciences are numerous, but the impact on understanding how the cardiac or nervous systems work, how they fails in disease and how we can intervene at a nanoscopic or even a molecular level is significant. For example, neural developmental factors, such as the cadherins, laminins and bone morphometric protein families, as well as their receptors, could be manipulated in new ways(126). The bottom-up nanowire nanotechnology offers the capacity to explore the functional specificity of these molecules by incorporating them into pre-defined locations in nanowire devices to have highly targeted effects towards single cells.

The merging of nanoelectronics or nanoscience in general with the entire fields of synthetic biology and/or system biology(46,47) is also tempting and could be highly rewarding. This would be one of the next big leaps in materials sciences and biological sciences. It is

especially true given that there's a whole toolbox of nanoelectronic and nanophotonic devices that one can think about building into cellular circuitry and merging them with biological information processing systems, and the fact that we have already achieved the intracellular interrogation(31) and the 3D electrical innervation of tissues(66) with semiconductor nanoelectronics!

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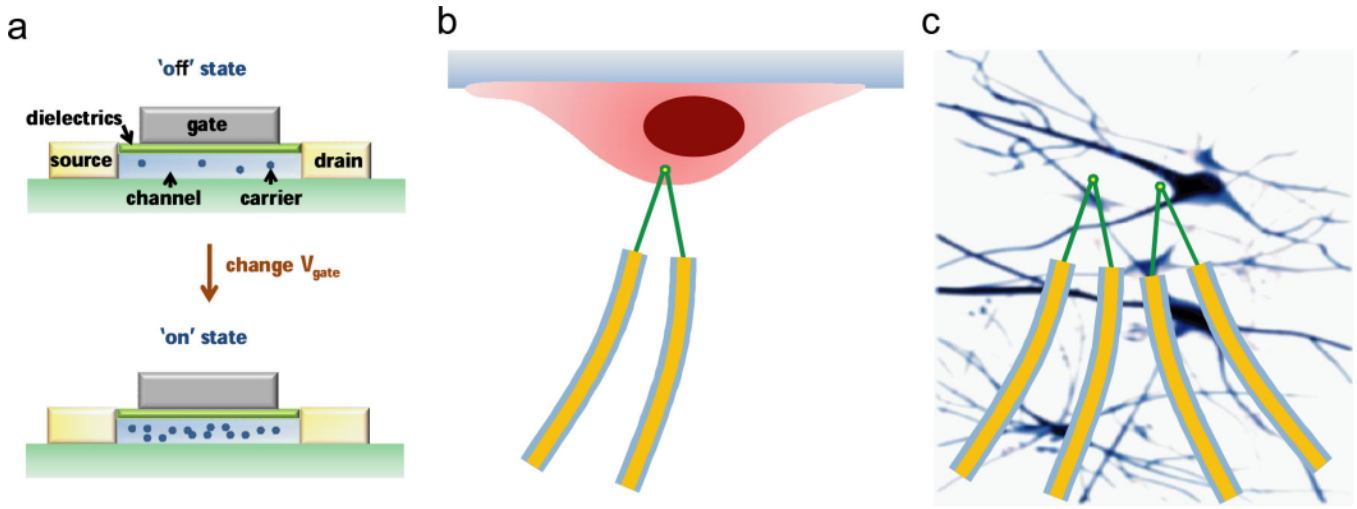


Figure 1. FET basics and electrical interfaces between nanoFET and biological systems

(*a*) Schematic of a planar FET device. In FET, current flows along a semiconductor path called the channel. At one end of the channel, there is an electrode called the source. At the other end of the channel, there is an electrode called the drain. The third electrode that applies a voltage to the channel is called gate, which modulates the electron/hole carrier density and the output of the FET devices. A small voltage change in gate signal can cause a large variation in the current from the source to the drain. This is how FET works and in particular, amplifies signals. (*b-c*) Schematics of electrically based cellular sensing using a kinked nanoFET, where intracellular potentials (*b*) or extracellular field potentials (*c*) can be used to change the nanoFET conductace, analogous to applying a voltage using a gate electrode.

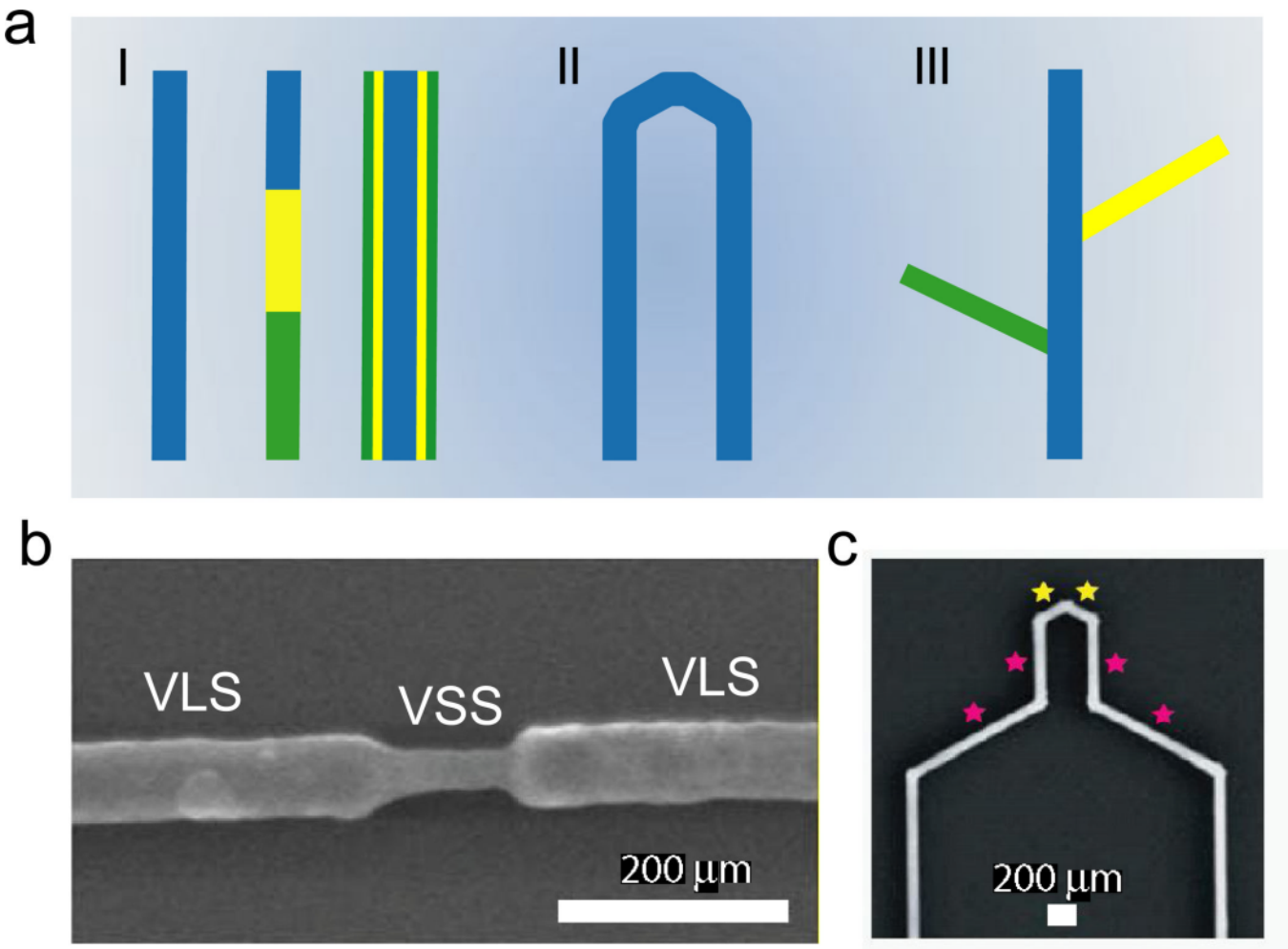


Figure 2. Semiconductor nanowire structural motifs for nanoFETs

(*a*) Schematics of 1D (I), 2D (II) and 3D (III) motifs. 1D motif (I) can have uniform composition and doping (I, left) or axially (I, middle) or radially (I, right) modulated. A kinked nanowire with structurally coherent "kinks" introduced in a controlled manner during axial elongation represents an example of 2D motif (II). Heterobranched nanowires yield 3D structure (III) and the branch junction (*e.g.*, blue/yellow segment junction) can be exploited for localized sensing. (*b*) An axial nanowire heterostructure made by modulation in VLS/VSS growth mechanisms. (*c*) A multiply kinked nanowire showing a probe structure. Yellow and magenta stars denote *cis*- and *trans*- conformations, respectively.

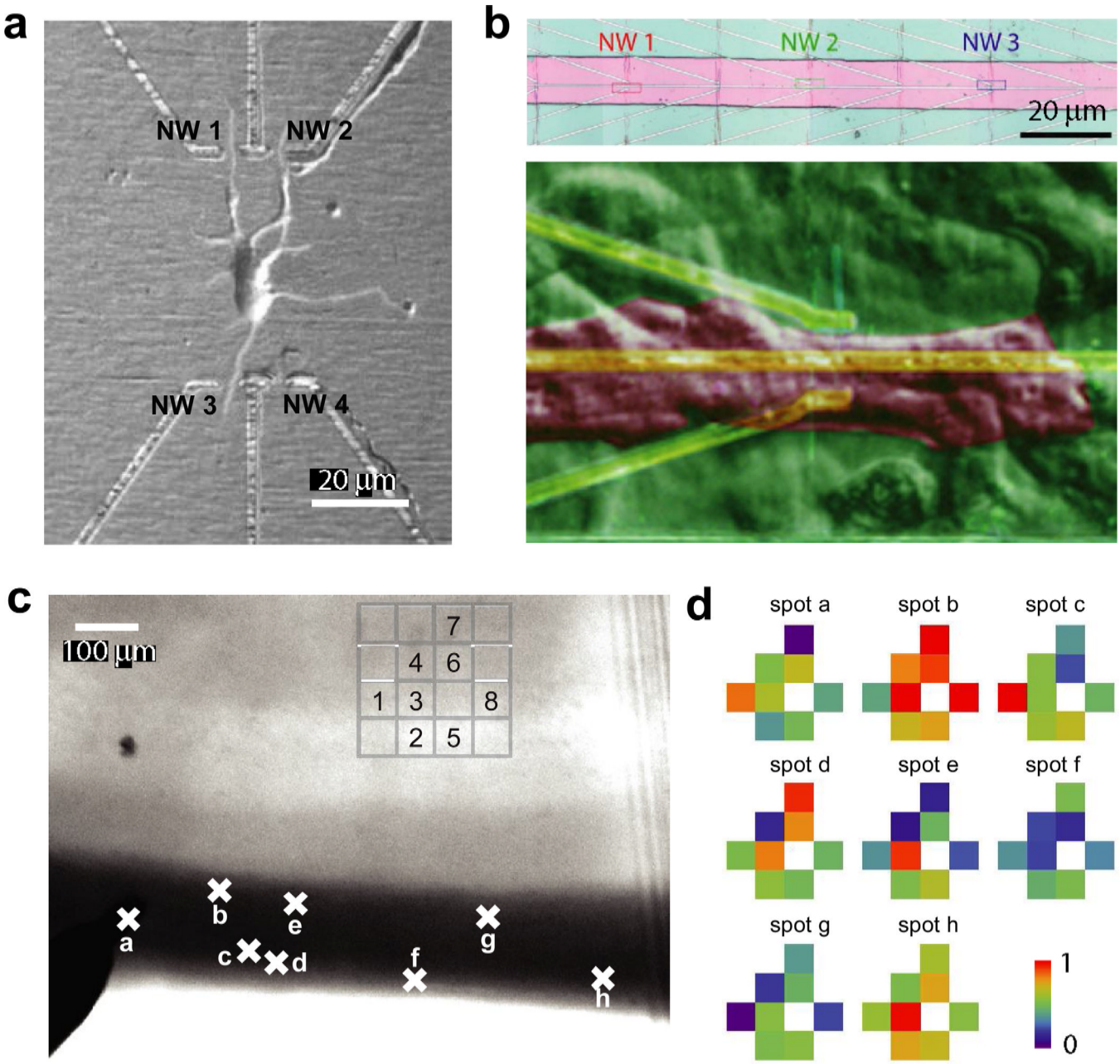


Figure 3. Multiplexed extracellular electrical recordings using nanoFETs

(*a*) Optical image of a cortical neuron interfaced to three of the four functional nanoFETs in an array. (*b*) upper panel, optical micrograph showing three nanoFET devices (NW1, NW2, and NW3) in a linear array, where pink indicates the area with exposed NW devices. Lower panel, a differential interference contrast bright field image showing individual cardiomyocytes (purple) and single nanoFETs (yellow). (*c*) Optical image of an acute slice over a 4 × 4 NWFET array. Signals were recorded simultaneously from the eight devices indicated on the image. Crosses along the LOT fiber region of the slice mark the stimulation spots *a–h*. The stimulator insertion depth was not controlled precisely in these experiments. (d) Maps of the relative signal intensity or activity for devices 1–8.

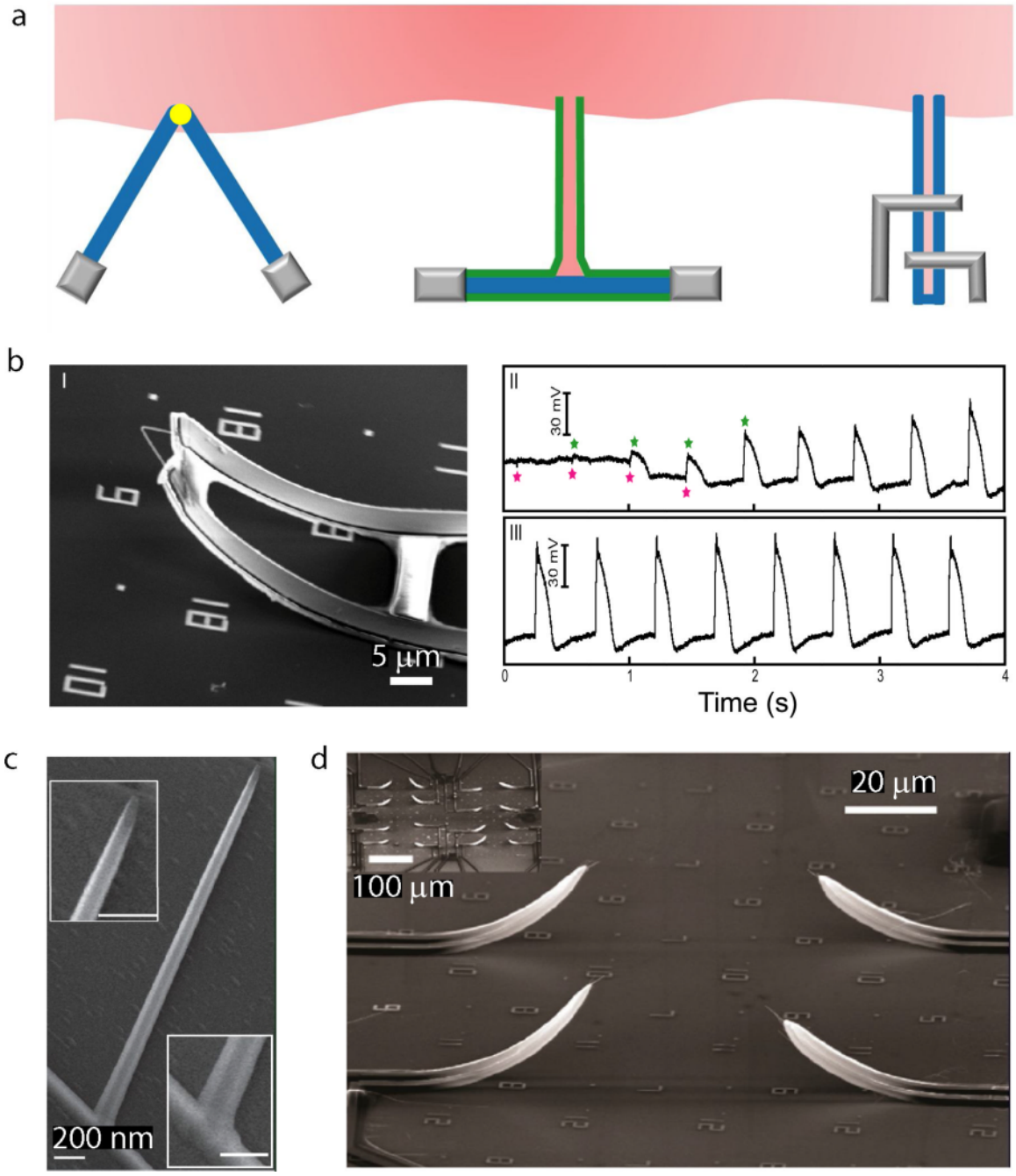
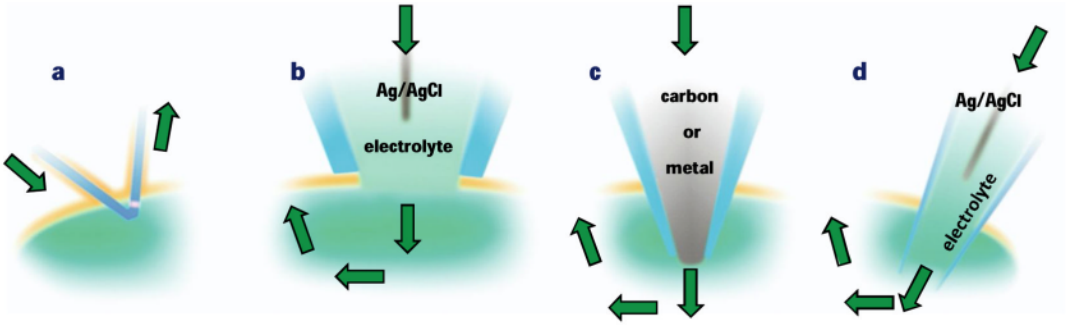


Figure 4. Intracellular electrical recordings using nanoFETs

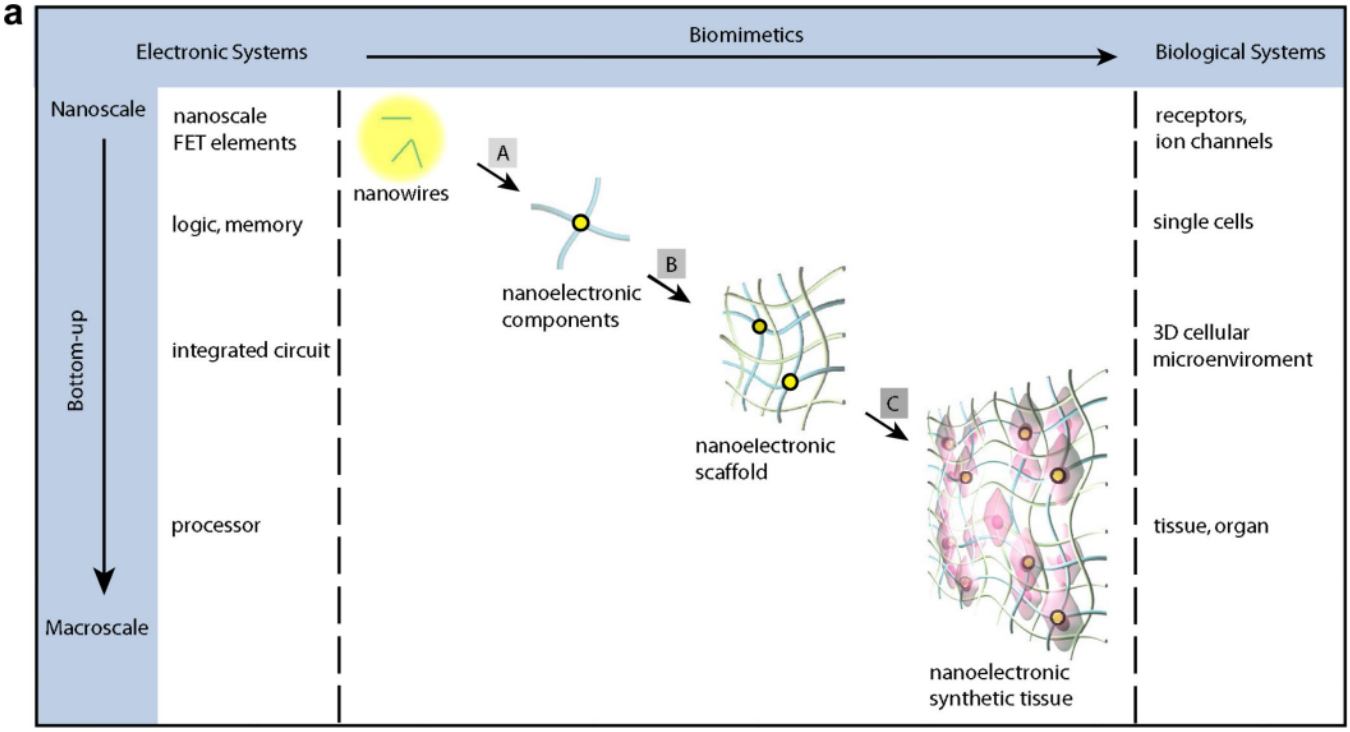
(*a*) Schematics of kinked nanoFET (left), BIT-FET (middle) and ANTT (right) probes. (*b*) SEM image of a kinked nanoFET probe (I) and its intracellular electrical recordings (II, III) from spontaneously beating cardiomyocytes. (*c*) SEM of a BIT-FET probe, insets highlight the tip and root parts of the hollow branch. (*d*) SEM image of ANTT probe array.



IC technique	Equivalent circuit	Size (nm)	Calibrations	Capabilities	Invasiveness	Cellular entrance
Glass micropipette (b and d)	EXTERNAL MEMBRANE INTERNAL Rs Rm Cm Rj Cj Cm Vm	~ 50-5000 Impedance limited	Both amplitude and shape	Can record both current and voltage, Single ion channel to whole cell recording	Electrochemical and mechanical	Mechanical or electrical
Carbon or metal micro-/nano-electrode (c)		~500-1000 Impedance limited	Both amplitude and shape	Can record both current and voltage, Whole cell recording	Electrochemical and mechanical	Mechanical or electrical
nanoFET (a)	EXTERNAL MEMBRANE INTERNAL Rs Rs Vm	~10-100	Amplitude	Can only record voltage, Whole cell recording, Multiplexing is scalable, High spatiotemporal resolutions	Minimal	Biological

Figure 5. A comparison between kinked nanoFET probe (a) and conventional intracellular tools (b–d)

The green arrows in (a–d) indicate the current flows. R_s, series resistance; R_j, junction resistance; R_m, membrane resistance; V_m, intracellular potential; C_j, junction capacitance; C_m, membrane capacitance.



b

	Targets	Approaches	Implementation Examples	Steps		
Biomimetics	Composition	+ Synthetic polymer	Deposit PLGA, alginate	A	B	
		+ Natural polymer	Add or secrete collagen, polysaccharides		B	C
		+ Cellular species	Biosynthesize proteins and lipids			C
		- Electronic materials	Reduce silicon, metals, dielectrics	A	B	
	Structure	+ Porosity	Increase to > 90%	A	B	
		- Feature size	Decrease to sub-micrometer	A	B	
	Mechanics	+ Flexibility	Decrease bending stiffness to < 10 nN·m	A	B	C
		+ Stretchability	Use serpentine device designs	A	B	C
	Bio-functions	+ Morphogenesis	Enable cell growth and proliferation			C
		+ Other Signalings	Activate ECM cues		B	C
		- Cytotoxicities	Use biocompatible materials	A	B	

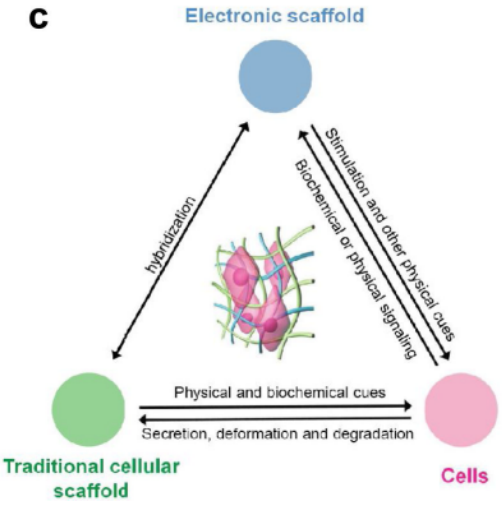


Figure 6. Integrating nanoelectronics with cells and tissue

Conventional bulk electronics are distinct from biological systems in composition, structural hierarchy, mechanics and function. Their electrical coupling at the tissue/organ level is usually limited to the tissue surface, where only boundary or global information can be gleaned unless invasive approaches are used. (*a*) A new concept was introduced where an integrated system can be created from discrete electronic and biological building blocks (for example, semiconductor nanowires, molecular precursors of polymers and single cells). Three biomimetic and bottom-up steps have been designed: step A, patterning, metallization and epoxy passivation for single-nanowire FETs; step B, forming 3D nanowire FET matrices (nanoelectric scaffolds) by self or manual organization and hybridization with traditional ECMs; step C, incorporation of cells and growth of synthetic tissue through biological processes. Yellow dots: nanowire components; blue ribbons: metal and epoxy

interconnects; green ribbons: traditional ECMs; pink: cells. (*b*) Rationale and approaches for biomimetic implementation of nanoelectronics innervated synthetic tissues. A, B and C are the same steps used in (*a*). (*c*) The new electronic scaffold component in synthetic tissues enables additional interactions with traditional cellular scaffold and cells.

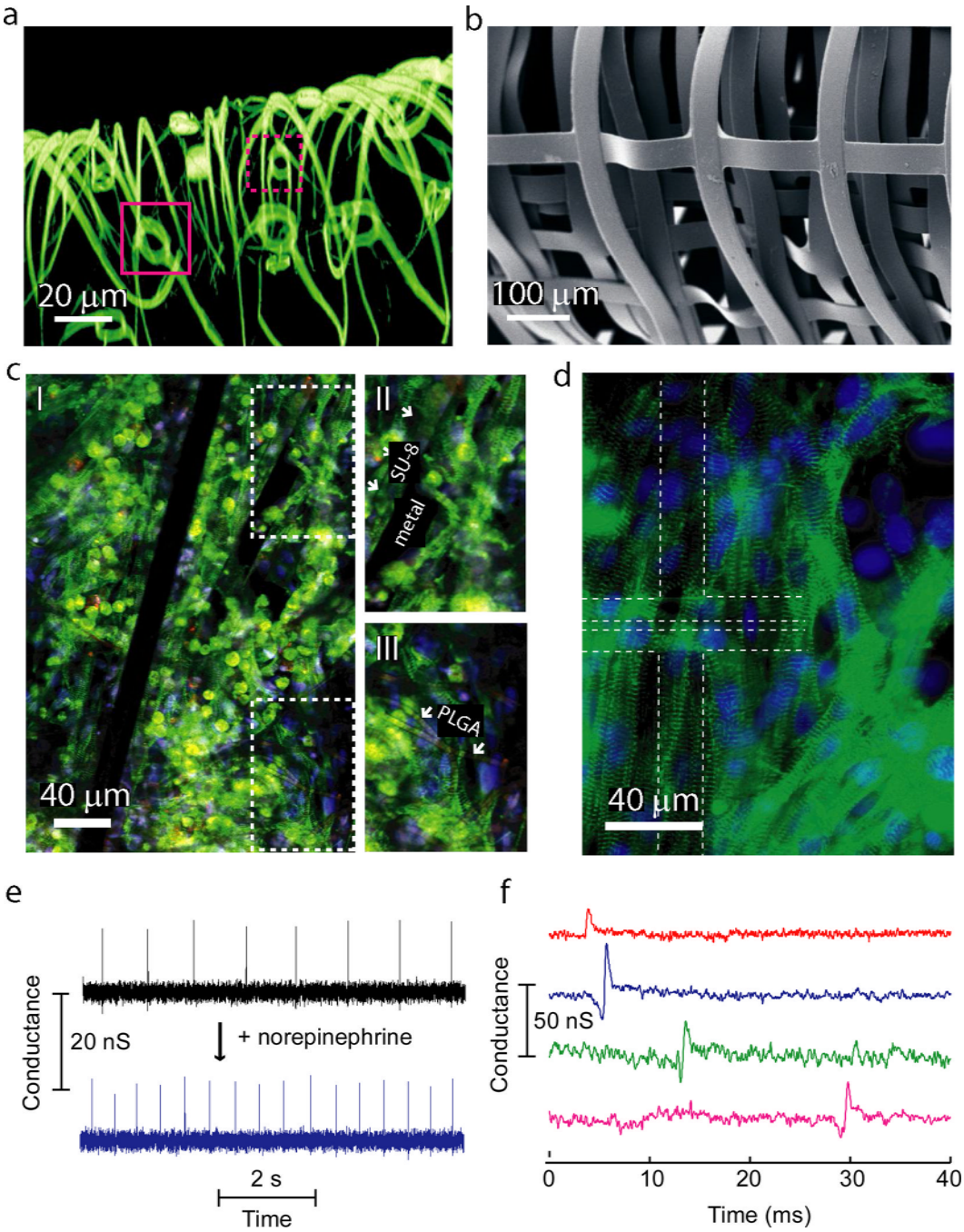


Figure 7. NanoES and synthetic tissues

(*a*) 3D reconstructed confocal fluorescence micrographs of reticular nanoES. The scaffold was labelled with rhodamine 6G. Solid and dashed open magenta squares indicate two nanowire FET devices located on different planes. (*b*) SEM image of a loosely packed mesh nanoES, showing the macroporous structure. (*c*) Confocal fluorescence micrographs of a synthetic cardiac patch. (II and III), Zoomed-in view of the upper and lower dashed regions in I, showing metal interconnects, the SU-8 scaffold (arrows in II) and electrospun PLGA fibres (arrows in III). (*d*) Epi-fluorescence micrograph of the surface of the cardiac patch. Green (Alexa Fluor 488): α-actin; blue (Hoechst 34580): cell nuclei. The position of the source–drain electrodes is outlined with dashed lines. (*e*) Conductance versus time traces

recorded from a single-nanowire FET before (black) and after (blue) applying noradrenaline. (*f*) Multiplex electrical recording of extracellular field potentials from four nanowire FETs in a mesh nanoES. Data are conductance versus time traces of a single spike recorded at each nanowire FET.

SHORT WAVE

Harvard Professor's Arrest Raises Questions About Scientific Openness

February 19, 2020 · 4:00 AM ET

GEOFF BRUMFIEL

Harvard University professor Charles Lieber leaves the Moakley Federal Courthouse in Boston late last month.

Charles Krupa/AP

Until late last month, Charles Lieber lived the quiet life of an elite American scientist. His lab at Harvard University researched things like how to meld tiny electronics with the brain. In his spare time, he grew award-winning pumpkins in front of his house.

EXHIBIT 17

SHORT WAVE

Harvard Professor's Arrest Raises Questions About Scientific Openness

February 19, 2020 · 4:00 AM ET

GEOFF BRUMFIEL

"This is a big, big case," says Frank Wu, a professor at the University of California Hastings College of the Law who tracks Chinese espionage cases. "This is a case that's all about U.S.-China relations. It's about competition. It's about how science should be done."

Calendar No. 577

114TH CONGRESS
2D SESSION

S. 2967

[Report No. 114–306]

To amend the Homeland Security Act of 2002 to require the Office of Management and Budget to execute a national biodefense strategy, and for other purposes.

IN THE SENATE OF THE UNITED STATES

MAY 23, 2016

Mr. JOHNSON (for himself and Mrs. ERNST) introduced the following bill; which was read twice and referred to the Committee on Homeland Security and Governmental Affairs

AUGUST 30, 2016

Reported under authority of the order of the Senate of July 14, 2016, by Mr. JOHNSON, with amendments and an amendment to the title

[Omit the part struck through and insert the part printed in italic]

A BILL

To amend the Homeland Security Act of 2002 to require the Office of Management and Budget to execute a national biodefense strategy, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

EXHIBIT 18

SECTION 1. SHORT TITLE.

This Act may be cited as the ''National Biodefense Strategy Act of 2016''.

SEC. 2. BIODEFENSE STRATEGY.

(a) IN GENERAL.—Title V of the Homeland Security Act of 2002 (6 U.S.C. 311 et seq.) is amended by adding at the end the following:

''SEC. ~~526~~ *527*. NATIONAL BIODEFENSE STRATEGY.

''(a) DEFINITIONS.—In this section—

''(1) the term 'biodefense' means any involvement in mitigating the risks of major biological incidents and public health emergencies to the United States, including with respect to—

''(A) threat awareness;

''(B) prevention and protection;

''(C) surveillance and detection;

''(D) response and recovery; and

''(E) attribution of an intentional biological incident;

~~''(2) the term 'biodefense enterprise' means the programs, projects, activities, and resources across the Federal Government that are involved in biodefense;~~

''~~(3)~~*(2)* the term 'Council' means the Biodefense Coordination Council established under subsection (b); ~~and~~

"(3) the term 'Federal biodefense enterprise' means the programs, projects, activities, and resources across the Federal Government that are involved in biodefense; and

"(4) the term 'Strategy' means the National Biodefense Strategy required to be established under subsection (b)(5).

"(b) BIODEFENSE COORDINATION COUNCIL.—

"(1) ESTABLISHMENT.—The President shall establish a Biodefense Coordination Council, which shall be comprised of, at a minimum—

"(A) the Secretary of Health and Human Services;

"(B) the Secretary of Agriculture;

"(C) the Secretary of Defense;

"(D) the Secretary ~~of Homeland Security~~;

"(E) the Secretary of State;

"(F) the Director of National Intelligence; and

"(G) the Administrator of the Environmental Protection Agency.

"(2) DUTIES.—The Council shall—

"(A) provide the expertise necessary to develop the Strategy; and

"(B) in coordination with the Office of Management and Budget, review, prioritize, and align necessary biodefense activities and spending across the Federal Government, in a manner consistent with the Strategy.

"(3) ROTATING CHAIR.—During the 4-year period beginning on the date on which the Council is established, and each 4-year period thereafter, each of the 4 Secretaries described in subparagraphs (A) through (D) of paragraph (1) shall serve as the chairperson for the Council for 1 year. The first chairperson of the Council shall be the Secretary of Health and Human Services.

"(4) PRESIDENT'S ANNUAL BUDGET.—The recommendations of the Council shall inform the budget submitted by the President under section 1105 of title 31, United States Code, with respect to biodefense activities.

"(5) STRATEGY.—The President shall develop a National Biodefense Strategy to direct and align the inter-governmental and multi-disciplinary efforts of the Federal Government towards an effective and continuously improving biodefense enterprise, including threat awareness, prevention and protection, sur-

veillance and detection, and response and recovery to major biological incidents.

"(c) COORDINATION.—

"(1) COUNCIL.—In developing the Strategy, the President shall utilize the Council.

"(2) OTHER AGENCIES.—In developing the Strategy, the President may utilize—

"(A) the Secretary of Commerce;

"(B) the Attorney General; and

"(C) any other Federal department ~~or agency the President determines appropriate~~, *agency, or interagency body the President determines appropriate, including the Public Health Emergency Medical Countermeasures Enterprise*.

~~"(3) PRIVATE SECTOR ENTITIES.—The President may receive input on elements of the Strategy from private sector biodefense entities.~~

"(3) OTHER ENTITIES.—The President may receive input on elements of the Strategy from private sector biodefense entities and State, local, tribal, and territorial governments.

"(4) ACADEMIC INSTITUTIONS.—The President may receive input on elements of the Strategy from academic institutions.

"(d) COORDINATION WITH EXISTING STRATEGIES.—The Strategy shall serve as a comprehensive guide for United States biodefense that directs and harmonizes all other strategies or plans established or maintained by a Federal department or agency with respect to biodefense.

"(e) CONTENTS.—

"(1) REQUIREMENTS.—The Strategy shall include, at a minimum—

"(A) a comprehensive description of the entities and positions of leadership with responsibility, authority, and accountability for implementing, overseeing, and coordinating Federal biodefense activities described in subsection (b)(5), including a description of how such entities coordinate on each aspect of biodefense;

~~"(B) a review of current and previous collaborative efforts between the Armed Forces and the civilian sector of the Federal Government on biodefense activities and coordination;~~

~~"(C) a detailed analysis of the—~~

~~"(i) relevant recommendations issued by external biodefense review panels or commissions, and the extent to which the recommendations have been considered and~~

~~implemented by Federal departments and agencies;~~

~~"(ii) lessons learned from the response of the Federal Government to public health emergencies occurring within the 5 years preceding the submission of the strategy;~~

~~"(iii) risks associated with major biological incidents;~~

~~"(iv) resources and capabilities needed to address identified risks;~~

~~"(v) resource and capability gaps in the biodefense enterprise, including gaps in—~~

~~"(I) each category of biodefense activity described in subsection (a)(1);~~

~~"(II) identification and research of emerging biological threats;~~

~~"(III) programs, projects, and activities in effect before the date of enactment of this section;~~

~~"(IV) strategies and implementation plans related to biodefense activities in effect before the date of enactment of this section;~~

~~"(V) the ability to reallocate Federal resources to address risks posed by emerging biological threats; and~~

~~"(VI) meeting the needs of vulnerable populations during the response to and recovery from a public health emergency; and~~

~~"(vi) prioritization and allocation of investment across the biodefense enterprise;~~

"~~(D)~~*(B)* 5-year goals, priorities, and metrics to improve and strengthen the ability of the Federal Government to prevent, detect, respond to, and recover from a major biological incident;

"~~(E)~~*(C)* short- and long-term research and development projects or initiatives planned to improve biodefense capability; and

"~~(F)~~*(D)* recommendations for legislative action needed to expedite progression toward the goals identified in the Strategy.

"(2) CONSIDERATIONS.—In developing the Strategy, the President may consider—

"(A) the trade-offs made between differing goals and requirements, due to constraints in

expected assets and resources over the time period of such goals and requirements; and

"(B) any other analysis the President determines appropriate.

"(3) ANALYSIS.—The Strategy shall include an appendix, which shall contain—

"(A) a review of current and previous collaborative efforts between the Armed Forces and the civilian sector of the Federal Government on biodefense activities and coordination;

"(B) a detailed analysis of the—

"(i) relevant recommendations issued by external biodefense review panels or commissions, and the extent to which the recommendations have been considered and implemented by Federal departments and agencies;

"(ii) lessons learned from the response of the Federal Government to public health emergencies occurring within the 5 years preceding the submission of the strategy;

"(iii) risks associated with major biological incidents;

"(iv) resources and capabilities needed to address identified risks; and

"(v) resource and capability gaps in the Federal biodefense enterprise, including gaps in—

"(I) each category of biodefense activity described in subsection (a)(1);

"(II) identification and research of emerging biological threats;

"(III) programs, projects, and activities in effect before the date of enactment of this section;

"(IV) strategies and implementation plans related to biodefense activities in effect before the date of enactment of this section;

"(V) the ability to reallocate Federal resources to address risks posed by emerging biological threats; and

"(VI) meeting the needs of vulnerable populations during the response to and recovery from a public health emergency; and

"(C) prioritization and allocation of investment across the Federal biodefense enterprise.

"(f) DEADLINE.—Not later than 24 months after the date of enactment of this section and ~~notwithstanding~~ *in*

accordance with subsection (k), the President shall submit the Strategy to the Committee on Homeland Security and Governmental Affairs of the Senate and the Committee on Homeland Security of the House of Representatives.

"(g) STATUS UPDATES.—Not later than 180 days after the date of enactment of this section, and every 180 days thereafter until the date on which the Strategy is submitted to the congressional committees described in subsection (f), the President shall submit to such congressional committees an update on the status of the Strategy.

"(h) REQUIREMENT.—~~Notwithstanding~~ *In accordance with* subsection (k), the Strategy shall be made available on a public Internet website.

"(i) FIVE-YEAR UPDATE.—Beginning 5 years after the date on which the Strategy is submitted to the congressional committees described in subsection (f), and not less frequently than every 5 years thereafter, the President shall update the Strategy.

"(j) ANNUAL BIODEFENSE EXPENDITURES REPORT.—

"(1) IN GENERAL.—Not later than 30 days after the date on which the President submits a budget to Congress under section 1105 of title 31, United States Code, the President shall submit to the appropriate congressional committees a report

detailing the total amount of expenditures on biodefense activities by all Federal departments and agencies *and how the expenditures relate to the goals and priorities required under subsection (e)(1)(B)*.

"(2) REQUIREMENT.—The first report submitted under paragraph (1) shall provide historical context by detailing the total amount of expenditures on biodefense for the 3 preceding fiscal years, in addition to the fiscal year requirements for the fiscal year covered by the report.

"(k) CLASSIFIED ANNEX.—To the fullest extent possible, any reports required to be made publicly available under this section shall be unclassified, but may include classified annexes that shall be submitted concurrently to the congressional homeland security committees.".

(b) TABLE OF CONTENTS.—The table of contents in section 1(b) of the Homeland Security Act of 2002 (6 U.S.C. 101 note) is amended by inserting after the item relating to section ~~525~~ *526* the following:

"Sec. ~~526~~*527*. National Biodefense Strategy.".

Amend the title so as to read: "A bill to amend the Homeland Security Act of 2002 to require the President to execute a national biodefense strategy, and for other purposes.".

Calendar No. 577

114TH CONGRESS
2D SESSION

S. 2967

[Report No. 114–306]

A BILL

To amend the Homeland Security Act of 2002 to require the Office of Management and Budget to execute a national biodefense strategy, and for other purposes.

AUGUST 30, 2016

Reported with amendments and an amendment to the title

The New York Times | https://www.nytimes.com/2021/04/05/us/covid-vaccine-evangelicals.html

White Evangelical Resistance Is Obstacle in Vaccination Effort

Millions of white evangelical adults in the U.S. do not intend to get vaccinated against Covid-19. Tenets of faith and mistrust of science play a role; so does politics.

By Elizabeth Dias and Ruth Graham

Published April 5, 2021 Updated April 6, 2021

Stephanie Nana, an evangelical Christian in Edmond, Okla., refused to get a Covid-19 vaccine because she believed it contained "aborted cell tissue."

Nathan French, who leads a nondenominational ministry in Tacoma, Wash., said he received a divine message that God was the ultimate healer and deliverer: "The vaccine is not the savior."

Lauri Armstrong, a Bible-believing nutritionist outside of Dallas, said she did not need the vaccine because God designed the body to heal itself, if given the right nutrients. More than that, she said, "It would be God's will if I am here or if I am not here."

The deeply held spiritual convictions or counterfactual arguments may vary. But across white evangelical America, reasons not to get vaccinated have spread as quickly as the virus that public health officials are hoping to overcome through herd immunity.

The opposition is rooted in a mix of religious faith and a longstanding wariness of mainstream science, and it is fueled by broader cultural distrust of institutions and gravitation to online conspiracy theories. The sheer size of the community poses a major problem for the country's ability to recover from a pandemic that has resulted in the deaths of half a million Americans. And evangelical ideas and instincts have a way of spreading, even internationally.

There are about 41 million white evangelical adults in the U.S. About 45 percent said in late February that they would not get vaccinated against Covid-19, making them among the least likely demographic groups to do so, according to the Pew Research Center.

"If we can't get a significant number of white evangelicals to come around on this, the pandemic is going to last much longer than it needs to," said Jamie Aten, founder and executive director of the Humanitarian Disaster Institute at Wheaton College, an evangelical institution in Illinois.

As vaccines become more widely available, and as worrisome virus variants develop, the problem takes on new urgency. Significant numbers of Americans generally are resistant to getting vaccinated, but white evangelicals present unique challenges because of their complex web of moral, medical, and political objections. The challenge is further complicated by longstanding distrust between evangelicals and the scientific community.

"Would I say that all public health agencies have the information that they need to address their questions and concerns? Probably not," said Dr. Julie Morita, the executive vice president of the Robert Wood Johnson Foundation and a former Chicago public health commissioner.

No clear data is available about vaccine hesitancy among evangelicals of other racial groups. But religious reasoning often spreads beyond white churches.

EXHIBIT 19

Vice President Kamala Harris met with religious leaders recently, urging them to encourage their communities to take the Covid-19 vaccine. Chip Somodevilla/Getty Images

Many high-profile conservative pastors and institutional leaders have endorsed the vaccines. Franklin Graham told his 9.6 million Facebook followers that Jesus would advocate for vaccination. Pastor Robert Jeffress commended it from an anti-abortion perspective on Fox News. ("We talk about life inside the womb being a gift from God. Well, life outside the womb is a gift from God, too.") The president of the Southern Baptist Convention, J.D. Greear, tweeted a photo of himself receiving a shot.

But other influential voices in the sprawling, trans-denominational movement, especially those who have gained their stature through media fame, have sown fears. Gene Bailey, the host of a prophecy-focused talk show on the Victory Channel, warned his audience in March that the government and "globalist entities" will "use bayonets and prisons to force a needle into your arm." In a now-deleted TikTok post from an evangelical influencer's account that has more than 900,000 followers, she dramatized being killed by authorities for refusing the vaccine.

Dr. Simone Gold, a prominent Covid-19 skeptic who was charged with violent entry and disorderly conduct in the Jan. 6 Capitol siege, told an evangelical congregation in Florida that they were in danger of being "coerced into taking an experimental biological agent."

The evangelical radio host Eric Metaxas wrote "Don't get the vaccine" in a tweet on March 28 that has since been deleted. "Pass it on," he wrote.

Some evangelicals across ethnicity believe that any Covid restrictions — including mask mandates and restrictions on in-person church worship — constitute oppression.

And some have been energized by what they see as a battle between faith and fear, and freedom and persecution.

"Fear is the motivating power behind all of this, and fear is the opposite of who God is," said Teresa Beukers, who said she is Mexican-American and travels throughout California in a motor home. "I violently oppose fear."

The Coronavirus Outbreak ›

Latest Updates ›
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- Migrant workers again flee India's cities as new lockdowns bite.
- Pfizer and BioNTech requested the F.D.A.'s authorization to use their vaccine in 12- to 15-year-olds.
- Vaccine passports could bring back international travel, in some cases at the risk of discrimination.

Ms. Beukers foresees severe political and social consequences for resisting the vaccine, but she is determined to do so. She quit a job at Trader Joe's when the company insisted that she wear a mask at work. Her son, she said, was kicked off his community college football team for refusing Covid testing protocols.

"Go ahead and throw us in the lions' den, go ahead and throw us in the furnace," she said, referring to two biblical stories in which God's people miraculously survive persecution after refusing to submit to temporal powers.

Jesus, she added, broke ritual purity laws by interacting with lepers. "We can compare that to people who are unvaccinated," she said. "If they get pushed out, they'll need to live in their own colonies."

One widespread concern among evangelicals is the vaccines' ties to abortion. In reality, the connection is remote: Some of the vaccines were developed and tested using cells derived from the fetal tissue of elective abortions that took place decades ago.

The vaccines do not include fetal tissue, and no additional abortions are required to manufacture them. Still, the kernel of a connection has metastasized online into false rumors about human remains or fetal DNA being an ingredient in the vaccines.

Some evangelicals see the vaccine as a redemptive outcome for the original aborted fetus.

The Vatican has said that vaccines are "morally acceptable," and Catholics in America are much less likely than white evangelicals to say they won't get vaccinated. Pope Francis visited a vaccination site in the Vatican on Friday. Vatican Media

Some Catholic bishops have expressed concerns about the abortion link, too. But the Vatican has concluded the vaccines are "morally acceptable," and has emphasized the immediate danger posed by the virus. Just 22 percent of Catholics in America say they will not get the vaccine, less than half the share of white evangelicals who say that.

White evangelicals who do not plan to get vaccinated sometimes say they see no need, because they do not feel at risk. Rates of Covid-19 death have been about twice as high for Black, Hispanic, and Native Americans as for white Americans.

White pastors have largely remained quiet. That's in part because the wariness among white conservative Christians is not just medical, but also political. If white pastors encourage vaccination directly, said Dr. Aten, "there are people in the pews where you've just attacked their political party, and maybe their whole worldview."

Dr. Morita, of the Robert Wood Johnson Foundation, said the method to reach white evangelicals is similar to building vaccine confidence in other groups: Listen to their concerns and questions, and then provide information that they can understand from people they trust.

But a public education campaign alone may not be enough.

There has been a "sea change" over the past century in how evangelical Christians see science, a change rooted largely in the debates over evolution and the secularization of the academy, said Elaine Ecklund, professor of sociology and director of the Religion and Public Life Program at Rice University.

There are two parts to the problem, she said: The scientific community has not been as friendly toward evangelicals, and the religious community has not encouraged followers to pursue careers in science.

Distrust of scientists has become part of cultural identity, of what it means to be white and evangelical in America, she said.

For slightly different reasons, the distrust is sometimes shared by Asian, Hispanic and Black Christians, who are skeptical that hospitals and medical professionals will be sensitive to their concerns, Dr. Ecklund said.

"We are seeing some of the implications of the inequalities in science," she said. "This is an enormous warning of the fact that we do not have a more diverse scientific work force, religiously and racially."

Among evangelicals, Pentecostal and charismatic Christians may be particularly wary of the vaccine, in part because their tradition historically emphasizes divine health and miraculous healing in ways that can rival traditional medicine, said Erica Ramirez, a scholar of Pentecostalism and director of applied research at Auburn Seminary. Charismatic churches also attract significant shares of Black and Hispanic Christians.

Dr. Ramirez compares modern Pentecostalism to Gwyneth Paltrow's Goop, with the brand's emphasis on "wellness" and "energy" that infuriates some scientists: "It's extra-medical," she said. "It's not anti-medical, but it decenters medicine."

The Centers for Disease Control and Prevention and Dr. Anthony Fauci are not going to be able to persuade evangelicals, according to Curtis Chang, a consulting professor at Duke Divinity School who is leading an outreach project to educate evangelicals about the vaccine.

The project includes a series of short, shareable videos for pastors, answering questions like "How can Christians spot fake news on the vaccine?" and "Is the vaccine the Mark of the Beast?" The latter refers to an apocalyptic theory that the Antichrist will force his sign onto

everyone at the end of the world.

These are questions that secular public health entities are not equipped to answer, he said. “The even deeper problem is, the white evangelicals aren’t even on their screen.”

Mr. Chang said he recently spoke with a colleague in Uganda whose hospital had received 5,000 vaccine doses, but had only been able to administer about 400, because of the hesitancy of the heavily evangelical population.

“How American evangelicals think, write, feel about issues quickly replicates throughout the entire world,” he said.

At this critical moment, even pastors struggle to know how to reach their flocks. Joel Rainey, who leads Covenant Church in Shepherdstown, W.Va., said several colleagues were forced out of their churches after promoting health and vaccination guidelines.

Politics has increasingly been shaping faith among white evangelicals, rather than the other way around, he said. Pastors’ influence on their churches is decreasing. “They get their people for one hour, and Sean Hannity gets them for the next 20,” he said.

Mr. Rainey helped his own Southern Baptist congregation get ahead of false information by publicly interviewing medical experts — a retired colonel specializing in infectious disease, a church member who is a Walter Reed logistics management analyst, and a church elder who is a nurse for the Department of Veterans Affairs.

On the worship stage, in front of the praise band’s drum set, he asked them “all of the questions that a follower of Jesus might have,” he said later.

“It is necessary for pastors to instruct their people that we don’t always have to be adversaries with the culture around us,” he said. “We believe Jesus died for those people, so why in the world would we see them as adversaries?”

Editors’ Note: April 6, 2021
An earlier version of this article included a photograph of an anti-vaccine protest in Atlanta. Although some protesters carried signs featuring Bible verses, the event was organized by a group that is not religiously affiliated.

Editors’ Note: April 6, 2021
This article was updated to include Teresa Beukers’ ethnicity.

Elizabeth Dias covers faith and politics from Washington. She previously covered a similar beat for Time magazine. @elizabethjdias

Ruth Graham is a national correspondent covering religion, faith and values. She previously reported on religion for Slate. @publicroad

A version of this article appears in print on , Section A, Page 1 of the New York edition with the headline: White Evangelical Resistance Is Obstacle in Vaccination Effort

MILITARY TECHNOLOGY SOCIAL MEDIA

DARPA to 'exploit social media, messaging & blog data' to track geopolitical influence campaigns

If abused, the data exploitation could end up serving geopolitical influences in its own right: perspective

Tim Hinchliffe 4 months ago no comment darpa , geopolitics , military technology , pentagon , perspective , social media monitoring

EXHIBIT 20

POPULAR RECENT

Better Announ Launc Of New Yoga App, Addin To Its Expar Portfo Of Health And Fitnes Apps

3 years ago

From bad to good: Chang the lives of the forme incarc

The power to monitor, track, and potentially quash online campaigns before they become popular is getting a whole lot easier.

With the goal of detecting geopolitical influence campaigns while they are still evolving, DARPA is looking to exploit data from social media, messaging, online blogs, and digital news sources with a new research program.

And today, the Defense Advanced Research Projects Agency (DARPA) held an invite-only proposers day on Zoom to go over its new INfluence Campaign Awareness and Sensemaking (INCAS) program.

> "INCAS will exploit primarily publicly-available data sources including multilingual, multi-platform

> social media (e.g. blogs, tweets, messaging), online news sources, and online reference data sources" — DARPA

The INCAS research program is aimed at detecting, categorizing, and tracking online geopolitical influence campaigns, including those that fly under the radar of most analysts, while simultaneously looking to reduce the influence of cognitive biases, such as confirmation bias, in the process.

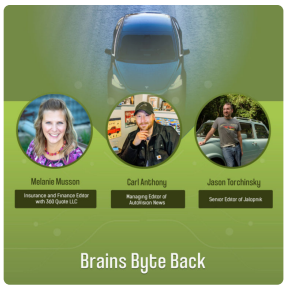
To achieve its goals, "INCAS will exploit primarily publicly-available data sources including multilingual, multi-platform social media (e.g. blogs, tweets, messaging), online news sources, and online reference data sources," according to the INCAS special notice.

If ever politicized, this type of DARPA-funded research could end up becoming its own antithesis — a geopolitical influence campaign in its own right.

DARPA has been funding research into monitoring social media and online news sources for a long time now, and big tech companies like Google, Twitter, and Facebook openly embrace this tactic with every type of coordinated inauthentic behavior removal update they give.

Back in 2011, DARPA launched the Social Media in Strategic Communication (SMISC) program "to help identify misinformation or deception campaigns and counter them with truthful information" on social media.

Sound familiar with what's happening on social media news feeds today?



Are Fully Autonomous Vehicles Fast Approaching?
In July 2020, speaking via video at the World Artificial Intelligence Conference in Shanghai, Elon Musk stated that[...]

> "The INfluence Campaign Awareness and Sensemaking program will develop techniques and tools that enable analysts to detect, characterize, and track geopolitical influence campaigns with quantified confidence" — DARPA

While DARPA serves to advance the capabilities of the US military, the technology developed often has a way of breaking-in to the private sector somewhere down the road.

For example, "DARPA-funded research [...] has led to the development of both military and commercial technologies, such as precision guided missiles, stealth, the internet, and personal electronics," according to a March 17, 2020 Congressional Research Service Overview report.

Are Fully Autonomous Vehicles Fast Approaching?
MARCH 2, 2021 · Sam Brake Guia

The Silk Road (Psychology After Dark)
FEBRUARY 23, 2021 · Sam Brake Guia

How To Unlock Your Creativity With Fun-Based Neuroscience Techniques
FEBRUARY 16, 2021 · Sam Brake Guia

How To Retain More Information, Improve Recall & Learn A New Language
FEBRUARY 9, 2021 · Sam Brake Guia

Bitcoin FOMO: How Our Psychology Drives The Price Of Bitcoin
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Changing The 'Chatter' Of Our Inner Voice From Destructive To

Curtis Hougland

Recently, it was reported that DARPA-incubated tech — which was originally developed for combating ISIS propaganda — was overtly politicized by a Political Action Committee (PAC) founded by an ex-DARPA contractor to target and monitor the president of the United States, although DARPA said the claim was misleading.

Back in May, the *Washington Post* reported that the Defeat Disinfo PAC, founded by Curtis Hougland, was "using open-source technology initially incubated with funding from DARPA," and that it was "in service of a domestic political goal — to combat online efforts to promote President Trump's handling of the coronavirus pandemic."

Following publication of *Washington Post* story that was later picked up by *FOX News*, DARPA issued a statement on Twitter saying that "Hougland's claim DARPA funded the tech at the heart of his political work is grossly misleading," and that the agency was "apolitical."

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Gregg Re @gregg_re · May 4, 2020
Dems deploying DARPA-funded information warfare AI-driven tool to target pro-Trump accounts fxn.ws/2z3bpdN #FoxNews

Dems deploying DARPA-funded AI-d...
An anti-Trump Democratic-aligned political action committee advised by...
foxnews.com

DARPA
@DARPA

Hougland's claim DARPA funded the tech at the heart of his political work is grossly misleading. He advised briefly on ways to counter ISIS online. He was not consulted to design AI or analysis tools, nor certainly anything remotely political. DARPA is strictly apolitical.

1:25 PM · May 4, 2020

46 75 Copy link to Tweet

Additionally, a DARPA spokesperson told *FOX News*, "Unequivocally, DARPA funding did not help advance the technology with which Hougland now works any more than does his use of other agency technologies like the internet or mobile phone."

The narrative remains; however, that "Hougland had received funding from DARPA [...] to assist in the

propaganda fight against ISIS, which had developed a small but sophisticated content machine that exploited social networks to amplify its vision," according to *Vanity Fair*.

Hougland would later found an AI startup called Main Street One, along with a Political Action Committee that leveraged his own startup's technology in a way that appears to be very similar to what he allegedly saw at DARPA.

His startup, Main Street One, aims "to win narratives online for campaigns, causes, and companies," according to a section of its mission statement.

> *"INCAS is not specifically focused on detecting misinformation or bot activity" — DARPA*

Now, DARPA is set to launch the INCAS program, which "will develop techniques and tools that enable analysts to detect, characterize, and track geopolitical influence campaigns with quantified confidence"
using automated influence detection across social media, digital media, and other online data sources.

If DARPA's INCAS program is successful in achieving its goals, the technology it develops would have the power to detect influence campaigns that are often overlooked by analysts because they get so little traffic.

DARPA says that these "'low and slow' campaigns are hard to detect early as their message volume may be beneath platform trending thresholds."

The research program "is *not* specifically focused on detecting misinformation or bot activity, as influence

campaigns may exploit a variety of tactics and true information, but should be able to exploit such signals from extant capabilities to aid in detecting influence messaging," according to the special notice.

Theoretically, DARPA's INCAS program could create technology that would allow analysts to detect and take action against online movements before they get a chance to grow.

Whether online campaigns be nefarious or benign, the power to monitor, track, and quash them before they gain popularity is getting a whole lot easier.

Facebook's Portal born out of Pentagon-inspired Building 8

Facebook has a new hardware product called Portal, a video sharing device which has Amazon's voice assistant Alexa built-in, and it is the first physical product released from Building 8. The breach of 50 million Facebook user accounts and a loss of $11 billion didn't stop Facebook CEO Mark Zuckerberg from today launching the presale ... Continue reading

DARPA looks to predict future real-world events with AI

DARPA is looking for AI projects that can understand what's going on in the world and then use that understanding to predict the future. The Defense Advanced Research Projects Agency (DARPA) seeks to create a schema-based AI capability to enable contextual and temporal reasoning about complex real-world events in order to generate actionable understanding of these events ... Continue reading

The Sociable 0

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DEFENSE ADVANCED
RESEARCH PROJECTS AGENCY

Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)

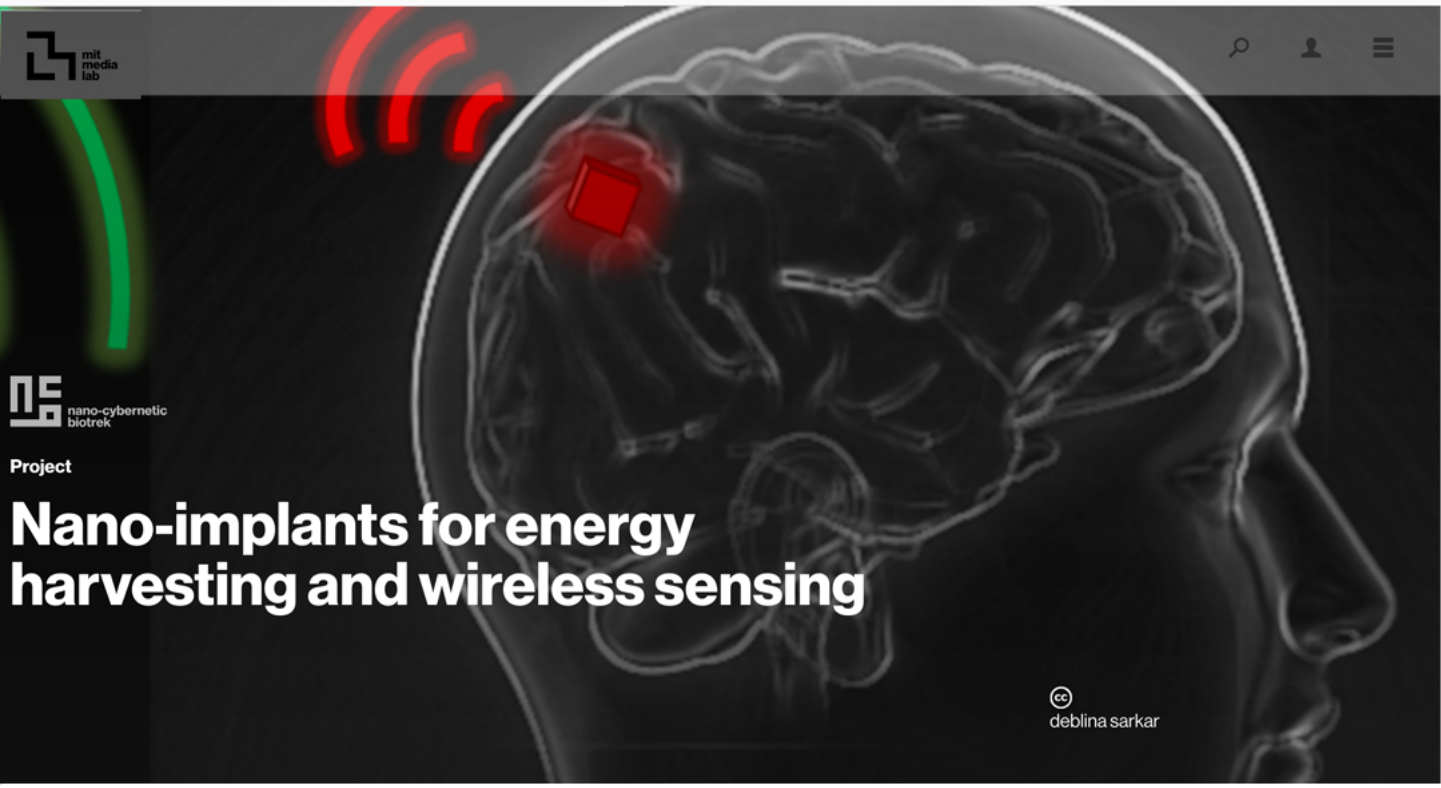
Dr. Amy Jenkins

The Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program supports individual troop readiness and total force health protection by developing technologies to rapidly identify and respond to threats posed by natural and engineered diseases and toxins. A subset of ADEPT technologies specifically support use by personnel with minimal medical training, delivering centralized laboratory capabilities even in the low-resource environments typical of many military operations. The program is part of a portfolio of DARPA-funded research aimed at providing options for preempting or mitigating constantly evolving infectious disease threats.

The ADEPT program's four thrusts cover simple-to-use, on-demand diagnostics for medical decision-making and accurate threat-tracking; novel methods for rapidly manufacturing new types of vaccines with increased potency; novel tools to engineer mammalian cells for targeted drug delivery and in vivo diagnostics; and novel methods to impart near-immediate immunity to an individual using antibodies.

ADEPT has pioneered use of nucleic-acid-based anti-infective technologies, valuable for their efficacy and adaptability. These tools—primarily coded genetic instructions to the body on how to produce its own protective antibodies against a specific threat—have the advantages of being easily manufactured at scale using largely synthetic processes, transported and stored without many of the cold-chain logistics required by traditional medical countermeasures, delivered with near-immediate efficacy, and safely expressed in the body for only a limited duration, causing no permanent alteration to the genome.

EXHIBIT 21



For more details and recent updates visit: https://web.mit.edu/deblina-sarkar/

We are developing **nano-devices using meta-materials** that can **non-invasively and remotely monitor** and modulate our biological system. The requirements of the system are: 1) they should be as small as possible such that the volume displacement of tissue due to the placement of the device is minimal, and 2) they should be **untethered/wireless** such that they can be remotely controlled. Such a device will sense the biological environment and send the information to a system outside the body in real time. The device will also have the capability to do internal analysis of the sensed data and depending on the analysis results, take further action such as electrical stimulation or drug delivery. The device will **harvest energy from external applied fields** for its functioning and also **modulate the external fields for communicating** sensed data.

The possibilities with such bioelectronic devices are endless, and we are exploring, among others, brain activity recording at a large scale with the precision of a single neuron, activity recording in spinal cord and peripheral nervous systems, monitoring tumor microenvironment, observing response to pathology development or external stimulus at a single cell level, along with integrated functionalities such as stimulation and drug delivery.

EXHIBIT 22

Research Topics

#synthetic biology #nanoscience