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.
_____/

PLAINTIFF'S OPPOSITION TO DEFENDANT SCHEIN's MOTION TO DISMISS

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Plaintiff, Dr. Leonard G Horowitz, hereby submits his opposition to Defendant Henry Schein's Motion to Dismiss the Complaint. Plaintiff meets the standards governing the form of a complaint contemplated by Federal Rule of Civil Procedure 8(a), this Court has subject matter jurisdiction in this matter, and the Complaint sufficiently alleges harm and damage to Plaintiff. Accordingly, Defendant Schein's Motion should be denied.

I. INTRODUCTION

Beginning in the 1980s to the present, the Department of Defense 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) the Defense Advance Research Projects Agency ("DARPA") "hit" upon the idea of using modified "nanogels" to conduct electricity through biologic tissue. This alleged DARPA derived science, provided renewed hope to a languishing "bioelectronic" industry, that a solution to bridge the gap between biology and electronics was indeed possible. (**Exhibit 1**)

With DARPA seed financing assured, University researchers and transnational corporations began work to develop the modified "hydrogel" industry (MHI). 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 MHI. Proponents and critics agreed, being "human" would no longer be scientifically definable. This controversial biosynthesis was termed "transhumanism."

Plaintiff became aware of Defendants' transhumanist agenda in 2019, but his focus stayed on utilizing his religiously-inspired product, "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 and his Judeo-Christian ministry.

Plaintiff had published at length on the use and abuse of bioelectronic frequencies. But it was not until 2019-2021 that Plaintiff realized Defendants were not only intending to misuse and disparage healing frequencies of sound and light, such as 528Hz/nm (i.e., a "key" frequency in bioelectronics and "intelligent design"), but intended to combine that misuse into vaccine hydrogels using nano-silver and structured water, as Horowitz had pioneered doing in 2006 through 2008.

Defendants' misuse of the Creator's "intelligent design" goes to the heart of Plaintiff's divinely-inspired works in health science and clinical care; and it now triggers Plaintiff's prophetic warning of what will occur if this technology is not deployed in service to humanity's free and natural sustainability.

Therefore, this lawsuit is Plaintiff's best effort to inform the Court how Defendants' actions have specifically injured his religious ministry, as well as to warn the

world how Defendants' godless approach to biosynthesis, if not curtailed, will have dire consequences.

II. STATEMENT OF FACTS

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^{TM} with 528" that pioneered a new paradigm in clinical care and commerce.

OxySilver^{TM} with 528 featured 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 drugs when desired.

Moreover, Horowitz's decision to energize the sH_2O with expressly the 528Hz/nm frequency of sound and light to bio-energetically empower his remedies merged medicine and religion, biophysics and spirituality, challenging the pharmaceutical industry to invest heavily in similar research and developments beginning nearly a decade or more later.

Plaintiff's products 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) basis in structuring organic molecules and chemistry; Plaintiff's businesses, products, and practices. This fact is confirmed textually 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 trademarked best-sellers that have been quoted widely by such luminaries as President Obama's minister, Reverend Jeremiah Wright.

Plaintiff's "528 Radio Network", with more than a dozen stations broadcasting different genres of music transposed into the frequency of 528Hz, is enjoyed by a large and growing international audience. The free service (at 528Radio.com) is claimed to be "therapeutic" and advertises "OxySilver^{TM} with 528" as a "Holy Water." From Horowitz's Bible and scientific studies, the Plaintiff claims "528" is the "key of the house of David" (Isaiah 22:22; Rev. 3:6-8) to which King David tuned his "healing harp."

Contrary to naysayers and skeptics, leading drug industrialists, including Defendants Schein, Pfizer and Moderna, are increasingly researching and developing products (such as modified ag-hydrogel composites) which are based on the frequencies of sound and light to accomplish therapeutic outcomes, and compete directly against the Plaintiff's commercial interests. (See: **Exhibits 2 - 5**.)

Defendant Schein's CEO, Stanley Bergman, is personally aware of Plaintiff's religious beliefs, publications, and Plaintiff's novel bioelectronic products and health oriented educational services, since Plaintiff engaged in multiple conversations on this subject with Mr. Bergman, his company president, Jimmy Breslawski, and director of new product acquisitions and marketing, Gail Koenigsburg.

Plaintiff avers Defendant Bergman (Schein) determined to crush Plaintiff's alternative narrative in the healthcare industry, including bioelectronic (a.k.a., "biospiritual") alternatives to hydrogels and pharmaceuticals. Additionally, in order to maintain a secular (i.e. "scientific") marketing narrative, Schein, in concert with media partner Hearst, engaged in a series of preemptive attacks against Plaintiff personally, religiously, and commercially, resulting in the deprivation of Plaintiff's constitutional

right to the free exercise of his religion, including 'religious commerce' advancing the bioelectronic/biospiritual product OxySilver™ with 528.

These preemptive attacks by Schein and its partner, Hearst Media, are evidenced in:

1. *Global News* (Hearst's partner with owner Corus). The **Exhibit 6** article smeared Horowitz and his 528Hz frequency-based 'medicinal music' on May 13, 2018.

2. *Forbes* magazine, on December 10, 2016 attacked Plaintiff's religion and religious-based natural products were specifically identified and disparaged.[1] (**Exhibit 7**)

3. *WIRED* magazine (Conde Naste Health Pharma and joint-venturer with Hearst) on February 9, 2016 in which Defendants state their intention to infiltrate and disrupt Plaintiff's activities. (**Exhibit 8**)

4. *Popular Mechanics* (Hearst Media) attack on August 17, 2016 in which Plaintiff was disparaged ad hominem and OxySilver™ with 528 misrepresented. (**Exhibit 9**)

Defendants Schein and Hearst jointly operate Schein's Health Care Division, utilizing Schein's MicroMD® Patient Portal and Hearst's First DataBank ("FDB").(**Exhibit 10**)

[1] On December 10, 2016, Forbes revised and referenced Hearst's *Popular Mechanic*s feature article. Forbes embellished Hearst's coverage publishing that Horowitz is "trying to sell treatments that compete with existing treatments approved and supported by legitimate government agencies such as the Food and Drug Administration (FDA) and the scientific community." To the contrary, Horowitz draws from the scientific community to advance novel products that compete against pharmaceuticals. Forbes added, "Len Horowitz" "describes himself as the "King of Natural Healing." That is false. The Plaintiff has never described himself as the "King of Natural Healing." Horowitz has been described by others as the "King David of Natural Healing." Forbes intentionally deleted the reference to "King David" to deny Horowitz's religious identity, divert from Horowitz's 528 bio-electric "key of the house of David" musical revelations, and offend others leading the natural healing community. *Forbes* also disparaged, Horowitz "has been trying to sell an herbal cream that he claims will make skin cancer fall off your body in less than 3 weeks." That is false. The referenced product is a "black salve," not a cream. Further, the salve has been successfully used by health professionals internationally for more than a century to prompt immunological rejections of otherwise growing, potentially deadly, skin cancers. (See: **Exhibit 7**)

According to *Wikipedia*, FDB Hearst is integral to Schein's pharmacy dispensing, formulary management, drug pricing analysis, claims processing, computerized physician order entry (CPOE), electronic health records (EHR), electronic medical records (EMR), electronic prescribing (e-Prescribing), electronic medication administration records (EMAR), population health and telemedicine/telehealth. (https://en.wikipedia.org/wiki/First_Databank)

MicroMD, in combination with Hearst's FDB, provides the core functionality for Schein's data management division (Technology and Value Added Services) central to Schein's marketing of its bioelectronic products competitive with Plaintiff. (See: https://www.henryscheinsolutionshub.com/ product/micromd/)

In addition, according to Businesswire.com, both Schein (Cardinal Health Inc.) and Hearst Health Ventures worked in tandem to jointly finance Aver Inc. Aver's strategic patent for a simplified healthcare reimbursement process have provided Schein and its financial partner, Hearst Health Ventures, with the data platform capability to wrest market share from Plaintiff and similarly situated small and mid-market competitors.[2]

In this way, Defendant Schein, Hearst Media, and Galvani BioElectrics/Pfizer/GSK, (**Exhibits 1- 5**) through their interlocking agents and publications (*WIRED* magazine/Conde Nast/Hearst Media/Popular Mechanics/*Forbes*/Forbes Health Summit, inter alia, acted to: (a) hide their conspiracy in attacking Plaintiff; (b) represent as "novel" their approach to therapies featuring Plaintiff's pioneering work to develop and market bioelectronic nano-silver products featuring structured H_2O and (c) subvert Plaintiff's evolutionary "528" frequency water

[2] See: https://www.businesswire.com/news/home/20200109005738/en/Cox-Enterprises-Invests-in-Aver%E2%80%99s-27M-Series-C-to-Accelerate-Implementation-and-Execution-of-Value-based-and-Bundled-Payments-Programs

memory technology for their own nefarious purposes with respect to modified hydrogel composites *inter alia*.

Plaintiff also alleges that based on his employment with Henry Schein, Schein, as well as Schein's Defendant partners, had personal knowledge of Plaintiff's businesses, knew Plaintiff's approach to ag-hydrogel modification was alternative to their own, and have engaged and continue to engage in a conspiracy utilizing the resources and inter-connections of the Pandemic Supply Chain Network to destroy Plaintiff's business reputation, religious practice, and livelihood. Defendants' published invectives, masquerading as objective reviews of Plaintiff's products, explicitly target Plaintiff's religious identity, doctrine, and commerce. (See footnote 1.)

It is Plaintiff's contention that Defendants' interference with Plaintiff's religious commerce was not due to Plaintiff's opposition to traditional vaccine platforms (as Plaintiff initially surmised), but for the purpose of marginalizing Plaintiff's alternative to silver-hydrogel technology. In this way, Defendants' conspired to minimize Plaintiff's ability to impact their carefully constructed narrative, regarding the benefits of novel biologics (the genetic gateway to transhumanism), which Defendants knew was made possible by their conversion of Plaintiff's 528-resonating silver-hydrosol technology. This interference with the Plaintiff's reputability, commercial viability, and Christian-science narrative was vitally important for their upcoming roll out of Defendants' bioelectric nano-silver products featuring likewise engineered H_2O. Defendants' use of hydrogel-infused modified water and silver, bioelectrically transmitting frequencies of sound and light energy, effectively converts the Plaintiff's discoveries and intellectual property into Defendants' pharmaceutical-bioenergetic narrative. (See **Exhibits 11 – 13.**)

It is unreasonable to dismiss these facts and conspiratorial scheme because Defendant Schein, for no less than 14-years, has been actively involved in the marketing and distribution of bioelectric medicine. (**Exhibits 2-3**) In 2006, the year Horowitz first

integrated OxySilver^{TM} (bonding structured water with nano-silver and 528 frequency technologies) to serve as an electro-chemical immune-boosting anti-oxidant, Defendant Schein entered into an exclusive contract with BioElectric Corp to distribute Acti-Patch, advertised by Schein as "Advanced Bio-Electric Healing Technology" that applies "pulsed electromagnetic field therapy." (See: **Exhibit 2**, SEC, Registration No. 555-136602, Dec. 6, 2006)

Schein is also the current distributor of BioWave, a neurostimulator for pain relief. (**Exhibit 3**)

Both Acti-Patch and BioWave are primitive versions of what Defendants are advancing with silver-impregnated hydrogels--technology that is based on Plaintiff's unique approach to silver–hydrosol composites for "soft [tissue] electronics". Hydrogel functionality is akin to OxySilver's impact in 528-bioelectric-field therapies leveraging specific frequencies of sound and light that resonate within the hydrated matrix, that then message cells to repair.

While Defendant Schein wishes to characterize the focus of this lawsuit as limited to Covid 19 vaccines, the RFRA, 42 USC 1983 and FUDPTA questions arise out from Plaintiff's 2000 copyright on the text *Healing Codes for the Biological Apocalypse* (TX0005256671/ 2000-08-09; **Exhibit 14**) largely responsible for this bioelectric technology, and Plaintiff's three decades of research, writing, and product developments relating to bioelectric fields and therapies using nano silver-water bonding.

Though Plaintiff admits that at this time, Plaintiff's market share presents little concern to Defendants, Plaintiff's characterization of Defendants' mis-guided approach to bioelectrics constitutes an imminent and material threat to Defendants. The Plaintiff's large and growing international audience threatens Defendants' Pandemic Supply Chain Network's plan for the future of medicine, (**Exhibit 15**) which envisions the transition from a systemic molecular approach to targeted bioelectronic hydrogels. (**Exhibits 11** and **12**)

Pursuant to Title 42 U.S.C. § 1983 (2000), as detailed below, the year before the NBSA was enacted, and subsequent research by Harvard's Charles Lieber and his protégés converted Horowitz's OxySilver bioelectric nano-technology to commercial hydrogel applications, Defendant Schein founded the Global Pandemic Supply Chain Network (PSCN), and became this enterprise's leading United States coordinator. (**Exhibit 15**)

PSCN is a traditional bio-defense public function, and its effective establishment and functioning within the territory of the United States required and continues to require Schein's entanglement and entwinement with the Federal Government and the United States Department of Defense. (**Exhibit 15**)

It is also noteworthy that among Defendants Moderna and Pfizer's benefactors is the U.S. Defense Department's Defense Advanced Research Projects Agency (DARPA), that operates to a large extent covertly, due to concerns for "National Security." Though Defendants Hearst/Schein's attacks against Plaintiff began in "FY2016," it was not until 2019 (two months before the revealing "Event 201" coronavirus predictive programming conference involving Schein) when DARPA announced its funding of Profusa's hydrogel biosensors to detect disease outbreaks. (**Exhibit 16**) That prompted Plaintiff to consider the National Biodefense Strategy Act (NBSA) of 2016's connections to Moderna's and Pfizer's key hydrogel nano-silver bioenergizing technology that is generally concealed from public discourse. (See **Exhibits 17, 18 and 19**)

This lacking scientific transparency extends to federally-indicted Harvard professor 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 17**). **Exhibits 12 and 13** evidence Lieber's main area of research and developments in the field of silver-impregnated hydrogels. (**Exhibit 18**) Lieber played a key role in

developing silver-water hydrogels made to "meld tiny electronics with the brain," explained *NPR*. (**Exhibit 19**)

NBSA also authorized the Defense Department to engage academics and private corporations to initiate media campaigns targeting religious group leaders and their followers espousing alternatives to pharmaceutical narratives considered to be among the leading "risks associated with major biological incidents." National Security is purportedly threatened by the untrusting public, and this distrust was prioritized to be neutralized, as exemplified by Horowitz's persecution. (See: **Exhibit 20**)

Thus, Plaintiff alleges it is Defendants' strategy to disparage and bankrupt Plaintiff by maligning his religiously-informed and bio-spiritually oriented products, so if by some chance Plaintiff tried to defend himself and his enterprise in federal court, he would need to do so *pro se*, where the chance of surviving a motion to dismiss would be infinitesimal.

III. FEDERAL SUBJECT MATTER JURISDICTION

The subject matter of this case involves federal questions per 28 USC 1331 as Defendant Schein, under color of law, interfered with Plaintiff's free exercise of his religious beliefs in contravention of the 1st Amendment of the United States Constitution. Defendant has also caused Plaintiff injury by disparaging his religion, his religious products, and religious commerce, in violation of RFRA, a federal statute.

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 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)).

IV. FED. R. CIV. P. 8(a)(2)

Per Fed. R. Civ. P. 8(a)(2), Defendant Schein, in coordination with its partner and Co-Defendant Hearst Health,[3] and Conde Nast (*WIRED* magazine) published and continues to publish false disparaging information regarding Plaintiff's religious businesses and products. (See **Exhibit 8**) This public disparagement of Plaintiff, by Schein's partner Hearst Health, benefitting Schein's prospective bioelectronic hydrogel products (which competes for *mindshare* with Plaintiff's alternative), constitute violations of RFRA, 42 USC 1983 and FUDPTA and entitles Plaintiff to relief in this Article III court (42 U.S. Code CHAPTER 21B—RELIGIOUS FREEDOM RESTORATION, 42 U.S.C. § 1983, Unfair Trade Practices Act (FDUTPA), F.S. §§501.201 et seq.).

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 courts throughout Florida have consistently held, Twombly and Iqbal do not change the fundamental analysis that a district court engages in and 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

[3] Schein's partnership with Hearst Health is evidenced by **Exhibit 10**.

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 considered 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). The simplified notice pleading standard relies on liberal discovery rules and summary judgment motions to define disputed facts and to dispose of unmeritorious claims. See *Swierkiewicz,* 534 U.S. at 512. Indeed, courts have found that if the information sought by the motion is obtainable through discovery, the motion should be denied. See, e.g., *Towers Tenant Ass'n v. Towers Ltd. P'ship*, 563 F. Supp. 566, 569 (D.D.C. 1983) (denying motion for a more definite statement because details such as "dates, times, names and places" are "the central object of discovery, and need not be pleaded").

V. SCHEIN IS A STATE ACTOR ACTING UNDER COLOR OF LAW

As introduced above, Defendant Schein is a state actor based on 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.) These three exceptions justify treating the Defendant as the government itself, in this particular instance.

To reiterate, Defendant Schein, beginning in 2015, founded the Global Pandemic Supply Chain Network (PSCN) at the WEF, and is this enterprise's leading United States coordinator. PSCN is a traditional bio-defense public function, and its effective establishment and functioning within the territory of the United States, required and continues to require, Schein's entanglement and entwinement with the Federal Government and the United States Department of Defense. (**Exhibits 15** and **16**)

Quoting in relevant part a Businesswire press release sourced by Schein:

> The PSCN, co-founded by Henry Schein, is a public-private initiative that brings together the private sector and global organizations – including the World Health Organization, World Economic Forum, the United Nations World Food Programme, the World Bank, the U.S. Centers for Disease Control, UNICEF, and approximately 60 health care manufacturers and suppliers – to embrace . . . operational coordination for health care products to more effectively match global demand with global supply. . . . enabling the sharing of information and facilitating the ability of key stakeholders to navigate together the supply chain challenges caused by global pandemics. (**Exhibit 21**)

Defendant thus acts under color of law; and while acting under color of law, deprived Plaintiff of his constitutional right to the free exercise of his religion and religious commerce in competing bio-defense oriented products and services.

"Under the Color of State Law" in 42 U.S.C. section 1983 Title 42 U.S.C. liability is imposed on every person who, under the color of a statute, ordinance, or regulation, causes the deprivation of another's federally protected right. 42 U.S.C. § 1983 (2000).

Acting with the "authority of [the] state" applies to both governmental entities and private parties acting in concert with state officers to deprive another of their 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)).

VI. SCHEIN AND HEARST CONSPIRED TO SUBSTANTIALLY BURDEN PLAINTIFF'S FREE EXERCISE

Plaintiff alleges the existence of a conspiracy involving Schein and Hearst as co-conspiring state actors, and with other Defendants as parties to that conspiracy, that deprived Plaintiff's free exercise of religion.

"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).

A. FREE EXERCISE CLAUSE

The Free Exercise Clause provides that "Congress shall make no law . . . prohibiting the free exercise [of religion]."

"'[I]f the purpose or effect of a law is to impede the observance of one or all religions or is to discriminate invidiously between religions, that law is constitutionally invalid even though the burden may be characterized as being only indirect.'" *Sherbert v. Verner* 374 U.S. 398 (1963)

B. RFRA

(a) IN GENERAL

Government shall not substantially burden a person's exercise of religion even if the burden results from a rule of general applicability, except as provided in subsection (b).

(b) EXCEPTION Government may substantially burden a person's exercise of religion only if it demonstrates that application of the burden to the person—

(1) is in furtherance of a compelling governmental interest; and

(2) is the least restrictive means of furthering that compelling governmental interest.

Accordingly, RFRA provides that 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).

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) (recognizing that "'substantial burden' in RFRA is what the Supreme Court had in mind in its pre-Smith opinion in Jimmy Swaggart Ministries v. Bd. of Equalization, 493 U.S. 378, 384-85 (1990)").

1. Substantial Burden

Defendant Schein with Hearst, and their agents, acting in concert and under color of law, explicitly identified and targeted Plaintiff by name and specifically maligned Plaintiff's businesses, products, and religious beliefs in their national publications. Defendants actions, designed to attack Plaintiff's OxySilver™ with 528 frequency (an alternative approach to bioelectronic medicine) substantially burdened the central tenant of Plaintiff's religious belief and practice.

Defendant Schein/Hearst's intent to individually target and harm Plaintiff's OxySilver™ with 528HZ frequency is evidenced by:

1. An article in *Forbes Magazine*, published on December 10, 2016, that is linked to Hearst's *Popular Mechanics* article in which Plaintiff's religious products were specifically identified and disparaged.[4]

2. *WIRED Magazine* (on February 9, 2016 Defendant Hearst/Schein agent, "Researcher" Collin McRoberts of Stratfor Intelligence (aka "Shadow CIA") (https://www.huffingtonpost.ca/2013/12/15/stratfor-canadian-government_n_4449505.html published his intention to infiltrate and disrupt Plaintiff's activities. (**Exhibit 5**) *WIRED* owner's Conde Naste is in partnership with Hearst Media via PubWorX.

3. *Popular Mechanics* (Hearst Media) attack on August 17, 2016 in which Plaintiff was disparaged ad hominem with an anti-Semitic slur. (**Exhibit 6**)

4. *Global News* (Hearst Canadian partner) smearing of Horowitz and his 528Hz frequency-based 'medicinal music' on May 13, 2018. (**Exhibit 7**)

2. Defendants' Damaging Actions have been Continuous and are Ongoing.

Under the Religious Freedom Reform Act ("RFRA"), general laws burdening broadly-defined religious exercises must be: (1) supported by government's compelling interests; and (2) furthered through least restrictive means.

[4] Forbes Magazine's partnership in the Defendants' public/private enterprise is evidenced by **Exhibits 3 and 4**. Forbes falsely and disparagingly published on December 10, 2016, in an article titled, "Are Chiropractors Backing The Anti-Vaccine Movement?," that: "**Len Horowitz:** who describes himself as the "King of Natural Healing" and has been trying to sell an herbal cream that he claims will make skin cancer fall off your body in less than 3 weeks." Forbes linked this alleged libel to Hearst's *Popular Mechanics* feature article similarly disparaging Plaintiff, his Jewish identity, and his frequency-based religious commerce. (**Exhibit 3**)

Defendants Schein and Hearst cannot demonstrate any compelling state interest for their actions, nor can they justify those actions as the least restrictive method of mitigating some perceived harm from Plaintiff's religiously-inspired products. 42 U.S.C. § 1983

To state a claim under 42 U.S.C. § 1983, a plaintiff must establish two essential elements: (1) the conduct complained of was committed by a person acting under color of state law; and (2) the conduct deprived a person of rights, privileges, or immunities secured by the Constitution or laws of the United States. See *Blanton v. Griel Mem'l Psychiatric Hosp*., 758 F.2d 1540, 1542 (11th Cir. 1985). Plaintiffs here allege both elements.

VII. UNFAIR TRADE PRACTICES ACT (FDUTPA), F.S. §§501.201 et seq.

Defendant Schein subjected the Plaintiff to deceptive acts and unfair trade practices. There is causation between such acts or practices and the Plaintiff's damages. Plaintiff suffered actual damages with loss of health products' sales and disparaged religious commerce.

Defendants Schein's and Hearst's deceptive acts and unfair practices in violation of FDUTPA are ongoing and continuous and are being conducted with the intent to cause commercial injury to Plaintiff's businesses and goodwill in Florida, as the Defendants' violations have caused. These injuries include damage to business reputation and quantifiable loss of sales of "Oxysilver™ with 528" and other "528Hz/nm" product sales and services administered by the Plaintiff or his agents.

A. IRREPARABLE HARM TO PLAINTIFF

Plaintiff seeks relief to enjoin irreparable harm to his businesses, his reputation, and his free exercise of religion, caused by Schein in coordination with Defendant Hearst

by and through their ongoing and continuing public disparagement of Plaintiff's businesses, products and reputation.

B. PLAINTIFF CLAIMS NOT PREEMPTED BY FEDERAL LAW

Plaintiff brings his claims under RFRA, 42 USC 1983 and FDUTPA based on injuries he sustained personally to his religiously-inspired businesses, practices, and products (OxySilver™ and '528 frequency therapeutics,' inter alia).

VIII. STATUTE OF LIMITATIONS

At some point, after Schein, as well as co-Defendants Pfizer (aka GSK), Moderna and Hearst Health (in partnership with WIRED/Conde Nast Health (PubWorX)) became aware that Plaintiff's unique solution to bridging the gap between biology and electronics was the most viable option, Defendants began the development of their own products. Though Schein/Hearst, as well as the other Defendants, publicly mocked Plaintiff's products and ideational approach to ag- bioelectronic hydro therapy, it was not until 2019 that Plaintiff first became aware of Defendants' intent to integrate Plaintiff's technology into their products. It was only at this time, in the context of Defendants' publicly announced intent to use Plaintiff's ideational approach to link electronics to biology, that Defendants' actual malice, in falsely disparaging Plaintiff's body of work, became actionable.

IX. CONCLUSION

If Plaintiff's theories were simply irrational frivolous diatribe, as Defendants claim, why do they continue to attack him and his products by name in their major publications?

If Plaintiff's beliefs and practices could be so easily dismissed as "conspiracy theory," why have dozens of peer-reviewed scientific review panels accepted the Plaintiff's works for publication?

Moreover, if Plaintiff's pioneering water science discoveries, bioelectric theories, and clinical therapies enabled by frequency-emitting technologies (such as OxySilver™ with 528), are "fringe," "unfounded," and risky to the public, why are Defendant Schein and its partners developing similar products and services emulating Horowitz's original published discoveries?[5],[6]

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[5] Researchers at the Massachusetts Institute of Technology ("MIT") are working to confirm Plaintiff Horowitz's unique approach of combining silver-oxygen in water (OxySilver™) and "hydrogels" to administer 'frequency therapeutics.' This will enable researchers to "discover" the interface between biology and electronics, "blurring the boundary between humans and machines." See: Yuk H, Lu B and Zhao X. Hydrogel bioelectronics, In: *Chemical Society Reviews*: 6; 2019. This express purpose has been stated succinctly by Schein's PSCN founding partner Klaus Schwab, President of the World Economic Forum ("WEF").

[6] The Science: Bioelectronic interfacing with the human body including electrical stimulation and recording of neural activities is the basis of the rapidly-growing field of neuroscience and bioengineering, diagnostics, therapeutics, and wearable and implantable devices.

Owing to intrinsic dissimilarities between soft, wet, and living biological tissues and rigid, dry, and synthetic electronic systems, the development of more compatible, effective, and stable interfaces between these two different realms has been one of the most daunting challenges in science and technology.

Recently, hydrogels have emerged as a promising material candidate for the next-generation bioelectronic interfaces, due to their similarities to biological tissues and versatility in electrical, mechanical, and biofunctional engineering. In this review, we discuss (i) the fundamental mechanisms of tissue–electrode interactions, (ii) hydrogels' unique advantages in bioelectrical interfacing with the human body, (iii) the recent progress in hydrogel developments for bioelectronics, and (iv) rational guidelines for the design of future hydrogel bioelectronics. Advances in hydrogel bioelectronics will usher unprecedented opportunities toward ever-close integration of biology and electronics, potentially blurring the boundary between humans and machines.

To avoid the undesirable trade-off between mechanical and electrical properties in metal–hydrogel composites, metallic fillers are typically introduced in the form of nanoscale particles or fibers.[104,105] For example, silver nanowires (AgNWs) have been successfully incorporated into the poly(acrylamide) hydrogel to form highly flexible micropatterned electrode arrays[104] (Fig. 10A). The conductive silver provides superior electrical conductivity, and nanoscale interactions between highly flexible AgNWs and hydrogel polymer networks allow great flexibility and low mechanical modulus comparable to the original poly(acrylamide) hydrogel.[104]

In short, Plaintiff's Complaint complies with the pleading requirements of the Federal Rules of Civil Procedure, Rule 8(a), and provides Defendants fair notice of the charges against them and the grounds therefor. Discovery and argument will add further detail later.

Additionally, Plaintiff has sufficiently alleged harm, and this Court, as stated herein, has subject matter jurisdiction.

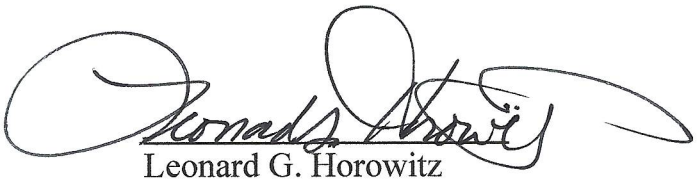
Finally, pro se Plaintiff is willing, should the Court find it necessary, to amend his Complaint in order to express these claims more succinctly and identify all actors and their connections with greater specificity. Plaintiff admits his Complaint is complex, but this complexity is not due to any fault of Plaintiff, but is the responsibility of Defendants', who have expertly hid their intentions and the object of their machinations. In fairness, Plaintiff pleads that this Court not reward Defendants for their inequity, by dismissing this Complaint and denying Plaintiff due process for the harm he has suffered.

Accordingly, for the reasons set forth herein, Plaintiff respectfully requests that the Court deny Defendant Schein's Motion to Dismiss the Complaint.

Respectfully submitted.

DATED: March 29, 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 Henry Schein, Inc.'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 21 are true and correct copies of the original documents in my possession.

Respectfully submitted.

DATED: March 29, 2021

/s Leonard G. Horowitz
Plaintiff, pro se

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that on this 29th day of March 2021, I filed a true and correct copy of the foregoing "Plaintiff's Opposition to Schein's Motion to Dismiss" including Exhibits 1 thru 21, 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
Ft. Myers Division U.S. Courthouse & Federal Building
2110 First St, Fort Myers, FL 33901
T: 239-461-2000

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 SCHEIN's MOTION TO DISMISS

EXHIBIT 1 –DARPA press release evidencing federal financing of bioelectronic hydrogels in health science, including mRNA vaccine developments by Moderna and Pfizer, published Feb. 6, 2019.

EXHIBIT 2 –Schein BioElectronics Distribution Agreement, SEC Registration No. 333-136602, filed Dec. 6, 2006.

EXHIBIT 3 –Schein advertisement of BioWavePRO Neurostimulator, March 28, 2021.

EXHIBIT 4 –Schein vaccine maker, Pfizer parent, Glaxo-Smith-Klein ("GSK") press release, heralding "GSK and Verily [Life Sciences (formerly Google Life Sciences), an Alphabet company] to establish Galvanai Bioelectronics – a new company dedicated to the development of bioelectronic medicines, August 1, 2016.

EXHIBIT 5 –Press release: Frequency Therapeutics company started by Pfizer former CEO, March 31, 2017.

EXHIBIT 6 –Hearst/Corus *Global News* article smears 528Hz and industry pioneer Horowitz, published May 13, 2018.

EXHIBIT 7 –*Forbes*/Hearst article smears Horowitz, products, and religious convictions, published Dec. 10, 2016.

EXHIBIT 8 –*WIRED*/Hearst article written by McChrystal Group agent and self-proclaimed infiltrator at "Conspiracy-sea conference", Colin McRoberts, Feb. 9, 2016, smearing the assemblage including Horowitz et. al.

EXHIBIT 9 –Hearst *Popular Mechanics* article smears Horowitz, his religious identity, 528 industry, and OxySilver's falsified ingredients, published Sept. 20, 2016.

EXHIBIT 10 –Schein prospectus heralding partnership with Hearst Health Network, First Data Bank, Inc. in MicroMD, copyrighted 2020.

EXHIBIT 11 –Ohm Y, et. al. An electrically conductive silver-polyacrylamide-alginate hydrogel composite for soft electronics. *Nature Electronics* 4: March 2021, 185-192.

EXHIBIT 12 –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^{TM} with 528 frequency.)

EXHIBIT 13 –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 14 –Plaintiff's Copyright on *Healing Codes for the Biological Apocalypse*, August 9, 2000; Registration No. TX0005256671.

EXHIBIT 15–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 16–Press Release by Profusa, Inc. Profusa and partners receive DARPA award to speed detection of disease outbreaks. Aug. 8, 2019.

EXHIBIT 17 –*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 18 –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 19 – Brumfiel G. Harvard Professor's Arrest Raises Questions About Scientific Openness. *NPR*, February 19, 2020.

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 – Press release by Henry Schein, Inc. Henry Schein named to Fortune Magazine's 'Change the World' list. *Businesswire*, Sept. 21, 2020.

Defense Advanced Research Projects Agency Intelligent Healing for Complex Wounds

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 1

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

SB-2/A 1 bioelectsb2a.htm FORM SB-2/A

As filed with the Securities and Exchange Commission on December 6, 2006
Registration No. 333- 136602

SECURITIES AND EXCHANGE COMMISSION

Washington, D.C. 20549

FORM SB-2/A

(AMENDMENT NO. 3)

REGISTRATION STATEMENT
UNDER
THE SECURITIES ACT OF 1933

BioElectronics Corporation

(Name of Small Business Issuer in Its Charter)

Maryland	**3845**	**52-2278149**
(State or Other Jurisdiction of Incorporation or Organization)	(Primary Standard Industrial Classification Code Number)	(I.R.S. Employer Identification No.)

401 Rosemont Avenue, 3rd Floor
Rosenstock Hall
Frederick, Maryland 21701
(301) 644-3906
(Address and Telephone Number of Principal Executive Offices)

Andrew J. Whelan, President
BioElectronics Corporation
4539 Metropolitan Court
Frederick, Maryland 21704
(301) 644-3906
(Name, address and telephone number of agent for service)

Copies to:
Robert S. Matlin, Esq.
Uche D. Ndumele, Esq.
Kirkpatrick & Lockhart Nicholson Graham
599 Lexington Avenue
New York, New York 10022-6030
Telephone: (212) 536-3900 Facsimile: (212) 536-3901

Approximate Date of Commencement of Proposed Sale to the Public: From time to time after this Registration Statement becomes effective.

If any of the securities being registered on this Form are to be offered on a delayed or continuous basis pursuant to Rule 415 under the Securities Act, check the following box. ☑

Exhibit 2

The information in this prospectus is not complete and may be changed. We may not sell these securities until the registration statement filed with the Securities and Exchange Commission is effective. This prospectus is not an offer to sell these securities and it is not soliciting an offer to buy these securities in any jurisdiction where the offer or sale is not permitted.

Prospectus

Subject to Completion, Dated December 6, 2006

23,182,889 Shares of Common Stock

BioElectronics
Makers of Drug Free, Anti-Inflammatory Patches

Makers of Drug Free, Anti-Inflammatory Patches

This prospectus relates to the resale of up to 23,182,889 shares of common stock (the "Common Stock"), of which 10,451,389 shares are issuable upon the conversion of promissory notes of BioElectronics Corporation (the "Company") and includes 166,667 shares for accrued interest and 249,999 shares for liquidated damages, 3,420,000 shares listed in connection with the Company's April 2005 Private Placement Offering, and 9,311,500 shares of Common Stock issuable upon the exercise of warrants of the Company by certain selling stockholders identified in this prospectus (the "Offering"). All of these shares, when sold, will be sold by these selling stockholders. The selling stockholders may sell their Common Stock from time to time at prevailing market prices. We will not receive any proceeds from the sale of the shares of Common Stock by the selling stockholders.

Bid and ask prices for our Common Stock are quoted from broker dealers on the Pink Sheets. The Company's symbol is "BIEL. OTC:PK."

See "Risk Factors" beginning on page 7 for risks of an investment in the securities offered by this prospectus, which you should consider before you purchase any shares.

Neither the Securities and Exchange Commission nor any state securities commission has approved or disapproved of the securities or passed upon the accuracy or adequacy of this prospectus. Any representation to the contrary is a criminal offense.

The date of this prospectus is _____, 2006

The clinical effectiveness of the product has been well established. Testing performed at the Bioelectromagnetics Research Laboratory at the State University of New York has shown that ActiPatch Therapy provides an adequate dosage of electromagnetic energy for the treatment of soft tissue, and that its power at the skin level is equivalent to that of traditional high-power devices. The power level is six to nine orders of magnitude higher than that which is required to show a biological effect. It also demonstrated that the cumulative effect of continuous delivery provides greater therapeutic benefit than sporadic treatments.

Clinical Trials

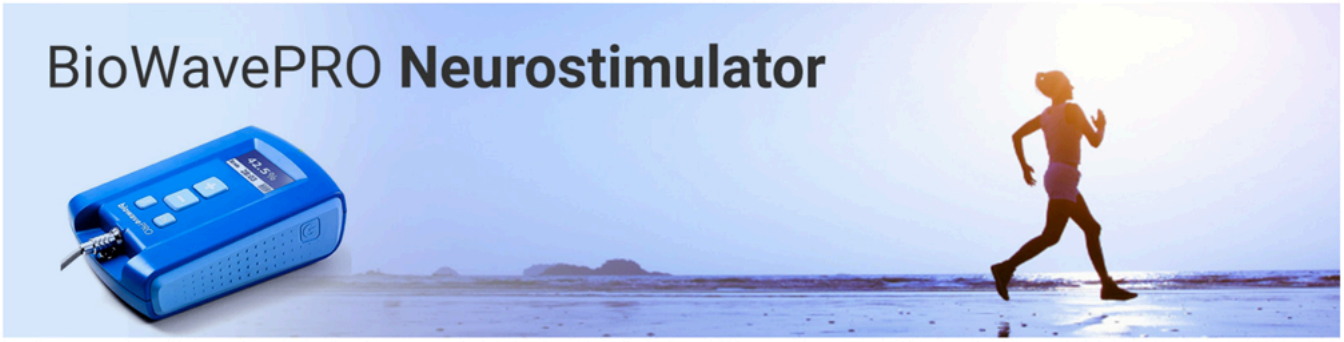
In 2006, the Company and the Lahey Clinic jointly announced a three-year program to study the effects of ActiPatch Therapy on a variety of soft tissue injuries and related medical conditions. The internationally renowned Lahey Clinic of Boston, whose faculty is affiliated with the Medical Schools of Harvard and Tufts, has committed to initiating a number of double-blind clinical studies on ActiPatch Therapy in the areas of plastic surgery, orthopedics and chronic wound care. Results from these clinical trials will be submitted to the United States Food and Drug Administration (the "FDA") for expanded indications for the use of ActiPatch Therapy.

Significant Strategic Marketing Relationships Recently Established

The Company, on December 4, 2003 signed an exclusive three-year supply and distribution agreement with Byron Medical, Inc. ("Byron") a subsidiary of Mentor Corporation (NYSE:MNT), a large supplier of medical products worldwide, to cover marketing of ActiPatch Therapy products to plastic surgeons worldwide. For the six months ended September 30, 2006 sales to Byron were approximately $97,000. The Byron Medical agreement is dated December 4, 2003. Byron is a wholly owned subsidiary of Mentor Corp., Santa Barbara, California. Mentor has announced that it intends to shut down its Byron Medical operations. The Company is negotiating with a major medical supplies distributor to market and sell its products to plastic and other surgeons. Should the Company not secure new distributors sales could be significantly impacted.

In July 2005, the Company announced an agreement with MaxMed Technologies ("MaxMed"), maker of the PedAlign ™ ("PedAlign") brand of custom orthotics products. The new wearable and disposable ActiPatch Therapy will be available as an insert into the PedAlign product as a unique offering to providers that order PedAlign custom orthotic products. At the present time the Company is not doing a significant amount of business with MaxMed.

In November 2005, the Company announced a partnership with Profoot, Inc. ("Profoot") for distribution of the ActiPatch Therapy product in Canada. The product will be available at prominent retail stores throughout Canada. Profoot is America's second largest brand of consumer foot care products and the brand is available at tens of thousands of mass-retail outlets in Canada, the U.S. and 20 other countries. The Company has also entered into a distribution agreement with Virginia-based Medical Sales Professionals, Inc (MSP). MSP sells and distributes medical supplies to professional and college sports teams and health care providers. Currently, ActiPatch Therapy is used by 14 professional sports teams. The Company does not expect significant sales volume from the professional or college market segment. In September 2006 the Company signed a Sales Agent Agreement with Extremity Solutions & Seacoast Surgical, of Attleboro, Massachusetts. Extremity Solutions & Seacoast Surgical will sell the ActiPatch product in six New England states and in October 2006 announced that Henry Schein, Inc., the largest provider of healthcare products and services to office-based practitioners in the North American and European markets has agreed to sell and distribute ActiPatch(TM). The amount of sales from these two companies has not been determined. Additionally, the Company is in the early stages of negotiations with other companies to distribute our products. However, there is no assurance that distribution agreements will be finalized.



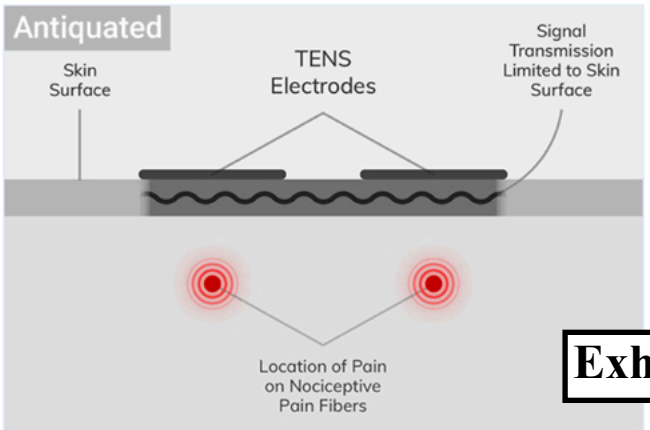
Relieve Your Athletes' Pain with Smarter Pain-Blocking Technology from the BioWavePRO Neurostimulator

The BioWavePRO neurostimulator uses a unique signal-mixing technology to deliver electrical signals through the skin directly to nerves for inhibiting pain transmission and improving function.

Clinical studies have shown that BioWavePRO with noninvasive electrodes can be used to reduce pain and improve function including increased range of motion, decreased stiffness, and reduction of muscle spasm for up to 24 hours following a single 30-minute treatment.

An Improvement over TENS

BioWavePRO's non-opioid, FDA-cleared, VA-prescribed, professional athlete-trusted, patented approach to chronic and acute pain relief that goes beyond old-fashioned transcutaneous electrical nerve stimulation (TENS) technology.



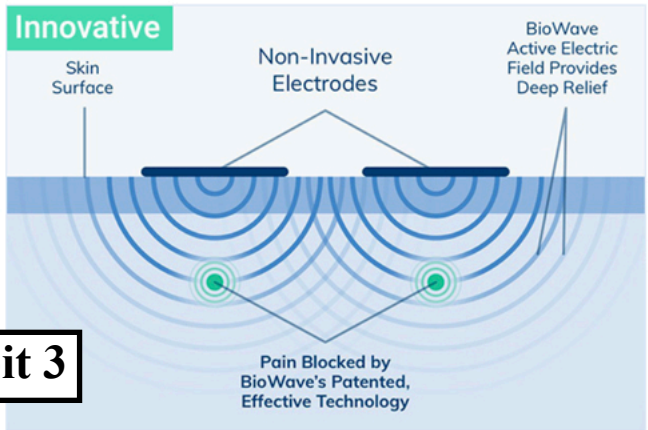


Exhibit 3

TENS Transcutaneous Electrical Nerve Stimulation

Transmits stimulation across the surface of skin which may act as a distraction to pain (gate control theory)

BioWave Subcutaneous Electrical Nerve Stimulation

Transmits stimulation beneath the surface of skin directly to nociceptive fibers blocking the transmission of pain signals to the

GSK logo linking to the homepage

01 August 2016

GSK and Verily to establish Galvani Bioelectronics – a new company dedicated to the development of bioelectronic medicines

Leaders in healthcare and technology to harness electrical signals in the body to treat chronic disease

GSK (LSE/NYSE: GSK) today announced an agreement with Verily Life Sciences LLC (formerly Google Life Sciences), an Alphabet company, to form Galvani Bioelectronics to enable the research, development and commercialisation of bioelectronic medicines. GSK will hold a 55% equity interest in the new jointly owned company and Verily will hold 45%.

Galvani Bioelectronics will be headquartered in the UK, with the parent companies contributing existing intellectual property rights[1] and an investment of up to £540 million over seven years, subject to successful completion of various discovery and development milestones.

Exhibit 4

Bioelectronic medicine is a relatively new scientific field that aims to tackle a wide range of chronic diseases using miniaturised, implantable devices that can modify electrical signals that pass along nerves in the body, including irregular or altered impulses that occur in many illnesses. GSK has been active in this field since 2012 and believes certain chronic conditions such as arthritis, diabetes and asthma could potentially be treated using these devices.

The agreement to establish Galvani Bioelectronics represents an important next step in GSK's bioelectronics research. The new company will bring together GSK's world class drug discovery and development expertise and deep understanding of disease biology with Verily's world leading technical expertise in the miniaturisation of low power electronics, device development, data analytics and software development for clinical applications. Initial work will centre on establishing clinical proofs of principle in inflammatory, metabolic and endocrine disorders, including type 2 diabetes, where substantial evidence already exists in animal models; and developing associated miniaturised, precision devices.

Moncef Slaoui, GSK's Chairman of Global Vaccines, who was instrumental in establishing GSK's investments in the field of bioelectronics, will chair the board of the new company. He said:

"Many of the processes of the human body are controlled by electrical signals firing between the nervous system and the body's organs, which may become distorted in many chronic diseases. Bioelectronic medicine's vision is to employ the latest advances in biology and technology to interpret this electrical conversation and to correct the irregular patterns found in disease states, using miniaturised devices attached to individual nerves. If successful, this approach offers the potential for a new therapeutic modality alongside traditional medicines and vaccines.

"This agreement with Verily to establish Galvani Bioelectronics signals a crucial step forward in GSK's bioelectronics journey, bringing together health and tech to realise a shared vision of miniaturised, precision electrical therapies. Together, we can rapidly accelerate the pace of progress in this exciting field, to develop innovative medicines that truly speak the electrical language of the body."

Brian Otis, Verily's Chief Technology Officer, said: "This is an ambitious collaboration allowing GSK and Verily to combine forces and have a huge impact on an emerging field. Bioelectronic medicine is a new area of therapeutic exploration, and we know that success will require the confluence of deep disease biology expertise and new highly miniaturised technologies.

"This partnership provides an opportunity to further Verily's mission by deploying our focused expertise in low power, miniaturised therapeutics and our data analytics engine to potentially address many disease areas with greater precision with the goal of improving outcomes."

Galvani Bioelectronics will be headquartered within GSK's global R&D centre at Stevenage in the UK, with a second research hub at Verily's facilities in South San Francisco. It will initially employ around 30 expert scientists, engineers and clinicians, and will fund and integrate a broad range of collaborations with both parent companies, academia and other R&D companies. GSK and Verily believe this collaborative way of working will rapidly accelerate the development of bioelectronic medicines.

Kris Famm, GSK's Vice President of Bioelectronics R&D, has been appointed President of the new company. Famm has pioneered work in both large and small molecule drug discovery and worked for a decade developing and delivering R&D strategy with a recurring focus on emerging

technologies. He has co-designed and led GSK's exploration of bioelectronics. A seven-member board, chaired by Moncef Slaoui, will also be appointed and will include Andrew Conrad, CEO of Verily. The new company will be fully consolidated in GSK's financial statements.

This agreement is subject to customary closing conditions (including requisite antitrust approvals) and is expected to close before the end of 2016.

GSK and bioelectronics

Since 2012, a dedicated team of scientists at GSK has been researching the potential of bioelectronic medicines. In that time, the company has established a leadership position in the field, including creating a global network of around 50 research collaborations and investing $50m in a dedicated bioelectronics venture capital fund. Through these collaborations and investments, GSK has seen encouraging proof of principles in animal models in a range of diseases. It believes the first bioelectronic medicines could be ready for approval within the next decade.

For further information visit GSK's bioelectronics media resource centre http://www.gsk.com/en-gb/media/resource-centre/bioelectronics/

The history of Galvani

Galvani Bioelectronics is named after Luigi Aloisio Galvani, an 18th century Italian scientist, physician and philosopher, who was one of the first to explore the field of bioelectricity. In 1780, he made the pivotal discovery that the muscles of a frog's legs twitched when he touched the sciatic nerve with two pieces of metal, leading him to propose the theory of bioelectricity. Galvani's discovery, while disputed by many of his peers, paved the way for

the modern study of electrophysiology and neuroscience – two fields that are key to the development of bioelectronic medicines.

GSK – one of the world's leading research-based pharmaceutical and healthcare companies – is committed to improving the quality of human life by enabling people to do more, feel better and live longer. For further information please visit www.gsk.com/about-us/.

Cautionary statement regarding forward-looking statements
GSK cautions investors that any forward-looking statements or projections made by GSK, including those made in this announcement, are subject to risks and uncertainties that may cause actual results to differ materially from those projected. Such factors include, but are not limited to, those described under Item 3.D 'Risk factors' in the company's Annual Report on Form 20-F for 2015.

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[1] Given the early stage nature of these assets, these currently have no carrying value.

FREQUENCY THERAPEUTICS

Former Pfizer President of R&D Joins Biotech Startup, Frequency Therapeutics

March 31, 2017 HHTM

John LaMattina, PhD

WOBURN, MASSACHUSSETTS — Frequency Therapeutics, a biotech firm developing drugs to re-create sensory cells in the inner ear, announced the appointment of John LaMattina, PhD, as a member of its Scientific Advisory Board and Senior Advisor to the CEO.

According to the company's press release, Dr. LaMattina is the former President of Pfizer Gobal Research and Development and Senior Vice President of Pfizer, Inc. During his tenure at Pfizer, the company discovered and developed many innovative and highly successful new drugs, including: Zoloft, Chantix, Lyrica, and many others.

About Frequency Therapeutics

Frequency Therapeutics is a leader in the development of medicines designed to activate progenitor cells within the body to treat degenerative diseases. The Company's progenitor cell activation (PCA) approach stimulates progenitor cells to create functional tissue with the aim of developing disease modifying therapies. The Company's lead product candidate, FX-322, is designed to regenerate auditory hair cells to restore hearing function. In a FX-322 Phase 1/2 study, statistically significant and clinically meaningful improvements in key measures of hearing function in patients with sensorineural hearing loss were observed. FX-322 is being evaluated in multiple ongoing clinical studies in patients with sensorineural hearing loss. The Company also is evaluating additional diseases where its PCA approach could create functional tissue, including in a pre-clinical program in multiple sclerosis.

Headquartered in Woburn, Mass., Frequency has an ex-U.S. license and collaboration agreement with Astellas Pharma Inc. for FX-322, as well as additional collaboration and licensing agreements with academic and nonprofit research organizations including Massachusetts Eye and Ear, Mass General Brigham and the Massachusetts Institute of Technology, The Scripps Research Institute and Cambridge Enterprises Limited, Cambridge University, UK. . For more information, visit www.frequencytx.com and follow Frequency on Twitter @Frequencytx.

Exhibit 5

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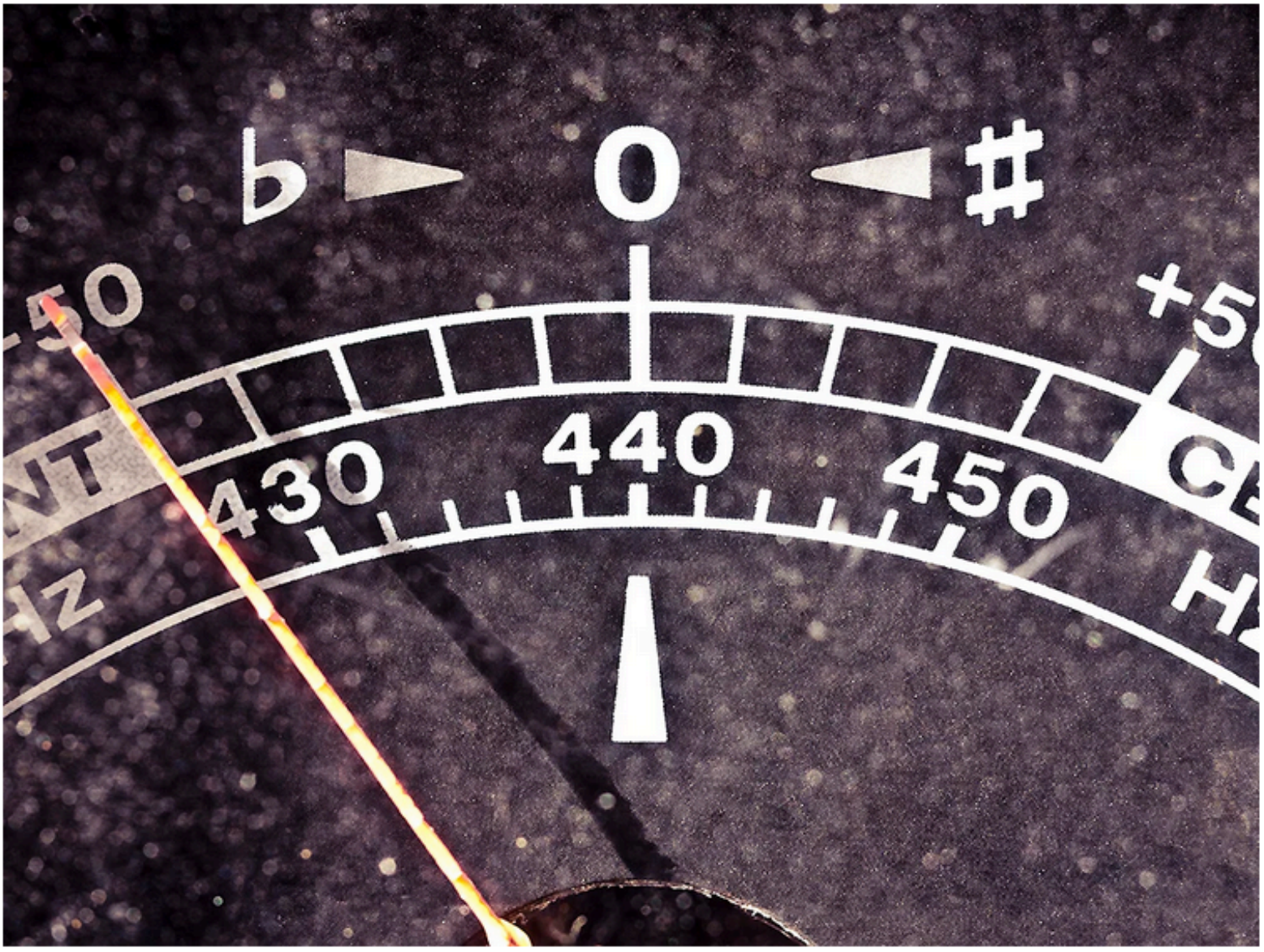
COMMENTARY

The great 440 Hz conspiracy, and why all of our music is wrong: Alan Cross

By Alan Cross · Global News
Posted May 13, 2018 9:00 am

Exhibit 6



A vintage plastic guitar tuner measures 440 Hz. **Getty Images**

-A A+

Gather 'round, kids. Those of you with tinfoil hats may wish to ensure that they're fitted snuggly. What I'm about to tell you will shake your faith in all the music you've heard in your life.

If you look down the right paths, it becomes clear that governments and various security apparatuses have used music to control us using music. All the music of the West that's based on the standard 12-tone scale is used for the management of crowds as well as thought control.

READ MORE: 'Big Brother Canada' Season 6 winner crowned

Let's begin with some music theory.

If musical performances were to sound the same the world over, some standardization was required. As early as 1885, the Music Commission of the Italian Government declared that all instruments and orchestras should use a tuning fork that vibrated at 440 Hz, which was different from the original standard of 435 Hz and the competing 432 Hz used in France.

In 1917, the American Federation of Musicians endorsed the Italians, followed by a further push for 440 Hz in the 1940s.

In 1953, a worldwide agreement was signed. Signatories declared that middle "A" on the piano be forevermore tuned to exactly 440 Hz. This frequency became the standard ISO-16 reference for tuning all musical instruments based on the chromatic scale, the one most often used for music in the West. All the other notes are tuned in standard mathematical ratios leading to and from 440 Hz.

This tone standard is now universally accepted, which is why a piano in Toronto sounds exactly the same as a piano in China.

Weirdly, no one can say for sure why this frequency was chosen in the first place. In fact, there those among us who vehemently disagree with this standard. In fact, they consider the 440 Hz middle “A” to be an abomination against nature.

READ MORE: Neon Dreams on their undefinable music and leaving the Hedley tour

Adherents to this theory claim that a more “natural” frequency for middle “A” is 438 Hz. Others believe that the correct middle “A” is 432 Hz (also known as Verdi’s A) because it has “a pure tone of math fundamental to nature” and is “mathematically consistent with the patterns of the universe, vibrating with Phi, the Golden Ratio. They point to how this pitch can be connected to everything from nautilus shells to the works of the ancients, including the construction of the Great Pyramid.

Furthermore, 432 Hz resonates with 8 Hz (the Schumann Resonance), the documented fundamental electromagnetic “beat” of Earth. It just *feels* better.

Research says that music tuned from this frequency is easier to listen to, brighter, clearer, and contains more inherent dynamic range. As a result, music with this tuning need not be played at higher volumes and thus reduces the risk of hearing damage.

The more radical among middle “A” haters insist that the true frequency should be 528 Hz because it’s a “digital bio-holographic precipitation crystallization [and] miraculous manifestation of diving frequency vibrations.” I have no idea what that means.

Here’s where the conspiracy comes in. There is allegedly something sinister and evil about 440 Hz. It is said that the Rockefeller Foundation had an interest in making sure the United States adopted the 440 Hz standard in 1935 as part of a “war on consciousness” leading to “musical cult control.”

Without going too far down this rat hole, this theory says that tuning all music to 440 Hz turns it into a military weapon.

I quote from one of the many online articles on the subject: “The monopolization of the music industry features this imposed frequency that is ‘herding’ populations into greater aggression, psychosocial agitation, and emotional distress predisposing people to physical illnesses and financial impositions profiting the agents, agencies, and companies engaged in the monopoly.”

READ MORE: Carrie Underwood goes into detail about facial injury in 1st TV interview since accident

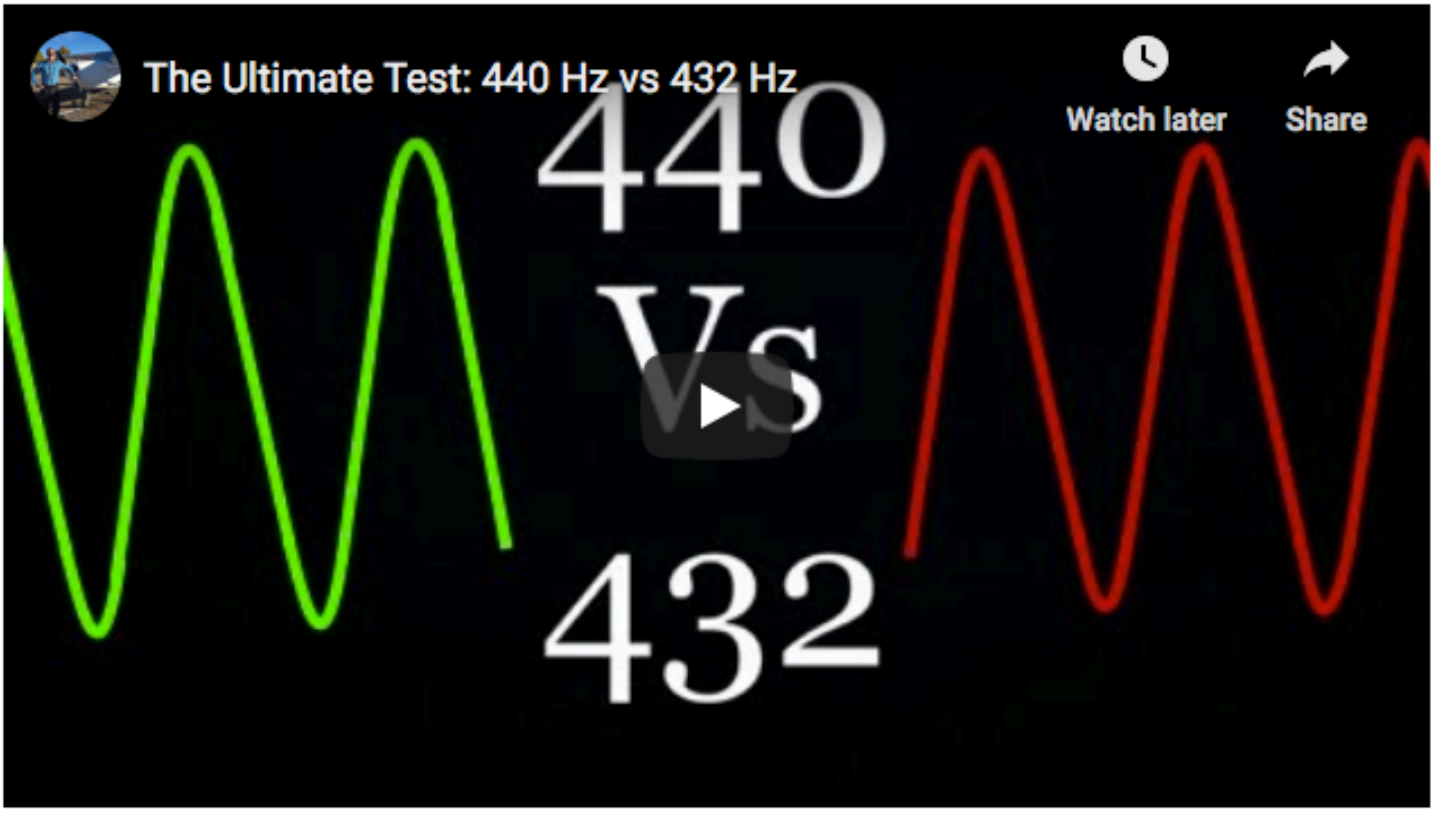
Whoa.

Going a little deeper, we end up at the doorstep of the Nazis. It is said that propaganda minister Joseph Goebbels insisted that on 440 Hz tuning in Germany because he believed it made people think and feel in specific ways, making them "a prisoner of a certain consciousness." And if you're trying to mobilize the population for Der Fuhrer, that's exactly what you want, right?

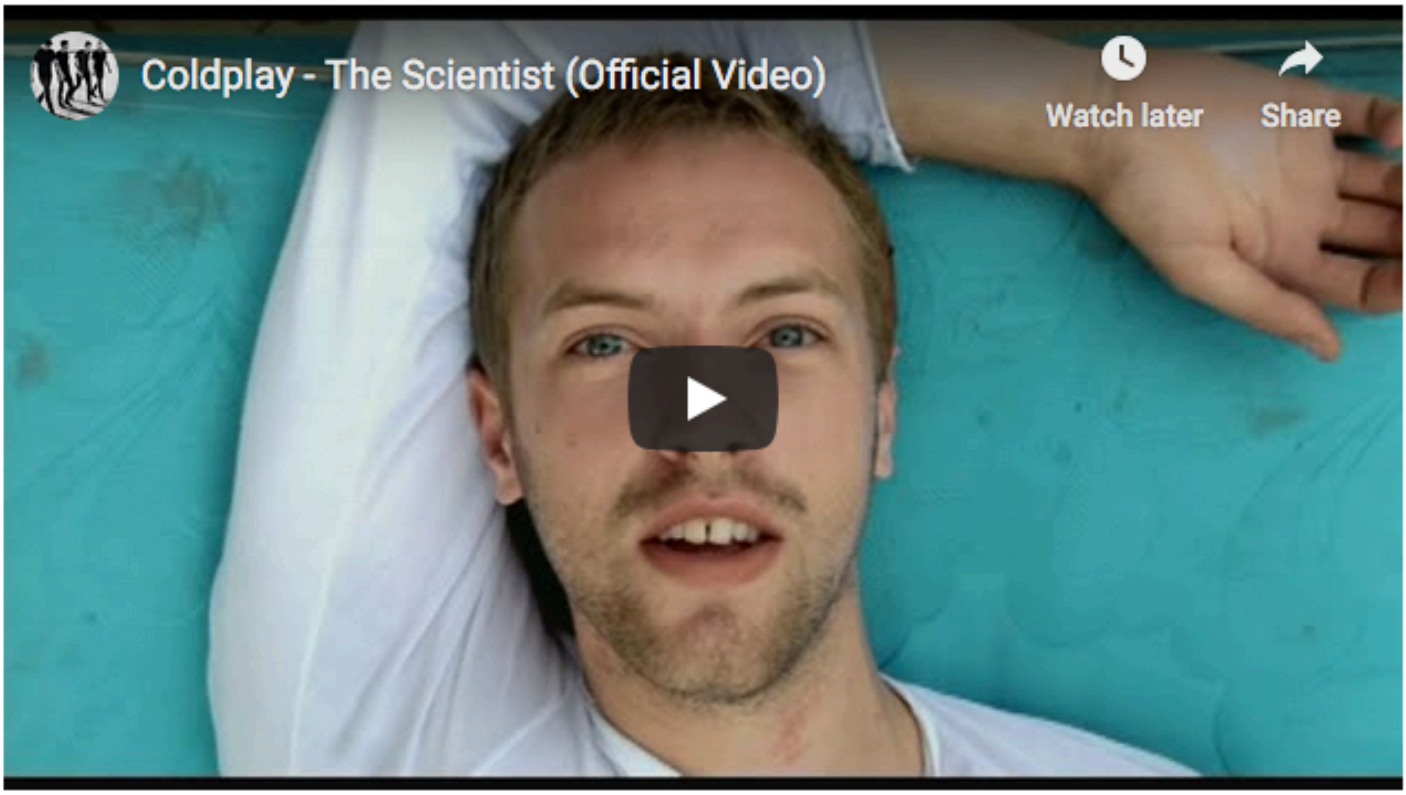
There's more from the Tinfoil Headphones crowd: "The powers that be are successfully lowering the vibrations of not only the young generation but the rest of us as well. These destructive frequencies entrain the thoughts towards disruption, disharmony, and disunity. Additionally, they also stimulate the controlling organ of the body — the brain — into disharmonious resonance, which ultimately creates disease and war."

There's something to think about the next time you pop in some earbuds. Does listening to music make you feel more warlike and diseased?

Let's test it out with this video.



Got that? Now try another experiment. Here are two versions of Coldplay's "The Scientist," starting with the standard version from their 2002 album, *A Rush of Blood to the Head*.



Any feelings of war or disease yet?

Now listen to this. It's a version of the same song that's been tuned down to the supposedly more natural frequency of 432 Hz. Can you feel a difference?

I've also been told that the different effects these frequencies have on our chakras. Songs tuned to 440 Hz work on the third eye chakra (the "thinking") while 432 Hz stimulates the heart chakra (the "feeling"). Therefore, 432 Hz music increases the spiritual development of the listener. It may even have healing properties.

There are numerous organizations advocating a universal switch to 432 Hz, but that would involve upsetting worldwide standards, not to mention the construction and re-tuning of millions of musical instruments. Nice idea, but it ain't gonna happen.

If that idea stressed you out, please meditate on this special 432 Hz music.

Alan Cross is a broadcaster with 102.1 the Edge and a commentator for Global News.

Subscribe to Alan's Ongoing History of New Music Podcast now on Apple Podcast or Google Play

Dec 10, 2016, 10:52pm EST

Are Chiropractors Backing The Anti-Vaccine Movement?

Bruce Y. Lee Senior Contributor

Healthcare

I am a writer, journalist, professor, systems modeler, computational and digital health expert, avocado-eater, and entrepreneur, not always in that order.

This article is more than 4 years old.

Dr Andrew Wakefield (center) was the first clinician to suggest a link between autism in children... [+]

Today Andrew Wakefield was a keynote speaker at the International Chiropractors Association's Annual Conference on Chiropractic and Pediatrics in Maui, Hawaii. Yes, the same Andrew Wakefield, who in 2010 was stripped of his medical license in the United Kingdom for

Exhibit 7

ethical violations and failure to disclose potential financial conflicts of interest. The same Wakefield who published a subsequently discredited and retracted study in the *Lancet* linking vaccines to autism that the *British Medical Journal (BMJ)* described as an "elaborate fraud". The same Wakefield who produced and directed an anti-vaccine "documentary" film, *Vaxxed: From Cover-Up to Catastrophe*, that pushed conspiracy theories about the Centers for Disease Control and Prevention (CDC) and vaccines. The same Wakefield who has not been able to provide scientific evidence to support his claims. Is this really the best way for a professional association and a conference to gain scientific legitimacy?

The Annual Conference on Chiropractics and Pediatrics now has something in common with the "Conspira-Sea Cruise," a week-long cruise hosted by the tour company Divine Travels to have conversations about--you guessed it--"conspiracies." Both have invited Wakefield as a guest speaker. David Gorski writing for *Popular Mechanics* mentioned some of the others on the cruise's preliminary list of speakers such as:

- **Robert O. Young:** who has claimed that the cause of all cancers is excess acidity and has been selling books and programs promoting alkaline diets. (Who would have thought that the Cancer Moonshot is just to make better Tums tablets?)

- **Robert Strecker:** who has claimed that HIV/AIDS is a man-made (or actually human-made) disease that was spread by the government (because the government just does not have enough to problems to address).

- **Len Horowitz:** who describes himself as the "King of Natural Healing" and has been trying to sell an herbal cream that he claims will make skin cancer fall off your body in less than 3

weeks.

The preliminary speaker list probably reflected the final list of speakers, unless the cruise was itself a conspiracy. As April Glaser reported for *Wired*, the cruise speakers included people who have broken the law such as Sean David Morton, who was indicted and fined by the U.S. Securities and Exchange Commission for making false (as opposed to truthful) claims to investors about psychic abilities to predict the stock market. (Apparently, his psychic abilities did not help him predict that the SEC would catch him.)

What Horowitz, Young and a number of others on the cruise have in common is that they are all trying to sell treatments that compete with existing treatments approved and supported by legitimate government agencies such as the Food and Drug Administration (FDA) and the scientific community. So, could conspiracy theorists have something to gain financially by discrediting the government and the scientific community? Could there be personal agendas behind certain conspiracy theories? In other words, could there be conspiracies behind conspiracy theories?

Let's go back to the "anti-vaccine movement." But before we do so, let's clearly distinguish "anti-vaxxers" from those who have earnest concerns or questions about vaccines, but are not staunchly opposed to the idea of vaccination. Vaccines are not 100% safe. Nothing is. Not even stuffed animals. (This is not to say that the risks of vaccines and stuffed animals are the same.) Indeed, vaccines can cause both minor and major side effects. But scientific studies have shown that the risks of major side effects are very low and have not shown any connection between vaccines and autism. The benefits of vaccines seem to far outweigh potential risks. Nonetheless, wondering about vaccine safety is perfectly reasonable. Science, medicine and public health need to keep

monitoring the safety of existing products and pushing for even safer products. Products can always get better. Science can always advance. A reasonable amount of skepticism can be healthy.

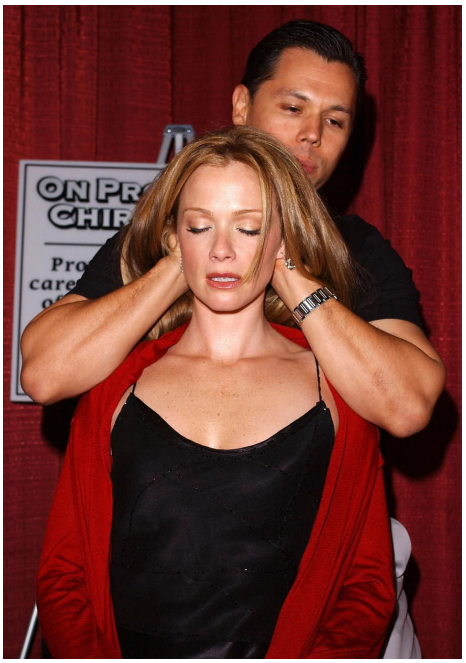
By contrast, the "anti-vaccine movement" seems to include some organized attempts to present information not necessarily supported by science and convince you to stop vaccinating yourself or your children. As she wrote in *Time* (actually in time for *Time*), Meghan Moran, Ph.D., an associate professor of health, behavior and society at the Johns Hopkins Bloomberg School of Public Health, led a study that analyzed 480 anti-vaccination websites and found many false claims and attempts to discredit the government and medical practitioners. In fact, some websites seem to be masquerading as legitimate vaccine authorities by using titles such as "national" and "information." Do these websites really represent honestly concerned citizens or actually organizations with hidden agendas?

How many chiropractors are behind these efforts? Well, some chiropractors may see potential financial gain if vaccination rates go down. Try doing a web search for "chiropractors" and "vaccination," "infectious disease," "influenza," "measles" and other vaccine-related topics and you'll some interesting claims about how chiropractic techniques can help prevent and treat infectious diseases. For example, in a website from the Chiropractic Leadership Alliance, Dr. Christopher Kent wrote:

> Even more impressive are some of the spectacular results reported by early chiropractors in patients with infectious diseases. One example where chiropractic care provided a beacon of light was the 1917-18 influenza epidemic, which brought death and fear to many Americans... The results were

> spectacular. Rhodes reported that in Davenport, Iowa, medical doctors treated 93,590 patients with 6,116 deaths—a loss of one patient out of every 15. Chiropractors at the Palmer School of Chiropractic adjusted 1,635 cases, with only one death. Outside Davenport, chiropractors in Iowa cared for 4,735 cases with only six deaths—one out of 866.

This statement has about as much science as a Barbie doll. Yes, of course, more people died from the flu under a doctor's care than a chiropractor's care, because most people really sick with the flu probably went to doctor rather than chiropractor. You could probably find similar patient mortality statistics for plumbers or cheese-makers. (If you go to a cheese-maker to get medical treatment, you have more problems than you realize.) Kent went on to make similar claims about smallpox, measles, scarlet fever and gonorrhea. He concluded, "In a world where we are faced with antibiotic-resistant bacteria, and viral diseases where effective treatments are lacking, the role of chiropractic care in allowing for optimum immune system function deserves thorough exploration."



A *USA Today* piece reported that "about 19%" of chiropractors are being vocal about opposing vaccines. The story quoted chiropractor Josh Handt as saying, "[The job of] chiropractic is to allow the body to function optimally without taking anything out or putting anything in," which is a very broad, vague, sweeping claim that essentially says nothing and applies to most health

Chiropractic adjustment such as the one actress Lauren Holly (right) is receiving here can help with... [+]

professionals including doctors, physical therapists and nurse practitioners. No, doctors don't think, "Hmm, what can I remove or put into the patient?"

Certainly, chiropractic techniques have proven to be helpful for certain musculoskeletal conditions. But trying to extend techniques and methods well beyond what they are intended to do is analogous to having a hammer and just trying to find ways to make the hammer seem more useful and thus more sell-able. "Oh, look, the hammer can be used as a spatula. Oh, I can use a hammer to brush my teeth. And who needs toilet paper when you have a hammer?"

Again, not all chiropractors necessarily have that agenda. There are chiropractors who use evidence-based approaches and recognize the strengths and limitations of their techniques. However, you have to wonder about the International Chiropractors Association's motivation behind featuring Wakefield as a speaker, especially without providing a balancing scientific talk. When people are staunchly opposed to vaccines, the medical profession or government agencies, how much of it is true belief and how much is a hidden financial agenda? How's that for a conspiracy theory about conspiracy theorists?

Follow me on Twitter or LinkedIn. Check out my website.

Bruce Y. Lee

I am a writer, journalist, professor, systems modeler, computational and digital health expert, avocado-eater, and entrepreneur, not always in that order. Currently, I am... **Read More**

APRIL GLASER SCIENCE 02.09.2016 08:00 AM

A Skeptic Infiltrates a Cruise for Conspiracy Theorists

Conspira-Sea is a seven-day cruise where fringe thinkers can discuss everything from crop circles to mind control on the open sea.

Exhibit 8

The Ruby Princess cruise ship docked at Port Everglades in Fort Lauderdale on November 3, 2014. ALAMY

SAY YOU'RE NOT one to believe the mainstream media. Maybe you think climate change is an elaborate hoax or the medical community is trying to hide the myriad dangers of vaccinations. Perhaps you are utterly convinced the government is overrun by reptilian beings.

Where on Earth can you go to get away from it all, and mingle with those who share your views? Well, Conspira-Sea, of course. It's a seven-day cruise where fringe thinkers can discuss everything from crop circles to mind control on the open sea. Last month's cruise featured a caravan of stars from a surprisingly vast galaxy of skeptics and conspiracy theorists, including Andrew Wakefield, known for his questionable research and advocacy against vaccines. Also aboard was Sean David Morton, who faced federal charges of lying to investors about using psychic powers to predict the stock market.

But they had an outsider among them, and not one from another planet. Harvard-educated attorney Colin McRoberts is writing a book about people who believe in conspiracy theories, and used a crowdfunding campaign to book passage on the cruise. He blogged about his adventure and told us all about it---including the bit where the IRS arrested Morton when the ship returned to port.

__What were some of the conspiracies discussed on board?

__

We had about a dozen presenters of all different stripes. Some technical or scientific experts, but only one scientific speaker, Wakefield, had a legitimate education. The rest were into new-age or were conspiracy theorists in the traditional sense. Or aliens. They all had their various specialities.

__And what were the attendees like? __

The people on the cruise tended to be there with a primary focus on one or two big issues. They were there to learn about vaccines. Or they were there to find out more about astrology. But they were interested in everything else. I didn't talk to anybody who wasn't willing to kind of go outside their comfort zone.

Most people had advanced degrees, for the most part master's. I talked to at least one woman who had a PhD, in counseling. There were also some people there who were blue collar. I talked to one person who was a metal worker, another who was a nurse. And I talked to a teacher and a couple who own a new-age bookstore. There was a pretty decent diversity in terms of backgrounds.

What was the relationship between the attendees and observers like you on board?

It was a very tense environment on the boat. There were a couple of instances in which the journalists on board had been treated poorly by a couple of the presenters. One of the journalists was ambushed in the Internet cafe by a couple who had accused her of being an agent of the CIA. She managed to persuade

them that she was not an undercover agent.

Did anyone succeed in indoctrinating people?

The anti-GMO track was probably the most effective in terms of changing people's behavior. The primary speaker worked very hard, not at convincing people that GMOs are evil, but in giving specific tools for convincing others that GMOs are evil. Which was, the ethics of it aside, a savvy way to activate some communicators and try and shift actual behavior in the real world.

__Wakefield was the most prominent personality on board. What was his presentation like? __

I think Wakefield is unhappy with the fact that his career has now taken him to a conspiracy conference in which he's sharing billing with the third dimensional delegates of the galactic roundtable. He sees himself as someone who can champion his issues as an issue of public health, and instead he winds up in sort of a side show.

In his presentation, he launched into a very direct, very passionate, and I think a very heartfelt defense of his own words, explaining essentially that he was unjustly demonized. I got the impression that he was wanting a sort of redemption story. I think this is his second arc. He's trying to redeem himself and start over, not as a medical expert, but as an issue activist.

What do you think motivates these fringe theory evangelists?

I thought that both of the pseudo-legal speakers were con-men. People left with specific, terrible, dangerous advice that could really ruin their lives. There's definitely a streak of con-artistry in a man that gets up and tells you this is how you get rid of your debts, and doesn't say, oh and by the way, I'm under indictment for doing this. Sean David Morton didn't know that he was going to be arrested right after he got off the boat. But he knew the IRS had raided him, I found out later, and was fighting the raid in trial for using some of the legal tricks

he talked about in his presentation.

At the same time I think those presenters believed what they were saying. It turns out that both pseudo-legal speakers were both doing it themselves. And that really surprised me because I didn't think that anybody would really spend that kind of time and effort learning how to pull these tricks off and not realize at some point that it will never work.

__What do the attendees get out of the cruise? __

I think a lot of people who get stuck in an ideology that's based on some irrational idea, like how Bigfoot exists or that vaccines cause autism or that GMOs are poisonous or the legal stuff, they kind of define the idea in opposition to the mainstream. So I think what a lot of them are looking for is a community and a culture that supports them and doesn't judge them for having this unusual belief. They come together not just on a cruise ship, but in a community.

Is there anything we can learn from the attendees?

We tend to receive information filtered through our friends, and colleagues, and

build a community around themselves of people who are also in opposition to science.

That happens to everybody, not just conspiracy theorists. We all do it. And that's why I think it's so important for us to kind of get outside of our little communities, step across the aisle, and have that conversation with someone who is different.

Andrew Wakefield, leader of the anti-vaccine movement and one of the marquee lecturers on the Conspira-Sea Cruise.

Exhibit 9

CLIMB ABOARD, YE WHO SEEK THE TRUTH!

Conspiracy theories are more popular than ever. Over half of all Americans believe in one. So what do you get when you stick some of the conspiracy world's biggest celebrities and their die-hard fans on a cruise ship in the middle of the Pacific Ocean for a week? Some fascinating insight into our strange times. And one near fistfight.

BY **BRONWEN DICKEY**

PHOTOGRAPHS BY DINA LITOVSKY

IT

It was a bit after seven, and I should have been downstairs on Plaza Deck, dressed in formal attire and enjoying dinner with the conspiracy theorists. There were about a hundred of them, and they were nearing the end of their week—the last week in January—aboard the *Ruby Princess*. Many of them were older people, and each of them had paid $3,000 (not including airfare and beverages on board) to participate in the first-ever Conspira-Sea Cruise, a weeklong celebration of "alternative science" hosted by a tour company called Divine Travels. For the past five days, they had debated UFOs, GMOs, government mind-control programs, vaccines, chemtrails, crop circles, and the Illuminati's plan for world domination, all while soaking up the mystical energies of three Mexican tourist towns known mainly for wet T-shirt contests and Señor Frog's.

But I was not on Plaza Deck. I was locked in my stateroom on Baja Deck, picking at a room-service cheeseburger. Earlier that afternoon, a pair of Conspira-Sea presenters had chased me—*chased* me—from a conference room. This wasn't our first confrontation, and now I feared they were tracking me around the ship, waiting to spring out from blind corners and empty doorways.

Understand that I don't consider myself the paranoid type. Although when I had come across the Conspira-Sea Cruise on a science blog a few months earlier, I'd known I wanted to go, but not because I fear dark forces are out to get me. I used to love *The X-Files,* and the prospect of discussing Roswell and JFK over piña coladas sounded like fun. So did getting to know some devoted conspiracy wonks. Wondering whether the world is actually as it seems is a uniquely American sport, and there's plenty of evidence that's worth wondering about—this is the country of Watergate and the Tuskegee experiments and the NSA tapping your phone.

But the *Ruby Princess* was no place for casual wonderers. The *Ruby Princess* was for people who scraped together three grand to be reassured that their fears and suspicions and theories aren't the lonely fever dreams of basement-dwelling outcasts, that those fears and suspicions are valid, and that others share them. It would be like a weeklong, in-person internet chat room.

Not that that's necessarily a good thing. Chat rooms can be terrifying (virtual) places, rabbit holes of self-reinforcing misinformation. Dip your toe into Reddit or Disqus and you will be bombarded with proof that Bigfoot lives in the mountains of the Pacific Northwest and that our government is run by giant lizards posing as politicians. Charlatans with slick websites can now manipulate data, doctor images, and fabricate documents, collecting thousands of followers. But it's not fair to dismiss all conspiracy theorists as web-dependent crackpots, and there's a difference between caution and paranoia—between reasonable skepticism and a wholesale rejection of scientific method. I didn't know what I'd find on this cruise. One of the great blessings of the internet is that it helps us find people who are like us, or who seem to be like us. For example, there are casual Phillies fans, and then there are the kind of Phillies fans who spend endless hours on Phillies fan websites e-conversing with the equally obsessed. Likewise there are people who kind of wonder, fleetingly, whether Lee Harvey Oswald acted alone before their thoughts return to work and family and whether to take the freeway or the local roads. And then there are people who fly far from home, at great expense, to spend a week on the Conspira-Sea Cruise.

Somewhere in the middle was me, deadbolted in my room. Paranoid.

ON A BRIGHTER, happier afternoon five days earlier, I boarded the *Ruby Princess* in San Pedro, California. Flanked by the port's grimy regiment of industrial smokestacks, the ship gleamed majestic white and soared almost two hundred feet into the air. She could accommodate more than three thousand passengers, occupying them with four swimming pools, twelve dining rooms and restaurants, an outdoor movie screen, two nightclubs, a full-service spa, and enough rococo baubles to satisfy Liberace. The ship's central atrium and its giant spiral staircase glittered like a pageant crown. Every corridor stretched into eternity, with identical stairwells crosshatching all nineteen decks.

"I'm so glad you made it!" said Adele McIntosh, the tour company's travel agent, when I finally located the Conspira-Sea check-in desk. She gave me a tight hug, then handed me my name tag and an orientation packet. When I wrote "Popular Mechanics" on my sign-in form, a woman to Adele's right shuffled some papers and nodded approvingly.

"Wonderful to have you with us," the woman said. "We're only now beginning to understand the quantum realm."

The week's seminars appeared to be split into two broad categories. There were those with a magical or highly new age component: "Astral Possession, Psychic Vampirism, and Exorcism," "Gaia-Sophia, Timelines and Global Alchemy," "How to Control the World with Mind Machines." And then there were those that detailed concrete, terrestrial dangers: "Are GMOs and Roundup Causing Disease in Millions?" "Vaccinations: Do You Really Know What's Coming Through That Needle?" A subset of the second group concerned itself with the U.S. legal and banking systems. Unfortunately, the nightly UFO watches had to be canceled because the man who was to lead them had recently suffered a stroke.

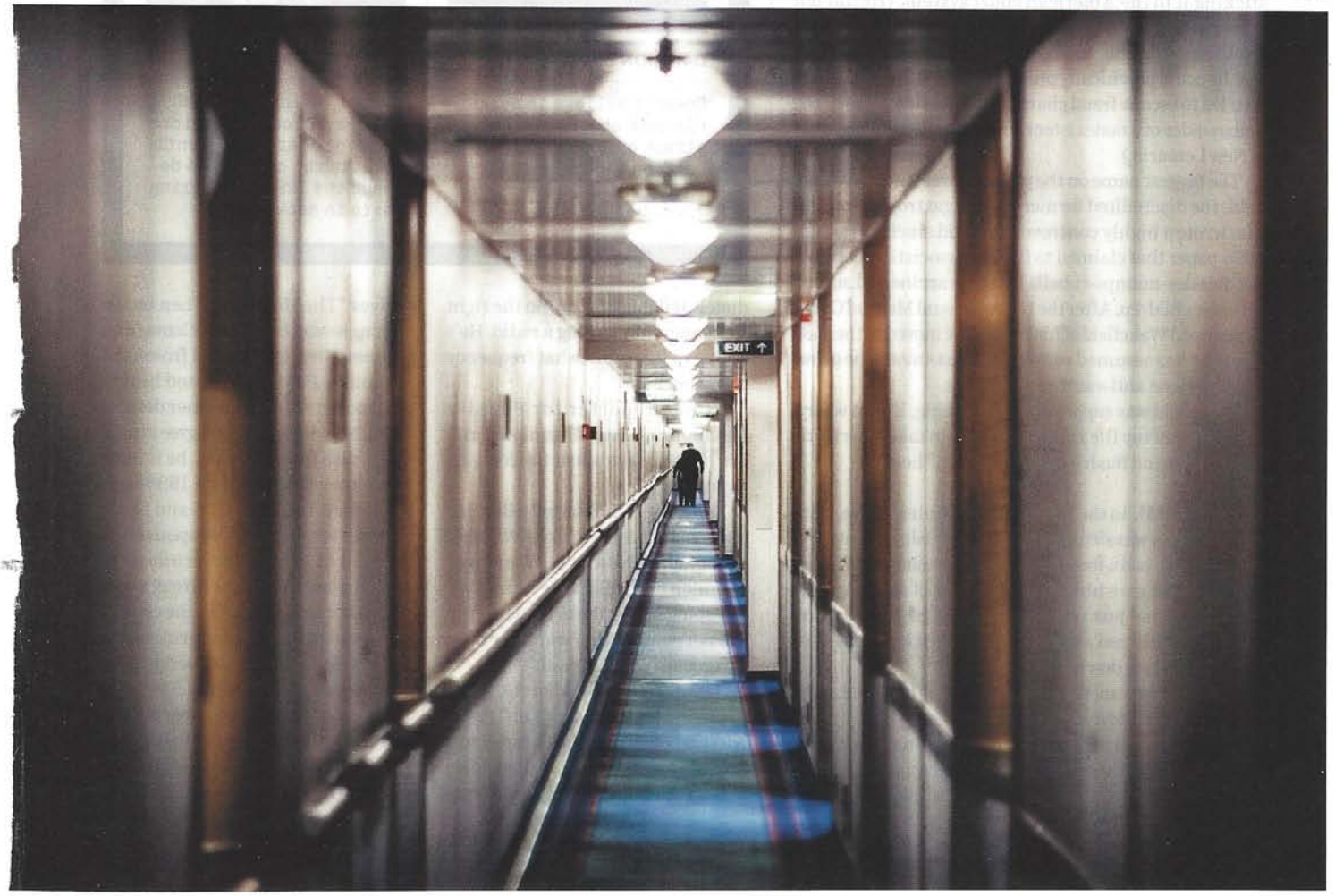
Inside my orientation tote bag was a shiny blue bracelet I was supposed to wear at all times. "Makes it easier to find members of the group," Adele said. But that wasn't necessary. Most of the cruisers—the vacationers, not our group—were generally outfitted in bright colors and loud prints. As the days passed, a lot of them began wearing novelty captain's hats from the gift shop. The conspiracy group, on the other hand, was mostly serious-looking senior citizens in "Infowars" T-shirts. Some of them wore casts, others walked with canes. Two relied on motorized scooters. None looked like he or she could afford to spend money frivolously. One eighty-year-old man's toes poked through the tops of his worn leather loafers.

I headed to the windowless conference room that had been temporarily renamed the Liberty Lab.

"Welcome everyone," said Dr. Susan Shumsky, the founder of Divine Travels and (claim to fame) one-time

"DEATH IS NOT REAL," HE SAID. "THAT'S THE BIGGEST BUNCH OF CRAP ON EARTH."

A predinner prayer in the ship's Michelangelo Dining Room; one of the maze-like hallways on the *Ruby Princess*.


EXIT

personal staff member of Beatles' guru Maharishi Mahesh Yogi. (Her doctorate in divinity is from the Teaching of Intuitional Metaphysics in San Diego.) "I'd like to begin with a prayer." Nearly everything the woman wore was either bright pink or sparkled. "Breathe in divine light!" she said. We closed our eyes and inhaled. Across the hall, in Gatsby's Casino, slot machines clanged to a piped-in soundtrack of Taylor Swift and Rihanna.

Then sixteen presenters introduced themselves and gave brief synopses of their seminars. Laura Eisenhower—great-granddaughter of Dwight!—said she had been invited in 2006 to join a secret American colony on Mars and that aliens, including some prominent U.S. politicians, are already living on earth in disguise. Dannion Brinkley, a *New York Times* best-selling author, announced that he had risen from the dead three times, the first after a lightning strike that sent him on a twenty-eight-minute sojourn through the afterlife. "Death is not real," he said. "That's the biggest bunch of crap on earth." Winston Shrout spoke of "commercial redemption," a philosophy that promises each American citizen access to giant piles of secret money.

"Generally I do speak from a little bit of a higher level," Shrout drawled in a thick Kentucky accent. "Because to understand commercial redemption, you have to go into the fifth, and even sixth, dimensions."

The attendees scribbled in their notebooks and eagerly circled items on the schedule. There were pitches for wishing machines, astrological charts, and dowsing rods, followed by screeds against Big Pharma and Monsanto. Sean David Morton, whom AM radio host Art Bell called America's Prophet, vowed to help us get out of debt while sticking it to the American court system. (He did not mention that in 2010 he was sued by the Securities and Exchange Commission for telling a group of investors that he could psychically predict the stock market or that he tried to escape fraud charges by declaring himself the ambassador of a nonexistent country called the Republic of New Lemuria.)

The biggest name on the program was Andrew Wakefield, the discredited former British gastroenterologist who wrote a highly controversial (and since retracted) 1998 paper that claimed to find an association between the measles-mumps-rubella (MMR) vaccine and autism in twelve children. After the U.K.'s General Medical Council stripped Wakefield of his license, he moved to the U.S., where he has assumed rock-star status among the growing American anti-vaccine movement.

Wakefield was superficially charming, if a bit weary. "The story of my life is basically how to take a perfectly good career and flush it down the toilet," he said.

LATER THAT NIGHT, in the Michelangelo Dining Room, Dannion Brinkley was sitting under an airbrushed painting of Poseidon. He is six-foot-four, and the flowing scarf under his sport coat gave him the appearance of an aging linebacker who had just returned from an ashram. Several fans were gathered around him. He motioned me over warmly and I sat down.

"What is your motive for being here," he asked, "and what is your *intention?*"

Puzzled, I looked to the young man on my left, who said he was an orthodontist from Calgary named Leo. He leaned over and whispered in my ear, "Dannion can immediately tell if people are on the right frequency, like tuning a radio. He's trying to figure out what frequency you're on."

"I'm a reporter for Popular Mechanics," I told Dannion, "and I'm here to learn about the conspiracy community."

He beamed and started telling me about his lightning strike. "Whether or not you believe me doesn't matter," Dannion said. "Because ultimately I'm going to win the argument. You are not going to die, and some of us can get up from the dead."

Before he could elaborate, a pair of presenters, Leonard "Len" Horowitz and his girlfriend, Sherri Kane, breezed into the room and sat down at our table. Online, they call themselves "The Horokane." Len bore a strong resemblance to the Count from *Sesame Street,* if you had frozen the Count in 1974 and dressed him in Hawaiian shirts. A former dentist from New Jersey with a degree in public health from Harvard, he is most well-known for writing a 1996 book that theorized the AIDS and Ebola viruses are genocidal weapons engineered by the U.S. government to depopulate the planet through vaccination programs. On the cruise, however, he would be lecturing on the key to lifelong health and world peace: the "miracle frequency" of 528 hertz.

According to Len, everything in the universe emits vibrations, and all the positive, life-affirming forces (including the green/yellow

THE ROCK STARS OF CONSPIRACY THEORY

Other than Andrew Wakefield (pictured on page 84), a few of the biggest draws on the Conspira-Sea Cruise.

LEONARD HOROWITZ

Theorizes AIDS is a genocidal weapon created by the government. Sells crystal pyramids for pain relief. Has a degree in public health from Harvard.

LAURA EISENHOWER

UFO fanatics think her great-grandfather Dwight held meetings with aliens in the White House. She claims many current politicians *are* aliens.

DANNION BRINKLEY

Doesn't believe in death. His book about getting struck by lightning and meeting angels in the afterlife was a *New York Times* best seller.

SEAN DAVID MORTON

Called "America's Prophet." Psychically predicts the stock market. Recently arrested on charges to defraud the IRS. Has amazing taste in neckties.

light in rainbows) "resonate" at a frequency of 528 hertz. Therefore, all music should be tuned in 528 hertz, rather than the 440 hertz of standard tuning, which he asserted was an evil plot imposed by the Rockefeller Foundation to militarize the world's populace. Len believes that standard tuning aggravates the pineal gland, making all of us emotionally distressed, sicker, and more destructive. He called this "musical cult control."

"You," he said to me, and then paused. "Are…a…digital, bio-holo*graph*-ic, precipitation, crystallization…mi-*rac*-ulous manifestation! Of divine frequency vibrations, forming harmonically in hydrospace."

"Okay," I said.

"That's the frequency that monks used to chant in while making brandy," Dannion added.

Len's face lit up. "When was that?"

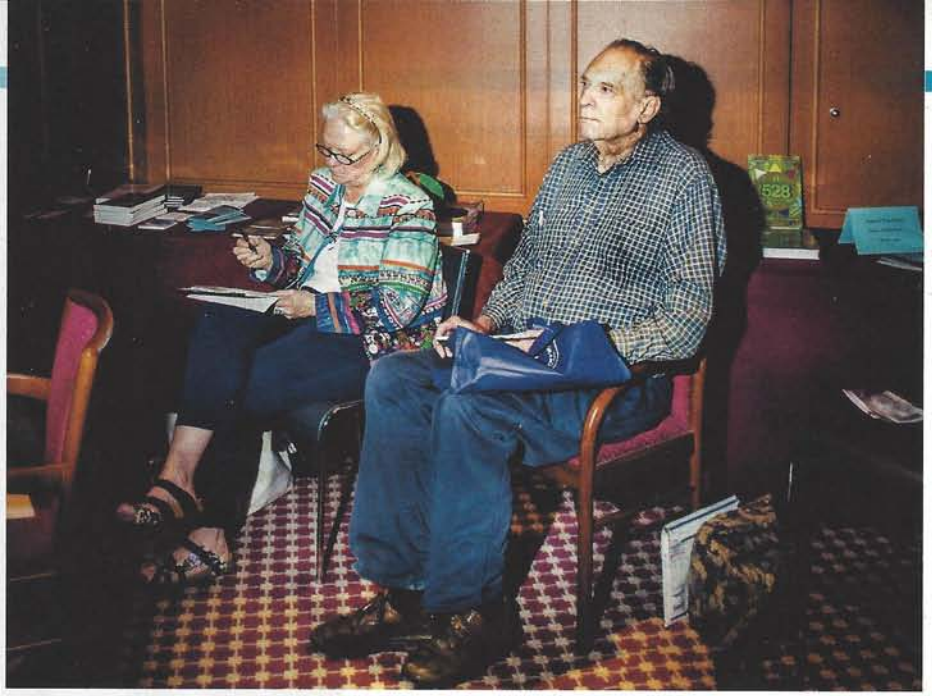
"In the 1340s," Dannion said.

"And how do you know that?" Len asked.

Dannion dabbed at the corners of his mouth with his napkin and said, "Because when you die, you know these things. I saw it when I crossed over."

Sherri introduced herself as an investigative reporter who "defected from Fox News." A pretty blond much younger than Len, she seemed to be the great love of his life. "If it weren't for her," Len said, "I might not have known that my ex-wife was working with the CIA to undermine me." (Reached by email, Len's ex-wife denied these allegations.)

"How do you know *I'm* not working for the CIA?" I joked.



Cruisegoers paid around $3,000 for the weeklong trip. Not including umbrella drinks.

Sherri waved the question off, laughing. "Because trust me, it would be obvious. If you were a plant, I would *know*."

When the ship lurched away from the dock and the ice cubes in our water glasses chimed under the drone of the propellers, Dannion requested that we all join hands to pray. Len lowered his voice and leaned across the table.

"The real question," he said, "is whether, after you've learned the truth about all this stuff, your editors at Popular Mechanics will even let you write it."

THE NEXT MORNING, shortly before Wakefield's lecture "Whistleblowing in the Public Interest," a tall, lean man wearing a shiny blue bracelet stood near the elevators. His name was Larry Cook. A soft-spoken fifty-one-year-old anti-vaccination activist from Los Angeles, he said he had joined the trip specifically to meet Wakefield, whom he regarded as something of a personal hero.

"The media has tried to destroy Andy," Larry said as he walked toward the back of a dining room where about fifteen other people were clustered. "But it's all lies and character assassination. We don't *need* drugs and vaccines. If we adopt a healthier lifestyle, we can regain our health without using them. Think about it: If vaccines actually worked, then why do these diseases still exist at all?"

The seminar began. For an hour, Wakefield paced in front of a projection screen, which ballooned his shadow to giant proportions. Slides of children born without arms and others screaming in pain flashed behind him.

"Your bodies are owned by Big Pharma," he said. "It's turning into a science-fiction movie." The audience gasped and shook their heads in disbelief. "This will be the end of the United States of America." During the Q&A portion,

THE TRUTH IS IN HERE

Popular Mechanics has a long history of covering conspiracy theories. Some of our more notable work:

JUNE 1907

"The Truth About Burning Ashes"
According to a popular rumor, you could mix a compound with ashes to make a fuel with more energy than anthracite coal. Uh, no.

JUNE 1961

"Facts and Myths About When to Change Oil"
Stop trusting your dipstick.

MAY 2001

"When UFOs Land"
Most scientists tell you there's no evidence of UFOs. Turns out that's not true.

JANUARY 2005

"Who's Spying on You?"
An exploration of the fragile state of personal privacy with the rise of GPS, sensors, and data aggregation.

MARCH 2005

"9/11: Debunking the Myths"
We consulted more than 70 professionals in aviation, engineering, and the military to disprove 16 common 9/11 conspiracy theories. We still get crazy emails.

Wakefield added, "This is a deliberate eugenics program, a deliberate population-control program."

I looked around the room. People were sitting and listening attentively. For the first two days, I was heartened by how open and friendly most of the group was, even if they sometimes said surprising things. They told me about their lives and how they were drawn to the conspiracy community.

"Ever since I was little, I've just known that something was off," a fit, stylish forty-seven-year-old office manager named Cary told me. "That we aren't being told everything. My family doesn't believe me, but they are totally brainwashed."

I asked her why she thought the government was poisoning its own citizens with vaccines and GMOs.

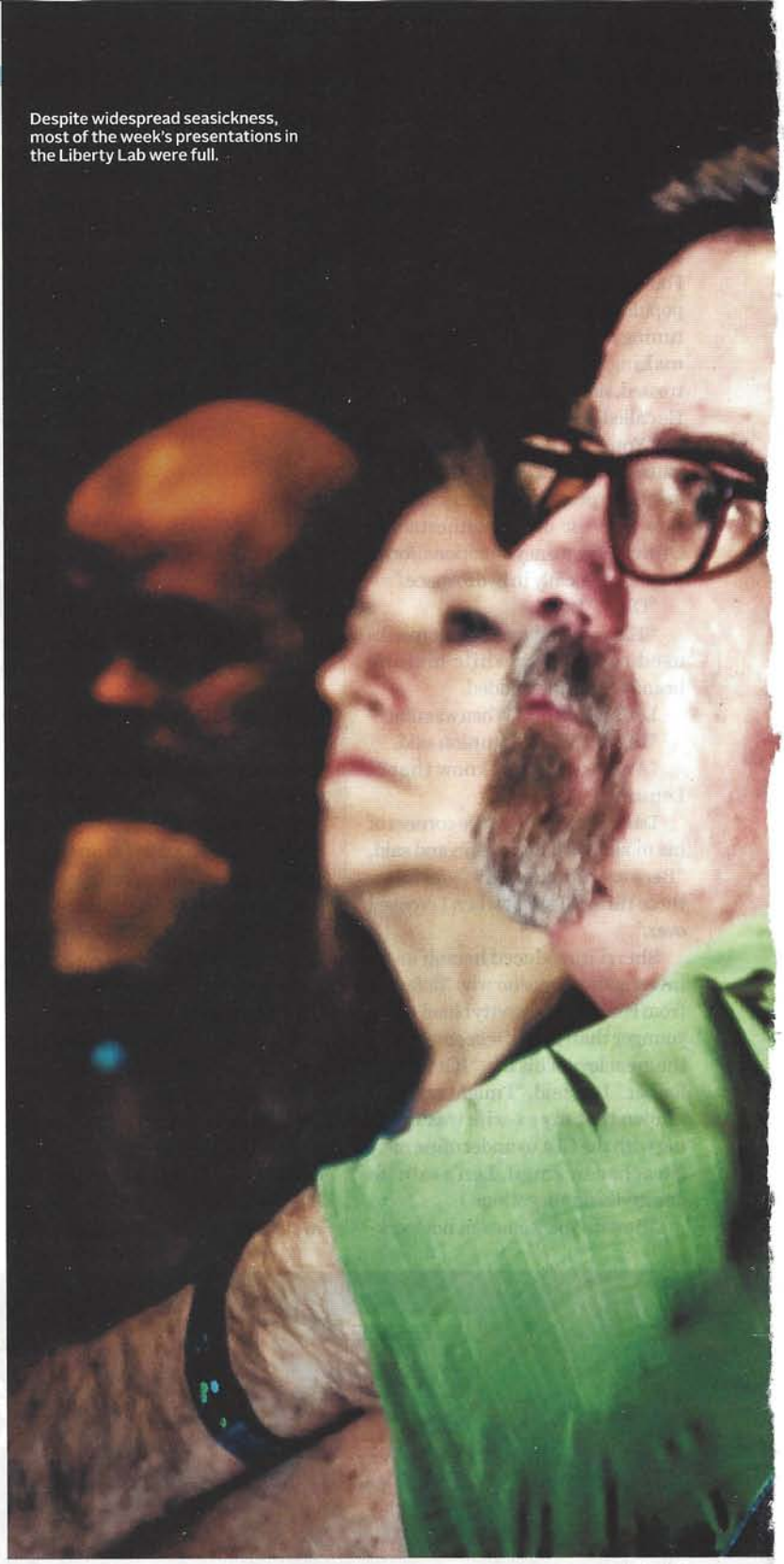
"Because they want to f--king kill us!" she said.

Not everyone was as cynical. Missy and Ron Hill were a married couple from Florida. Missy had a tousled thatch of short blond hair and wore a black leather jacket. Ron wore sandals and floppy fishing hats. The two had met in church roughly fifteen years ago. When Ron, a truck driver for a cryogenics company, was assigned longer runs, Missy went to truck-driving school so that they could see the country together. It was out on the open road that the couple began listening to the late-night AM radio show *Coast to Coast AM,* hosted by Art Bell, who is best known for broadcasting interviews with UFO researchers from a remote station in the middle of the Nevada desert.

"There was so much stuff I had never realized was going on," Ron said. "After that, we were kind of hooked, I guess." The couple's interest in "star gates" and global energy fields inspired them to travel to places like Ireland, France, and Spain. Unlike some of the other cruisers, they explored the world rather than hiding from it.

As the week went on, word spread among the participants that I was writing for a magazine that often covered the world of science. First, Susan Shumsky informed me and Dina Litovsky, the photographer on the story, that Wakefield had requested we not attend the preliminary screening of his documentary, *Injecting Lies,* which alleges that the Centers for Disease Control and Prevention has ironclad evidence that vaccines are linked to autism but has chosen to hide this alarming connection from the public. (Months later, the film—its title changed to *Vaxxed: From Cover-Up to Catastrophe*—would cause a heated national debate when it was accepted, then rejected, by the Tribeca Film Festival. In reviews, *Variety* called it a "scientifically dubious hodgepodge of free-floating paranoia" while *The Guardian* said it was "probably headed straight to the junkheap with all the other conspiracy films." Only when contacted by Popular Mechanics' research department five months later did Wakefield—through his publicist—offer to send me a link to the film.) Then we were asked by Jeffrey Smith, an anti-GMO activist whose previous career involved "yogic flying," to leave two other panels. After that, attendees began ducking out of photos and complaining about Dina's flash.

On Tuesday morning, we sat down in the front row of a presentation we had not yet been barred from: Len Horowitz's lecture on 528 hertz. While Len fussed with the projector, Sherri set out boxes of nutritional supplements and crystal pyramids for sale. Their flagship product, OxySilver, retailed for $49.40. It contained one listed ingredient: purified water, though its nutritional table also included 5 micrograms of colloidal silver.



Despite widespread seasickness, most of the week's presentations in the Liberty Lab were full.

"I took some OxySilver, and I'm already feeling better!" a woman in a scooter who'd suffered a recent bout of cancer announced to the room.

Dressed in a black velour jacket and white shirt with a butterfly collar, Len walked over to me. "I just want you to know that if you degrade and disparage me and libel me in your article," he said, "I will devote everything I have to exposing Popular Mechanics and the people behind it."

"I'm not here to degrade anyone, Len," I said. I was somewhat in shock, because our conversation at dinner the first night had been so

pleasant. "And certainly not to libel them. What is going on?"

"I am living a *nightmare!*" he sputtered, his voice rising like water starting to boil. "Every day of my life is like a roller coaster in *The Twilight Zone*. But I do this because I will not stand by and *watch this genocide!*" His eyes began to fill with tears. "I think that people should be able to choose how they are going to die, and not be *wiped out by the government!*"

THE INITIAL THRILL of a tropical vacation soon curdled into tension and distrust.

Maybe it was the claustrophobia of all those small, windowless rooms. Or the seasickness that seemed to claim more Conspira-Sea participants by the day. I saw fewer of them relaxing by the pool or playing Texas Hold'em. At breakfast one morning, a woman whose father had survived the Holocaust told me that she broke down in tears when another cruiser claimed it never happened.

(One bright spot: During a day trip to the Las Labra-

Attendee Larry Cook (left) defends the Popular Mechanics team from presenters Len Horowitz and Sherri Kane.

das petroglyphs—carvings etched into large boulders on a beach near Mazatlán—Larry Cook calmly mentioned that the reason few people were now talking to me was that I was "pro-vaccine." We had a civil conversation about the issue—me conceding I was swayed by scientific consensus and the mountain of rigorously controlled peer-reviewed studies that have proved vaccines to be safe and effective, Larry remaining skeptical. Neither of us changed our minds, but we didn't get into a heated shouting match or assault each other's motives. In the two-dimensional world of the internet, it is easy for people on the opposite sides of a controversy to become ciphers to be vanquished rather than human beings with legitimate questions and concerns. It's much harder to dismiss someone right in front of you, a person whose story you know.)

That night the ocean whipped itself into twelve-foot swells. Even more people grew seasick. Still, there were enough to pack the Liberty Lab for the Horokane's screening of their documentary about the Paris terrorist attack on the Bataclan concert hall in November 2015, which they maintained was part of one large false-flag operation. It turned out to be a plotless pastiche of Hollywood movie trailers (*Wag the Dog, Our Brand Is Crisis*), interview segments with survivors of the Bataclan theater attack downloaded from YouTube, and clips of Sherri and Len talking in front of a green screen that had been digitally rendered to look like a news desk. Drawings of Satan and banners denouncing the militant media scrolled behind Sherri's head, as did several advertisements for Len's supplement company, Healthy World Organization.

The film's central thesis went like this: Hollywood superagent Ari Emanuel (who represents Eagles of Death Metal, the band that was playing at the Bataclan when it was attacked) was in cahoots with the Lagardère Group, a French media conglomerate that had purchased the Bataclan in September 2015. Because Qatar Holding has a stake in Lagardère, and because the government of Qatar has been criticized for tacitly allowing terrorist groups to do their banking in the United Arab Emirates, and because—and this is where they totally lost me—Ari Emanuel is the brother of Rahm Emanuel, the mayor of Chicago, the Horokane believed that Lagardère must have orchestrated the attack with the help of Ari Emanuel.

When the film ended, Sherri grabbed the microphone. Her face had turned into a grim, ugly mask, the corners of her mouth pulled downward as if by strings.

"I don't want anybody to leave the room right now," she said. "I have a question." She pointed at Dina, our photographer, who was circling the room taking pictures.

"Come up here," Sherri said. "I want you to tell everybody who you work for."

"I'm with Popular Mechanics," Dina said. "Everybody knows that."

As though she were talking to a small child, Sherri continued, "And can you tell everybody what Popular Mechanics has to do with a *conspiracy cruise?*"

Someone in the audience interrupted, "You know she's the photographer, not the reporter?"

"Let me ask the questions, okay!" Sherri snapped, turning back to Dina. "And can you tell everyone why Popular Mechanics would be interested in people like us?"

Dina just smiled. "What, you don't think you are interesting?"

"You're taking photos so that you can label us conspiracy theorists!"

Dannion Brinkley groaned. "Let's keep it in 528, y'all," he said.

A woman named Abbie, who taught free yoga classes every morning, also stepped in. "That's enough, guys," she said.

"And who are *you?*" Sherri said.

"She's a plant!" someone yelled from the audience.

Eyes rolled. Heads shook. People filtered out.

Someone muttered, "She's the yoga teacher."

WHEN WE ARRIVED at the Liberty Lab the next afternoon, Len accosted Dina in the doorway. His eyes were the size of dinner plates.

"I want you to see something!" he shouted as he tried to force a packet of papers into her hands, then mine. They were articles from Popular Mechanics debunking bad science. Apparently Len and Sherri had been up all night Googling the magazine and printing out documents in the ship's computer center. There was also a Wikipedia entry that linked the magazine's parent company, Hearst, to the Lagardère Group.

I tried to laugh it off and go around him, but Len wouldn't let me pass.

"Look at this!" he shouted, his face contorting with rage. "Look at this! *This is why you're here!* You're here in *bad faith!*"

Larry Cook, who had also been milling around in the hallway, stepped in front of Len to keep him from lunging at me.

"Get your hands off me!" Len shouted at him. "Get your f--king hands off me!"

Armed with a camera, Sherri darted out from behind Len and chased me around the hallway, demanding that I explain myself. As I tried to block my face from the camera, I got trapped against the wall between Len and Larry, who seemed seconds away from a full-on brawl.

"If you don't stop this, I'm calling security," Larry said. Len then challenged Larry to a fistfight in the ship's gym.

That's when I ducked out of the corridor, fled Fiesta Deck, and deadbolted myself in my cabin for the rest of the night. We had sailed far from the Mexican coast, over reason's horizon. We were now bobbing around on the waters of pure insanity.

THE HALLWAY SHOWDOWN turned the rest of the trip into a blur. Wakefield chummily invited me and Dina to his third presentation, which we declined, only to learn from others who attended that he had planned to ambush us by reading aloud from Popular Mechanics. Dannion Brinkley "read my energies" by giving me a long hug. "You were flowing beautifully just then," he said. "But you're putting love out there to someone who isn't giving it back. You're giving this person too much power. You need someone who can appreciate you... like me!" Winston Shrout, in his farewell lecture, reasserted his position as the third-dimensional delegate to the Galactic Roundtable, noting that many of his clients were "fairies and elves." I learned from Laura Eisenhower that Hillary Clinton may have a supernatural agenda for world domination. "She's not even human," Eisenhower said. "You don't want to know what she is."

WE WERE BOBBING ON THE WATERS OF PURE INSANITY.

I also witnessed something called the Baked Alaska Parade. It was the final night of the cruise. I was eating dinner with Dina in the Da Vinci Dining Room, taking long pulls on overpriced beer. The lights dimmed. The waitstaff, holding LED-lit trays of meringue cakes over their heads, formed a conga line and began snaking around the tables to the song "Hot Hot Hot." Someone with a microphone shouted, "Ladies and gentleman, get those napkins up!" And they did. Everybody in the dining room except Dina and I twirled their napkins in the air while singing along. *Olé, o-lé, olé, o-lé.* It was kind of silly, but I think the point was to make people feel they were a part of something bigger.

The conspiracy community does the same thing. Its emotional power is much stronger than facts. It offers a worldview in which chaos, randomness, happenstance—the messy, frightening qualities of life that science depends upon and our minds find so hard to accept—simply do not exist. For some, a sinister reason for life's disappointments is more satisfying than no reason at all.

When we finally disembarked, after Dina and I had driven away, a team of special agents with the Internal Revenue Service arrived at the port and arrested Sean David Morton and his wife, Melissa, on fifty-six counts of fraud, including filing a false tax return that sought a refund of $2,809,921. If convicted, the two face more than six hundred years in prison. (Both have pleaded not guilty.) A couple months later, Winston Shrout was indicted for allegedly printing more than $1 *trillion* in fake financial documents. (He has also pleaded not guilty.) Len and Sherri returned to their home in Hawaii and wrote a long, angry blog post charging me with war crimes and claiming I was part of a top-secret cell of "Pharma Trolls." They also charged Larry, who tried to protect me, as being a double agent for Big Pharma.

Even then, I had a hard time feeling angry at Len.

"I had a brilliant mother who scrubbed the streets at Nazi gunpoint in Vienna," he revealed during one of his last panels, which I attended only after Adele's assurance that she would call security if the Horokane caused any more scenes. "By miracle my mother made it onto one of the last ships out of Europe. By a miracle I am sitting here today. My mother used to say, 'Lenny, you have no idea. Corporate fascism and neo-Nazism could arise at any time and anywhere, in any country.' And I said, 'Mom, I understand your pathology. You're neurotic. Had I been through what you went through, I certainly would feel the same way. You see Nazis everywhere. But I'm sorry, I can't go along with that agenda. I would recommend some good therapy.'"

Then Len's mother received the 1976 swine flu vaccine. After that, she developed Guillain-Barré syndrome, a disease that attacks the peripheral nervous system. She also developed uterine cancer. When she died, Len became convinced that the vaccine—which *was* linked to a small uptick in Guillain-Barré, according to the CDC—was responsible for her illness and subsequent death.

Len Horowitz saw something troubling in the world. When bad things happen without cause, some people turn to religion for comfort. Some look for a scientific reason. Some conclude that bad things happen and there's nothing we can do. Not Len. Len wanted a direct explanation. There had to be one. You just had to know where to look. PM

A sign that was held up to presenters to keep them on schedule.

ICD-10

MICROMD EMR VERSION 10.0

UPDATE GUIDE

Exhibit 10

HENRY SCHEIN®

MicroMD®

Clinical Quality Measures

43 Clinical Quality Measures have been updated for Stage 2 to include ICD-10 codes as well as ICD-9 codes. These updates are done behind the scenes in the reference database.

Form Encounters and the Administrative Form Builder

Users can create forms using the Form Encounter or the Administrative Form Builder to create forms containing ICD-10 codes. The codes will work with checkboxes, options buttons, pick lists and when inserting medical information or assessments with ICD view/print.

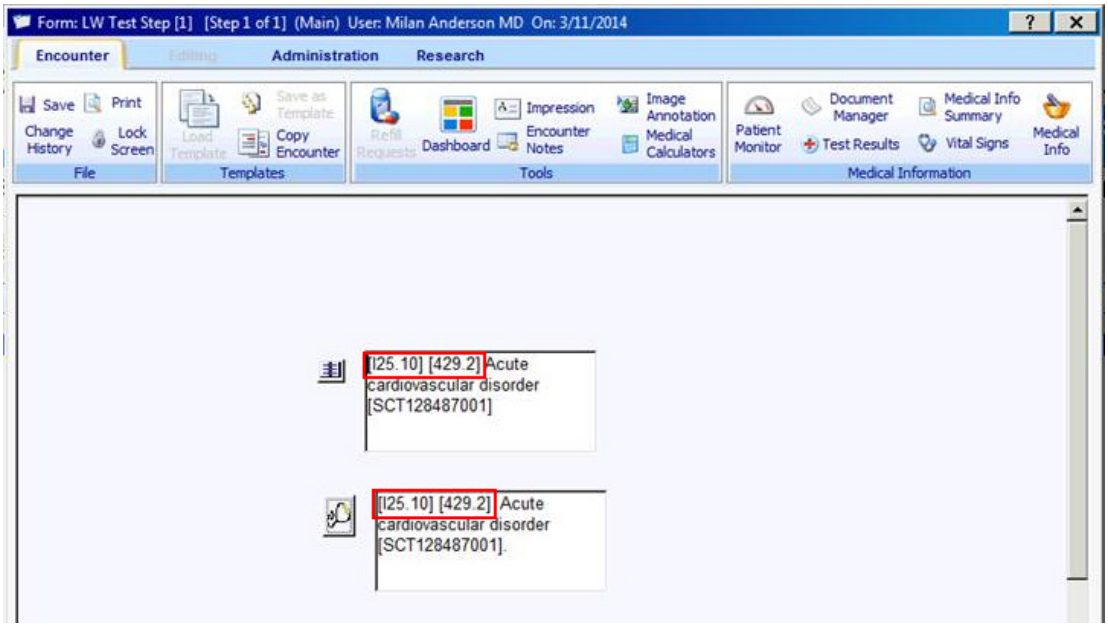


Figure 1.34 ICD-9 and ICD-10 codes in the Form Builder

Drug-to-ICD Warnings

MicroMD has incorporated First DataBank's Medical Lexicon Module, which integrates all existing ICD-10 codes into the EMR, and drug-to-ICD warnings are current with the new code set.

First Databank (FDB) Empowers Medical Decision-Making

First Databank is the leading provider of drug databases that are integrated into HIT systems. We create innovative solutions to meet clinical and other healthcare business decision support needs. And, we've launched a new database platform to help improve the identification, utilization, and tracking of medical devices.

- Unmatched experience in developing and integrating drug and medical device databases
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First Databank (FDB) is the leading provider of drug and medical device knowledge that helps healthcare professionals make precise decisions. We empower our information system developer partners to deliver valuable, useful, and differentiated solutions used by millions of clinicians, business associates, and patients every day. For more than four decades, our medical knowledge has helped improve patient safety, operational efficiency, and healthcare outcomes. For a complete look at our solutions and services, please visit **www.fdbhealth.com** and follow us on **Twitter**, **LinkedIn**, and **YouTube**.

nature electronics

ARTICLES

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

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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

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nature COMMUNICATIONS

ARTICLE

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Non-equilibrium signal integration in hydrogels

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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 12

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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

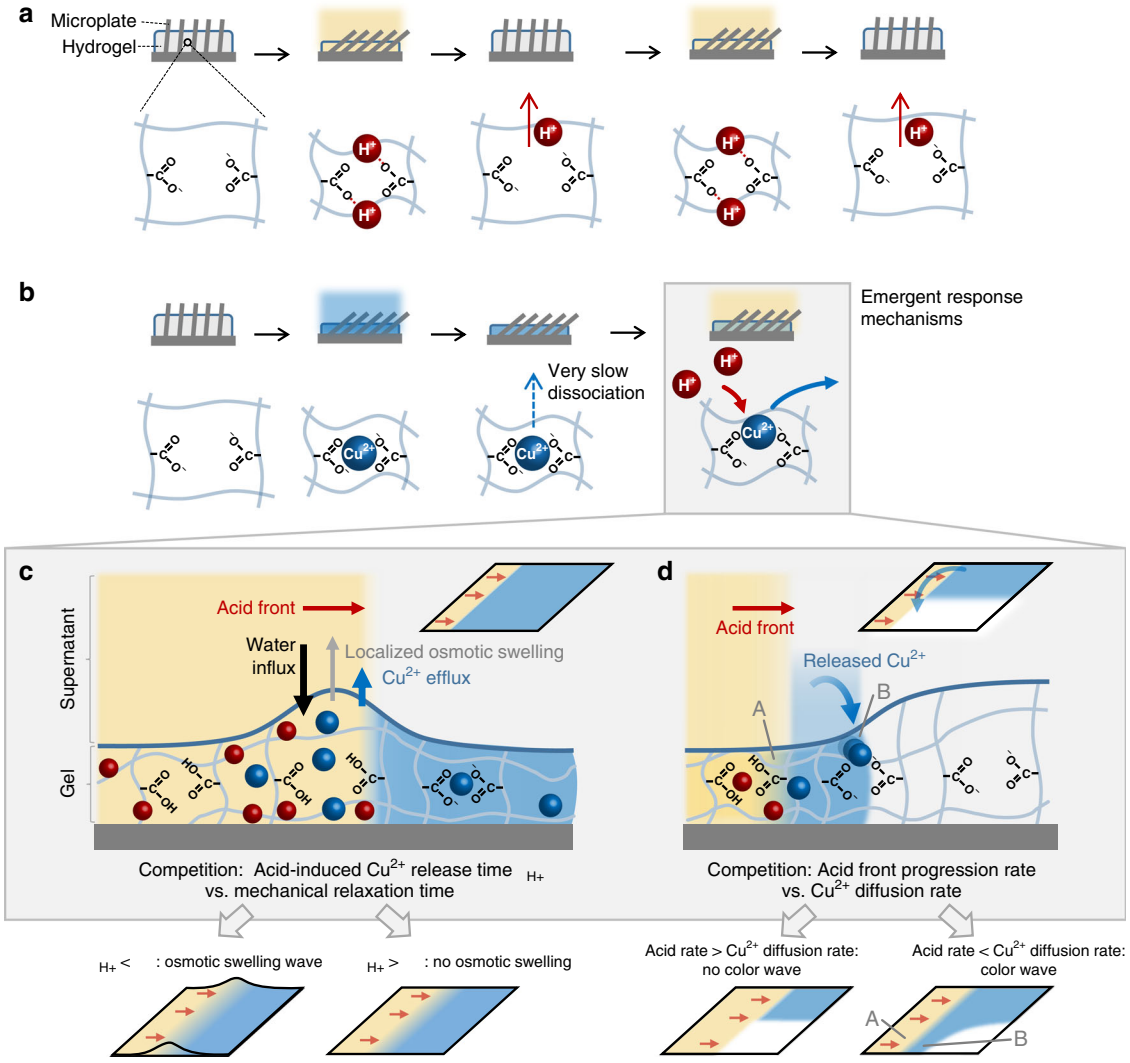

Fig. 1 Non equilibrium coupling of stimuli across time. a Traditionally, a responsive polyacrylic acid (PAA) hydrogel contracts and swells directly in-phase with the presence or absence of an acid stimulus (yellow). Here, hydrogel contraction tilts an array of embedded microplates (gray). **b** In contrast 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).

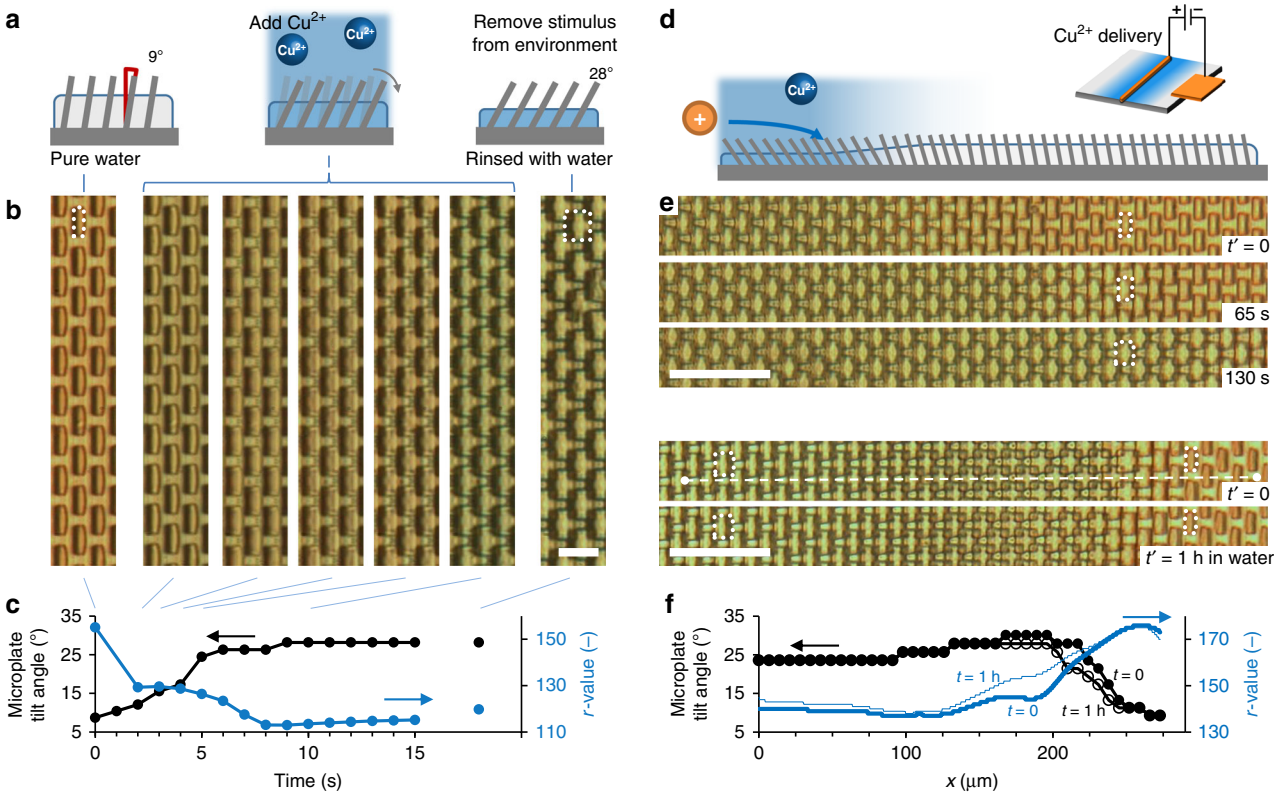

Fig. 2 Delivery and storage of a Cu^2 stimulus. a Scheme of the Cu^2 complexation, hydrogel contraction, and microplate tilting upon exposure to Cu^2 , and the maintenance of this response upon the formation of kinetically stable complexes after the stimulus is removed from the external environment. **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

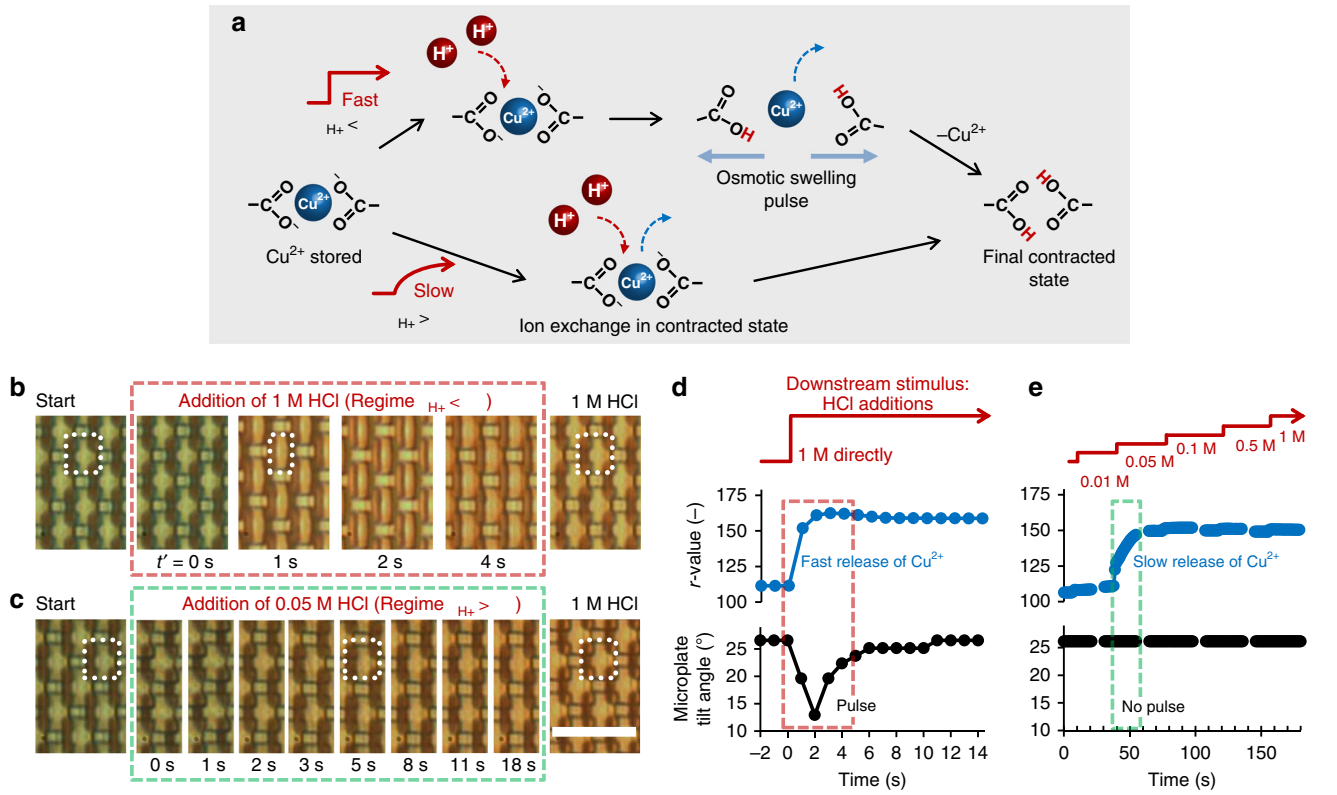

Fig. 3 Cu^{2} ions generate a transient osmotic swelling pulse upon rapid release by an acid stimulus. a Schematic presentation of the mechanism, showing how acid delivered after Cu^{2} has been removed from the external environment of the hydrogel protonates carboxylate groups and thereby releases the 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 $v_{C} > 10$ µm 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 µm 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 $v_{C} = 0.76$ µm s ^{1}. In contrast, fast progression ($v_{C} \geq$ 95 µm 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(δ^{0}, ϵ^{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.

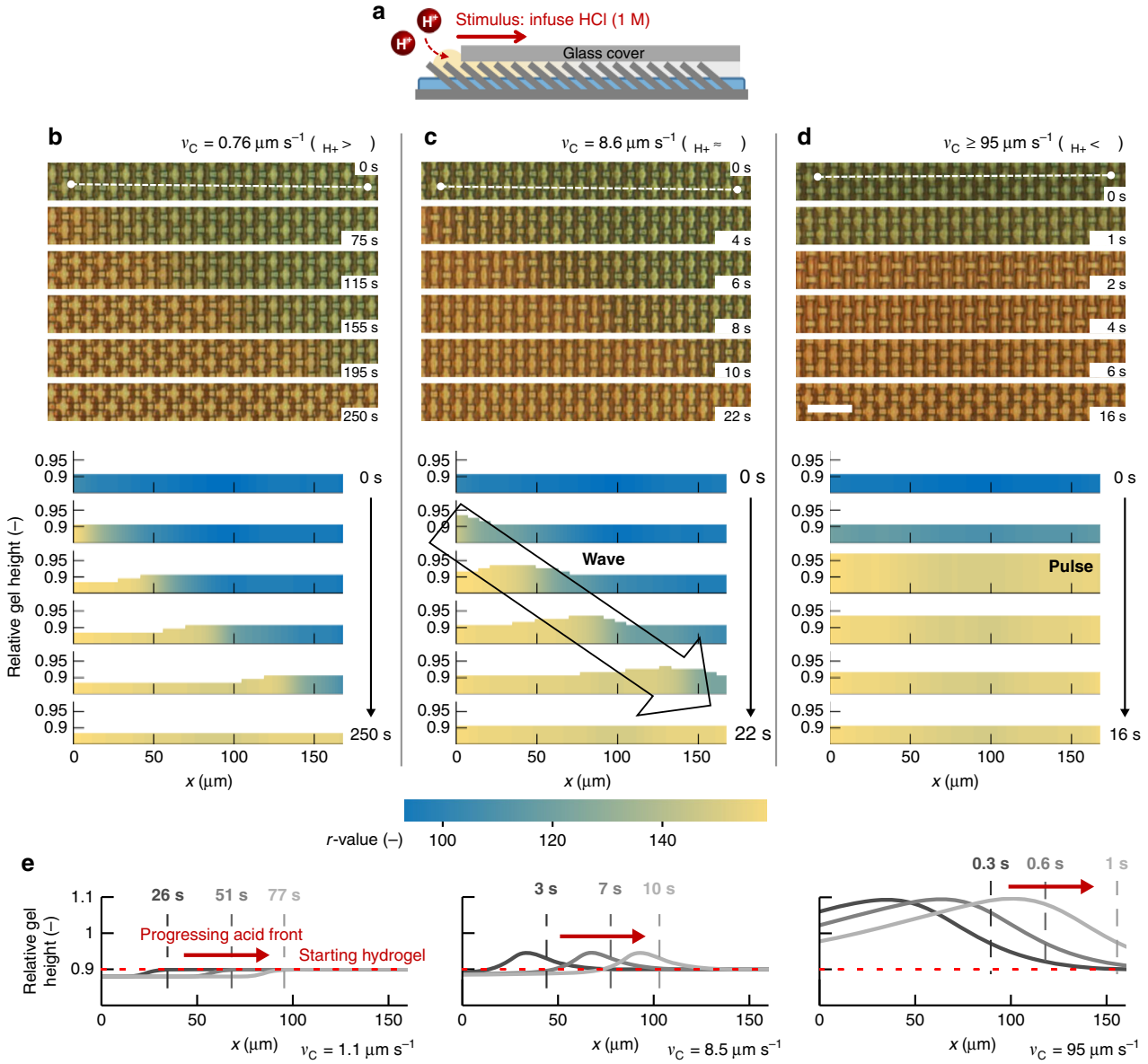

Fig. 4 Traveling swelling waves that are sensitive to the acid progression rate. a Schematic of the experimental design: HCl (1 M) is added from the left side of a Cu^{2} -contracted substrate covered with a thin water film and a glass cover (see Methods). **b d** (Top) Micrographs showing the progression 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 ($v_C = 8.6$ 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

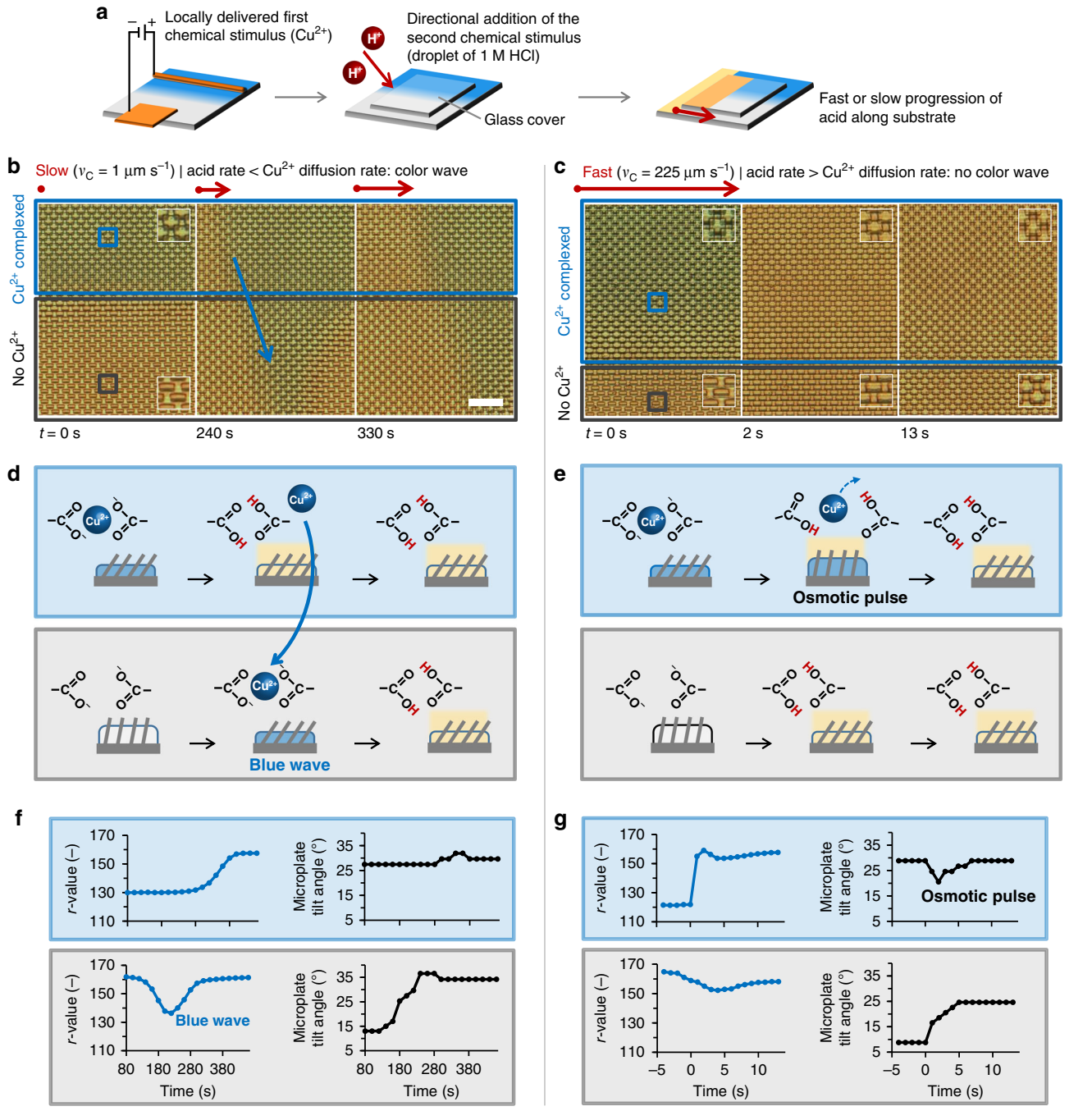

Fig. 5 Traveling color waves selectively reporting slowly progressing acid stimuli. a Schematic presentation showing the mechanism for the appearance of the travelling color waves: Cu^2 is initially delivered electrochemically to one side of the substrate (blue region in diagram). A glass cover is then 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 μm 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 $v_C = 3$ μm 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 $v_C < 5$ μm s ^{1}, assuming $D^{(a)} = 10^{9}$ m^2 s ^{1} and $_{Cu2}$ = 10 s. Indeed, at fast progression rates ($v_C = 225$ μm 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 (λ_{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 13

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EXHIBIT 14

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

EXHIBIT 15

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

can reach the world's most vulnerable people in times of crisis, NEC will focus on gning 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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Profusa and Partners Receive DARPA Award to Speed Detection of Disease Outbreaks

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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 16

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 17

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. YE Acted as an Agent of the PRC without Notification to the Attorney General

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
	)	
	)	Violations:
v.	)	
	)	Count One: Smuggling Goods From
ZAOSONG ZHENG,	)	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 18

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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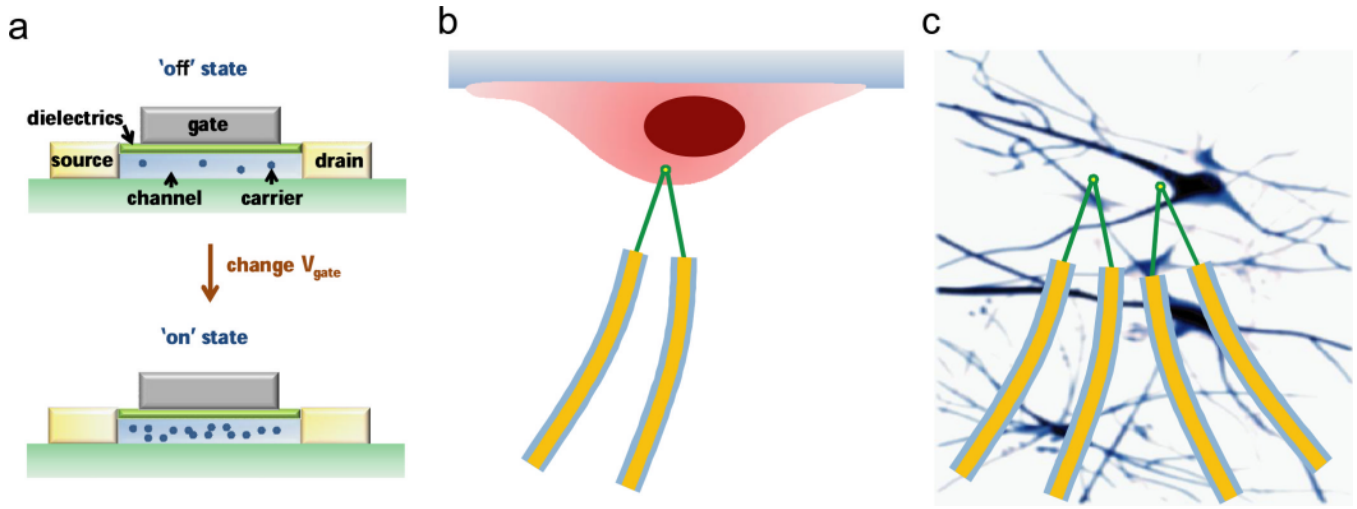


Figure 1. FET basics and electrical interfaces between nanoFET and biological systems

(*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.

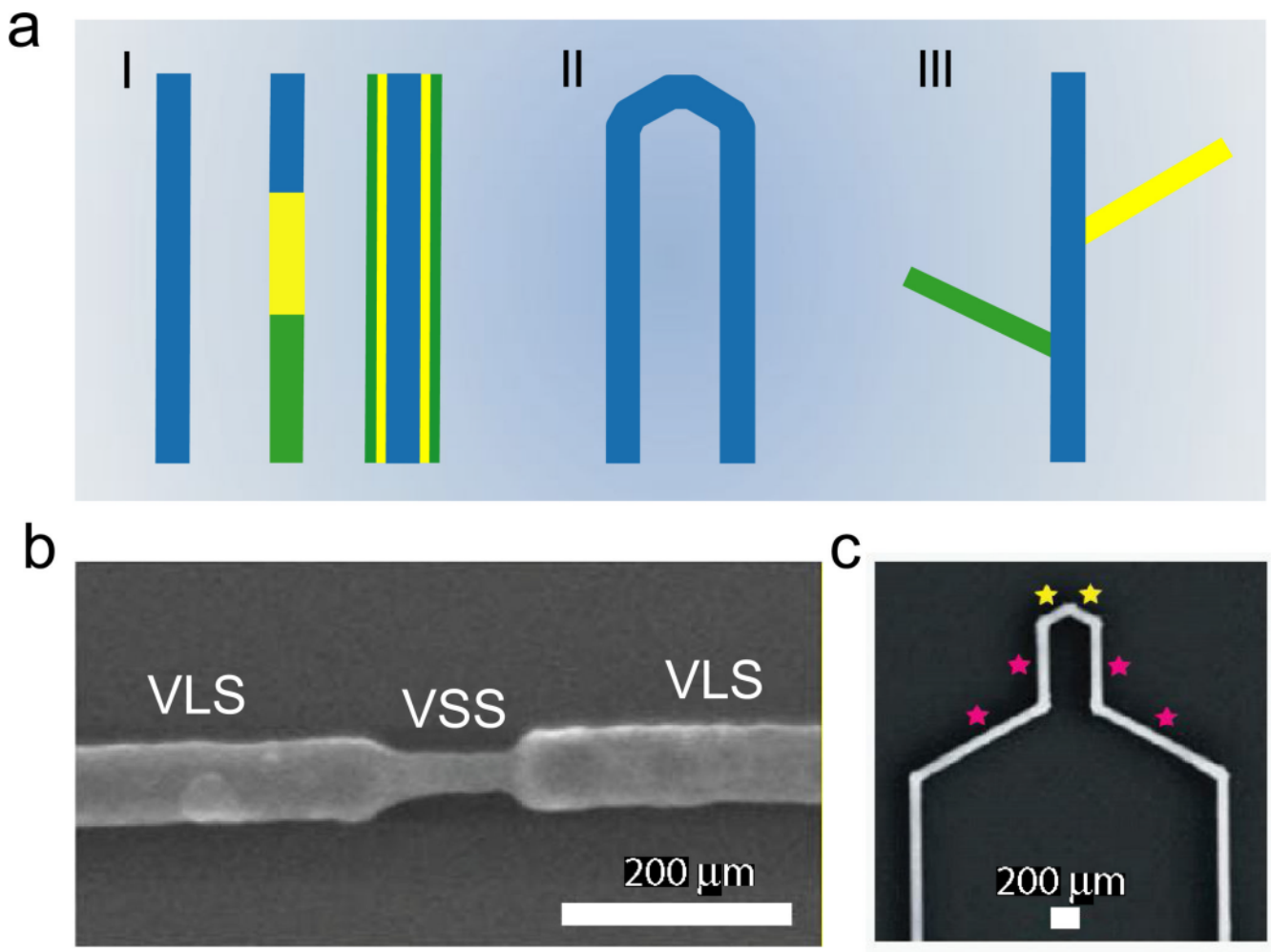


Figure 2. Semiconductor nanowire structural motifs for nanoFETs

(*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.

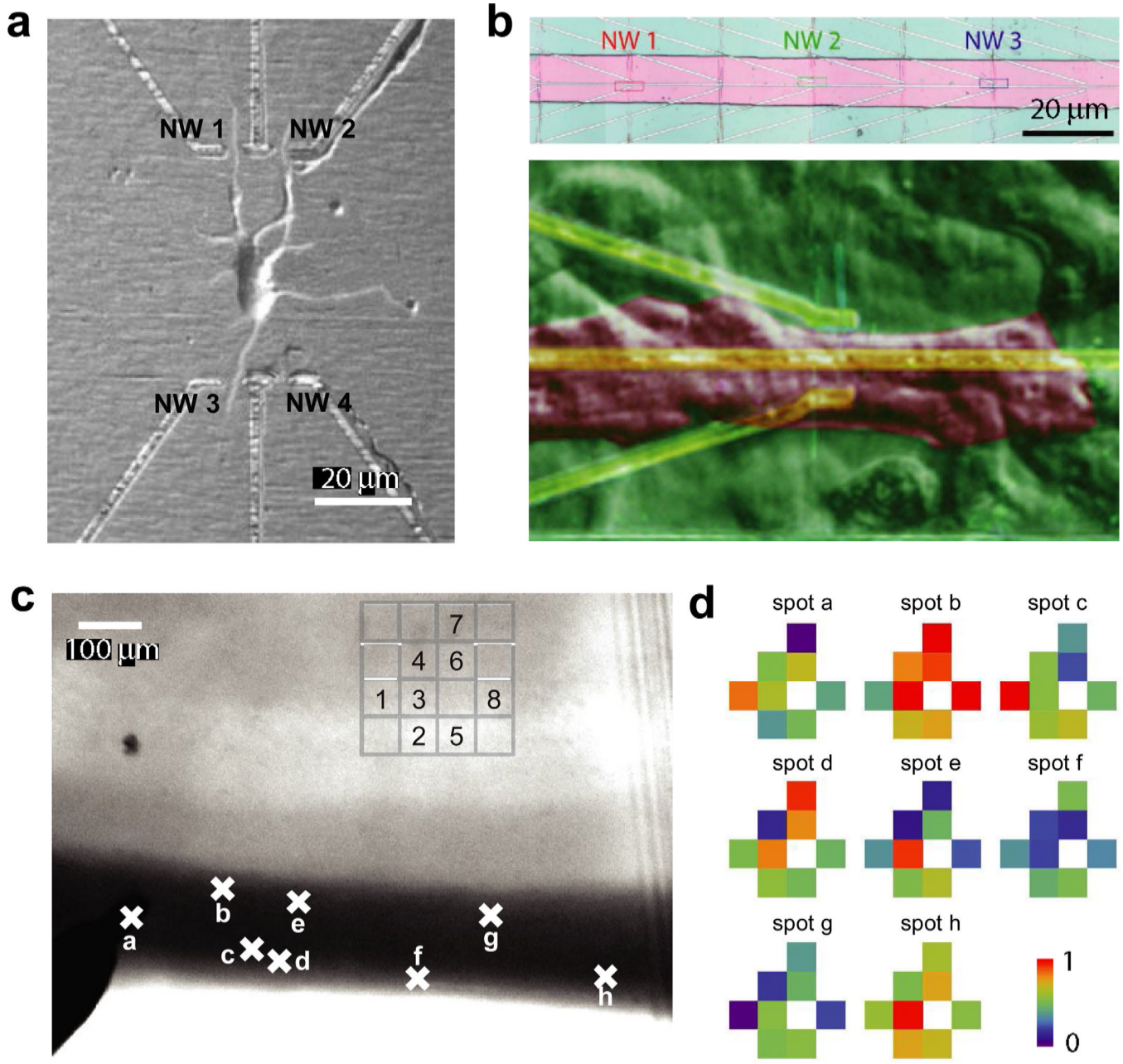


Figure 3. Multiplexed extracellular electrical recordings using nanoFETs

(*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.

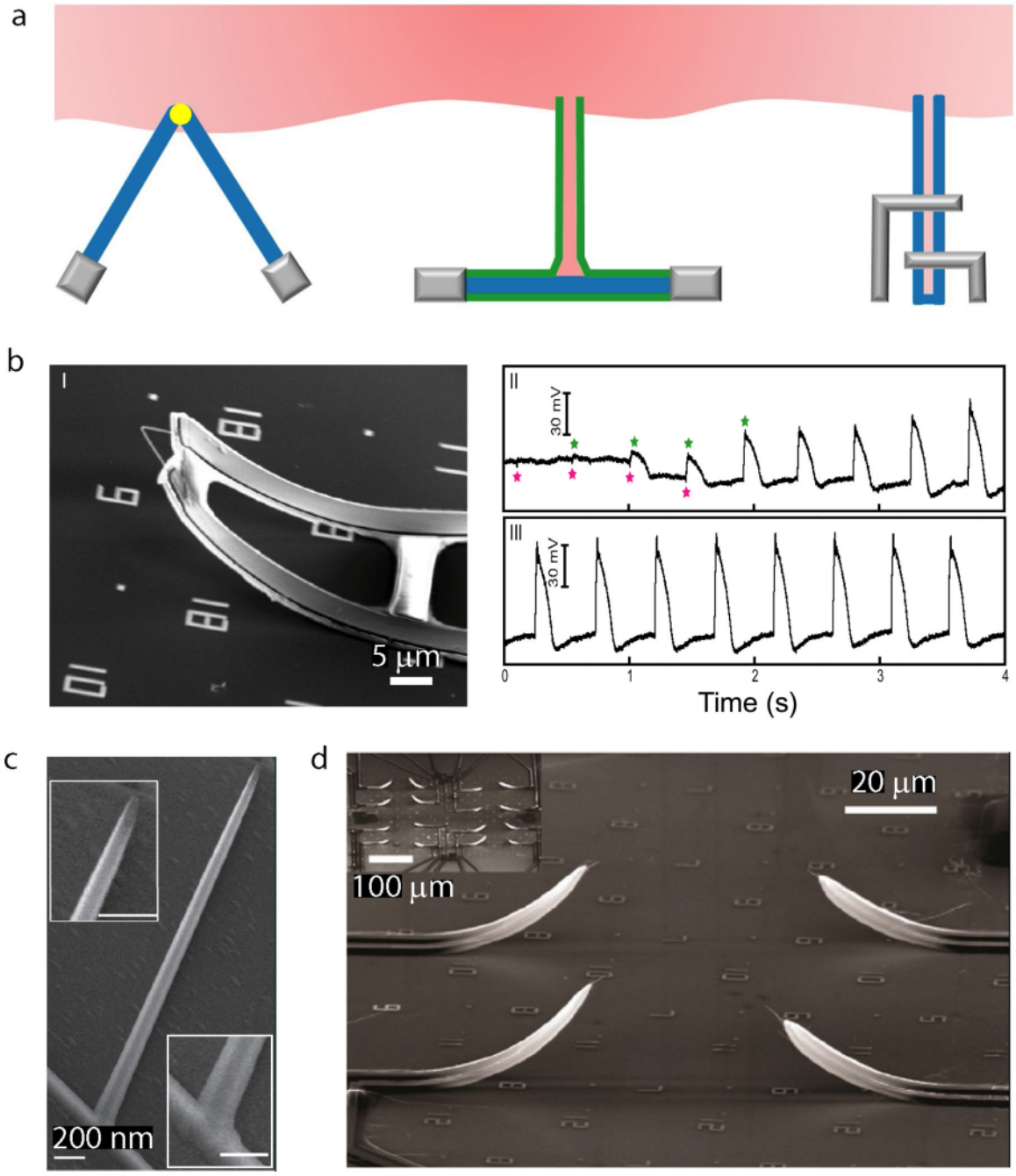
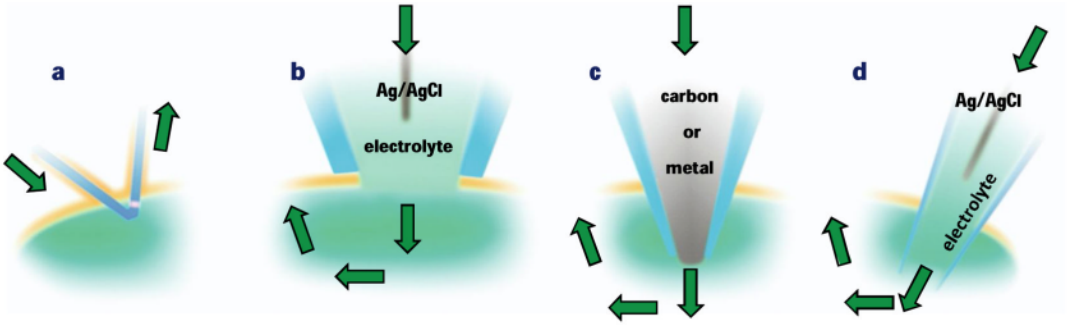


Figure 4. Intracellular electrical recordings using nanoFETs

(*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.



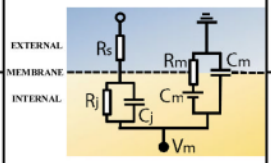
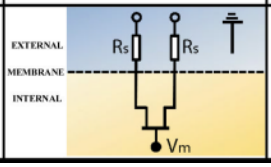
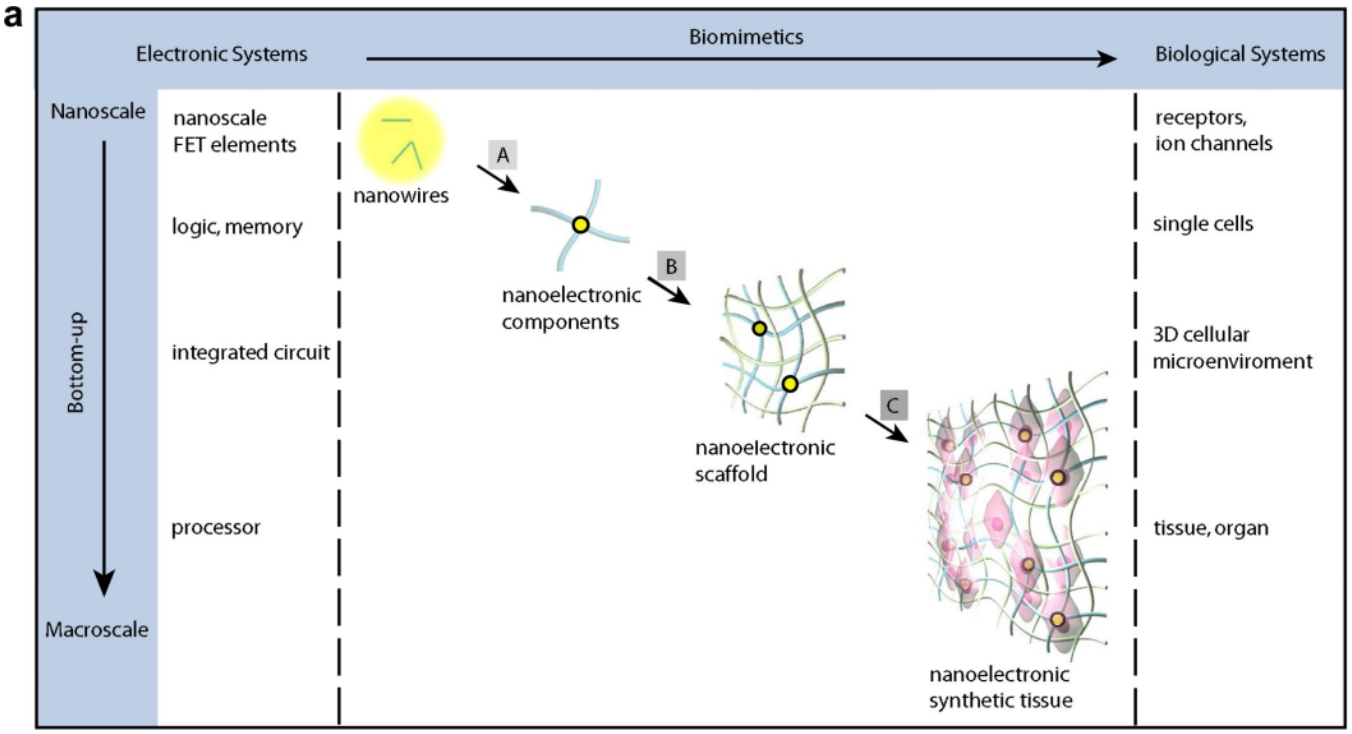
IC technique	Equivalent circuit	Size (nm)	Calibrations	Capabilities	Invasiveness	Cellular entrance
Glass micropipette (b and d)		~ 50-5000 Impedance limited	Both amplitude and shape	Can record both current and voltage, Single ion channel to whole cell recording	Electrochemical and mechanical	Mechanical 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)		~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	

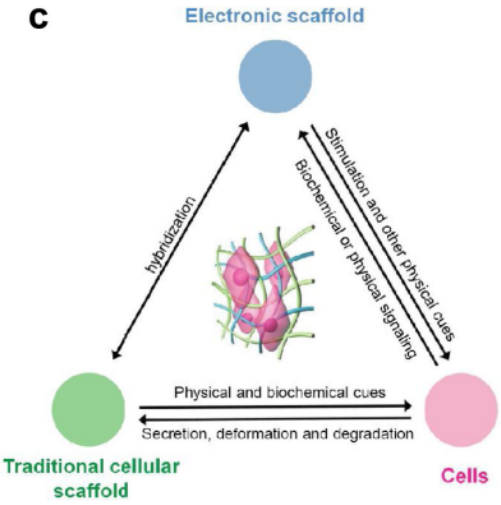


Figure 6. Integrating nanoelectronics with cells and tissue

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.

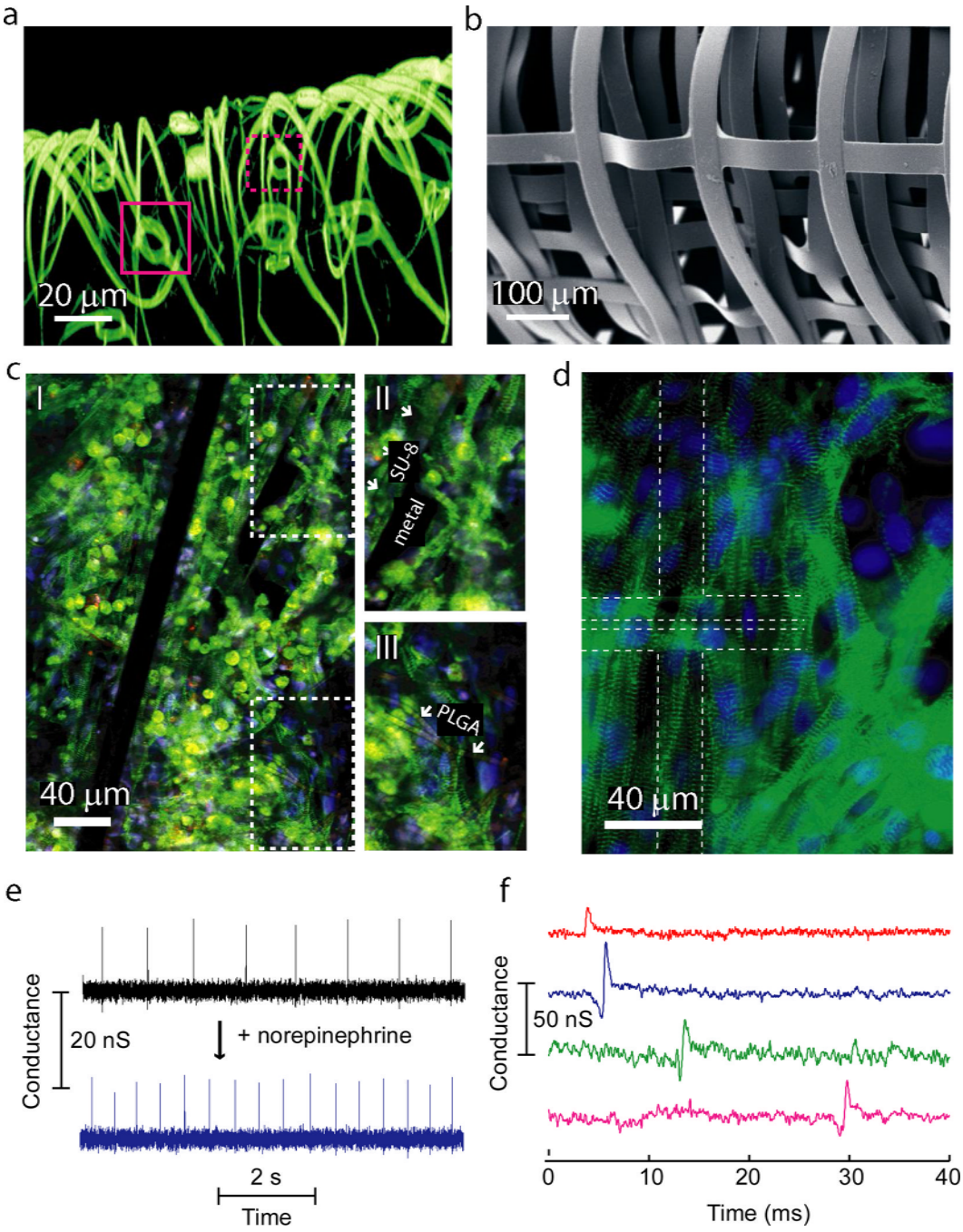


Figure 7. NanoES and synthetic tissues

(*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.

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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 19

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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."

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

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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*

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TECH AND SOCIETY

> *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?

> *"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.

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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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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

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CIA ‘Siren Servers’ can predict social uprisings 3-5 days in advance

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How many missile test events will North Korea conduct in August 2019? Will there be a locally-transmitted case of the Zika virus in Brazil in July 2019? These are just a couple of the hundreds of sample questions that the Intelligence Advanced Research Projects Activity (IARPA) has for its Geopolitical Forecasting Challenge (GFC) 2. “Who controls … Continue reading

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IARPA awards a research contract for extracting data from text to Raytheon BBN, which harvests the text of social media postings and other data. “An opportunity to develop better methods to extract complex semantic information from documents” The Intelligence Advanced Research Projects Activity (IARPA) has awarded contracts for its Better Extraction from Text Towards Enhanced Retrieval … Continue reading

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Tim Hinchliffe

Tim Hinchliffe is the editor of The Sociable. His passions include writing about how technology impacts society and the parallels between Artificial Intelligence and Mythology. Previously, he was a reporter for the Ghanaian Chronicle in West Africa and an editor at Colombia Reports in South America.
tim@sociable.co

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Henry Schein Named to Fortune® Magazine's 'Change the World' List

Company Recognized for Its Role as Co-Founder and Private Sector Lead of the Pandemic Supply Chain Network

EXHIBIT 21

https://fortune.com/change-the-world/2020/search/ (Graphic: Business Wire)

September 21, 2020 08:05 AM Eastern Daylight Time

MELVILLE, N.Y.--(BUSINESS WIRE)--Henry Schein, Inc. (Nasdaq: HSIC) announced today that it has been named to FORTUNE® magazine's "Change the World" list, an annual ranking of companies that have had a positive social impact through activities that are part of their core business strategy. Henry Schein was recognized for its role in helping to create the Pandemic Supply Chain Network (PSCN), a public-private partnership aimed at saving lives by strengthening the resilience of the global health supply chain in response to pandemics. Henry Schein serves as the PSCN's private sector lead.

The PSCN, co-founded by Henry Schein, is a public-private initiative that brings together the private sector and global organizations – including the World Health Organization, World Economic Forum, the United Nations World Food Programme, the World Bank, the U.S. Centers for Disease Control, UNICEF, and approximately 60 health care manufacturers and suppliers – to embrace a common commitment to a cause. Since the PSCN's inception, Henry Schein, as private sector lead, has worked intensively to develop a platform for data sharing, market visibility, and operational coordination for health care products to more effectively match global demand with global supply.

The trust-based relationships built between sectors through the PSCN has been crucial in enabling the sharing of information and facilitating the ability of key stakeholders to navigate together the supply chain challenges caused by global pandemics.

"Henry Schein is driven by a sense of purpose and mission, and we are honored to be named to FORTUNE® magazine's 'Change the World' list for our enduring commitment to these values," said Stanley M. Bergman, Chairman of the Board and Chief Executive Officer of Henry Schein. "Since our founding in 1932, Henry Schein has been guided by the belief that we can align our strengths as a business with the needs of society to make a positive difference. Through the Pandemic Supply Chain Network, we have had the opportunity to work with leaders from all sectors of society to help create a safer world through more effective pandemic preparedness and response."

Since the onset of the COVID-19 pandemic in late 2019, the PSCN has taken an active role in developing critical tools to strengthen the supply chain, including advocacy, procurement, and product recommendations. Henry Schein's long-term leadership in the PSCN enabled the Company to deploy insights in response to the COVID-19 pandemic, specifically advocating for and disseminating guidelines for proper usage of personal protective equipment (PPE) to promoting the judicious use of PPE. The Company's collaboration with its PSCN partners reinforces Henry Schein's commitment to public-private partnerships as a means of addressing complex societal issues.

FORTUNE® magazine's "Change the World" list celebrates companies and leaders that embrace corporate purpose and recognize how it can add value to business and society. FORTUNE® evaluates the companies by measurable social impact, business results, degree of innovation, and corporate integration. To view the entire list, please visit: https://fortune.com/change-the-world/.

About Henry Schein, Inc.

Henry Schein, Inc. (Nasdaq: HSIC) is a solutions company for health care professionals powered by a network of people and technology. With approximately 19,000 Team Schein Members worldwide, the Company's network of trusted advisors provides more than 1 million customers globally with more than 300 valued solutions that improve operational success and clinical outcomes. Our Business, Clinical, Technology, and Supply Chain solutions help office-based dental and medical practitioners work more efficiently so they can provide quality care more effectively. These solutions also support dental laboratories, government and institutional health care clinics, as well as other alternate care sites.

Henry Schein operates through a centralized and automated distribution network, with a selection of more than 120,000 branded products and Henry Schein private-brand products in stock, as well as more than 180,000 additional products available as special-order items.

A FORTUNE 500 Company and a member of the S&P 500® index, Henry Schein is headquartered in Melville, N.Y., and has operations or affiliates in 31 countries. The Company's sales from continuing operations reached $10.0 billion in 2019, and have grown at a compound annual rate of approximately 13 percent since Henry Schein became a public company in 1995.

For more information, visit Henry Schein at www.henryschein.com, Facebook.com/HenrySchein, and @HenrySchein on Twitter.

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