RESILIENCE & SUSTAINABILITY

STANFORD OFFICE OF TECHNOLOGY LICENSING

FY 2022 ANNUAL REPORT

“The one thing we need more than hope is action.
Once we start to act, hope is everywhere.
So instead of looking for hope, look for action.
Then, and only then, hope will come.”

— Greta Thunberg,
Environmental Activist

STANFORD UNIVERSITY
OFFICE OF TECHNOLOGY LICENSING
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FEATURES

2 New HIT Fund Takes Flight

6 Safer, Targeted Blood Stem Cell Transplantation

8 Magnetic Brain Stimulation Treatment For Depression

10 Crossing The Blood Brain Barrier

12 Low Carbon, Resilient Cement

14 Capturing Carbon To Produce Sustainable Plastics

16 Transforming Pollution Into Products

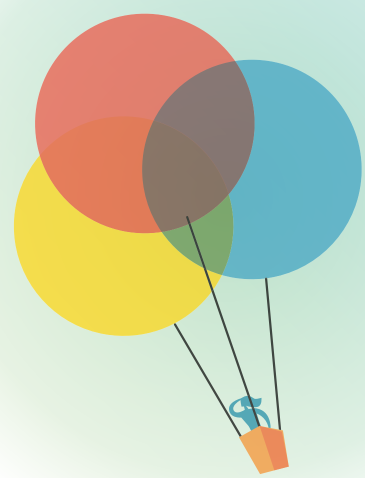
18 The Impact Of Collaborative Strategic Alliances

20 ICO's Critical Role In Enabling Industry Sponsored Research

22 Year In Review OTL

23 Year In Review ICO

New HIT Fund Takes Flight



OTL is uniquely positioned to deliver maximum benefit through the HIT Fund: inventions made with university resources are disclosed to OTL so team members have a birds-eye view of the most innovative work on campus; OTL staff have deep connections to industry because they regularly license Stanford technologies to commercial entities; and, unlike other accelerator-type programs on campus that work within specific schools or technology sectors, OTL engages across the university, meaning it can provide funding in any area.

"We can fill in the white space—the unmet need in areas that don't yet have access to translational or proof-of-concept funding," Immergluck said.

In 2022, OTL set aside $17 million in licensing income to launch HIT, hiring Director Nitin Parekh and Program Manager Laura Clark Murray to bring the initiative to life.

Parekh started out by identifying what Stanford researchers needed in their quest to commercialize their technologies. Last spring, he went on a listening tour, meeting with professors who had successfully licensed their inventions in the past, young researchers who were interested in starting companies, and OTL staff who were in regular communication with industry representatives.

"What was also clear through the entire HIT Fund experience is how much effort goes into finding the best application to bring to market. The team really forced us to shift and push our thinking and even our research efforts."

—Jonathan Fan,
Associate Professor of Electrical Engineering

"As I talked to various people, I realized it wasn't all about the money," Parekh said. "Equally important was this idea of building a customized team, offering patent strategy and business guidance, and providing industry connections. We're trying to give them the tools and skill sets so they can be successful on their journey of commercialization or entrepreneurship."

The High Impact Technology (HIT) Fund aims to accelerate the delivery of Stanford-based innovations to the world.

Hundreds of new inventions are disclosed to the Stanford University Office of Technology Licensing (OTL) each year to initiate the process of protecting and commercializing the new technologies. Only a fraction of those discoveries make it across the innovation "valley of death" to the market where they can benefit the public. A new initiative of OTL, which is part of the Office of the Vice Provost and Dean of Research (VPDoR), hopes to bridge the gap between the academic lab and a commercial partner, which might be a multinational corporation or a startup created by Stanford researchers.

The High Impact Technology (HIT) Fund, which launched as a pilot last year, provides milestone-based funding, mentoring, and campus and industry connections to Stanford researchers whose ideas have commercial appeal. The fund is part of Stanford's vision to accelerate the delivery of solutions for society's greatest challenges.

"We realized there are a lot of new invention disclosures that aren't quite ready for prime time," said Karin Immergluck, Associate Vice Provost for OTL. "We needed to invest resources in helping our inventors mature their ideas more fully in order to make them attractive for investors and industry partners."

The results have been promising. Parekh selected 13 technologies for the pilot, including several focused on sustainability. Some of the researchers did not require funding; others received amounts of up to $200,000. All teams had access to domain experts and industry executives, Stanford Graduate School of Business MBA student interns, and regular contact with Parekh and Murray, who provided mentorship and general support.

Of those 13 project teams, three have already created companies and are engaged in licensing negotiations. Collectively, the HIT Fund has facilitated discussions for project leaders with more than 150 industry experts and stakeholders, including potential partners, possible customers, and venture capital investors.

"That's the big thing I took from the HIT Fund experience: Learning to think like an entrepreneur."
—John Feist, PhD,
Stanford School of Chemistry, 2023

SAFER, LONGER-LASTING BATTERIES

By the time Zhiao Yu '22 PhD connected with the HIT Fund team, he was already exploring commercialization of the use of a breakthrough electrolyte to make lithium-metal batteries a practical reality. Lithium-metal batteries have higher energy density than lithium-ion batteries but their instability makes them susceptible to short-circuiting and fires. Yu's electrolyte eliminates the stability problem, and batteries produced with his technology have energy density as high or higher than existing options, a greater cycle life (the number of times a battery can be charged and discharged over time), and can be manufactured using the same processes as lithium-ion batteries.

Yu said the HIT Fund's support—including introductions to industry contacts with whom he continues to collaborate—was invaluable in the creation of his company, Feon Energy.

The HIT funding also allowed Yu to see if his technology could be scaled to a level commensurate with commercial manufacturing requirements—a "go- or no-go decision." And it could.

"In our first batch, we went from tens of grams to five kilograms," he recalled. "That's a huge jump in process engineering and optimization."

BUILDING BETTER COMPOSITES

When Stanford post-doctoral researcher Dan C. Lee and John Feist '23 PhD were first selected for the HIT Fund last year, they knew they had an important technology—a fast-curing resin produced from a byproduct of the oil industry—that could change the world of composites. They just weren't quite sure what kind of change would be most amenable to the market.

Composites, including some types of plastic, are made from a combination of materials that are stronger than the sum of their parts. The resin created by Lee and Feist can help synthesize composites with higher performance, more efficient manufacturing, and end-of-life recycling. With introductions initiated by HIT, the pair met and discussed their technology with representatives from the National Renewable Energy Laboratory, the textile industry, and 3D printing, battery packaging, and even sporting-goods manufacturers. Ultimately, they decided to focus on how their technology can simplify the production of wind turbines.

The HIT Fund team's mentorship was crucial, the pair said.

"When we were struggling with making a decision, they never told us how to think or what to do, but they held us to a standard of making sure that what we were doing made sense," Lee explained.

Feist added that the fund's guidance through the entrepreneurial process was also invaluable. "That's the big thing we took from the HIT Fund experience: learning to think like an entrepreneur," Feist said and Lee agreed.

"Thanks to them, we're months ahead of where we thought we would be," Lee said.

ELECTRIFYING THE CHEMICAL INDUSTRY

Stanford Professor Jonathan Fan is also determined to change the way an entire industrial process works. His focus is the chemical manufacturing industry, which typically burns fossil fuels to reach the high-grade temperatures necessary to process chemicals. Prof. Fan's technology electrifies the heating process, relying on an inductive heating platform that uses a metamaterial plate within a reactor to produce a customized volumetric heating profile. Assuming the electricity is produced with renewable energy, his process would make the industry significantly more sustainable.

For Prof. Fan, the HIT Fund organized and participated in discussions with senior strategic executives at leading companies, brought on an MBA student as an intern, and hired an industry expert who helped with customer discovery and completed a techno-economic and competitive analysis.

"We know that the decarbonization of high-grade heat is a huge opportunity, but what was also clear through the entire HIT Fund experience, is how much effort goes into finding the best application to bring to market," Prof. Fan said. "The team really forced us to shift and push our thinking and even our research efforts. At the end of the day, this technology only matters if it translates into real-world solutions."

"The HIT Fund works with innovators to identify the best way forward, supporting them at a pivotal stage to help make their research a reality."

—Arun Majumdar,
Dean of Doerr School of Sustainability

LOOKING AHEAD

The HIT Fund will formally launch this summer with an annual competitive solicitation. Applications will be reviewed by an advisory board composed of industry executives, venture capitalists, and Stanford faculty. Milestone-based awards will be up to $250,000.

In its first year, the HIT Fund addressed specific concerns that faculty shared about the gap between the discovery of a new technology and the delivery of a product or service.

"The researchers we work with have discovered innovative technologies that have demonstrated a high potential for impact," Parekh said. "We help them identify obstacles to entry in the market and find viable pathways to commercialization by connecting them with key partners and advisers — for today and for their future."

Doerr School of Sustainability Dean Arun Majumdar said the HIT Fund is an important partner in accelerating the delivery of technical solutions to the world's most pressing problems.

"To have impact, great ideas need to leave the lab and enter the world," Majumdar said. "The HIT Fund works with innovators to identify the best way forward, supporting them at a pivotal stage to help make their research a reality."

Randy Harward, a former Senior Vice President of Material and Manufacturing Innovation for Under Armour who advised one of the project teams, said the HIT Fund is a model for encouraging innovation and ensuring impact.

"Serving in this capacity has been an incredibly rewarding experience, allowing me to share my years of expertise in material development and R&D with sharp entrepreneurial students and academics within a dynamic community," said Harward. "Our collaboration to shape the direction of innovative ideas ensures they align with current market and societal needs."

Safer, Targeted Blood Stem Cell Transplantation

One of the areas of medicine with the most exciting possibilities is stem cell research.

Stem cells can replace damaged or malfunctioning cells and can treat a wide variety of illnesses. Bone marrow transplantation is a subset of this field with the potential to help patients with autoimmune conditions such as lupus and multiple sclerosis, but currently it's too dangerous to be used for patients who don't have high-risk, life-threatening conditions such as blood cancers or genetic disorders of blood formation.

Professor Judith Shizuru's lab has been working for 20 years to make blood stem cell transplantation safer and more effective. Transplantation works by replacing the stem cells of a recipient with blood-forming stem cells from a healthy donor. For this procedure to succeed however, the recipient's stem cells need to be depleted from specialized niches within the bone marrow to make room for the new stem cells. To remove the cells already there, clinicians use chemotherapy or radiation, which is one reason transplantation is so dangerous and only a fit for patients with severe, life-threatening conditions.

Prof. Shizuru's lab is exploring another safer and targeted way to deplete recipient stem cells to make room for donor stem cells. They are working with an antibody that targets the blood-forming stem cells in recipients. This antibody specifically inhibits a molecule on the surface of blood stem cells that these cells need for survival called CD117. Prof. Shizuru explained, "To take away the danger of chemotherapy, we wanted to specifically use a protein to target the blood stem cells to deplete them."

"I do think part of the reason that even today there's limited female representation in the sciences, both in the academic side and in the industry side, is just a lack of exposure. I'm very grateful to Stanford for providing me those opportunities."

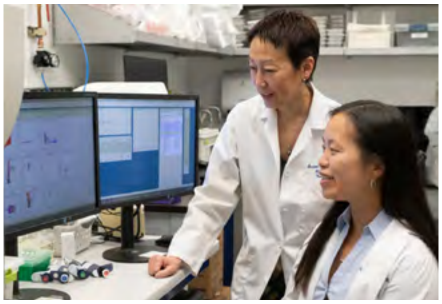
— Wendy Pang, PhD,
Senior Vice President of Research and Translational Medicine at Jasper Therapeutics

Some patients who most need bone marrow transplantation, such as children with a lethal genetic disorder called severe combined immunodeficiency, are also the most at risk for complications from chemotherapy and radiation. This antibody can help them, as well as make stem cell transplantation more broadly accessible. Right now, transplants can only be performed in specialized academic centers. As transplantation becomes safer and more effective, it should be able to reach more patients.

Prof. Shizuru's lab also found that this antibody can be used in patients who have blood cancers because it targets the cancer-initiating hematopoietic stem cells. It's been effective in treating leukemia in combination with low doses of radiation and has the potential to make treatment much less toxic for patients. Prof. Shizuru's clinical program was funded by the California Institute for Regenerative Medicine (CIRM) to safely condition patients prior to hematopoietic stem cell transplantation.

To bring this antibody into hospitals, Prof. Shizuru co-founded a company, Jasper Therapeutics. Dr. Wendy Pang, Senior Vice President of Research and Translational Medicine at Jasper, first met Prof. Shizuru in high school through the Center for Clinical Immunology summer program. She did her postdoc with Prof. Shizuru then decided to join Jasper to follow the research she'd been working on in the lab through clinical trials. Dr. Pang spoke about the impact that being introduced to research in high school had on her. "I do think part of the reason that even today there's limited female representation in the sciences, both in the academic side and in the industry side, is just a lack of exposure. I'm very grateful to Stanford for providing me those opportunities."

This anti-CD117 antibody could possibly make it safer to use stem cell transplantation to treat conditions such as sickle cell anemia, severe combined immunodeficiency, HIV, multiple sclerosis, lupus, disorders of the blood and lymphoid system, neurologic disorders, and more.



Prof. Judy Shizuru, reviews data with Wendy Pang, PhD

Magnetic Brain Stimulation Treatment for Depression

Depression is a major cause of disability worldwide, a problem worsened due to the Covid-19 pandemic.

For patients who don't experience relief from treatments like antidepressants and psychotherapy, it can be difficult to know what to try next. An all-too-common scenario is that patients having psychiatric emergencies are admitted to a hospital or clinic, given medication that may or may not help, and then essentially left to wait out the crisis until they are released. There is a strong need for effective prevention and treatment that can be used in these emergencies.

Professor Nolan Williams works to find ways to help patients suffering from treatment-resistant major depressive disorder (MDD). His lab develops experimental therapeutics that can help patients unresponsive to traditional treatments while also revealing more about the biology of the brain.

Prof. Williams' lab has invented a technology called Stanford Accelerated Intelligent Neuromodulation Therapy (SAINT), a faster and more advanced, accurate application of neurostimulation. Before treatment, patients undergo a special type of MRI scanning in order to map their individual neural networks and identify a personalized treatment target. Once the personalized target is identified, SAINT utilizes a customized treatment plan to deliver focused neurostimulation called intermittent theta-burst stimulation. SAINT sends a high-dose pattern of repetitive magnetic pulses to the brain at a more rapid rate than other conventional neurostimulation treatments. These rapid pulses modify activity in brain networks related to depression, resulting in restoration of mood regulation.

In 2020, the team completed a double-blind randomized controlled trial that showed 79% of patients treated with SAINT entered remission, compared with 13% in the placebo group. A new company, Magnus Medical, was formed to commercialize the technology. The US Food and Drug Administration (FDA) has granted Breakthrough Device Designation to Magnus' neurostimulation technology and 510(k) clearance. The regulatory process usually takes two to three years, but SAINT was approved in only a year and a half.

Brett Wingeier, PhD, co-founder and chief technology officer of Magnus Medical (left) and Brandon Bentzley, MD, PhD, co-founder and chief scientific officer (right) in front of the Magnus SAINT Stimulator in Magus' lab

OTL supported the development of this technology through this complex process by providing assistance including patent strategy and education. Prof. Nolan Williams said OTL's help was invaluable for "teaching us about how to take an idea and turn it into intellectual property."

A patient being treated with SAINT™ neuromodulation therapy

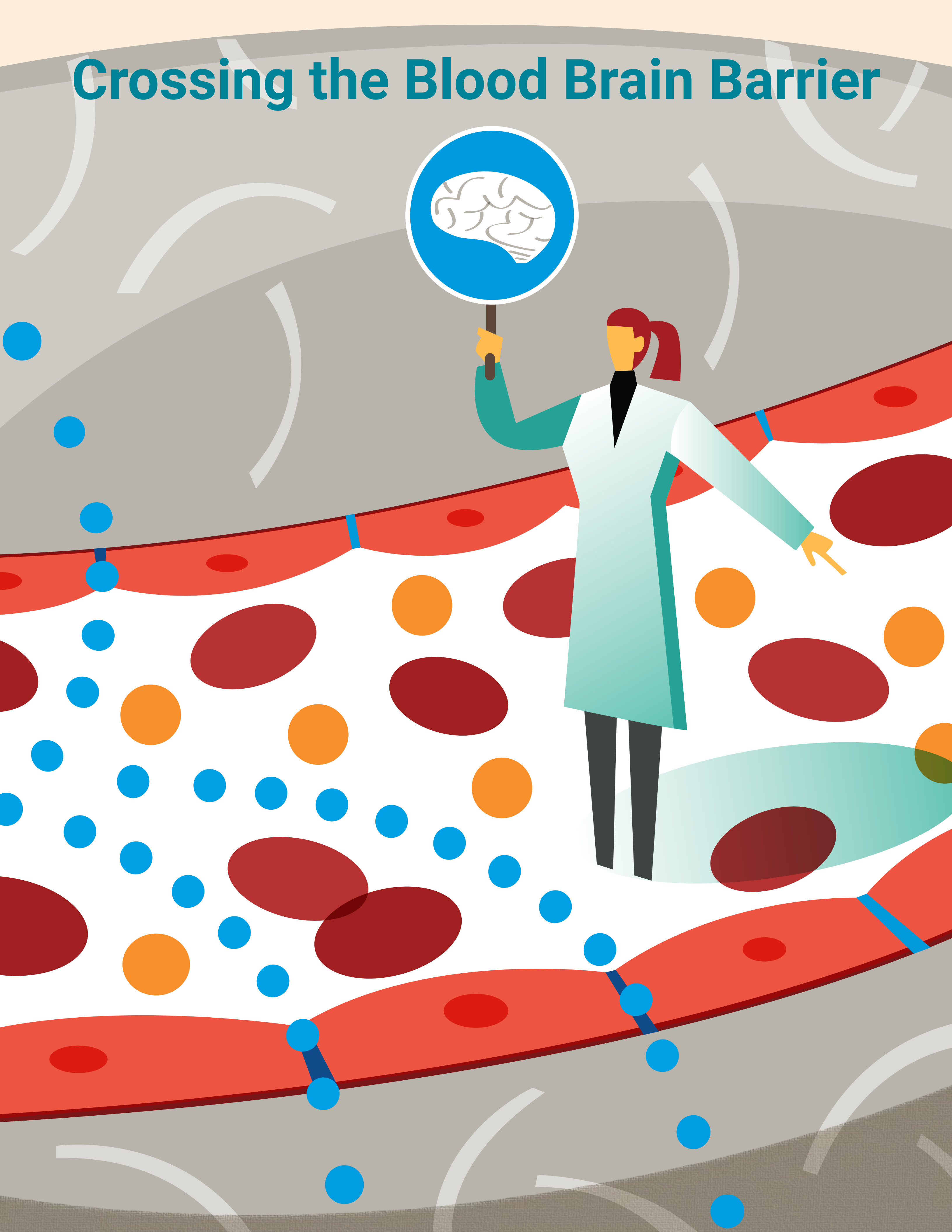
One of the first patients the lab treated struggled with severe depression for 40 years and had tried many treatments without success, including traditional transcranial magnetic stimulation (TMS). The team didn't expect SAINT to work for him, but within five days, he was in remission. Patients who have such severe conditions generally need ongoing treatment after initial improvement and the team is working on a device that can deliver maintenance stimulation as needed over time. Prof. Williams described the potential of this work. "Magnus Medical is making the revolutionary SAINT treatment, developed at Stanford, globally accessible for individuals with treatment-resistant major depression disorder; this not only restores hope to patients but also holds the potential to save countless lives."

The Magnus team is developing a device so that this treatment can be given in crisis situations, such as emergency rooms and psychiatric wards. If a patient needs emergency treatment in the future, the protocol would involve conducting an MRI scan, sending files to Magnus' cloud for processing, then providing the patient with a personalized treatment plan.

"Magnus Medical is making the revolutionary SAINT treatment, developed at Stanford, globally accessible for individuals with treatment-resistant major depression disorder; this not only restores hope to patients but also holds the potential to save countless lives."

—Prof. Nolan Williams,
Associate Professor, Department of Psychiatry and Behavioral Sciences (Major Labs & Translational Neuroscience Incubator) and by courtesy, of Radiology (Neuroimaging and Neurointervention)
Director, Interventional Psychiatry Clinical Research
Director, Brain Stimulation Laboratory

Crossing the Blood Brain Barrier



Drug delivery across the blood brain barrier (BBB) is one of the biggest challenges in medicine.

The BBB protects the brain from toxins and harmful substances but it can also block therapeutic drugs, particularly large molecules. For a long time, it was thought of as an impenetrable barrier, but researchers now understand it as a sophisticated filter. As research into the BBB advances, there's potential to revolutionize drug development for conditions affecting the central nervous system, such as Parkinson's and Alzheimer's disease.

Professor Tony Wyss-Coray's lab works to solve medical challenges facing the aging population. Research into brain diseases at a molecular level typically derives from studying donated brains. Prof. Wyss-Coray's lab collects blood from living subjects and studies its composition to infer neurological information. One of his key discoveries was that blood from young organisms can revitalize older brains whereas blood from older organisms can accelerate brain aging. Prof. Wyss-Coray described his research focus, "My main interest is to understand how the brain ages and becomes susceptible to neurodegeneration, and especially how the body as a whole impacts the brain and the role of the immune system."

To understand how proteins in the blood communicate with the brain, Prof. Wyss-Coray's lab extracted proteins from blood, purified, and traced them. Researchers then injected the labeled proteins into a mouse and a few hours later removed the blood and checked if the proteins were in the brain or blood vessels. They found that the vascular tree of the brain was covered with the labeled proteins, showing that there was extensive uptake of proteins from blood, a revelation to the field.

Once the team discovered that proteins were getting into the brain, they investigated how this transport occurs. After developing proprietary technologies and methods, the lab was able to correlate protein uptake with gene expression to identify more than 100 genes in BBB cells that relate to receptors and transporters which can shuttle specific agents into the brain. The team is working on engineering proteins

Left: A chinotto tree in Prof. Wyss-Coray's backyard.
Right: Fluorescent proteins in vessels from Prof. Wyss-Coray's research light up the similarly branching structure of a vascular tree.

that bind to these specific receptors and transporters while carrying therapeutic payloads such as antibodies, enzymes, and nucleic acids. This process takes advantage of an endogenous pathway for brain delivery. Emerging research has also shown that certain receptors of the BBB can direct delivery to specific cell types within the brain which could ultimately boost the efficacy and safety of future therapeutics through better targeting.

Prof. Wyss-Coray and Lyndon Lien have co-founded a company called Qinotto to commercialize this platform technology. The name Qinotto comes from the italian chinotto, a kind of bitter orange. When trying to pick a name, the founders wanted to express the revolutionary potential of this invention, which could have as large of an impact on biotechnology as a certain company named after a fruit had on tech. OTL was able to help Qinotto launch as an early stage company.

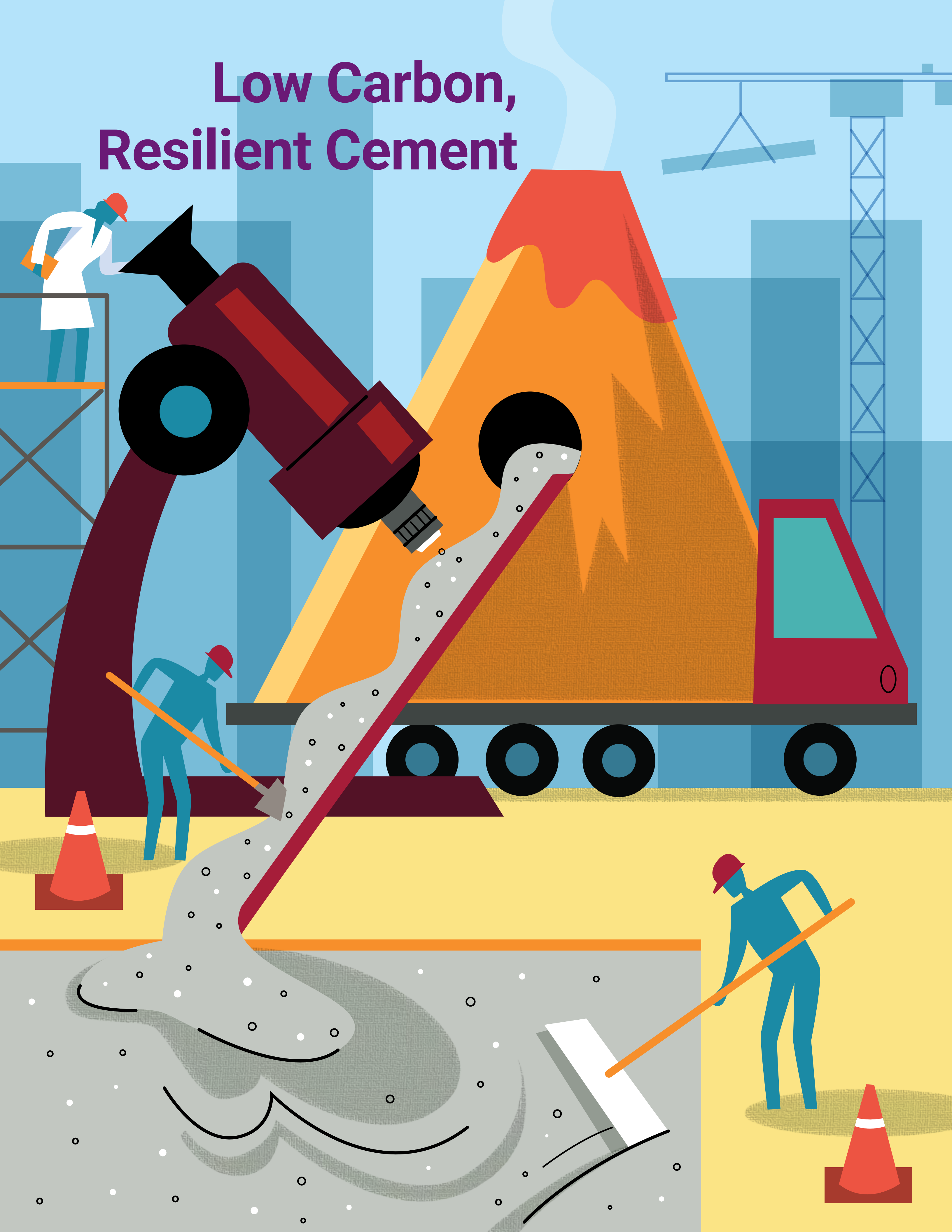
R&D for central nervous system therapeutics is challenging and relatively underfunded. However, Lien thinks that this is an exciting time to be working in this field because of new break-through technologies and ongoing positive developments. He said, "Enabled by our platform, we have an opportunity to overcome a major hurdle in drug brain delivery and address huge unmet medical needs for brain diseases."

"My main interest is to understand how the brain ages and becomes susceptible to neurodegeneration, and especially how the body as a whole impacts the brain and the role of the immune system."

—Prof. Tony Wyss-Coray,
Professor of Neurology
and Neurological Sciences

Prof. Tony Wyss-Coray, the D.H. Chen Distinguished Professor of Neurology and Neurological Sciences and the Director of the Phil and Penny Knight Initiative for Brain Resilience

Low Carbon, Resilient Cement



Cement production accounts for 8% of the world's carbon dioxide emissions, mostly through its use of limestone, the calcination of which represents two thirds of its greenhouse gas (GHG) emissions.

Once poured, cement has a lifespan of around 80 years and is prone to cracking and degradation, especially in harsh environments. Furthermore, rebar is often added for additional strength and structural integrity, thus increasing the environmental footprint of concrete. Durability and serviceability of cement are key to many applications, from well bore cement sheaths to rocket launchpads, which require high performance under extreme stress, under fluctuating temperatures, and when exposed to a variety of fluids. Not only does the quality of a cement job have a direct impact on the economic longevity of a given structure, but it also has a significant effect on the environment. Researchers currently address cement production's carbon footprint by focusing on carbon dioxide mineralization into cement as carbonate phases. However, this approach leads to inferior performance and does not address the root cause of cement degradation. Researchers within Stanford across three different fields–geophysics, materials science, and chemical engineering–have come together to bring their unique disciplinary expertise to provide a more serviceable and sustainable cement. The carbon free-composition and the enhanced serviceability results in a reduction of the carbon footprint of cement both in the short- and long- term.

Professor Tiziana Vanorio's lab studies the response of rock properties to processes within the Earth's crust, and ultimately mimics the process-derived microstructure. This research led her to study the fibrous microstructure of certain rocks from volcanic regions and faults to mimic, in form and function, their cementation – the process of lithification by which rock is created from sediment particles. Carbon-free volcanic rock could be used not only to replace limestone in the cement manufacturing process, but also to provide a unique composition as fibers grow in-situ within cement to reinforce the microstructure at the nanoscale.

Across campus, Professor Alberto Salleo read about Prof. Vanorio's work in the Stanford Report. He is passionate about connecting to other labs within Stanford and shared, "Stanford's a campus where interdisciplinarity is really valued. The key to success is to connect to other faculty in other departments that do other things and build an interdisciplinary network that generates exciting research ideas." Prof. Salleo's lab studies nanotechnology and polymeric semiconductors for thin film electronics in solar cells and energy storage. One of his students became interested in characterizing the minerals found within Roman concrete using spectroscopy. They connected with Prof. Vanorio to study the nanofibers found in certain volcanic rocks and Roman concrete, as they may provide a mechanism to reinforce the concrete from within, reducing if not eliminating the need for rebar.

The researchers will continue to investigate how to mimic the Earth's crust as it heals over time after fractures and fissures to explore the possibility of self-healing cement. Prof. Vanorio explained, "The self-healing of the Earth's crust is similar to that of our skin. Just as the fibrous bundles of scratched skin are healed over time through the activity of a vascular system transporting nutrients, oxygen, carbon dioxide, and blood cells, so fibrous rock microstructures are autonomously and incessantly created by the activity of fluids in the Earth's crust. It could be an interesting process to apply to materials." Prof. Vanorio and Prof. Salleo are looking forward to continued collaboration that leverages knowledge across disciplines and potentially founding a startup from this technology.

"Stanford's a campus where interdisciplinarity is really valued. The key to success is to connect to other faculty in other departments that do other things and build an interdisciplinary network that generates exciting research ideas."

—Prof. Alberto Salleo,
Professor of Materials Science and Engineering

*Prof. Tiziana Vanorio,
Director of Rocks and Geomaterials Lab
Associate Professor of Earth and Planetary Sciences and, by courtesy, of Civil and Environmental Engineering and Geophysics
Stanford Doerr School of Sustainability*

*Prof. Alberto Salleo,
Professor of Materials Science & Engineering
Affiliate of Precourt Institute for Energy*

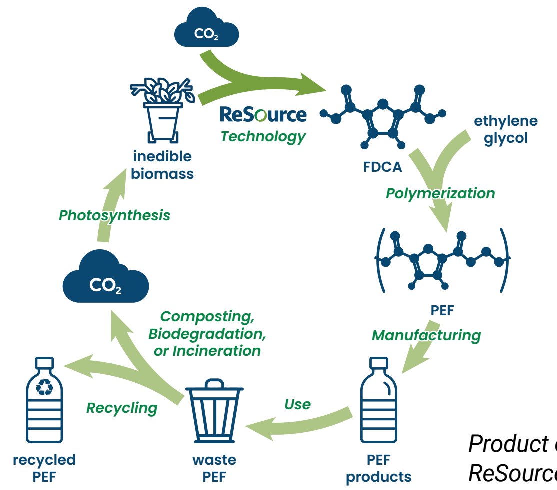
Capturing Carbon to Produce Sustainable Plastics

The plastic industry is plagued with harmful emissions and environmental issues throughout the entire product lifecycle.

Over 99% of plastics today are derived from petroleum. The production of these plastics accounts for 4% of total greenhouse gas emissions. Mishandling of plastic waste at the end of its life often leads to pollution of soil and bodies of water. Over the past 15 years, numerous companies have tried to address these issues by shifting from petroleum-based plastics to bioplastics, but bioplastics have fallen short in a number of ways. Nearly all of them are produced from food crops, which have substantial emissions from the use of fertilizers and increase demand for agricultural land. The companies have also struggled with high process complexity, leading to high production costs. Most bioplastics have inferior performance and higher cost than petroleum-based plastics, which has impeded adoption. Researchers in Professor Matthew Kanan's laboratory have created technology to produce bioplastics that are truly sustainable and outperform the industry standard. They have also launched a successful startup called ReSource Chemical Corp. which has received significant interest and funding.

The Kanan lab explores ways to use carbon dioxide to make chemicals, fuels, and minerals. In 2016, Prof. Kanan and Dr. Aanindeeta Banerjee discovered a way to use carbon dioxide and waste biomass to make the key building block for a sustainable plastic called polyethylene furanoate (PEF). PEF stands apart from other bioplastics because it has better performance than the petroleum-based plastics it is meant to replace. PEF provides a stronger barrier to gasses like oxygen, which leads to a longer shelf life for perishable products. The thermal properties of PEF allow for greater reuse of the product over time. Once it can no longer be used, PEF degrades more quickly than petroleum-based plastics. Additionally, by using carbon dioxide and waste biomass, ReSource avoids the emissions of growing food and does not incentivize deforestation. Critically, the carbon dioxide utilization technology greatly simplifies the production of PEF, which enables a major cost reduction.

Believing in the promise of the technology, Prof. Kanan and Banerjee applied for research grants to start the process of moving the product from the lab to full scale production. Beginning with the Innovation Transfer Grant, from the TomKat Center for Sustainable Energy, the team was able to hire an experienced engineering consultant to develop the technology process model. "That initial funding was critical. The process model demonstrated our economic advantage over our



Product cycle of ReSource's technology

competitors." Banerjee explained, "We could point to concrete numbers to back our claims."

In 2021, the Advanced Manufacturing Office of the U.S. Department of Energy awarded ReSource $2.5M, which helped secure a seed round of investment, laid out the development path, and helped validate the process on a larger scale. Another critical source of support was the Activate Fellowship program, which provided access to lab space in Berkeley and venture capital connections which assisted with the launch of ReSource.

Prof. Kanan shared his appreciation for the impact OTL has had on technologies from his lab. "The ability of OTL to reach a broad audience of companies interested in developing technology can not only solicit marketing feedback and explore licensing opportunities, but also enable partnerships and industry-sponsored collaborations. In addition to the critical role it plays in helping researchers translate technologies into society, OTL is itself an innovator, proactively experimenting with new ways to help researchers go faster." He is looking forward to further research, and with the support of OTL, translating technologies for the benefit of society.

"The ability of OTL to reach a broad audience of companies interested in developing technology can not only solicit marketing feedback and explore licensing opportunities, but also enable partnerships and industry-sponsored collaborations.

—Prof. Matthew Kanan,
Associate Professor of Chemistry

Aanindeeta Banerjee, PhD,
Co-founder & CEO of ReSource Chemical Corp.

Prof. Matthew Kanan,
Associate Professor of Chemistry, Director of the TomKat Center for Sustainable Energy

Transforming Pollution into Products

From plastic to fiber, ethanol is embedded into products we use every day.

To extract ethylene and produce ethanol, petrochemical plants typically use oil or natural gas as a feedstock. Climate neutral substitutes could ease the amount of greenhouse gas (GHG) emissions produced each day from chemical industrial plants. GHG emissions are the main contributor to climate change, resulting in higher sea levels, more severe weather, and changes in agricultural crop yields, among many other detrimental environmental impacts. Researchers in Professor Thomas Jaramillo's lab have discovered a way to transform emissions into useful products and is launching a successful startup from their technology.

Prof. Jaramillo's lab researches sustainable energy technologies in order to capture carbon from emissions, create useful products, and reduce our dependence on fossil fuels. The research in the lab is specifically focused on chemical reactions that produce fuels and other chemicals from water and carbon dioxide using energy from renewable sources, and reactions that then convert these fuels into a renewable source of electricity. Prof. Jaramillo described his experience working on sustainability within the Stanford ecosystem, "The Stanford community realizes how scholarly potential can have an impact for billions of people, and that's how we're really going to change our world. For sustainability, if you're not impacting billions of people, it's hard to move the needle on climate change. We're also drawing from OTL's expertise, which has been a wonderful conduit to do exactly that."

In 2016, Dr. Yi-Rung Lin met Prof. Jaramillo through her post-doctoral appointments with CalTech and Stanford University after obtaining her Ph.D. degree in Chemistry from National Taiwan University. Her passion derives from discovering ways to recycle carbon through carbon electrolysis—a technique that uses electricity to drive a chemical reaction—and creating new eco-friendly technologies.

Lin returned to Taiwan during the pandemic and saw a gap in the sustainability sector, specifically around technologies that reduce carbon emissions. With her scientific background and Prof. Jaramillo's encouragement, she seized the opportunity to start CarbonClean Energy Company, the first company of its kind in Taiwan.

The mechanism of this net-zero carbon technology is similar to artificial photosynthesis, as both processes require inputs of carbon dioxide and water, and create outputs of oxygen and carbohydrates. The goal is to reduce the need for petroleum and other fossil fuels in production by pulling carbon dioxide from the air to produce hydrocarbons that can be used to create either fuels or products. Carbon dioxide, once an atmospheric pollutant, can instead become a valuable resource through this process. By capturing carbon, the process reduces GHG emissions.

"The Stanford community realizes how scholarly potential can have an impact for billions of people, and that's how we're really going to change our world. For sustainability, if you're not impacting billions of people, it's hard to move the needle on climate change. We're also drawing from OTL's expertise, which has been a wonderful conduit to do exactly that."

—Prof. Thomas Jaramillo,
Professor of Chemical Engineering at Stanford University
and Professor of Photon Science at
SLAC National Accelerator Laboratory

Currently, Lin is working on a first-generation prototype that is similar in size to a washing machine that produces chemicals from carbon dioxide in air. Although she is starting small, the plan is to build up to a shipping container sized prototype that will convert the majority of carbon dioxide exhaust from a petroleum or chemical industrial plant, and eventually grow into a large-scale solution for the net-zero carbon emission field, based on customer needs.

This field is relatively new, and there are many ways to interact with and study carbon transformation technologies. Lin shared, "I want to have more impact on the Taiwanese community to inspire the younger generation to start working on this." Lin is looking forward to further developments and collaborations in her research.

Yi-Rung Lin, PhD,
Founder & CEO of CarbonClean Energy Company

Prof. Thomas Jaramillo,
Professor of Chemical Engineering
at Stanford University and Professor of Photon Science at SLAC National Accelerator Laboratory
Director of SUNCAT Center for Interface Science and Catalysis

The Impact of Collaborative Strategic Alliances

OTL's Strategic Alliances team facilitates strategic, collaborative agreements that support relationships between Stanford investigators and industry or non-profit institutions while advancing Stanford research. Combining scientific, business development, and contract expertise, they shepherd important programs through conception, development, and license processes. The team meets with Stanford investigators to learn how they can help to further their research goals and creatively structures agreements with companies that wish to develop alliances with Stanford. These alliances could manifest through research funding, in-kind services, and collaboration with institutions such as biotech, pharma, and research tool companies or venture capitalists.

The Strategic Alliances team helps to manage campus-wide initiatives and agreements that impact multiple stakeholders by collaborating with various Stanford translational programs. They ensure successful research collaboration by providing due diligence to identify any conflicts and managing the licensing of any resulting inventions, with the ultimate goal of developing innovative products that can benefit the public. The team also provides a framework and support for research funding, confidentiality, and material transfer agreements, and coordinates patent strategies. In this process, they confirm that agreement terms meet Stanford requirements and result in broad benefits for both Stanford investigators and external collaborators. The team works closely with Stanford investigators to facilitate communication with companies or institutions regarding the research plan and ensures that funding, collaboration, and other agreements between Stanford and these entities meet their needs. Karin Immergluck, Associate Vice Provost of OTL, described the team, "The Strategic Alliances team is highly experienced in handling the rapidly increasing complexity of Stanford's intellectual property (IP) landscape. The team negotiates and manages a growing number of complicated, multifaceted relationships that Stanford is developing with external collaborators."

The Center for Definitive and Curative Medicine (CDCM) collaborates with the Strategic Alliances team to create IP strategies around developing therapies. Launched in 2017, CDCM is the translational arm of the Institute for Stem Cell Biology and Regenerative Medicine, providing the infrastructure to translate stem cell biology and regenerative medicine research done in the lab into therapies ready for patients. CDCM makes it possible to perform proof of concept clinical trials at Stanford prior to licensing. Jennifer Cory, the Director of Strategy and Operations for CDCM, said of the Strategic Alliances team, "Having that dedicated support really makes a difference in terms of how we're thinking about projects," and added that it's very helpful to have a contact at OTL as CDCM thinks long-term about potential collaborations. Professor Matthew Porteus, co-Director of CDCM, said, "Working with the Strategic Alliances team has been extraordinary. Not only do they have the knowledge and skills to navigate the complicated landscape of cell and gene therapy, they have the academic mindset to learn and teach." In the coming year, CDCM hopes to accelerate clinical trials and to expand patient recruitment to a more diverse population.

The Strategic Alliances team frequently collaborates with the Innovative Medicines Accelerator (IMA). IMA accelerates the translation of diverse biomedical discoveries into high quality medicines. The team works with IMA to develop projects with strong IP potential and create alliances with research tool providers, as well as biotech, pharma, and venture capital collaborators. Professor Chaitan Khosla, the Director of IMA, said, "I don't think we could have written a better script for the collaboration between IMA and OTL than how it has turned out in reality, because it allows each side to do what we're best suited for with minimum to no duplication wasted." This strong collaboration allows IMA to focus on accelerating medicines while the Strategic Alliances team supports the framework.

The Stanford Medicine Catalyst program is an emerging health care launchpad that magnifies the impact of innovation from the Stanford community and helps fill the gap between early-stage research and bedside medicine at Stanford. It awards up to $1M to projects with substantiated research and the potential to have a dramatic impact on healthcare. Kevin Wasserstein, Catalyst's Executive Director, described Catalyst, "We are a funding source, a partner, an incubator, an accelerator, and a translator. We work side-by-side with project teams to catalyze their progress beyond the bench, at industry speed, to help bring their ideas to the bedside more rapidly." Jessica Kennedy, the Director of Innovation Development, said, "We work closely with OTL from the very beginning to get great perspectives on our assessments of the IP. This close relationship has been very helpful, and we lean on many of the different members of OTL that have very specific domain expertise."

The Strategic Alliances team also works closely with the Center for Cancer Cell Therapy (CCT). The CCT is committed to innovative basic research, improving outcomes for patients with liquid and solid tumors, and executing first-in-human clinical trials that deliver biologically and clinically meaningful correlative insights. The Center strives to make lasting and meaningful impacts on the lives of every patient treated. Its model for bench-to-bedside-to-bench research applies fundamental discoveries to advance human health. Since its inception, OTL has worked with the Center to capture innovations, IP, and collaboration and licensing opportunities to advance the Center's impact across Stanford Medicine and the field of cancer immunotherapy. Professor Crystal Mackall, the Center's founding Director, described this collaboration, "Stanford OTL has been just an incredible asset to my program since we launched in 2016. They are really our partners. They help us to create patent applications that are likely to be defensible. This isn't something you learn as a scientist or a physician. And so we rely on the expertise in OTL, as they're extremely helpful, responsive, and reliable experts."

The internal collaborations between Stanford's translational programs and the Strategic Alliances team help develop strong relationships with industry and non-profit institutions. These relationships lead to successful collaborations that provide research funding, support innovative technology development, complement research programs, and provide breakthrough technologies for the public good.

"The Strategic Alliances team is highly experienced in handling the rapidly increasing complexity of Stanford's IP landscape. The team negotiates and manages a growing number of complicated, multifaceted relationships that Stanford is developing with external collaborators."

—Karin Immergluck,
Associate Vice Provost of OTL

ICO's Critical Role in Enabling Industry Sponsored Research

The Industrial Contracts Office (ICO) reviews, negotiates, and signs research-related agreements on behalf of Stanford with industry and nonprofits. The last year featured increased resilience, adaptability, and transparency. From administering new and existing industrial affiliate programs, to transferring databases, to reviewing structures and adapting new systems, ICO has experienced many opportunities for growth.

This year, ICO completed the transfer of contracts data from a localized database previously only available to OTL due to confidentiality, to a more accessible university-wide database, called Stanford Electronic Research Administration (SeRA). With this transition, a significant amount of data cleanup was required for quality and accuracy purposes.

Glennia Campbell, Director of ICO, shared, “The ICO team has shown enormous resilience in managing the database transfer. The staff has really risen to the challenge and done an extraordinary job.” This transition provided more transparency for the larger Stanford administrative community into contracts negotiated by ICO that enable research across campus.

As in previous years, ICO continues to administer Industrial Affiliate Programs (IAPs) on behalf of Stanford by processing new affiliate program requests, renewals, and new membership applications. These programs provide two-way engagements where faculty and students can gain access to pressing industry issues while corporate members are exposed to fresh ideas and innovations coming out of

Stanford. IAPs focus on many-to-many relationships with multiple faculty interfacing with numerous companies and each membership has unique benefits. Two of the most successful programs, Computer Forum and the Center for Artificial Intelligence in Medicine and Imaging (AIMI), aim to benefit companies, the greater Stanford community, and the public through providing spaces for collaborating, learning, and mentoring.

Founded in 1968, Computer Forum is one of the oldest and most successful IAPs. Computer Forum acts as a guide for companies interested in learning more about technologies coming from the electrical engineering and computer science departments within Stanford. The primary benefits of membership for companies include recruitment of students, exposure through meetings, workshops, career fairs, and the visiting scholars program. Jason Lin, Director of Computer Forum for the last five years, shared how adaptable the program continues to be as it reacts to the needs of students, faculty, and staff, "We work together to figure out where companies fit best, depending on what their goals are." As an entry point to Stanford, a company that joins Computer Forum can learn about other Stanford programs and plug into other departments as interests align. Relationship building and networking are fundamental to Computer Forum's growth. Companies are introduced through references from faculty, staff, other affiliate programs, corporate relations from the School of Engineering, individuals with prior experience working with Computer Forum who change companies and bring their new companies in, individual research from companies, and Computer Forum's own outreach. This interconnected network witnesses the value and impact that Computer Forum has, which helps membership grow at a sustainable rate each year.

AIMI started in 2018 with the drive to build a community of scientists to solve clinically important issues using AI. AIMI has been incredibly successful over the past five years, with over 150 affiliated faculty across 20 departments, mostly in the schools of medicine and engineering. Since its inception, AIMI has developed relationships with GE Healthcare, IBM, Google, Microsoft, and Lunit, a leading medical AI company from South Korea, among other industry affiliates. Nine startups have spun out of affiliated faculty labs in the AI and Health area. Professor Curtis Langlotz, Director of AIMI, shared, "Stanford is a unique place to do this kind of work." He cites as AIMI's key resources Stanford's eminent research labs, clinicians' need for decision support, top faculty, and access to Silicon Valley's ecosystem. The strong ties between Silicon Valley and Stanford nurture growth of the AIMI affiliate program with new industry collaborators. Johanna Kim, Executive Director of AIMI, shared her take on collaborations that come from the affiliate program, "There's a shared aspiration to collaborate and advance the field. AI has the potential to revolutionize healthcare, and we welcome engagement with our industry affiliates to explore various perspectives to harness all its possibilities." The affiliate program provides an anchor for companies at Stanford, making it possible to facilitate discussions and explore collaboration opportunities.

Looking forward, ICO is reconsidering how it operates within the larger Stanford ecosystem and is restructuring its organization and processes to readily adapt to changing times. The office has been resilient in the face of continuous changes and is excited to create opportunities to sustain their energy and productivity in the future.

"The ICO team has shown enormous resilience in managing the database transfer. The staff has really risen to the challenge and done an extraordinary job."

—Glennia Campbell, Director of ICO

FY 2022 Year In Review

LICENSING FACTS AND FIGURES

In FY 2022, Stanford received $89.6M in gross royalty revenue and equity from 1,099 technologies. Twelve inventions received $1M or more in royalties or equity, and 70 technologies generated between $100,000 and $1M. While the number of technologies that brought in more than $100,000 in FY 2022 has increased significantly from the previous five years, 93% of our technologies generate less than $100,000 in royalties or equity and are major contributors to the steady royalty base for Stanford. In fact, royalties and equity ranged from $8 to $15.4M per invention.

We evaluated 510 new technology disclosures and signed 147 new agreements. Seventy-five of the licenses were nonexclusive, 39 were exclusive and 33 were option agreements. There were 38 new startups based primarily on Stanford technology that received an option or license in FY 2022.

ROYALTY DISTRIBUTION

Stanford's royalty-sharing policy provides for the distribution of cash net royalties (gross royalties less 15% for OTL's administrative expenses, minus direct expenses) to inventors, their departments, and their schools. OTL distributed personal income totaling $15.73M to 1,085 inventors. Stanford departments received $15.69M and schools received $12.81M after the University assessed an infrastructure charge on their shares of royalty income. Stanford also paid $2.97M to joint IP owners and research sponsors.

EQUITY

As of August 31, 2022, Stanford held equity in 196 companies as a result of a license agreement. During FY 2022, equity from 18 companies was liquidated, generating $22.37M in revenue. For equity received as partial consideration under a license, Stanford's practice is to sell these shares once they can be traded on the public market. In FY 2022, we signed licenses that included equity with 23 companies.

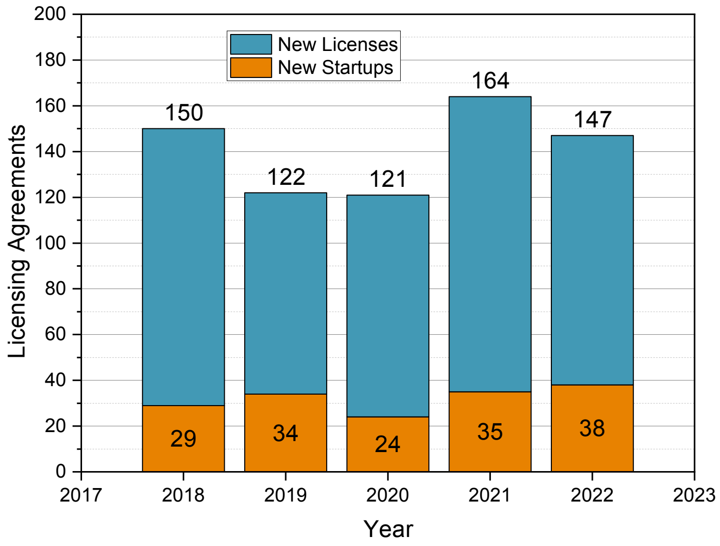


Fig. 1: LICENSING TREND

The figure above shows licensing agreement and startup trends for OTL over 5 years. Note: Beginning in 2022, a new methodology aligned with industry standards was used for this data.

FY 2022 Year In Review

ICO FACTS AND FIGURES

The Industrial Contracts Office (ICO) is a group within OTL that specializes in research agreements with industry. In FY 2022, ICO finalized a total of 177 new industry sponsored research agreements (SRAs), where companies fund and sometimes collaborate on research projects at Stanford, and 317 amendments to existing SRAs.

The School of Medicine accounted for more than half of these agreements with 107 new industry-sponsored research agreements. The Department of Medicine was home to the largest number of new industry sponsored research agreements, with 27 new SRAs. The Pediatrics Department had 16 new SRAs, Radiology accounted for 9, Dermatology accounted for 6 and Pathology had 7 new SRAs.

The School of Engineering accounted for one quarter of the total SRAs, with 50 new industry-funded research agreements and 71 amendments to existing SRAs. The Electrical Engineering Department was home to the largest number of new Engineering industry research agreements with 12 new SRAs, Aeronautics and Astronautics had ten, Chemical Engineering had nine, Computer Science had nine, Mechanical Engineering accounted for seven, and Civil and Environmental Engineering accounted for two new SRAs. ICO provided expertise and guidance on intellectual property terms and Stanford policy to faculty, staff and partner organizations on an additional 307 transactions in FY 2022.

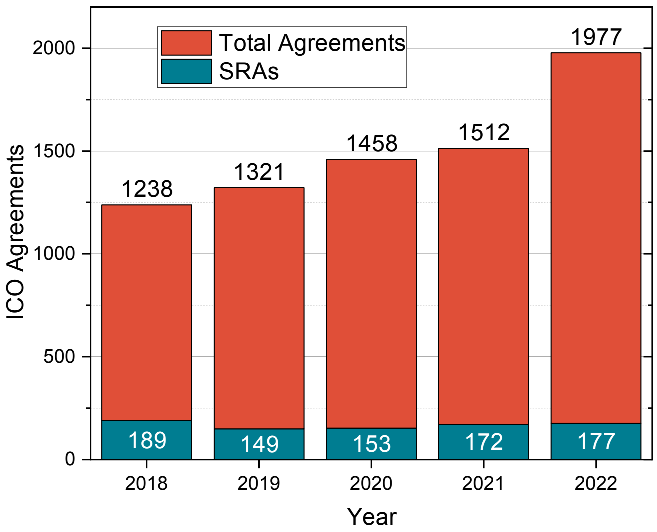


Fig. 2: AGREEMENT TREND
The figure above shows Sponsored Research Agreement (SRA) and total agreement trends for ICO over five years.

INDUSTRIAL AFFILIATES PROGRAMS

ICO also handles Industrial Affiliates Program approvals, renewals and related agreements. During the year, 73 programs brought in a total of $35.4M. SystemX in the School of Engineering continued to be the largest program, with $6.8M in funding.

Eight new Affiliates Programs were approved in the past fiscal year, including three in the School of Medicine, two in the School of Engineering, one in the School of Humanities and Sciences, one in the School of Law, and one in the Office of the Vice Provost and Dean of Research:

SCHOOL OF MEDICINE

- Stanford Healthcare Innovation Lab
- Stanford Medical Mixed Reality
- Stanford Pediatric Radiology Innovation and Translation Center

SCHOOL OF ENGINEERING

- Center for Automated Reasoning
- SDGC Long-Term Investing Initiative

SCHOOL OF HUMANITIES AND SCIENCES

- Big Local News Data-Plus

SCHOOL OF LAW

- CodeX Affiliate Program

OFFICE OF THE VICE PROVOST AND DEAN OF RESEARCH

- Human-Centered Artificial Intelligence Corporate Affiliate Program

All in all, ICO finalized 1,977 agreements in FY 2022. This includes 627 Material Transfer Agreements (MTAs); 23 Human Tissue Transfer Agreements; 78 Unfunded Collaborations; 60 Data Transfer Agreements; eight Equipment Loans and a variety of other research-related agreements with companies. Additionally, ICO processed 2,471 non-negotiable MTAs.

OTL offers its special thanks and appreciation to the Stanford researchers and external partners who offered their expertise and time to create this Annual Report.

We look forward to continuing our support of groundbreaking Stanford research focused on cultivating a more resilient and sustainable planet for all.

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