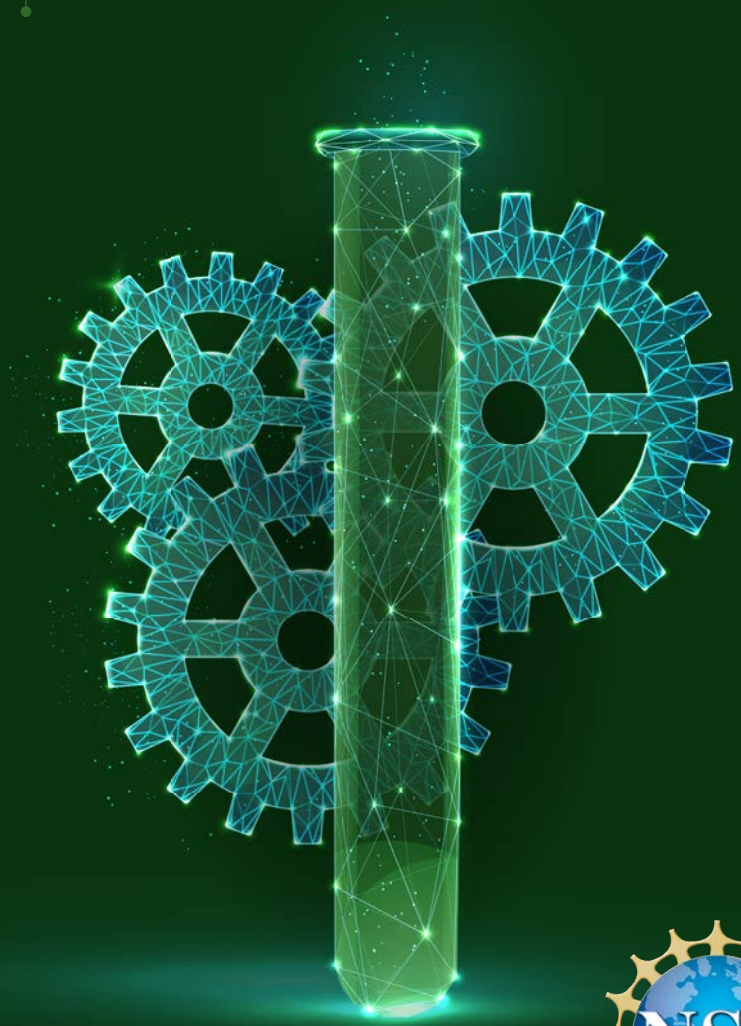
Advanced Technologies for the Preservation of Biological Systems

ATP·Bio℠

Public Annual Report
Year Two



A National Science Foundation
Engineering Research Center

Our Mission

ATP-Bio℠'s mission is to make transformative discoveries, train a diverse workforce, and connect resources and partnerships to ethically translate technologies for the storage and distribution of living biological systems.

Our Vision

ATP-Bio℠'s vision is to stop biological time, allowing living products to be readily available across the globe to advance healthcare, biodiversity, and food supply and sustainability.

Our Pillars

diversity & culture of inclusion

engineering workforce development

convergent research

innovation ecosystem

ethics & public policy

Contents

Message from the Director

John Bischof, Ph.D., Center Director

Director, Institute for Engineering in Medicine; Distinguished McKnight University Professor, Carl and Janet Kuhrmeyer Chair, Mechanical Engineering; Medtronic-Bakken Endowed Chair for Engineering in Medicine, University of Minnesota

I've always believed in the power of convergent team science. Now, after two years as ATB-Bio director, even I am surprised by how much a great team can accomplish.

The details are in the following pages. But I'll note here that each Thrust Area has exceeded expectations for Year 2 and made some exciting and unexpected discoveries on the way. Our researchers (along with industry partners) have also leveraged ATP-Bio work for millions in additional funding from NIH and other sources to drive biopreservation into diverse clinical and technological applications.

Not to be outdone, our other four pillars—Engineering Workforce Development, Diversity and Culture of Inclusion, Innovation Ecosystem , and Ethics and Public Policy—also exceeded expectations in Year 2. After getting ATP-Bio off the ground in Year 1, these pillars have helped make the Center a comprehensive foundation for the near- and long-term future of biopreservation.

Due to COVID and some unexpected personnel changes, ATP-Bio didn't quite reach all of its Year 2 goals. In particular, we have more to offer industry partners (and vice versa), and too many potential industry partners still don't know about us. We also can do more to help our graduate students become more connected to ATP-Bio research outside of their labs and institutions. I look forward to exceeding our goals for these and other components of ATP-Bio in Year 3.

I'm always excited to share reports like this. The growing ATP-Bio team keeps proving that we have the tools to make biopreservation a standard procedure is multiple fields. This includes the "tool" of establishing new collaborations quickly and efficiently. If you have ideas and energy to share, please reach out. The more strengths that converge, the more we'll accomplish.

Leadership & Advocacy

Academic institutions

ATP-Bio℠ is a world-class partnership between engineering, medicine, science, education, business, and ethics at six premier research universities. It supports the crucial advancement of biopreservation technologies and enables innovation, commercialization, and diverse workforce development. Across ATP-Bio℠, the institutional resources are abundant.

University of Minnesota (UMN) is the lead institution as ATP-Bio℠ headquarters. UMN's expertise includes heat transfer, nanomedicine, cryobiology, particle technology, aerosols, 3D printing, cell therapies, physiology, bioelectronics, chemistry, advanced manufacturing, STEM education, psychology, bioethics, law and policy, business, innovation and commercialization.

Massachusetts General Hospital (MGH), ATP-Bio℠'s co-lead institution, is a world leader in every facet of cryobiology including biopreservation, biomineralization, biostabilization, microfluidics, tissue engineering, cryopreservation, BioMEMS, chemical engineering, organ reengineering, organ preservation, metabolomics.

University of California-Berkeley (UCB) provides pioneers in cryobiology, micro-physiological systems, micro and nano energy conversion, organoids, drug discovery, and thermal measurement technologies.

University of California-Riverside (UCR) is a Hispanic-Serving Institution (HSI) and one of America's most successful at graduating students from underrepresented and disadvantaged backgrounds. UCR brings expertise in nanofabrication, nanostructures, nanoparticle development, laser technology, and optics.

Texas A&M University (TAMU) is the biggest university in America and has recently become an HSI. TAMU brings expertise in optics, laser nanowarming, molecular systems biotechnology in inflammatory diseases, microfluidic model systems, and intersections of thermodynamics and biology in biopreservation and conservation biology.

Carnegie Mellon University (CMU) brings cryobiology, cryosurgery, and cryomedicine research to the Center.

Genesis of ATP-Bio℠

ATP-Bio℠ by the Numbers

SEPTEMBER 1, 2021 – JUNE 30, 2022

ATP-Bio℠ Personnel

31 Senior Personnel

6 Administrative Staff

30 Research Staff

81 Trainees
Postdocs, Graduate Students, Undergraduate Students, Technicians

Research Inputs & Outputs

27 Core Publications (peer-reviewed journals)

42 Associated Publications (peer-reviewed journals)

$13.1 MILLION Associated Project Funding

Formal & Informal Dissemination

47 Workshops, Short Courses, Trainings, Webinars

9 Innovation-Focused Events

37 Conferences, Symposia, Colloquia, Invited Talks

Education & Outreach

13 New Courses, or Existing Courses Modified with ERC Content

8 Research Experiences for Undergraduates (REU) Program

13 Pre-College Teacher Professional Development

24 High School Engagement Program (Young Scholars)

14 Graduates (PhD, Masters)

Innovation Ecosystem

19 ATP-Bio Partners (Industry, Innovation, NGO Members)

5 Core & Associated Inventions Disclosed

2 Core and Associated Provisional Patent Applications Filed

1 Core and Associated Patents Awarded

Center Diversity

Women, Racial & Ethnic Minorities, Persons with Disabilities

Leadership Team	60%	12%	14%
Faculty	19%	13%	7%
Trainees	35%	13%	3%
REUs	76%	65%	12%

Societal Benefits

ATP-Bio℠ is a visionary engineering research center leading the field of biopreservation and developing a diverse and inclusive STEM workforce to continue to drive this important field. ATP-Bio℠'s vision is to accelerate technologies that enable widespread preservation and distribution of cells, microphysiological systems, tissues and organs, and whole organisms. These advancements will eliminate barriers that currently prevent biological systems from providing massive societal benefit through the biomedical, aquaculture, and several other global industries.

ATP-Bio℠ will accomplish this through three focused areas of research:

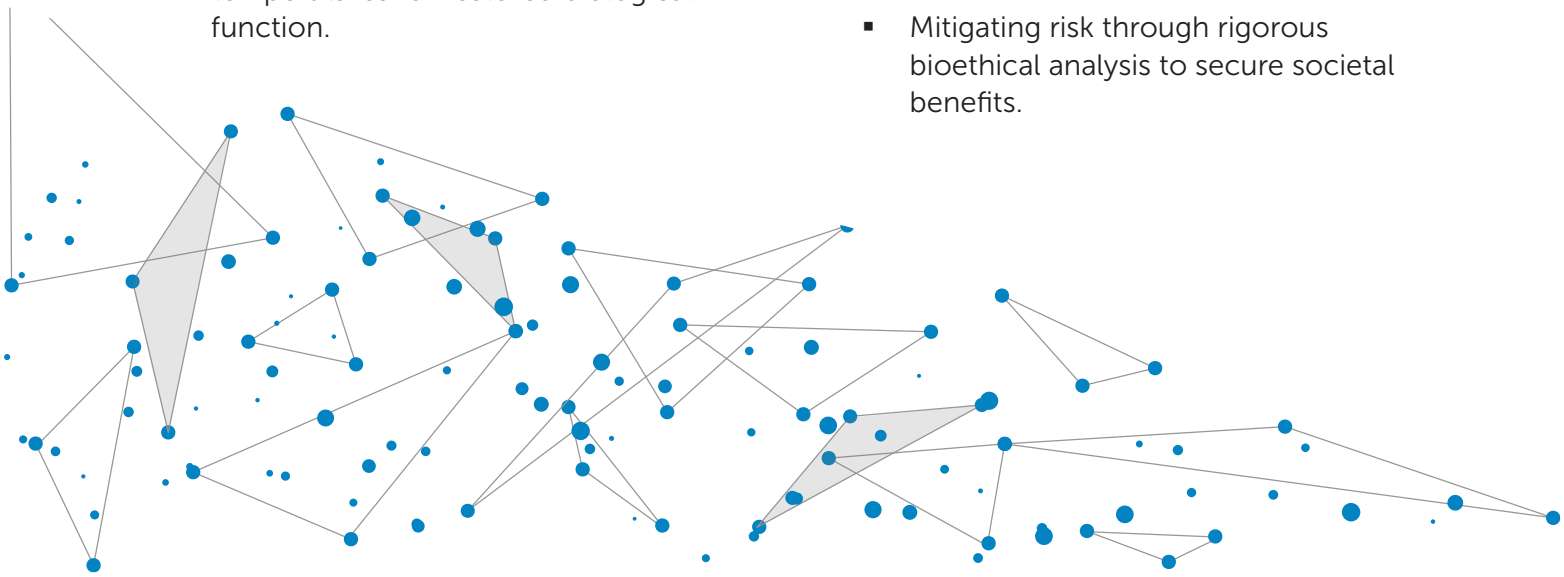
- **Thrust 1, Biological Engineering:** Preparing the biological testbed to survive preservation by cooling or "cryopreservation."
- **Thrust 2, Multiscale Thermodyanamics of Water:** Entering a cryopreserved state by cooling the testbed to a subzero temperature.
- **Thrust 3, Rapid and Uniform Warming:** Rewarming the system to physiological temperatures for restored biological function.

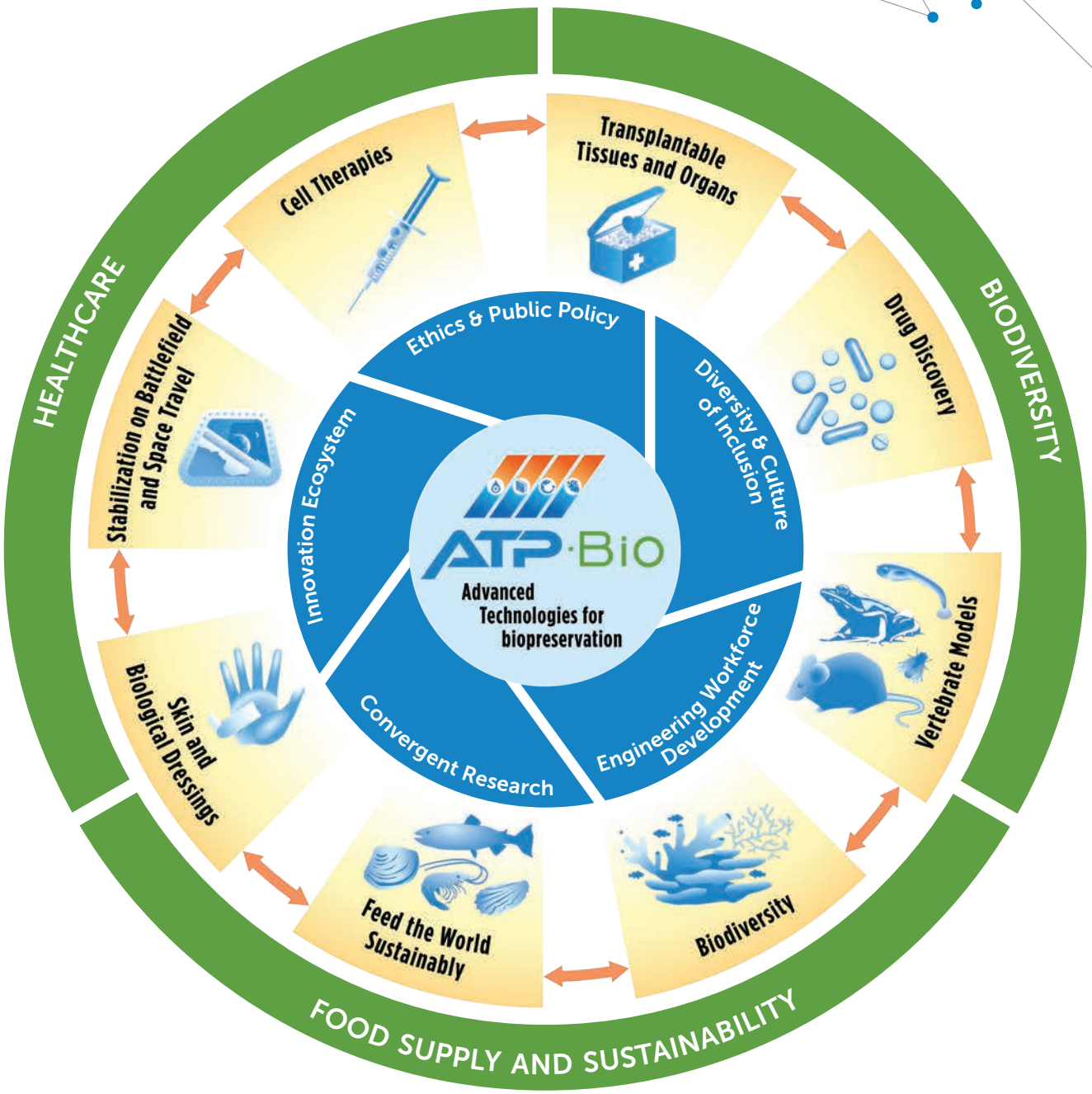
At each stage, convergent engineering research will aim to:

- eliminate or control ice
- mitigate toxicity from cryoprotective agents
- prevent thermal and mechanical stress

Through transformative biopreservation technology, ATP-Bio℠ is:

- Building a sustainable STEM workforce in biopreservation and developing a culture that fosters inclusivity and diversity.
- Using and sustaining STEM education research and best practices to develop programs, curriculum, and experiences that reach diverse groups currently underrepresented in STEM.
- Incorporating the ecosystem's priorities through our scientific and industry advisory boards.
- Commercializing and translating technologies to revolutionize cell therapy, regenerative medicine, aquaculture, and organ and tissue markets.
- Mitigating risk through rigorous bioethical analysis to secure societal benefits.




HEALTHCARE
BIODIVERSITY
FOOD SUPPLY AND SUSTAINABILITY
Cell Therapies
Transplantable Tissues and Organs
Drug Discovery
Vertebrate Models
Biodiversity
Feed the World Sustainably
Skin and Biological Dressings
Stabilization on Battlefield and Space Travel
Ethics & Public Policy
Diversity & Culture of Inclusion
Engineering Workforce Development
Convergent Research
Innovation Ecosystem
ATP·Bio
Advanced Technologies for biopreservation

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Diversity & Culture of Inclusion

DCI

ATP-Bio℠ will broaden participation from groups that historically have been under-represented in STEM so that we increase the potential for impact and innovation.

Although there are many ways that such increased diversity can be understood, our primary focus is on broadening participation with respect to race, ethnicity, gender, disability, socioeconomic status, veterans, and first-generation students.

We will promote diversity, inclusion, and societal benefit across all ATP-Bio℠ institutions and levels of the Center, including leadership, faculty, staff, trainees, students, industry partners, and other stakeholders.

We will build and sustain a culture of inclusion in which all members feel valued and welcomed, can contribute creatively, and can gain respect and mutual benefit from participating. This includes intentional accessibility practices that ensure facility, technology, and activity access for individuals with a wide range of disabilities.

Year Two Highlights

- **DCI Launched DCI Cafés to create an informal space** for ATP-Bio℠ members to engage in discussions about critical issues related to diversity, equity, and inclusion. Some of the meetings focused on creating inclusive labs, creating anti-racist labs, and making STEM accessible.
- **ATP-Bio℠ industry partners, research faculty, trainees, and staff met to revisit the ATP-Bio℠ Code of Conduct and Statement of Diversity and Inclusion.** These are living documents that shape the climate and culture of our center.
- **ATP-Bio℠'s leadership formed new partnerships** with the GEM consortium, Southern Regional Education Board, and the Presidents' Postdoctoral Fellowship Program to advance our work to recruit and retain center members from historically underrepresented backgrounds.
- **The external evaluator and DCI pillar enacted a center-wide climate assessment** in order to understand experiences and identify perceptions of the organizational climate from diverse perspectives within the ERC.

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Engineering Workforce Development

EWD

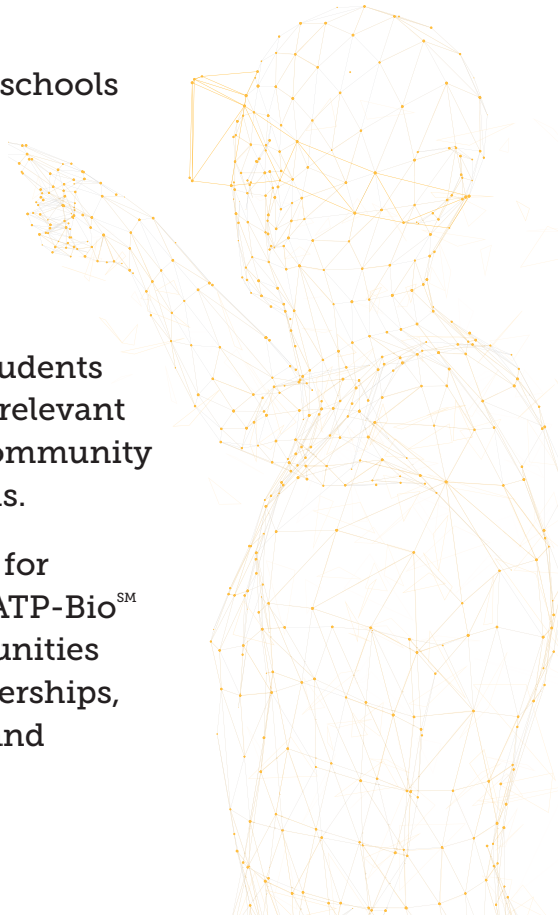
ATP-Bio℠ will educate a STEM workforce that is a demographic reflection of the nation and recognizes that diversity of perspective strengthens STEM fields.

Cell therapy, regenerative medicine, aquaculture, and organ and tissue markets are estimated to be between $300B–600B (US-World) and are predicted to grow substantially by 2025, making workforce development a critically important part of ATP-Bio℠.

ATP-Bio℠ will improve the quantity and quality of engineering intellectual capacity, diversifying the workforce to be representative of U.S. demographics by using inspiration from ATP-Bio℠'s science and engineering. "STEM identity" is a primary driver of sustained pursuit in the STEM disciplines, especially for those underrepresented in STEM.

We will do this sequentially through:

- Strategic partnerships with diverse middle and high schools to increase integration of engineering into middle and high school science classrooms using culturally responsive approaches and improved STEM identities for all students experiencing ATP-Bio℠ activities.
- Supporting the perseverance of underrepresented students in STEM by providing research experiences in areas relevant to ATP-Bio℠, and by creating programs to support community college students transferring to ATP-Bio℠ institutions.
- Providing cross-institutional learning opportunities for ATP-Bio℠ trainees through increased knowledge of ATP-Bio℠ relevant science and engineering principles, opportunities for convergent science and cross-institutional partnerships, and opportunities to understand impact on society and applications in industry.



Year Two Highlights

- **EWD collaborated with UMN SciSparks Outreach and St. Paul Public Schools** to host a two-week summer STEM program for under-represented high school students. Four students from the two-week program continued on to participate in a six-week internship with labs at UMN.
- **ATP-Bio℠ REU Program at UMN and MGH** hosted eight underrepresented students in STEM and participated in an in-person research experience and a virtual cohort experience.
- **EWD launched the ATP-Bio℠ Exchange Program** for graduate students, post-docs, and research staff to support trainees in the education, training, and professional development to advance education and experience.

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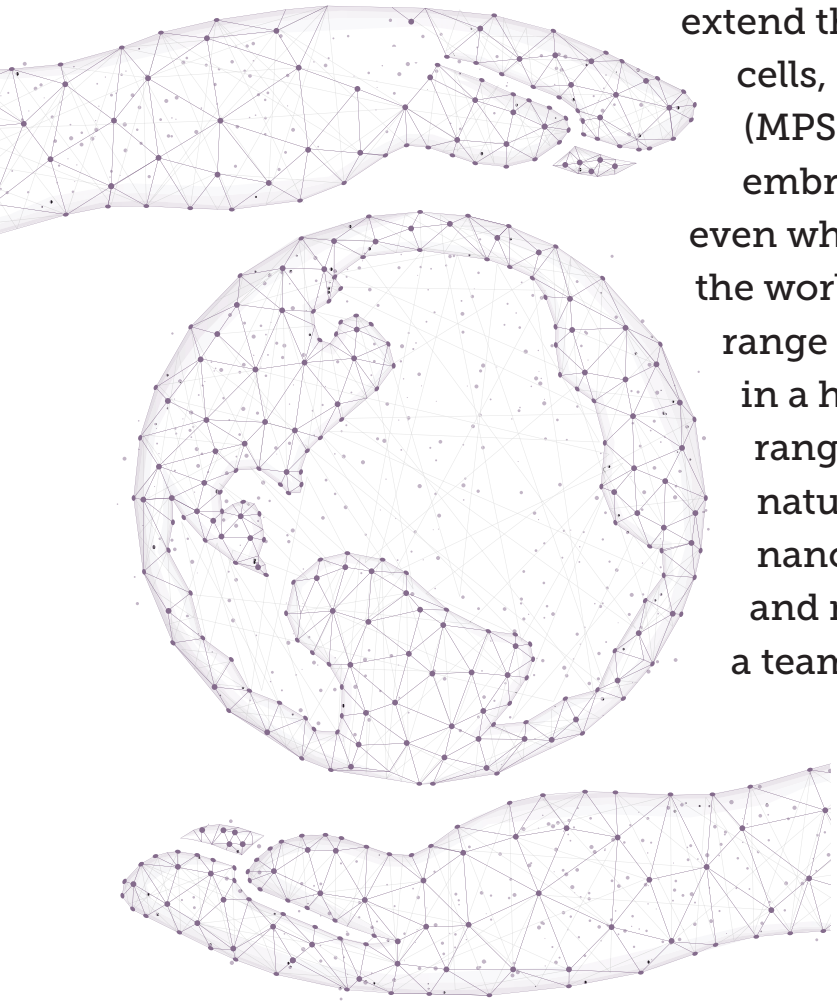
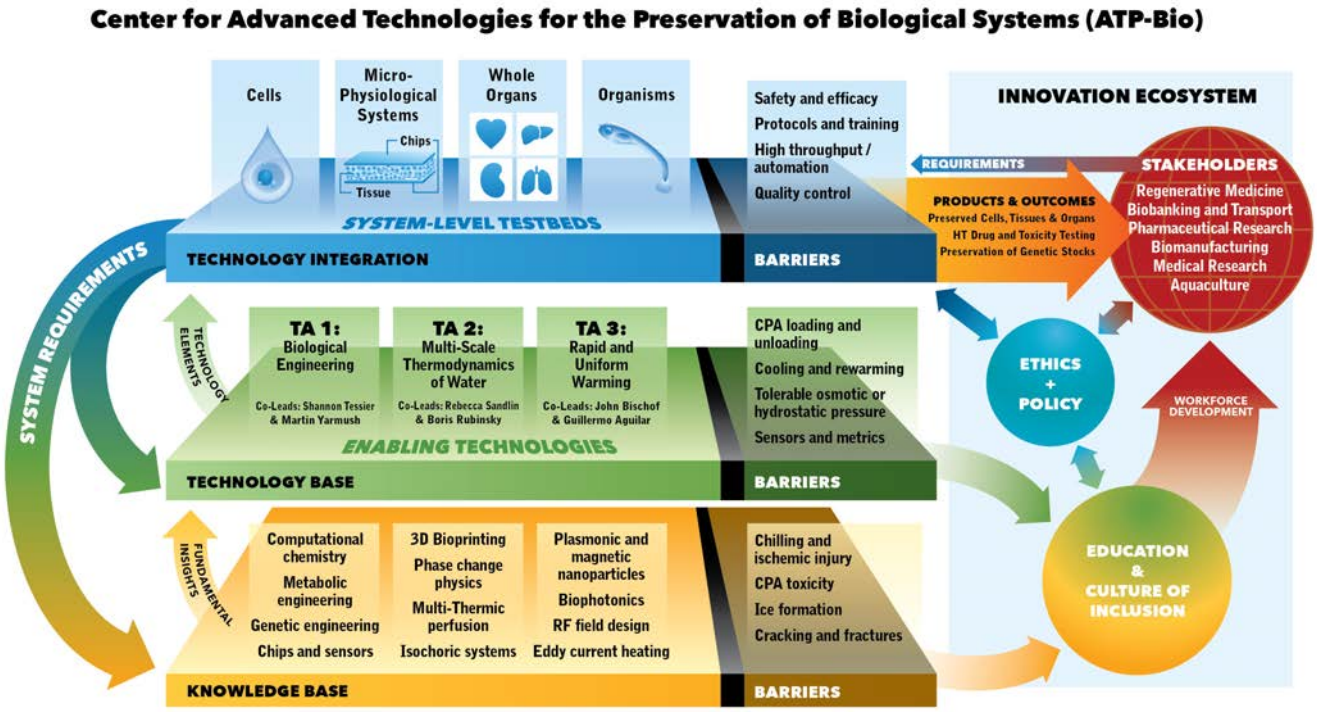
Convergent Research & Engineering

CR

ATP-Bio℠ will accelerate technologies that enable widespread preservation and distribution of cells, microphysiological systems, tissues and organs, and whole organisms.



ATP-Bio℠ will "stop biological time" to radically extend the ability to bank and transport cells, micro-physiological systems (MPS or "organs-on-a-chip"), aquatic embryos, tissue, skin, whole organs, and even whole organisms. ATP-Bio℠ envisions the world a decade from now when a vast range of biological systems are preserved in a high throughput manner for a wide range of benefits to humankind and the natural environment, with advances in nanotechnology, 3D printing, genetics, and numerous other fields. Using a team approach to build advanced preservation technologies, the convergent science of ATP-Bio℠ will develop the foundational knowledge base, which will inform the technology base; together these are integrated at the testbed level. Thrust areas will use enabling technologies to tackle barriers of ice formation, CPA toxicity, and thermal and mechanical stress.



Year Two Highlights

- **ATP-Bio℠ researchers demonstrated successful vitrification of mouse, porcine, and human stem-cell derived beta islets,** and their rapid rewarming by a modified cryomesh approach. This research is published in Nature Medicine and the technology has been protected by a provisional patent.

- **ATP-Bio℠ researchers demonstrated successful partial freezing of rodent livers** by controlling the formation of ice within the mammalian organ at high-subzero temperatures. This research is published in Nature Communications and the IP portfolio underlying the technology was optioned for licensing by an ATP-Bio℠ Partner company, Sylvatica Biotech.

- **ATP-Bio℠ UCB Postdoc joins the ranks of Assistant Professor at Texas A&M University,** the ERCs newest partner institution. Dr. Matthew Powell-Palm is currently building the TAMU Public Thermodynamics Lab to address a variety of projects, squarely in the areas of interest for ATP-Bio℠.

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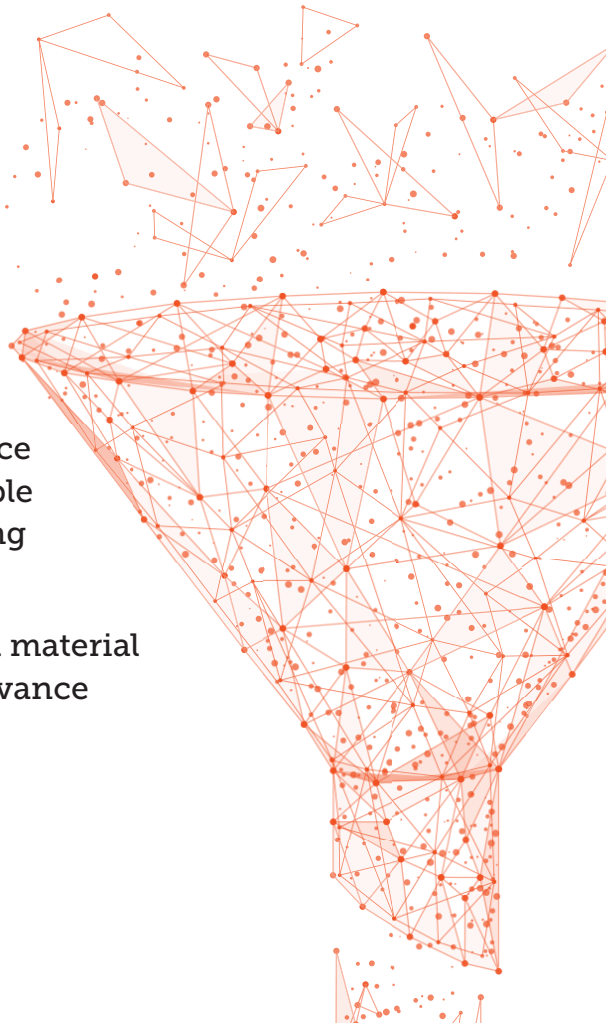
Innovation Ecosystem

IE

ATP-Bio℠ will build a healthy, self sustaining ecosystem that brings together all stakeholders to solve the most complex issues in the preservation of biological systems.

We will produce a significant portion of the next-generation biopreservation workforce in both industry and academia. Our mission is to be a robust academia-industry consortium energized by ATP-Bio℠ leaders. We will develop dozens of biopreservation technologies that will break through existing bottlenecks and enable companies of all sizes to bring their living products to market, no longer bound by limits on supply chain management issues such as shipment and storage.

- Create the next generation of leaders in the biopreservation field
- Enable the biopreservation industry to identify areas of need and pain points
- Develop technologies to reduce existing bottlenecks and enable companies to bring their living products to market
- Broadly engage the biological material preservation ecosystem to advance solutions to serve society



Year Two Highlights

- **ATP-Bio℠ Partner membership grew to 19.** Twelve of those members are industry, with 2 full, 4 sustaining, and 6 associate level members. Six of the partners are Non-profit/Government members, and 1 partner is in the Innovation category.
- **Used the resources created in Y1, membership documents, and processes based on ERC best practices** to engage and support the ATP-Bio℠ Partners. This helped to discern member goals and provide high value engagements through the additional membership categories ("Non-Profit/Government" and "Innovation") for all member types.
- **Hosted inaugural IAB meeting on February 23, 2022 to elect the Chair and Vice Chair,** collect initial feedback from the Partners, and roll out the IP Management Process.

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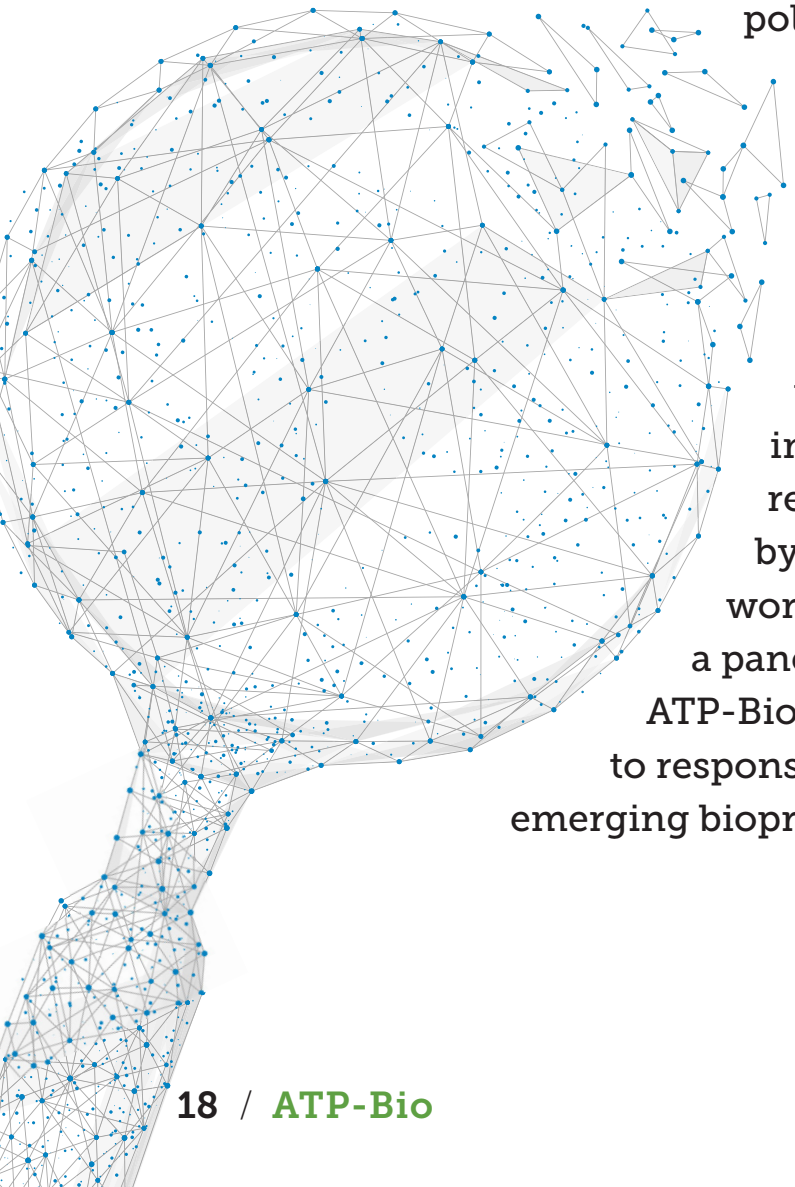
Ethics & Public Policy

EPP

Through ethics and public policy analyses, ATP-Bio℠ will establish guidance for the responsible development and deployment of ATP-Bio℠ technologies for societal benefit.

ATP-Bio℠ advanced biopreservation technologies will transform practices from organ transplantation to conservation biology. Achieving societal benefit and minimizing risk of misuse requires a clear understanding of the ethical and public policy implications of ATP-Bio℠ discoveries, as well as strategies to mitigate potential ethical concerns. ATP-Bio℠ breaks new ground among ERCs by incorporating an explicit Ethics & Public Policy component to identify and address the ethical, legal, and societal implications (ELSI) of ATP-Bio℠ research and the challenges posed by these emerging technologies. This work—conducted in collaboration with a panel of top experts—will enable the ATP-Bio℠ research community, and others, to responsibly research, develop and deploy emerging biopreservation technologies.



Year Two Highlights

- **EPP leadership served on the NSF Stakeholder Steering Committee, collaborating on workshops for** NSF's wider Gen-4 ERC program focusing on stakeholder engagement to secure societal benefits.
- **Collaborated with Convergent Research, EWD, and DCI leaders** to submit a grant proposal to NSF (now funded) on "NetEthics: Building Tools & Training to Advance Responsible Conduct in Complex Research Networks Pioneering Novel Technologies."
- **Hosted two ERC-wide EPP seminars presented by members of the Ethics & Public Policy Panel (EP3)**—Prof. Michele Bratcher Goodwin, JD, LLM, SJD (UC Irvine) on "Racial Equity in Evaluating Biomedical Technologies: From Body Parts and Organ Transplantation to Reproductive Technologies" and Prof. Kenneth Oye, PhD (MIT) on "Managing Risks of Emerging Technologies: Exemplary Cases and Cautionary Tales."

Get Involved

atp-bio.org

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