Passionate

IITA

BTI Boyce Thompson Institute

2018 IN REVIEW

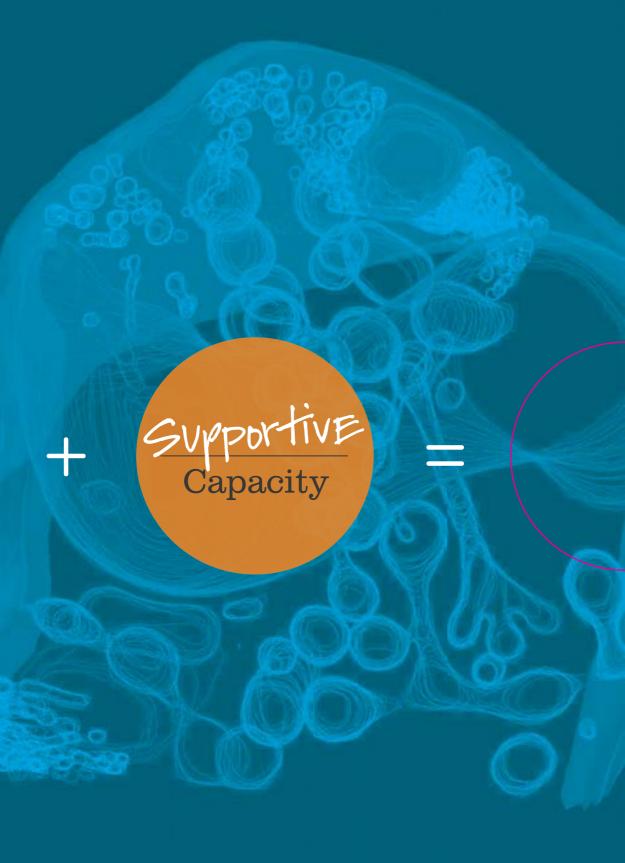




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population predicted to reach nine billion by 2050, understanding the principles underlying agriculture is increasingly crucial. BTI faculty researchers are dedicated to making scientific discoveries that can speed the development of sustainable agriculture and healthier food production. BTI discoveries have the potential not only to help increase the food supply, but also to enhance the nutritional value of foods in developing worlds, to reduce the need for fertilizers and pesticides, and to produce cheaper vaccines.



Mission To advance and communicate scientific discovery in plant biology to improve agriculture, protect the environment, and enhance human health

Vision The Boyce Thompson Institute will be known internationally for research excellence in plant biology and discoveries that benefit society

About the cover: BTI's Guillaume Bauchet (left) with Ismail Rabbi, a cassava geneticist from the International Institute of Tropical Agriculture, at a cassava research trial plot of the National Crops Resources Research Institute in Namulonge, Uganda.



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BTI has over 9,500 sq. ft. of

sq. ft. of greenhouse space devoted to research

To view this report online, please visit **www.BTIscience.org.**

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Dear Friends,

"Food security" refers to having adequate access to affordable, nutritious food, and was at the top of William B. Thompson's mind as the Institute was conceived nearly 100 years ago. It is, however, a deceptively simple concept because culture, diet, political and emotional factors also play a role.

BTI, in keeping with its mission, focuses on the scientific needs behind improving food security locally, nationally and globally. Our hope is that BTI discoveries will contribute to an integrated solution to a dynamic global challenge impacted by population growth, migration and climate change.

The way in which agriculture responds to climate change will have much to say about future food security. One relevant area in which BTI excels is plant response to stress. For example, insect, bacterial and fungal pathogens invade new territories as weather patterns change. Discoveries about bacterial speck resistance in diverse tomato species, unravelling the mysteries of how viruses and bacteria infect crops, and understanding how natural variation contributes to species resilience, all have possibilities for further applications.

There is also a strong cultural connection to food security, such as the desire to eat seasonally and locally. One exciting project in 2018 involved groundcherry, a little-known but highly nutritious relative of the tomatillo



that is increasingly livening salads, jams and dessert choices. BTI partnered with Cornell University and the Cornell Cooperative Extension to involve local farms and citizen scientists in groundcherry growth and marketing trials. Simultaneously, a high-profile study in collaboration with Cold Spring Harbor demonstrated the ability to domesticate groundcherry through gene editing. These new varieties are being designed to create new economic opportunities for farmers, while providing the public with an attractive and nutritious food option.

At BTI, discoveries are at the heart of our mission, which must be connected to those who can further their commercial applications, to ultimately benefit society. BTI has an outstanding team that manages licensing, partnerships and startups to provide space for entrepreneurial

opportunities. At the same time, behind every discovery is a scientist—or more often a team of scientists—who themselves benefit from BTI's unique and dedicated business and core facilities support staff, whose services span project management to laboratory safety, freeing researchers to focus on their science. BTI's advancement office and outreach department engage the public, alumni, budding scientists and educators to involve them in our mission through events, communications and internships.

Food security, like the climate change that overlays it, is a problem of our time. BTI believes in being at the forefront of science that can help humanity both cope and thrive in the face of such challenges. By emphasizing collaboration across the institute, and by allying with scientists across the campus and around the world, BTI is fully committed to making a difference. To find out more about our accomplishments and plans, please explore our report.

David SternPresident

BTI

Dear Friends and Colleagues,

The first thing I would like to do at the end of a successful year at BTI is to thank my predecessor, Laura Philips, for her outstanding leadership as Board Chair. Laura brought business expertise, scientific acumen and thoughtful reflection to the BTI Board. Under her leadership, the board grew in diversity, depth and engagement, all to the benefit of the Institute. I am also very grateful that Laura has agreed to continue her involvement with BTI through our new Development Task Force.

The experience and expertise on the board is exceptional, and it became even more so in 2018 when we added Mary Opperman and Charles Trautmann to our ranks. Both Mary and Charlie possess exceptional resumes and have strong ties to the greater Ithaca area. Mary is the VP and Chief Human Resource Officer for Cornell University, where she oversees 18,000 faculty and staff across Cornell campuses in Ithaca, Geneva (NY), New York City and Qatar. Mary is a fellow of the National Academy of Human Resources, and in 2015 was named as one of Human Resource Executive magazine's top 15 most influential women leaders in HR. She is also active on regional economic development and local non-profit boards.

Charlie Trautmann recently completed a 26-year tenure as the Executive Director of the Ithaca Sciencenter. He is credited with transforming a small-town science museum into a nationally recognized center

for discovery. Having served as the chair of the Sciencenter board. I saw first-hand how Charlie's work inspired both our local community and the one million people across the country he touched by way of traveling exhibits. Charlie is also a visiting scholar in Cornell's Department of

Human Development, and has served on the boards of community organizations such as Engineers for a Sustainable World, Ithaca Montessori School, Tompkins County Area Development, and many more.

As BTI continues to diversify revenue streams, including the evolution of our internal development team, I'm proud to report the board once again saw 100% of our volunteer members donate to the annual fund. 2018 saw nearly \$1.9 million in philanthropic support for the Institute, allowing BTI faculty to take on high-risk high-reward research topics, as well as enabling education, outreach and communications initiatives.

Though we are located in Ithaca, our roots are in the New York City area, and we look to grow those connections. Board member



Oliver Schulze was instrumental in arranging a private gathering at The Knickerbocker Club in New York City, which provided the board and representatives from the advancement office an opportunity to share BTI science with prominent New York professionals.

Research at BTI plays a pivotal role in many of the most pressing issues in agriculture and human health, through both fundamental research investigations and translational work that leads to commercial opportunities. It is my great honor to be elected to Board Chair of this amazing organization.

Greg Galvin

Chair, Board of Directors

Dear BTI Community,

"Food drives life, and the struggle for food is the struggle for life. This makes hunger an economic issue, a national security issue, and without a doubt a moral issue. Through innovation, we can help alleviate hunger and malnutrition today, but more than that we can fulfill our responsibility to tomorrow." — Former US Secretary of State, John Kerry

At BTI, we understand that food security—being able to feed a fast-growing world population with dwindling natural resources—is a major challenge that we collectively face. This challenge sounds insurmountable at times, but it isn't. William Boyce Thompson understood that food security is essential to the success of our species and of all the natural world. He also understood that science-based innovation is an important tool for addressing this challenge.

Understanding the biological processes of plants is integral to the work that we do at BTI. Our science covers a vast field of discovery from studying plants and their interactions with insects and other pests, to investigating viruses and how they interact with their hosts, to the study of small molecule chemistry, and much more. In 2018, BTI researchers authored 128 peer-reviewed scientific publications reporting successful research results, including improved fruit quality, higher yield and increased nutritional value in crops. We are a relatively small



institute that continues to generate results at an amazing level of productivity.

I had the distinct pleasure of becoming BTI's new Director of Research at the beginning of 2018. It has been thrilling to be a part of the senior leadership team and to oversee first-hand the Institute's ongoing scientific programs that continue to answer fundamental questions and drive innovation. The excitement of scientific discovery fuels our endeavors, grounded by the aspiration to benefit society through plant science.

Although BTI is involved in many projects that continue to make progress toward better food security, I will highlight just two of them. In October, BTI's new Computational Biology Center (BCBC), along with Cornell University and our Genomics Open Source Breeding Informatics Initiative (GOBii), hosted a

workshop entitled, "Transforming Breeding through Integrated Data Management and Analysis." Plant scientists, plant breeders and computational biologists from all over the globe gathered at BTI for a week-long intensive course featuring keynote speakers, workshops and training sessions to ensure that science can speed up the breeding process and bring hope of better food security to many parts of the world.

Another example of BTI's potential to improve global food security is ongoing work in the Stern lab, which recently published its success in engineering corn plants to increase the activity of a primary enzyme in the photosynthetic pathway,

leading to improvements in growth. From the fields of Iowa to the small farm plots of a struggling African farmer, corn is a plant on which billions of people rely for food every day. This is a great example of how basic research can be the bedrock for impactful innovation well beyond the lab.

Thanks to all of you who have supported BTI and who will continue to support BTI as we make important contributions to human welfare.

Paul Debbie

Director of Research

Director of New Business Development BTI



GARY BLISSARDHow do viruses interact with insects?



MICHELLE HECK
How do pathogens commandeer
plants and insects to promote their
own transmission?



JIM GIOVANNONI
What is the genetic basis of fruit ripening and nutritional quality?



GEORG JANDERHow do plants defend themselves against insect herbivory?



FAY-WEI LIWhat are the evolutionary and genetic factors that shaped plant diversity?



LUKAS MUELLERHow can genomics contribute to improved crop breeding?



FRANK SCHROEDERWhich biogenic small molecules control development and aging?



JOYCE VAN ECKHow can biotechnology create better crops?



CARMEN CATALÁ

The making of a fruit: What are the processes involved in fruit formation?



ZHANGJUN FEIHow can scientists access and use massive amounts of plant genomics data?



MARIA HARRISON

How do plants form symbiotic associations with fungi to access phosphate from the soil?



DANIEL F. KLESSIG

What are salicylic acid's roles at the crossroads of plant and human health?



GREGORY MARTINHow do bacteria infect plants and how do plants defend themselves from attack?



ERIC J. RICHARDS

How does the three-dimensional organization of the genome within the cell affect gene activity?



DAVID STERNHow can combining genetics and Big
Data help us understand and improve photosynthesis?

BTI had
128
peer-reviewed
scientific publications
in
2018

Food Security for a Changing Planet

As we enter 2019, Earth's population continues to explode, the climate continues to change and natural resources remain limited. Disruptive weather patterns can result in challenging growing conditions for crops, in terms of both abiotic stresses like suboptimal temperature and rainfall, and biotic stresses like new pests that have expanded their reach. On top of these difficulties, there is only so much acreage on which to grow food, and a limited amount of phosphorus for fertilizing these crops.

For many people who are not fortunate enough to live in food-secure regions, it can be difficult to find enough calories for survival, let alone to find healthy, nutritious food. Even for those who are fortunate enough to live in a region where there is plenty of food, thousands of people's lives are impacted by agricultural diseases that are decimating crop yields.

More than 100 years ago, William Boyce Thompson understood that new discoveries and applications in plant science would be essential to supply the world with nutritious food under exactly such circumstances. Thanks to his foresight, researchers at BTI continue to make tremendous progress towards helping solve some of these problems. In the past year, BTI researchers have made key discoveries that could lead to more nutritious crops, decreased use of synthetic fertilizers, increased yield and less crop damage by disease.

Improving a Minor Crop

As researchers work tirelessly to support our current staple crops, there are some who are trying to create new ones from existing minor crops. Such is the case in Joyce Van Eck's lab at BTI, where work on the largely unknown groundcherry is producing hope there could soon be a new addition to a produce section near you.

The groundcherry (Physalis pruinosa) is approximately the same size as a cherry tomato, but with a

much sweeter. tropical-tast-

ing flavor.

The fruit is also a

powerhouse in

terms of nutri-

tional value. Packed

with Vitamin C, Vitamin B,

beta-carotene, phytosterols and antioxidants, plus anti-inflammatory and medicinal properties, the groundcherry might just be the next superfood.

While the groundcherry offers plenty to be excited about, there are hurdles to overcome before it can become a grocery store

at BTI.

staple. First and foremost, the tiny fruit's current genetic makeup hinders large-scale production. However, using the genome-editing tool CRISPR, Joyce Van Eck's group may have found a path to correct some undesirable characteristics to make mass production more realistic.

CRISPR holds great promise for rapid improvement of orphan crops such as groundcherries because they often have weedy, unmanage-



able growth habits and low crop productivity similar to their wild ancestors. Leveraging knowledge gained from experience with model crops—such as the tomato—can lead to approaches to improve plant architecture, flower production, fruit size and more.

To learn more, the Van Eck lab enlisted the help of farmers across New York State and local citizen-scientists to be part of a special project. Volunteer farmers obtained groundcherry seeds from the Van Eck group, planted the seeds at their farm, and monitored their progress. Citizen-scientists-some of whom were recruited through local organization partners



like the Ithaca Children's Garden, Cayuga Nature Center and Cornell Botanic Gardens-conducted similar experiments. The results provided the group with information to help guide their subsequent efforts to improve the groundcherry's potential to be produced on a larger scale.

In our fight to produce more nutritious food for a rapidly accelerating population, developing crops

once thought to be inadequate for large-scale production could be a key to success. In the case of the groundcherry, don't judge it by its size; judge it by its potential.

Unlocking Secrets of an Ancient Relationship

Relationships between different species can take many different forms, such as predator and prey, parasite and host, or competitors battling for resources. While the interactions occurring above ground garner much of the spotlight, there are also peaceful collaborations happening below the surface. It is these mutually beneficial relationships that are the focus of Maria Harrison's lab at BTI.

The Harrison lab continues to be a leader in research on mycorrhizal symbiosis. For hundreds of millions of years, these fungi have formed symbiotic relationships with plant roots to deliver crucial nutrients to the plant in exchange for lipids and carbohydrates. Understanding this natural partnership could ultimately lead to a reduction in the use of phosphate fertilizers in the agricultural industry.

A potentially crucial aspect of the plant-fungi symbiotic relationship is the additional symbiotic relationships that the fungi have with bacteria. Despite their importance to agriculture and plant science research as a whole, genomic information about mycorrhizal fungi and their symbiotic bacteria have been relatively sparse, thus hindering our understanding of their biology and evolution.

To shed some light on this network of mutually beneficial relationships, the Harrison



Understanding the relationship between burclover and its symbiotic fungi could help reduce the use of synthetic fertilizers.

lab partnered with BTI's Fei lab to sequence the genome of Diversispora epigaea, a species of mycorrhizal fungus, and its endobacteria. A paper describing

"This research

could ultimately have

applications that lead to

the reduction of synthetic

fertilizer usage," said

Maria Harrison, William

at BTI.

the genomes, as well

as the results of comparative genomic and evolutionary analyses, was published in the research iournal New Phytologist in 2018.

H. Crocker Professor This work generated fundamental insights into the co-evolution of the fungus and

its endobacteria, and could also lead to new hypotheses about their co-evolution with the plants whose roots they colonize. These ideas will be of great value to plant scientists, and may ultimately help lead to a solution for a world that could run out of chemical fertilizers before the end of the century.

Studying Insects to Save Citrus

Pouring a glass of orange juice to accompany breakfast is a morning routine for many...or at least it is for now. Having a glass of OJ may soon occur with much less frequency because a vicious bacterium has hijacked a tiny insect to spread devastation across citrus-growing regions in the U.S. and around the world.

More than 33.000 acres have abandoned due to citrus greening disease

The bacterial culprit, Candidatus Liberibacter asiaticus (CLas), resides within the Asian citrus psyllid, which is an insect about the size of a sesame seed. The bacteria are sucked up when a psyllid feeds on an infected tree, and then replicate inside the

insect and infect healthy trees as the psyllid feeds throughout a grove.

The end result is citrus greening, also known as huanglongbing. Trees with this disease are unable to get enough nutrients from the soil, thus causing their leaves to turn yellow, young twigs to die back, and fruit to

remain small, green and unsuitable for sale. After only a few years, the trees die.

Currently, every citrus tree in Florida is be-

"We want to understand the insect's immune system as deeply as possible so that we can identify new ways number of trees in to reduce transmission of California. Texas and CLas by these insects," said other citrus-growing states. To Angela Kruse, a graduate combat this disease, student in Michelle researchers Angela Heck's lab at BTI. Kruse and John Ramsey from Michelle Heck's lab at BTI dipped into the psyllid's blood and, in doing so, extracted new discoveries that could help plant scientists better understand how the insect's im-

mune system reacts to the bacteria in hopes

Kruse and Ramsey used tiny needles to take blood samples from over 300 psyllids, and looked at the differences in blood proteins between infected and uninfected insects. They found that the blood proteins most affected by CLas help insects fight bacterial infections and increase fat metabolism. By adding to their knowledge of the insect's immune response to the bacteria, Angela and John hope these insights could help develop strategies for controlling the spread of citrus greening.



While you may find yourself thinking the elimination of OJ from your breakfast routine wouldn't be the end of the world, the same sentiment is not shared by those maintaining family farms across Florida. In that state alone, citrus greening causes about \$1 billion of damage and eliminates thousands of jobs each year. A popula-



tion struggling to feed itself can ill afford to lose a major crop like citrus. and BTI's Heck lab is part of a large effort that hopes to bring this epidemic to an end.

Psyllids, an insect the size of a sesame seed, spread the bacteria that causes citrus greening disease.



BTI President David Stern and Coralie Salesse-Smith. one of his lab members, engineered corn to improve crop yields.

Boosting Photosynthesis

As the world's population increases, we will not be able to feed everybody just by cultivating more land. Indeed, more than one-third of Earth's 150 million km² of surface land area is already dedicated to agriculture, and much of the remaining acreage is unsuitable for raising food.

Thus far, many solutions to grow more food with less land have involved chemical

fertilizers, pesticides or intensive irrigation, which can harm the environment and human health. David Stern's lab at BTI has come up with a clever solution that may increase crop yield without the negative impact of traditional methods.

David and Coralie Salesse-Smith, a researcher in his lab, inserted genes into corn that increased the expression of two proteins: Rubisco, which incorporates carbon dioxide from the atmosphere into molecules that become sugars, and RAF1, which helps build Rubisco. As a result, the plants received a boost to their photosynthetic machinery, making them grow taller, weigh more and mature faster than unmodified corn.

The Stern lab hopes to see similar results in other plants that have similar biochemical pathways, such as millet. The Rubisco/RAF1 method could also be combined with other strategies to turbocharge photosynthesis, which is a major global target to improve agriculture.

lab translate to the field, then new strains of crops could be developed with similar characteristics, with the hope that more rapid and robust growth will translate to a higher yield per acre, ultimately helping to feed a growing population in a more sustainable way.



"Collaboration" is one of BTI's core values that is easy to see in our researchers' efforts to improve food security in a time when global undernourishment is on the rise.

According to the United Nations' Food and Agriculture Organization, the number of people facing chronic food deprivation reached nearly 821 million in 2017, which is 10.9% of the global population. After decreasing for decades, these numbers have been increasing since their nadirs in 2014, when just under 784 million—or 10.7% of the global population—were

Enabling technologies for former in undernourished. The rates are highest

for farmers in food-insecure understanding the print

With the world population expected to reach nine billion by 2050,

in Sub-Saharan Africa, which has a 23.2% undernourishment rate.

regions understanding the principles underlying agriculture is increasingly crucial. William Boyce Thompson awakened to this notion 100 years ago when he joined the American Red Cross

on a relief mission to Russia during the country's civil war. He came to believe that agriculture, food supply and social justice are linked, and that world stability depends on access to adequate food.

Col. Thompson's epiphany still holds true today and drives BTI's efforts to speed the development of sustainable agriculture and healthier food production. The Institute's researchers work toward this goal through basic research, as well as through the implementation of new breeding paradigms, such as genome-based breeding methods. These new breeding methods require advanced databases that encourage research collaborations among international plant science research institutions.







PART I:

CASSAVA

One database created in Lukas Mueller's lab is Cassavabase. The database was made possible thanks to funding by Cornell University through a

grant from the Bill & Melinda Gates Foundation, and is a collaboration with partners such as the International Institute of Tropical Agriculture, the National Root Crop Research Institute in Nigeria, the National Crops Resources Research Institute in Uganda, and others in Tanzania, Brazil and Colombia.

Although native to Latin America, cassava (Manihot esculenta) is an

extremely important staple crop in Africa, second only to maize. Indeed, about 500 million Africans—or about 40% of the continent's population—consume the starchy root every day.

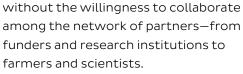
Cassava holds potential to become a staple crop in even more countries as climate change renders land unusable because of changing temperature and rainfall patterns. The woody shrub has low input requirements, is resistant to drought, is able to grow in marginal soils, and its roots are able to remain edible even when left in the ground for a few years.

Despite these benefits, cassava has drawbacks that make it difficult to improve via traditional plant breeding techniques. Specifically, many cassava varieties flower infrequently, and they often do not produce many seeds when they do flower. These traits cause additional hurdles for a breeding process that has historically taken about five years.

With the sequencing of the cassava genome in 2012 came the potential for breeders to perform crosses based on genomic data without having to wait years to see how well the roots grow. Launched in 2013, Cassavabase is specifically designed to be a database for breeders. Thanks to its ease-of-use and an engaged breeder community, the database now contains information on more than 3 billion genetic marker scores, as well as over 10 million phenotypic data points on how plants have performed in the field.

Today, using genomic selection enabled by Cassavabase, cassava breeders have shortened the breeding cycle to as little as one year, helping them speed the development of cassava strains with positive traits, such as resistance to cassava brown streak disease and high dry matter content. However, this would not have been possible

> among the network of partners—from funders and research institutions to farmers and scientists.



PART II:

Yams, Bahahas and Sweet Potatoes

Mueller's lab has created three more databases that are designed to help

Upper left: An example of the symptoms of cassava brown streak disease under field conditions at Tanzania Agriculture Research Institute, Lake Zone Agriculture Research institute, Mwanza. Left: A woman carries bananas, an important staple crop in East Africa.



Below: The Cassava Breeding Team at the National Root Crops Research Institute Nigeria. Bottom: BTI researcher Alex Ogbonna with Dr. Brigitte Uwimana, the lead Banana Molecular Breeder at the International Institute for Tropical Agriculture, Uganda.

breeders develop improved crops for foodinsecure regions: Yambase, Sweetpotatobase and Musabase. They are all similar to Cassavabase in that they include associations between genotypes and phenotypes, and are easy for breeders to use.

Yams—tubers of the genus Dioscorea—are an especially important staple crop in West Africa, where more than 50 million tons are produced each year. Unfortunately, pests and diseases can reduce yam yields by up to 80%. Traditional breeding methods take about nine years to develop a new variety of yam. Yambase holds the same promise as Cassavabase to help shorten this breeding period and speed the release of yams that have improved characteristics. For example, Ph.D. student Alex Ogbonna is using genetic markers to shorten the tuber's breeding cycle, and to develop yams with higher yield, starch content and resistance to yam mosaic virus (YMV).

While cassava and yam are full of high-calorie carbohydrates and can help feed the growing population, they contain few nutrients and will thus need to be supplemented with vitamin-rich foods. Sweet potato (*Ipomoea batatas*), in particular, could help fight Vitamin A deficiency, which affects 40% of children in Sub-Saharan Africa and is a leading cause of blindness and premature death. The crop is also frequently devastated by pests like the sweet potato weevil.

Improving sweet potato traits is difficult because it has six copies of each chromosome, which makes sequencing its genome very

tricky. This hurdle has hampered the discovery of the genetic, molecular and physiological basis of kev agronomic traits. In November 2018, members of Zhangjun Fei's lab at BTI published the sequence of two of sweet potato's diploid relatives and resequencing data for 16 sweet potato varieties commonly used in African breeding programs. Once the data are entered into Sweetpotatobase, they will

help facilitate genome-enabled breeding of the tuber by partners like the International Potato Center (CIP) in Peru.

Banana is another important staple crop in East and Central Africa but many strains are seedless, which makes them difficult to cross-breed and highly susceptible to disease. Musabase is a database for breeders that is focused on strains that are important to the continent, with most data coming from breeding programs in Uganda (NARO Kwanda and IITA Sendusu) and Tanzania (IITA Arusha).

CONCLUSION:

Real-world benefits

All four of these databases are prime examples of how BTI researchers are creating digital tools that benefit farmers in food-insecure



regions. Cassavabase has already helped reduce the breeding cycle from five years to one year, and Yambase, Sweetpotatobase and Musabase have the potential to lead to similar reductions for yams, sweet potatoes and bananas, respectively. Ultimately, these databases will enable breeders to more quickly improve crops' traits such as yield, nutritional value, disease resistance and drought tolerance, and thus help provide food security in parts of the world that need it the most.



Gregory Martin's lab is making discoveries that could be used to develop tomato strains that are resistant to bacterial speck.

Drumming up New Business

The American writer and naturalist Joseph Krutch once wrote, "Technology made large populations possible; large populations now make technology indispensable".

BTI scientists are explorers. They seek and open up new areas of research, making important discoveries along the way. Helping to translate these discoveries into practical applications is an important part of BTI's mission and the Institute's new strategic plan that was put into place in May. This work is managed by the Technology Transfer team, for which 2018 was a year of expansion and re-imagining.

BTI brought Erica Fishel on board to become the new Director of Technology Transfer.

Along with strong technical knowledge of plant biology and a Ph.D., Erica brings years of technology transfer and patent law experience to the Institute. Kelli Monce also joined as a technology transfer specialist. In her new role, Kelli manages our technology transfer and intellectual property data, which are essential to a successful program.

When BTI opened its doors in 1924, William Boyce Thompson and his advisers were keenly aware of the importance of food security to the stability of populations and human health. This awareness is more acutely felt today than ever before, and the Technology Transfer

team has been instrumental in pursuing projects that could have a positive impact on advancing agricultural technologies. In 2018, a few such notable projects included:

- The discovery of new resistance genes in tomato for protection from newly emerging varieties of bacterial pathogens
- The development of new ways to grow beneficial fungi that have positive associations with many plants, including food crops. These methods could lead to decreased fertilizer use, thus improving food production and limiting the environmental impacts of farming
- The development of new naturally derived compounds to protect agricultural crops from numerous diseases, as well as the first successful field trials with these compounds in wheat
- The development of new strategies to fight the citrus greening epidemic, which is ravaging the U.S. citrus industry
- The development of "turbocharged" corn plants by increasing the amount of the photosynthetic rate-limiting enzyme Rubisco



Along with traditional technology development and commercial partnering projects, another aspect of BTI's new strategic plan focuses specifically on technology development through starting new companies based on BTI technology. To help facilitate these and other new business development projects, the Institute created a new position, Director of New Business Development, a position taken on by Paul Debbie, BTI's former Director of Technology Transfer.

New business ventures provide great opportunities for BTI researchers and volunteers to bring their insights to private sector projects.

Exciting New Ventures



Ascribe Bioscience Inc. – This Ithaca-based startup focuses on novel seed coatings with natural small molecules to improve agricultural production in several important crop species. In 2018, the NSF recommended phase I SBIR funding for the new company, and the U.S. Patent and Trademark Office awarded a patent that protects the underlying technology (U.S. Patent No. 10,136,595). In 2019, this new company will be moving into the McGovern Family Center for Venture Development, a life sciences business incubator on the Cornell University campus.



EFFECTOR RX.

EffectorRx Inc. – This new company is focused on using BTI-patented technology to improve the production of proteins in plants, such as vaccine antigens and other proteins valuable to the pharmaceutical industry. Many proteins are difficult or impossible to produce in plants, and this technology could help overcome this hurdle. The Institute's Technology Transfer team has engaged a large agricultural biotechnology company to set up a pilot project to test this new technology.



THE COMMUNITY AND EDUCATORS

2018 saw increased engagement with the public through local collaborations. Fay-Wei Li thrilled 110 families at the Ithaca Sciencenter's Wicked Plants exhibit opening. In December, the Sciencenter's "After Dark" cocktail party-style program featured seven faculty and lab members who displayed their research and inspired conversation around the importance of plant research for food security and human health. The community also learned more about groundcherries and bryophytes when the Li and Van Eck labs attended the Judy's Day Festival at the Cornell Botanic Gardens. Members of the Jander lab travelled to the NYC Cornell Center for Material Research to train 40 high school teachers on how to utilize a new classroom kit, using wallflowers and aphids to educate students about pest resistance. Members of the Heck lab shared their citrus greening and aphid research with 50 students from Southern Cayuga School district during an elementary school tour.

Summer

INTERNSHIP PROGRAM

BTI hosted 23 undergraduate students as part of the NSF and USDA-supported Plant Genome Research Program (PGRP), eight donor-supported high schoolers, and a Triad Foundation-supported Science Communications Intern for a summer of research and education. For almost two decades, the summer internship program has significantly

impacted the lives of more than 200 participants.



SUMMER INTERNS BY THE NUMBERS

For 18 years, BTI's PGRP summer internship program has engaged a diverse population of undergraduate and high school students to support their entry into STEM careers. After crunching 14 years of data, we now have the metrics to show our success. Of the 199 summer interns over the past 14 years:

identified as under-represented minorities

in sciences

95%
of intern alumni
are currently
in a STEM field

60% of interns were female

36%
were first-generation
college students
(only tracked since 2010)

55%
were from small colleges
with few research opportunities

SCIENCE COMMUNICATIONS

communicati SCIENCE

Science communication remains a critical component of the BTI mission,

helping build public support and awareness of the Institute's work and science in general, as well as enhancing collaborations and relationships with funders. BTI continued efforts to push Institute research into the mainstream conversation through a variety of tactics including digital media, media relations, video production and community engagement.

Science Communication

at the Institute.

intern Serena Stern presents her analysis of Art@BTI, a public outreach event held

The year began with a visit to Washington, D.C. to meet the communications teams of the National Science Foundation, the Department of Energy, the United States Department of Agriculture and the American Association for the Advancement of Science. These meetings helped BTI communicators develop deeper collaborations, while offering funders compelling stories to share with the policymakers who determine their budgets.

With donor support, live streaming capacities were enhanced in 2018, enabling the production of high-quality, engaging live broadcasts that reached an international audience. Broadcasts included the BTI Computational Biology Center symposium, the 2018 summer intern symposium, several faculty seminars, and a day of scientist interviews on Giving Tuesday.

2018 also marked the first year with a donor-supported Science Communications summer intern embedded within the Plant Genome Research Program. Serena Stern, a Cornell undergraduate student, gained hands-on experience with the Institutional communications team. She produced science articles, managed social media channels, produced a documentary-style video, and had one-on-one

> 2018 also featured more Art@BTI, with works by photographer Nancy Ridenour and fiber artist Sarah Gotowka. Ithaca-area friends of the Institute and Cornell's Alliance for Science were able to to attend a screening of the film Food Evolution at Cinemapolis, which was followed by an enthusiastic panel discussion. In the autumn, the Institute held a Flash Science event in which researchers were challenged to share

INTERN SPOTLIGHT Emmanuel Gonzalez

Emmanuel spent his summer in the Giovannoni Lab researching cold tolerance in tomato hybrids. Emmanuel has a strong interest in botany that intersects with his love of photography outside of the lab.



career path."

interviews with several professional science communicators. their work for a general audience in three minutes or less.

Postgraduate Society: Fostering community and professional development

Led by a committee of graduates, postgraduates, and technicians, the PGS organizes a successful mentor program and events where members interact scientifically and socially to sharpen research, communication and networking skills.

Guest Speakers

PGS hosts a variety of speakers who provide new perspectives on research and the opportunity to network within lecture settings, as well as during meals or happy hours. 2018 featured two distinguished lecturers, Cyril Zipfel (University of Zurich, Switzerland) and Jennifer Nemhauser (University of Washington). Seminars called "PGS Fests" typically are given by BTI/ Cornell scientists or visiting scholars in residence with an aim of crossfertilizing communication and interaction among labs across the campus. In 2018, PGS Fest speakers included Buz Barstow (Cornell Department of Biological and Environmental Engineering) and Angela E. Douglas (Cornell Departments of Entomology and Molecular Biology and Genetics).

Annual Retreat

PGS's annual symposium, themed "High-End Research Meets Tech-Transfer: How Small Molecules Can Change Our World," took place at the Cornell Lab of Ornithology and featured eight speakers from academia, industry and the investor community. The symposium included a poster session, lunch and happy hour, which helped improve communication between the BTI research community and industry.

Mentoring Program

The PGS Mentorship Program aims to provide professional development resources for members interested in diverse scientific careers by connecting mentees with mentors in their chosen career fields. In 2018, PGS paired six sets of mentees/mentors based on both the mentees' academic and professional goals and the mentors' career experience.

Professional Development Workshop

PGS organized a professional development workshop, "Understanding the Visa process," to assist both international employees and U.S. citizens who might hire international scientists in the future. The workshop featured two talks, one with BTI's Denise VanDyne and Lori Dempsey, and one with David Wilks, an immigration attorney from Ithaca law firm Miller and Mayer.





New Resources for BTI Alumni

In 2018, the opt-in BTI Alumni Network reached 150 members. Four alumni visited the Institute for presentations and workshops, and six participated in the PGS mentor program, providing resources and guidance to their early-career counterparts. Anyone who has worked at BTI can learn more at BTIscience.org/alumni.

Resources

As the Alumni Network grows, so does the suite of resources for members. The new alumni listserv hosts discussions about career opportunities and potential collaborations. The quarterly *BTI Biome* newsletter highlights alumni, resources and opportunities specific to the alumni community. The BTI Alumni Directory allows members to connect with peers from their days at the Institute. BTI is proud of the transformative work being accomplished by researchers at the Institute and alumni elsewhere, and hopes that these platforms provide more opportunities for BTI alumni to grow professionally and stay connected.

Recognition In spring 2019, BTI will recognize and honor three accomplished individuals at the inaugural round of Alumni Recognition Awards. Keep in touch with BTI to learn more! Professional development Alumni Network Opportunities Recognition

Alumna Spotlight: Erica Fishel

Originally from St. Louis, Missouri, Erica was once a summer PGRP intern in Haiyang Wang's lab. After earning her Ph.D. from Washington University in 2013, she found her passion at the intersection of plant biology, law and entrepreneurism while working for an intellectual property law firm. She soon became the Director of Technology Transfer at Donald Danforth Plant



Science Center in 2014, and returned to BTI as the Director of Technology Transfer in 2018. "I am delighted to return 'home' and help transition technologies from the bench to the marketplace," says Erica.

Remembering Alumni:

Dr. Eleanor Storrs "Polly" Burchfield helped to advance chemical analyses at BTI from 1958 to 1962 and passed away in May, at the age of 92. She worked with her husband Dr. Harry Burchfield, operating the Analytical Services Lab. Together, Polly and Harry wrote *Biochemical Applications of Gas Chromatography*. After leaving BTI, Polly earned her Ph.D. and later became



involved in armadillo research. Her team's discovery that armadillos serve as models for leprosy research was a major breakthrough. Polly will be remembered as one of BTI's successful women in science and a mentor to students of her time.

You help to plant the seeds of discovery

BTI is grateful to the following individuals and organizations whose generosity makes the research and programs at BTI possible.

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Designations

- Education and Outreach
- Events
- PGS
- Research
- OPSRN Plant Summit
- STEM Scholarships

\$1.9 million philanthropic support in 2018

Memorials & Tributes

In Honor of

Mary Clutter Machi Dilworth Aaray Bakshi Aditi Rambani

In Memory Of

Edward H. Buckley Janet Buckley

A. Carl Leopold Lynn Bradley Leopold

Leonard & Sylvia Weinstein David & Libbie Silberman Robert & Roberta Kohut



Every effort has been made to ensure the accuracy of these lists. If we have unknowingly made an error, please notify the development office.

2018 SUSTAINERS

BTI is fortunate to receive support from a very special community of committed, long-term donors, and we recognize this loyalty with our utmost gratitude. The following individuals and organizations have given gifts over the course of 10 or more years, and/or give recurring monthly, quarterly or payroll deduction gifts, showing dedicated support of BTI's mission. Many have also given the gifts of time and guidance, and will forever leave their mark on the Institute.

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Christian C. & Nora R. Hohenlohe Triad Foundation, Inc.

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* Recurring Donors

W.B. Thompson Living Legacy Society

BTI recognizes living individuals who have expressed intent to remember BTI in their estate plans or with other methods of planned giving. Through their generosity and foresight, W.B. Thompson Living Legacy donors help to secure the future of the Institute. BTI would like to thank them for announcing their commitment to BTI, and appreciate them in their continued generosity and passion for the Institute's mission. If you have included BTI in your plans, please let us know.

Brian & Claire Federici
David & Karen Stern

Legacies Remembered

The memories of the following deceased individuals, who, over the course of the Institute's history, have included BTI in their estate plans, will endure through the work being done to honor W.B. Thompson's vision for the future.

Charles & Margaret Abell
John & Magdolna Bank
Evelyn Berezin
Anthony (Andy) Grefig
John & Mayfred Hirshfeld
George & Helen Kohut
George & Elizabeth McNew
William Boyce Thompson

Legacy Spotlight: Evelyn Berezin

BTI Emerita board member and former board chair Evelyn Berezin passed away on December 8, 2018, at the age of 93. Evelyn led an inspiring life, achieving many significant accomplishments in a fledgling computer industry; for example, she built the first true word processor, and she founded and led a company, Redactron.



She was also a remarkable leader, and BTI was fortunate for her board service from 1994 to 2010. Evelyn continued supporting BTI by making annual gifts for 22 years, including in 2018. She will be missed.

Every effort has been made to ensure the accuracy of these lists. If we have unknowingly made an error, please notify the development office.

A new "development"

Despite the Institute's philanthropic origins, BTI's active, consistent pursuit of philanthropy is fairly new—and growing. It is an exciting time to invest in BTI science because every gift makes a noticeable difference at this early stage of our philanthropic program. Gifts support potentially groundbreaking discoveries, STEM careers and a greater awareness of science.

An Independent Affiliate

While affiliated with Cornell University and located on campus, BTI is an independent, non-profit research institution. We are fiscally separate and rely on our own endowment, grants, collaborations and philanthropy for revenue. We do not receive revenue from Cornell's fundraising or endowment.

Why is philanthropy important?

Grants are highly restricted to specific project needs. Gifts from people like you help fund everything from internal competitive funding programs for innovative research projects not yet covered by grants (i.e., pursuing those "Eureka!" moments), to enriching post graduate training and educational programs such as internships and community or teacher outreach initiatives.

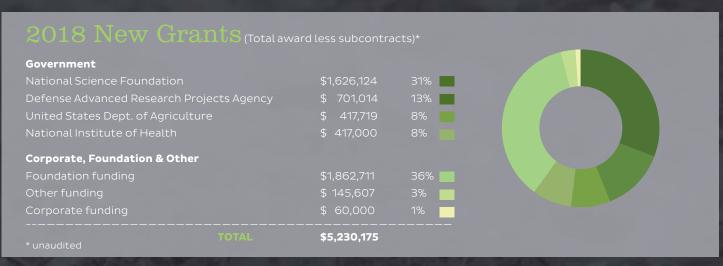
Support science your way!

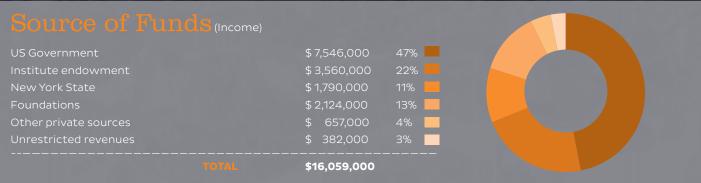
There are many ways to make a gift to BTI. You can make a gift to the annual fund, to the endowment, or we can work with you to designate your gift toward a program or initiative of your choosing. We have worked with individuals, financial advisors, donor advised funds, foundations, associations, clubs and businesses to identify meaningful and impactful opportunities for support. To get started, please contact us today by calling 607-288-3554 or emailing bti-dev@cornell.edu. You can also visit BTIscience.org/give to make a secure online contribution.



Jean McPheeters

Jean McPheeters "is in awe" of the work of BTI scientists and is especially delighted by the PGRP summer internship for high school and college students. She believes that BTI helps to grow the next generation of scientists. Jean also enjoys Art@BTI, which features artist presentations blended with a talk by a scientist. Though she has very little science training, she and her husband, Dan, believe in science as a way of understanding and exploring the universe and solving problems such as disease, food insecurity and climate change.

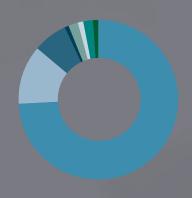




This is an unaudited financial report. This audited report will be available in June, 2019. Please contact BTI's Development department at bti-dev@cornell.edu or (607) 254-3554 if you would like to review the audited report.

Use of Funds (Expenses)

Research		\$12,038,000	75%
Administration		\$ 1,857,000	12%
Research support		\$ 1,120,000	7%
Equipment & facility		\$ 121,000	1%
Non-research		\$ 291,000	2%
Development		\$ 270,000	1%
Communications		\$ 295,000	2%
Education & Outreach		\$ 67,000	<1%
	TOTAL	 \$16,059,000	
		— + 10,000,000	



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*We are grateful for the dedicated service of Laura Philips (2006 through 2018). She brought an unflagging passion and devotion for the BTI mission, always imagining a brighter and more impactful future. Under her gracious leadership, BTI diversified and strengthened its board, maintained an openness and thirst for new ideas and directions, and fostered a sense of community and mutual engagement. We are stronger for her belief in mentoring, growth and the possibilities of plant science.

** BTI welcomes new Board member, Charles H. Trautmann and new Scientific Advisory Board member, Jane Silverthorne.

*** Evelyn Berezin, Emeritus Director, passed away in December.

