Brain scans don't lie: The minds of girls and boys are equal in math

By Katie Hunt, CNN

(CNN) — Several studies have already debunked the myth that boys are innately better at math than girls, but those are largely based on analysis of test scores.

Now, researchers also have brain imaging that proves young children use the same mechanisms and networks in the brain to solve math problems no matter their gender. The study was published Friday in the journal *Science of Learning*.

"We'd studied the behavior of young girls and boys on mathematics tests, and we'd observed that their performance was statistically equivalent; they were indistinguishable. They'd developed the same abilities at the same rates in early childhood," says Jessica Cantlon, a professor of developmental neuroscience at Carnegie Mellon University and the study's senior author. "But there was this lingering question of what's going on under the hood? Is it the same neural mechanism that allows them to accomplish this equivalent behavior?"

To answer this question, Cantlon and her team got 104 kids between the ages of 3 and 10 to perform cognitive tests and watch videos of engaging math lessons while in an MRI scanner. It's the first study to use neuroimaging to evaluate biological gender differences in the math aptitude of young children.

"We looked at which areas of the brain respond more strongly to mathematics content in the videos and tasks, compared to non-math content like reading or the alphabet. So you can define the math network that way by looking at regions that respond more strongly," she said.

"When we do that in little girls, we see a particular network of the brain (respond), and when we do that same analysis in boys, we see the exact same regions. You can overlay the network from girls on top of the network from boys, and they are identical," she added.

Carnegie Mellon University Professor of Developmental Neuroscience Jessica Cantlon led the first study to utilize neuroimaging to evaluate biological gender differences in the math aptitude of girls and boys.

What Cantlon's study doesn't answer is why the belief that boys are stronger in STEM subjects than girls still persists. The stereotype is so pervasive that one research team even issued a consensus statement clarifying that "no single factor," including biology, "has been shown to determine sex differences in science and math."

Cantlon said she thinks society and culture are likely steering girls and young women away from math and STEM fields.

Previous studies show that families spend more time with young boys in play that involves spatial cognition, while teachers also preferentially spend more time with boys during math class, she said. Also, children often pick up on cues from their parent's expectations for math abilities.

"Typical socialization can exacerbate small differences between boys and girls that can snowball into how we treat them in science and math," Cantlon said. "We need to be cognizant of these origins to ensure we aren't the ones causing the gender inequities."

CMU TEAM USES AI
to Help Machines Play Nice with Humans

OCTOBER 15, 2019

Carnegie Mellon University researchers Cleotilde Gonzalez at the Dietrich College of Humanities and Social Sciences, Henny Admoni at the Robotics Institute and lead investigator Anita Williams Woolley at the Tepper School of Business received a $2.8 million DARPA grant to study team collective intelligence and the theory of mind in relation to human and machine interactions.

AN INTERDISCIPLINARY GROUP OF RESEARCHERS HAS RECEIVED A $2.8 MILLION DARPA GRANT TO ENHANCE MACHINE-HUMAN TEAM COLLABORATIONS

Three Carnegie Mellon University researchers — the lead investigator, Anita Williams Woolley at the Tepper School of Business, along with co-investigators Cleotilde Gonzalez at the Dietrich College of Humanities and Social Sciences and Henny Admoni at the Robotics Institute in the School of Computer Science — are leveraging their expertise in organizational science, cognitive science and artificial intelligence to explore how AI can help humans work better together.

Woolley believes this award is an important achievement not only for her and her co-investigators but also for Carnegie Mellon.

"As leaders in both team research and technology, it's an important acknowledgment of the role we have played and continue to play in pushing the frontiers of these disciplines," Woolley said.

The researchers received a $2.8 million DARPA grant to study team collective intelligence and the theory of mind in relation to human and machine interactions. Team collective intelligence relates to the ability of a team to work together

"AI has become part of our lives. Every day, we talk to our phones, and these machines understand and collaborate with us. We want to expand this concept to situations in which a group of individuals and machines are performing a task together and can interact in effective ways."

— Cleotilde Gonzalez,
Carnegie Mellon University Research Professor

across a range of tasks. Theory of mind explores how a person can understand what others are thinking and how they may react to something based on subtle nonverbal cues.

"AI has become part of our lives," Gonzalez said. "Every day, we talk to our phones, and these machines understand and collaborate with us."

"We want to expand this concept to situations in which a group of individuals and machines are performing a task together and can interact in effective ways."

The researchers aim to leverage these concepts to develop a machine theory of mind for a synthetic team coach that can interact with a group to improve task outcomes.

A synthetic team coach will benefit from a previously developed cognitive model that can remember the actions of the team members. This memory will allow the coach to understand and accurately predict what the team members will do next and intervene at the team level at the right time to improve the task at hand.

"I'm very interested in how intelligent synthetic agents can help teams coordinate better," Admoni said. "I am looking forward to using my knowledge of AI and human-robot interaction in this domain of group coordination, which is a new area for me."

The goal is to have the coach work with team members to aid in the exchange of ideas and improve collaborations so that tasks are performed faster and more efficiently.

The cross-disciplinary team behind this cutting-edge research is as intriguing as the research itself. Gonzalez lends cognitive and decision sciences prowess, Admoni offers human-robot interactions knowledge, and Woolley brings expertise in collective intelligence in teams.

"We continue to push the frontiers of these disciplines," Woolley said. "Since ours is an all-female Carnegie Mellon-based team of scientists, it shows that women are leaders in these fields where they have been typically underrepresented."

The project also is drawing on the talent at all faculty levels at CMU and offers young researchers, both undergraduate and graduate, a model of a women-led team in the male-dominated fields of science and engineering.

"I hope that I can be a role model for women in computer science," Admoni said. "I think that science would benefit greatly from more diversity in the field."

ABOUT THE RESEARCH

This research, titled "An Integrated Theory of Human-Machine Teaming," will expand on existing models to test theories and evaluate the quality of intelligence collected in a variety of environments. DARPA supports projects in technological research useful for national security.

AMERICA'S AIR QUALITY WORSENS,
Ending Years of Gains, Study Says

This article has been reprinted by The New York Times. *Visit the full article online.*

The New York Times

THURSDAY, OCTOBER 24, 2019

CLEANING OUR WATER
with Groundbreaking 'Bioinspired' Chemistry

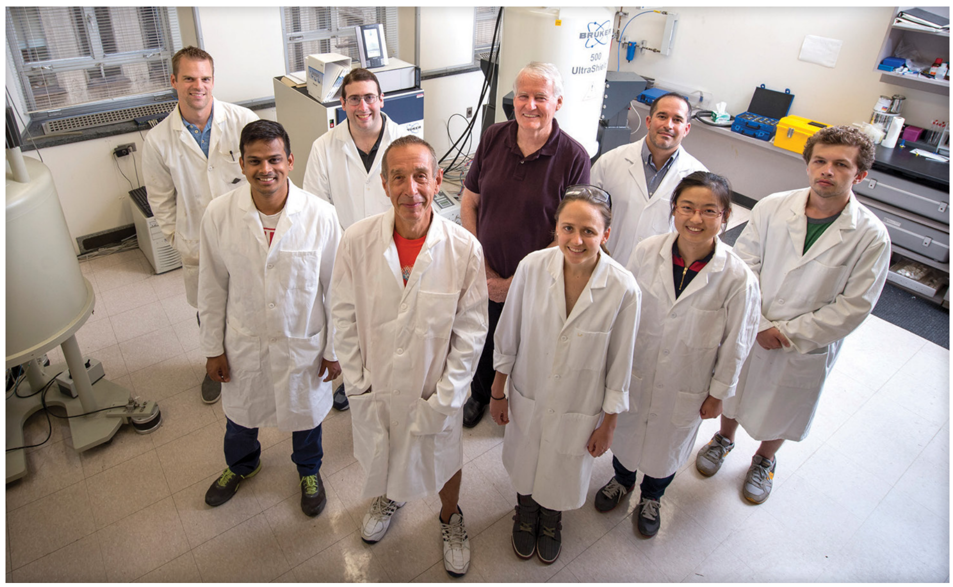
JULY 23, 2019

The 20th and 21st centuries have seen an explosion in the use of synthetic chemicals worldwide, including pesticides, medications and household cleaners — many of which end up in our waterways. Even in small amounts, these substances can affect wildlife, plants and humans, and a number of them have shown resistance to normal water treatment methods, leaving them to build up in the environment unchecked.

In a study published this week in the journal *ACS Catalysis*, researchers at Carnegie Mellon University's Institute for Green Science (IGS) blazed the trail for a new field of sustainable chemistry by unveiling powerful, safe and inexpensive oxidation catalysts inspired by the biological processes within us that break down even the most stubborn micropollutants.

"It's maybe the most important paper that we've produced in 20 years," says Terrence J. Collins, Teresa Heinz Professor in Green Chemistry, who directs the IGS.

Collins, who has been concerned with the harmful biological effects of synthetic chemicals since his days as an undergraduate student in New Zealand, has spent the last four decades working to develop



Researchers at Carnegie Mellon University's Institute for Green Science within the Mellon College of Science have developed a new field of sustainable chemistry featuring environmentally friendly oxidation catalysts that break down micropollutants in our waterways.

> *"It's maybe the most important paper that we've produced in 20 years."*
>
> *— Terrence J. Collins, Teresa Heinz Professor in Green Chemistry*

methods to remove these chemicals from water using the process of oxidation, a process intrinsic to the human body.

"Oxidation chemistry is some considerable percentage of the biochemistry going on within us," Collins notes. "This is how nature deals with the problem of converting organic matter, particularly very chemically resistant organic matter, into usable material for its biochemistry or into energy to keep the organism going. Sometimes the resistance is too great for the enzymes that drive the oxidation chemistry, and we have persistent compounds against which nature is powerless."

The substrate of choice for many oxidation reactions within our bodies and elsewhere in nature is hydrogen peroxide, which peroxidase enzymes activate to break down molecules from food and other substances we take in. Since 1980, Collins' goal essentially has been to recreate the power and efficiency of these enzymes with artificial catalysts of his creation called tetra-amido macrocyclic ligands (TAMLs).

"We had to make the iron center of our catalysts do the same kind of chemistry as the iron center of the peroxidase enzymes," Collins says. "We spent 15 years systematically figuring out how to make the TAMLs catalyst composition perform properly. After getting the first one, we spent 20 years trying to make it better."

In this new study, Collins describes the "record-setting" performances of these improved catalysts called NewTAMLs. Testing has shown that infinitesimal amounts of these catalysts activate hydrogen peroxide to eliminate the common and persistent micropollutant propranolol from water in less than five minutes.

Because of their speed and efficiency, Collins envisions NewTAMLs having major cost savings over current water treatment techniques such as ozone purification. Even more important to him than cost and power, however, is safety. A catalyst that eliminated micropollutants would be pointless if the catalyst itself ended up causing harmful effects in living organisms.

"It's trivial to find out if something's acutely toxic — it's when something is surreptitiously toxic in parts per trillion in your body that you have a big problem," Collins explains.

"Endocrine hormones in your body work in parts per trillion to low parts per billion concentrations. They control how much of life develops and what we become. The current host of everyday, everywhere chemicals that we have discovered that are endocrine disruptors reads like a science fiction horror story — but it is reality."

To test the catalysts' safety, Collins helped world leaders of endocrine disruption science to identify appropriate assays and arrange them logically to screen for low-dose adverse effects of chemicals. TAMLs and NewTAMLs have been used for beta-testing the resulting Tiered Protocol for Endocrine Disruption. The NewTAMLs paper incorporates an endocrine disruption assay in mice, which the candidate catalyst passed with flying colors.

Furthermore, Collins and his team ended up rejecting potential catalyst elements that could greatly improve the performance of TAMLs because of their lack of presence in living organisms. Adding fluorine to TAMLs, for example, greatly improved their performance and stability, but fluorine is a substance rarely found in living things. The researchers worried that building it into catalysts deployed in drinking water could increase fluoride and fluorochemical degradation products in the treated water.

"There were no negative toxicity results when we tested," Collins says. "The decision to try to reproduce fluorine's singular and remarkable electronic properties without using it turned out to be a key reason we were rewarded with NewTAMLs. The best way to stay safe for toxicity is to build your chemical technologies from the same elements that you're made of."

This "bioinspired" approach to chemistry is a pillar of the new field of sustainable ultradilute oxidation catalysis pioneered by Collins and the IGS.

Additional authors of the study were Genoa R. Warner, Yogesh Somasundar, Kyle C. Jansen, Evan Z. Kaaret, Cindy Weng, Abigail E. Burton, Matthew R. Mills, Alexander D. Ryabov, Saborni Biswas and Michael P. Hendrich of IGS; Longzhu Q. Shen of the University of Cambridge; Gabrielle Pros and Tomislav Pintauer of Duquesne University; and Julia A. Taylor and Frederick S. vom Saal of the University of Missouri.

Funding for the study was provided by the Heinz Endowments, the Heinz Family Foundation, the National Institutes of Health and the National Science Foundation.

AT THE HEART OF INNOVATION

CMU Researchers Solve Hard Problem of 3-D Printing Soft Tissue

AUGUST 1, 2019

Arthur Hamerschlag Career Development Professor and Professor of Biomedical Engineering and Materials Science & Engineering Adam Feinberg and a team of Carnegie Mellon researchers invented a new 3-D bioprinting method that brings the dream of bioengineered human hearts one step closer to reality.

A team of researchers from Carnegie Mellon University published a paper in *Science* that details a new technique allowing anyone to 3-D bioprint tissue scaffolds out of collagen, the major structural protein in the human body. This first-of-its-kind method brings the field of tissue engineering one step closer to being able to 3-D print a full-sized, adult human heart.

The technique, known as Freeform Reversible Embedding of Suspended Hydrogels (FRESH), has allowed the researchers to overcome many challenges associated with existing 3-D bioprinting methods, and to achieve unprecedented resolution and fidelity using soft and living materials.

Each of the organs in the human body, such as the heart, is built from specialized cells that are held together by a biological scaffold called the extracellular matrix (ECM). This network of ECM proteins provides the structure and biochemical signals that cells need to carry out their normal functions. However, until now, it has not been possible to rebuild this complex ECM architecture using traditional biofabrication methods.

"What we've shown is that we can print pieces of the heart out of cells and collagen into parts that truly function, like a heart valve or a small beating ventricle," said Adam Feinberg, Arthur Hamerschlag Career Development Professor and professor of biomedical engineering (BME) and materials science & engineering in the College of Engineering, whose lab performed this work. "By using MRI data of a human heart, we were able to accurately reproduce patient-specific anatomical structure and 3-D bioprint collagen and human heart cells."

More than 4,000 patients in the United States are waiting for a heart transplant, while millions of others worldwide need hearts but are ineligible for the waitlist. The need for replacement organs is immense, and new approaches are needed to engineer artificial organs that are capable of repairing, supplementing or replacing long-term organ function. Feinberg, who is a member of Carnegie Mellon's Bioengineered Organs Initiative and the Next Manufacturing Center, is working to solve these challenges with a new generation of bioengineered organs that more closely replicate natural organ structures.

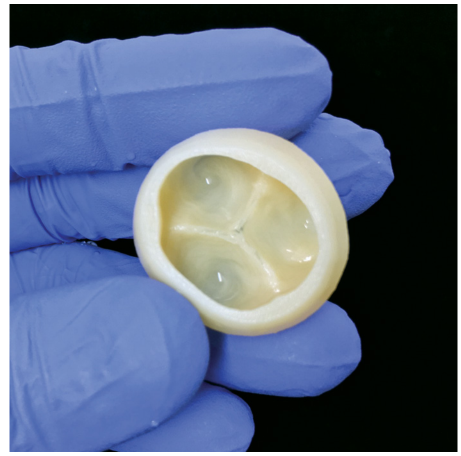
"Collagen is an extremely desirable biomaterial to 3-D print with because it makes up literally every single tissue in your body," said Andrew Hudson, a BME Ph.D. student in Feinberg's lab and co-first author on the paper. "What makes it so hard to 3-D print is that it starts out as a fluid, so if you try to print this in air, it just forms a puddle on your build platform. We've developed a technique that prevents it from deforming."

The FRESH 3-D bioprinting method developed in Feinberg's lab allows collagen to be deposited layer by layer within a support bath of gel, giving the collagen a chance to solidify in place before it is removed from the support bath. With FRESH, the support gel can be easily melted away by heating the gel from room temperature to body temperature after the print is complete. This way, the researchers can remove the support gel without damaging the printed structure made of collagen cells.

This method is truly exciting for the field of 3-D bioprinting because it allows collagen scaffolds to be printed at the large scale of human organs. It is not limited to collagen, as a wide range of other soft gels including fibrin, alginate and hyaluronic acid also can be 3-D bioprinted using the FRESH technique, providing a robust and adaptable tissue engineering platform. Importantly, the researchers also developed open-source designs so that anyone from medical labs to high school science classes can build and have access to low-cost, high-performance 3-D bioprinters.

Looking forward, FRESH has applications in many aspects of regenerative medicine, from wound repair to organ bioengineering, but it is just one piece of a growing biofabrication field.

"We're making real progress toward engineering functional human tissues and organs. This Science paper is one step along that path."
— Adam Feinberg, Arthur Hamerschlag Career Development Professor and Professor of Biomedical Engineering and Materials Science & Engineering



A valve component for an adult human heart now can be 3-D printed using a new method pioneered at CMU.

"We're talking about the convergence of technologies — not just what my lab does in bioprinting but also from other labs and small companies in the areas of stem cell science, machine learning and computer simulation," Feinberg said.

"It is important to understand that there are many years of research yet to be done, but there should still be excitement that we're making real progress toward engineering functional human tissues and organs. This *Science* paper is one step along that path."

Other collaborators on the paper include co-first author Andrew Lee, a BME Ph.D. student in Feinberg's lab; BME postdoctoral researcher Dan Shiwarski; BME Ph.D. students Joshua Tashman, T.J. Hinton, Sai Yerneni and Jacqueline Bliley; and BME Research Professor Phil Campbell.

NOT SO RUSTY

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WINTER 2019/2020

A RIDE TO REMEMBER

Interdisciplinary Team Thrills Judges in Amusement Park Contest

DECEMBER 4, 2019

In their first outing at the Ryerson Invitational Thrill Design Competition, Carnegie Mellon University students wowed judges at Universal Studios in Orlando with a creative approach to adapting an existing amusement park ride.

The interdisciplinary team, which included undergraduate and graduate students, won an overall team award for Engineering Design Challenges as well as awards for Accommodation Design, Safety and User Experience. Judges included executives from Universal and other industry companies.

Throughout the four-day competition, 120 students from 16 invited universities were tasked with selecting multiple design challenges that best suited their talents, skills and interests. Using their imaginations, computer software and rhetorical skills, they prepared solutions to problems over a long weekend, rather than an entire semester, employing CAD drawings, design sketches, complex mathematics and proof of plausibility.

The competition was a microcosm of the work the students have been doing for years at CMU.

At the Ryerson Invitational Thrill Design Competition at Universal Studios, Monica Toren, Nidhi Ramanathan, Conor Triplett, Carolyn Youstra and James Biltz won an overall team award for Engineering Design Challenges as well as awards for Accommodation Design, Safety and User Experience. The interdisciplinary team prepared top-secret solutions to adapt an existing amusement park ride for greater accessibility.

The team's award-winning work remains top secret and proprietary intellectual property of Universal Creative, which sponsors the competition with Ryerson University.

"They couldn't even tell me what they did," said Shirley Saldamarco, a special faculty member from Carnegie Mellon's Entertainment Technology Center (ETC) and the team's mentor.

The team included ETC graduate students Conor Triplett and Nidhi Ramanathan, mechanical engineering senior James Biltz and sophomore Carolyn Youstra and fifth-year architecture student Monica Toren.

The competition organizers offered preparatory workshops and information on collaboration across fields of study. Saldamarco said engineers, architects and artists all speak different languages when it comes to expressing their ideas or verbalizing their processes. For the CMU team, opportunities to blur the boundaries between their disciplines are woven into the fabric of the Integrative Design, Arts and Technology (IDeATe) and ETC courses they take with Saldamarco.

"What makes CMU stand head and shoulders above other universities is that we embed this sense of collaboration and interdisciplinary teamwork into our pedagogy," Saldamarco said.

Graduate students at the ETC spend two years building virtual worlds, assisting actual clients with interactive experiences and completing cooperative work assignments at places like Walt Disney World or, in Triplett's case, the Fred Rogers Center in Latrobe, Pennsylvania.

Undergraduate students have the opportunity to merge technology and creativity through the IDeATe network, which offers undergraduate minors and courses in game design, animation and special effects, sonic arts and more.

Biltz , Toren and Youstra participate in CMU's Theme Park Engineering Group (TPEG), which created The Old Mill dark ride immersive experience in Skibo Gymnasium for Carnival 2019.

"What makes CMU stand head and shoulders above other universities is that we embed this sense of collaboration and interdisciplinary teamwork into our pedagogy."

— Shirley Saldamarco
Special Faculty Member at Carnegie Mellon University's Entertainment Technology Center

"We are used to collaborating across disciplines, so we all knew terminology and what is possible from team members in other fields," Biltz said.

Knowing what Toren can do as an architect, for instance, helped the engineers on the team divide up the work and prepare a polished presentation under pressure.

One of the Ryerson challenges the team pursued concerned accessibility in theme parks, Triplett said.

"The industry is really focused right now on how we can make experiences safe for guests of all abilities," he said. "Our challenge focused on how to retrofit an existing experience to help one subset of the community to better experience it."

Triplett couldn't say whether they focused on guests with visual impairments, mobility challenges or neurological differences, but he did say his team experienced the park with new awareness of the user experience. They used their competition guest passes to research Universal Studios with a focus on accessibility.

The team also studied requirements of the Americans with Disabilities Act, travel and transportation regulations, and the approach other theme parks have taken to address similar challenges.

Ramanathan first visited a theme park in eighth grade and said she was mesmerized by Universal Studios Singapore. She was determined to find a way to combine her passion for technology with her creativity. She viewed the competition as a prescreening for the types of jobs she and other students were pursuing.

"We learned so much about how extensive and thorough the entertainment industry is," Ramanathan said. "We also saw how we can fit in there as creatives, engineers and experience designers."

That time will come sooner than later for part of the team. Triplett, Toren and Ramanathan walked away with internship offers at Disney and Universal beginning in January. As for the remaining members, they are deep into work on a new dark ride for Carnival 2020.

Highmark Health and Carnegie Mellon University Expand Longstanding Relationship with New Building to Address STUDENT WELL-BEING

NOVEMBER 7, 2019

Highmark Health and Carnegie Mellon University announced a $35 million grant from Highmark Inc. to support the construction of a new student health, wellness and athletics center at CMU. The 160,000-square-foot building will, for the first time, unite critical student well-being services under one roof on the university's Pittsburgh campus.

A $35 million lead grant from Highmark Health will help to create a health, wellness and athletics facility by expanding Skibo Gymnasium with enhancements and a modern addition. The facility will house all student well-being services for the first time in university history and assist CMU students in developing their whole selves through initiatives inside and outside of the classroom.

Rising on the corner of Tech and Margaret Morrison streets, the project will preserve and enhance the existing Skibo Gymnasium for recreational use and construct a modern addition on the surrounding site. The expansion will include space for University Health Services, Counseling and Psychological Services, and CMU's intercollegiate athletics program, as well as wellness and mindfulness programming, recreational sports, religious and spiritual life activities, and sports medicine. The building will face Schenley Park and serve as a gateway to campus.

"Highmark Health is committed to continuing to invest in the western Pennsylvania region, both in our continued expansion of Allegheny Health Network (AHN) and in our partnerships with organizations who share our vision for a health system that provides remarkable experiences to consumers," commented David Holmberg, president and CEO of Highmark Health.

"This new centralized facility will improve access to health services, counseling, wellness and athletics activities, with the goal of supporting students in building habits that will be the foundation for their future health, lives and careers."

The state-of-the-art facility will accelerate Carnegie Mellon's vision to support students in practicing positive self-care behavior and maintaining their physical and psychological well-being as they pursue a life-changing education. The integrated approach is part of the university's model for assisting students to develop their whole selves through initiatives inside and outside of the classroom.

"This new centralized facility will improve access to health services, counseling, wellness and athletics activities, with the goal of supporting students in building habits that will be the foundation for their future health, lives and careers."
— David Holmberg, president and CEO of Highmark Health

"Helping our talented students develop and maintain healthy bodies and minds is paramount to ensuring their lifelong success, both personally and professionally," CMU President Farnam Jahanian said. "We are delighted to extend our partnership with Highmark Health to bring to fruition our vision for a unified, comprehensive facility that supports many facets of students' well-being."

In 2013, CMU and Highmark Health established a research partnership to identify and accelerate the development of health information technologies with the potential to impact patient care and the patient's experience. To date, Highmark Inc. has invested $16 million in the partnership, including the establishment of the Disruptive Health Technology Institute as well as the endowed Highmark Distinguished Career Professor.

In December 2017, the organizations further evolved their relationship with new strategic agreements that cover all research projects, as well as other types of projects such as course sponsorship and design efforts, by AHN, Highmark Health and Highmark Inc. in collaboration with CMU schools or faculty members. This partnership has been funded by Highmark Health and has allocated up to $2.5 million annually.

The research partnership has several projects already underway, which vary in maturity from being conceptual in nature to more developed prototypes with a demonstrated value proposition. CMU is helping Highmark Health and AHN to better understand opportunities for technologies to find large-scale deployment, and the technical and commercial hurdles that could keep them from maturing.

Highmark Inc.'s investment also supports *Make Possible: The Campaign for Carnegie Mellon University*, which was publicly launched in October. The campaign seeks to raise $2 billion in support of the university's aspirations, which include a focus on the CMU experience. To date, more than 42,000 donors have contributed more than half of the goal, accelerating CMU's leadership at the nexus of technology and humanity.