February 2024

GEORGIA PATHWAYS
MAGAZINE

Apprenticeships
The Georgia path forward.

Where Is The Pain?

The Next Challenge For Manufacturers

TAG Technology Association of Georgia

TAG TAG-Ed Education Collaborative

The Technology Association of Georgia Education Collaborative (TAG-Ed) strengthens the future workforce by providing students with relevant, hands-on STEAM learning opportunities and connecting them to Technology Association of Georgia (TAG) resources. Formerly the TAG Foundation, TAG-Ed is a 501(C)(3) non-profit organization formed by TAG in 2000. Later, the organization's name was re-branded to TAG Education Collaborative to facilitate our role as the leaders for K-12 STEAM education in Georgia.

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High School Internships: A Key to College Admissions and Future Employment

Collegiate admissions are rife with competition from high school students, with many different aspects of an application setting the top students apart from the rest of their class. Historically, academics, community service, and extracurricular activities have been some of the most important factors considered. However, completing an internship while in high school is often an overlooked way to set oneself apart from other applicants while gaining valuable skills.

Internships provide a wide array of benefits to those who participate in them, including basic workplace skills, a chance to explore a potential career path, and a showcase of one's commitment to learning. Additionally, this experience showcases the student's willingness to leave their comfort zone and gain hands-on experience in a potential profession. These outcomes reflect positively on a student's potential college application, plus the skills they develop will benefit them in higher education and their professional careers.

Searching and applying for internships can be intimidating for high schoolers, as it is often their first entry into a professional environment. A necessary first step in this process is to create a one-page resume to accompany the student's application.

While it is common for a high school student to lack professional experience, including extracurricular activities or any leadership positions is a wonderful way to convey their personality, interests, and career objectives.

This is exactly why TAG-Ed launched our Internship Program for high school students. Our program serves as an opportunity for talented students to further develop their abilities as interns for premier companies in Georgia.

Selected high school students are matched with companies based on their interests and qualifications, providing them with experience and exposure to whichever professional field they are considering. Searching for internships can be an arduous task for high school students, and TAG-Ed is committed to making this journey as simple as possible. To learn more about the TAG-Ed internship program, or to apply, please visit our website.

Larry K. Williams
President
TAG / TAG-Ed

Larry K. Williams serves as the President and CEO of the TAG and the TAG Education Collaborative. TAG-Ed's mission is to strengthen Georgia's future workforce by providing students with relevant, hands-on STEM learning opportunities by connecting Technology Association of Georgia (TAG) resources with leading STEM education initiatives.

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TAG | TAG-Ed Education Collaborative

TAG EDUCATION COLLABORATIVE PRESENTS

GEORGIA STEM DAY

March 1, 2024

Georgia STEM Day is a day for schools & organizations to raise awareness and engage in activities involving science, technology, engineering and math!

Last year's STEM Day attracted over 50,000 students from more than 82 different school districts across the state of Georgia.

How to get involved:

- Educators: Incorporate fun and innovative STEM activities into your classroom on March 1st.
- Companies: Volunteer to speak at a local school about your exciting STEM career, or host a field trip for students at your business for local students.
- Partners: Promote STEM Day by providing resources and activity ideas for participants!
- Be sure and share with us your exciting plans for Georgia STEM Day.

#GASTEMDay

Register today to participate: CLICK HERE

For more information, group and student applications, visit:
www.tagedonline.org

Questions? Contact Bebita Metellus: bebita@tagonline.org

The Importance of Apprenticeships In Georgia

By Wayne Carley

Apprenticeships are work-based training method that combines formal instruction with on-site, occupation-related training. Apprentices typically work 30-40 hours per week and receive classroom training through part-time attendance at technical colleges, universities or approved training providers.

Using the apprentice model can help businesses grow their own talent and build a motivated and qualified workforce. Employers use apprentice programs to recruit and train new employees and to upskill their current workforce

Employer Benefits

Participation in a customized apprenticeship program that attracts high caliber candidates who are seeking a nationally recognized credential and entry into a career path are an effective guide to success as you explore the career field of interest. Assistance with completing Registered Apprenticeship application, developing work standards and navigating the US Department of Labor registration process will be available to help in placement.

Connection to the Technical College System of Georgia and other education/training partners who can provide occupation-related instruction is a valuable and effective relationship, and it's for the taking today.

A **Registered Apprenticeship** Program (RAP) is a robust & comprehensive work-based learning and training model that helps employers transform and develop entry-level employees into high-skilled talent. This prepares individuals for skilled trades through paid On-the-Job Learning (OJL) with Related Technical Instruction (RTI).

Tech apprenticeships provide access to high-demand tech positions such as Software Developer, Cybersecurity Analyst, IT Business Analyst, and others. The Georgia Apprenticeship Standards include the following:

The term of the apprenticeship is approximately 2000 hours of OJL with the attainment of 7 competencies, supplemented by the minimum required 440 hours of related instruction. Depending on the occupation, apprentices are paid a progressively increasing schedule of wages based on either a percentage or a dollar amount of the current hourly journey worker wage rate.

For example, the journeywork hourly for a Software Developer is $32.69 after the completion of the required 2000 hours. Roughly one year term of approximately 2000 hours of OJT:
- 1st 6 months of OJT/0 – 1000 hours = $19.61
- 2nd 6 months of OJT/1001 – 2000 hours = $22.88

The Technical College System of Georgia (TCSG) along with Georgia's 22 technical colleges serve as the state's largest network of registered apprenticeship sponsors. Each technical college, in partnership with TCSG's Office of Workforce Development, can help employers access the support and guidance needed to get a RAP off the ground, including:

- Understanding U.S. Registered Apprenticeship Model
- Identifying Apprenticeable Occupations
- Identifying the approved Training Models (including Work Processes and Technical Instruction Outlines) and assisting with aligning models to employer needs
- Serving as a Liaison with the US-DOL Office of Apprenticeship
- Serving as the Apprenticeship Sponsor and Technical Instruction Provider
- Access to Apprenticeship Funding Opportunities

Why be an apprentice?

An apprenticeship program trains you to become skilled in a trade or profession. Apprenticeship training typically combines classroom learning with hands-on work. Community colleges, technical training schools, and even employers provide these job-related educational courses.

Benefits of an apprenticeship

An apprenticeship offers several notable advantages in addition to getting paid and on-the-job training. Apprentices also receive classroom instruction, mentorship with an experienced professional, and credentials upon program completion.

Do apprentices get paid?

Because apprenticeships are considered full-time work, you get paid! According to the U.S. Department of Labor, the average starting wage for a new apprentice is $15 an hour. This "learn while you earn" model increases both the skills and salary as they gain experience.

Apprenticeships are common in skilled trades like carpentry, plumbing, electrical, hairstyling, hospitality, transportation, and manufacturing.

But these programs are also available in professionalized industries such as healthcare, finance, business, aerospace and information technology.

How long do apprentices work before graduating?

Times and needs are changing across every industry, but in past years, apprentices worked for seven years under a "master" trades person before becoming a master themselves. Today, you can find apprenticeship programs that last three to four years or less.

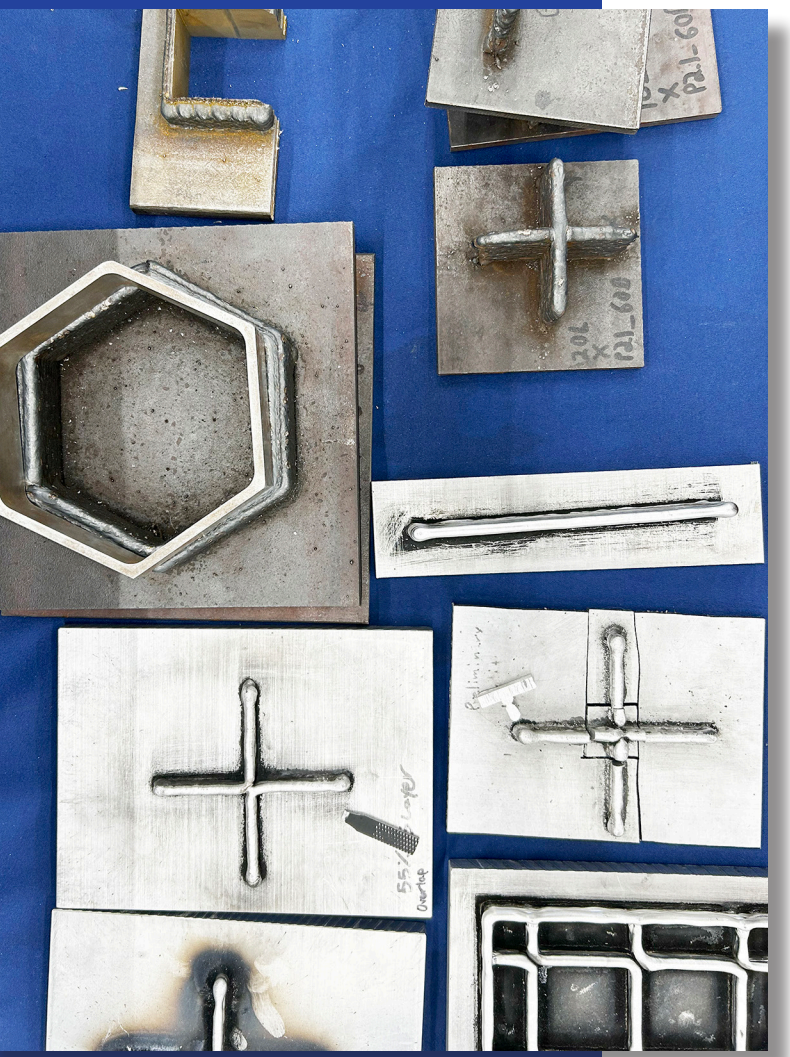
After your apprenticeship, you will earn a nationally recognized certificate. This credential tells employers that you are qualified for the job. You may even receive credits that can lead to a college degree.

Georgia needs apprentices in every industry you can name. Visit us online at www.tagedonline.org

GEORGIA AIM
Artificial Intelligence in Manufacturing

The Next Challenge For Manufacturers: Get smart!

Integrating artificial intelligence in a manufacturing process requires planning and small steps, say experts with Georgia AIM



The flat, wheeled robot gingerly moved across the floor, aiming for a taped square in the far corner.

Suddenly, someone stepped into its path. The robot stopped, blinked its lights, then carefully turned to a slightly different path. Its goal remained the same, but it adjusted the route on the fly.

"This is an autonomous mobile robot," explained Sean Madhavaraman, project manager specializing in industry 4.0 strategy and leadership development for the Georgia Manufacturing Extension Partnership (GaMEP) at the Georgia Institute of Technology's Enterprise Innovation Institute (EI2). "No programming experience is necessary, and it can map a room by itself. It's also very safe — you can step in front of it, and it will reroute."

That demonstration was one of several on display at a recent event hosted by EI2's Georgia Artificial Intelligence in

Manufacturing (Georgia AIM) and the Georgia MBDA Business Center. The program of speakers, a tour and a panel discussion took place at Georgia Tech's Advanced Manufacturing Pilot Facility and served as an introduction into the world of artificial intelligence.

With about 50 manufacturers and engineers in attendance, the goal of the event was twofold, said Donna Ennis, Georgia AIM co-director. First, it served as an introduction to the Advanced Manufacturing Pilot Facility, which conducts research on new manufacturing technologies through its public-private partnerships. But also, it was an opportunity for manufacturers of all sizes to learn about the roles AI can play in their processes.

"Artificial intelligence has the power to bring transformative change to our manufacturers and our workforce, but it can seem overwhelming — where do you start?" Ennis said. "We wanted to create an opportunity to show manufacturers that you don't need a large investment or a large time commitment to begin to implement AI. Think about your process, explore your options, and use the resources we have available to you."

A Statewide Initiative

Georgia AIM was created through a $65 million Build Back Better Regional Challenge grant awarded through the U.S. Economic Development Administration. The grant funds 17 projects/subprojects throughout the state that work in education, manufacturing, workforce development and new technologies. At its core, Ennis said, Georgia AIM is working to reach all Georgia residents — specifically residents in communities underrepresented in manufacturing spaces, including veterans; women; Black, indigenous and people of color; rural residents; and older workers — and empower them to fully participate in a diverse AI manufacturing workforce.

In the area of workforce development, the grant supports programs that upskill adults in the workforce, as well as programs that reach K-12 students, technical college students and those attending four-year universities. For example, Georgia AIM is supporting the construction of a new lab at South Georgia Regional Technical College that will train students and area residents on new technologies in food processing—a key industry in that region.

Another project partner, Georgia Tech's Center for Education Integrating Science, Mathematics and Computing (CEISMC) is developing curricula and educational materials for K-12 students and hosts regional STEM-based competitions to promote science and technology.

K-12 education is a key component of Georgia Artificial Intelligence in Manufacturing. One partner in the project is Georgia Tech's Center for Education Integrating Science, Mathematics and Computing (CEISMC), which is developing STEM-based cirrucula for schools and also hosts the annual InVenture Prize for students. (Photo courtesy Georgia Tech)

Other projects are connecting with communities to help train the workforce on AI technologies. A partnership between the University of Georgia and the Russell Innovation Center for Entrepreneurs is developing a mobile lab stocked with technology "vignettes" — self-contained examples of real-world AI applications.

This mobile lab, as well as two others developed by Middle Georgia's 21st Century Partnership, will travel across the state to work with schools and community organizations. The goal is to introduce underserved communities to AI technologies and open new doors to employees—and employers.

"We recognize that not every community across the state has had equal access to these new technologies. We want to break down those barriers," added Ennis. "By taking these smart technologies to traditionally underserved communities, we aim to inspire and encourage Georgia's workforce.

This technology has the power to be transformative for our manufacturing community."

Other programs offered by Georgia AIM focus on manufacturers and adoption of new technologies. And that was part of the presentation offered by Ennis and project co-director Aaron Stebner, associate professor of mechanical engineering and materials science engineering at Georgia Tech. In addition to workforce development and deployment, Georgia AIM also offers cybersecurity assessments and assistance with technology development and deployment for manufacturers.

For example, the GaMEP project provides a range of assistance, including cyber assessments, gap assessments and automation training. Another partner, EI2's Advanced Technology Development Center, assists new tech startups and can help connect them with manufacturers that could use the technology. And Georgia Tech's Advanced Manufacturing Pilot Facility provides a space for companies to try new technologies without losing time on their own manufacturing line.

"We're really a proving ground for new technology adoption," Stebner said. The Georgia AIM grant is funding an expansion of the facility, which will allow for more smart technologies in the space.

Panelists discuss the use of AI in their manufacturing process during a recent event at Georgia Tech's Advanced Manufacturing Pilot Facility. The panel helped inform manufacturers about next steps as they looked to adopt AI in their workplaces and included expertise from (from left) Sean Madhavaraman, project manager with Georgia Manufacturing Education Partnership (GaMEP); Mitchell Weltman Tatar, process engineer at CJB Industries in Valdosta; and Subbu Vishnubhatla, director of product management at Hexagon Manufacturing Intelligence. The panel also included Senthil Ramamurthy, a project manager at Novelis.

"Our plan is to integrate autonomous robots and build out the manufacturing units to provide even more examples of manufacturing integrating with smart technologies."

The facility's new Georgia Tech Manufacturing 4.0 Consortium is a member-based group that connects industry with academic and government research resources. Consortium members gain access to facility equipment, workforce training programs, new manufacturing systems and networking opportunities with other members. (For details, visit ampf.research.gatech.edu/how-engage.)

Manufacturers and other business owners tour the Advanced Manufacturing Pilot Facility at Georgia Tech, which serves as a proving ground for new technologies in the manufacturing process. The facility is a partner on the Georgia AIM project. (Photo courtesy Georgia AIM)

AI: More than 'the spice'

But first, Ennis and Stebner told the manufacturers and business owners gathered at the manufacturing pilot facility, it was important to take stock of their current processes and think of where automation might occur. Start small and identify repetitive motions or places where human-machine collaborations might occur. Perhaps adding some sensors could help predict a mechanical failure, or a small automation might make a process more streamlined.

During a tour of the Advanced Manufacturing Pilot Facility, attendees met graduate students who specialize in metals, 3-D printing technologies and other areas and got first-hand looks at new innovations in action. Some stations at the facility represented old practices merged with updated technology — such as a welder merged with a computer numerical control (CNC) device to automate its movements. In other places, entirely new technologies, such as large-format 3-D scanners, helped attendees think about new production methods that might incorporate smart technology.

Madhavaraman and other GaMEP representatives demonstrated the use of sensors, collaborative robots and autonomous mobile robots in the manufacturing process. Attendees were intrigued, especially as Madhavaraman explained how the robots could be integrated into a manufacturing process to work alongside a person.

"That's why we call them 'co-bots,' not robots," he said. "Collaborative robots are great for packaging and palleting products. No programming experience is necessary — you can use a tablet to tell the robot what to do or point the robot in the direction you want it to go."

Before the event closed, a panel of three experts fielded questions from Madhavaraman on AI adoption and making the leap into smart technologies. The panel included Mitchell Tartar, project engineer with CJB Industries; Sentil Ramamurthy, senior engineer with Novelis; and Subbu Vishnubhatia, director of project management for Hexagon Management Intelligence.

In addition to addressing workforce needs, the panel stressed that manufacturers walk — not run — toward embracing smart technologies. Find the pinch points, start collecting data and think about small, holistic changes, they said.

"AI is not the spice in the dish that makes it very tasty," said Vishnubhatia. He and the other panel members agreed it is best to start small. Incorporating smart technologies doesn't need to be overly expensive or time-consuming — but it does require managers and employees to think outside the box.

And, getting buy-in from those who work with manufacturing. Not only is training imperative, added Tartar, but it's important to have everyone on board with adopting new technology. Change is hard, but it doesn't have to be difficult.

Manufacturers and other business owners tour the Advanced Manufacturing Pilot Facility at Georgia Tech, which serves as a proving ground for new technologies in the manufacturing process. The facility is a partner on the Georgia AIM project. (Photo courtesy Georgia AIM)

"Involve your people—they are going to know when the data is wrong," she said. "You don't need to do it all at once; if you want to get involved with AI, you can really break those costs down and do it a little piece at a time."

For more information on Georgia AIM and the opportunities provided through its partner projects, visit:
georgiaaim.org

Shawna Rochelle Kimbrell

The United States Air Force's first African American female fighter pilot.

ISS NATIONAL LABORATORY®

No Container, No Problem -

Studying Self-Contained Spheres of Liquid Protein in Space Could Help Improve Medicine on Earth

How could studying liquid drops of protein solution in space help solve an Achilles' heel in medicine production on Earth? Find out in the latest issue of Upward, the official magazine of the International Space Station (ISS) National Laboratory.

Protein-based therapeutics treat and prevent a wide range of conditions, from cancer to HIV, but protein clumping during manufacturing is a problem. Finding a way to avoid or reverse clumping could remove a major roadblock, but studying the complex motion of proteins in solution on Earth is difficult. This is because the proteins interact with the walls of the container holding the solution, which affects their behavior.

In the microgravity environment on the space station, researchers from Arizona State University and Rensselaer Polytechnic Institute did something impossible on Earth—they studied protein solutions without a container. In the absence of gravity, the liquid forms into a floating, self-contained sphere, allowing the team to study protein motion in new ways and create models to better understand the factors that lead to protein clumping.

"The critical part of the Ring Sheared Drop system is the ability to observe these deployed drops in real time and induce shear into the drop by spinning the lower ring," said Paul Galloway, who recently retired from his position as senior systems engineer at Teledyne Brown Engineering. "The shear induces flow within the drop, and we use the cameras to view the flow field."

For this investigation, the team used two proteins: human serum albumin (HSA) and bovine serum albumin (BSA), which make up the majority of protein in the blood of humans and cattle, respectively. The team chose these proteins because they are very accessible and well-studied. Also, HSA and BSA are similar in structure

ESA astronaut Lt. Samantha Cristoforetti installing the Ring Sheared Drop system into the Microgravity Science Glovebox

and behavior to many other proteins, explained Joe Adam, a postdoctoral researcher at RPI who was on the research team.

The team hopes to use fundamental knowledge gained from the investigation to improve predictive models and better understand the factors that lead to protein aggregation in highly concentrated solutions. "At the fundamental level, understanding how proteins denature at an interface, their general flow, and mechanics is required for developing applied knowledge," Adam said. "We can then determine, is this reversible? Can you use another fluid mixing process to reverse the state of the proteins and correct them?" Being able to control or reverse protein aggregation in therapeutic manufacturing would be a game-changer in the medical industry.

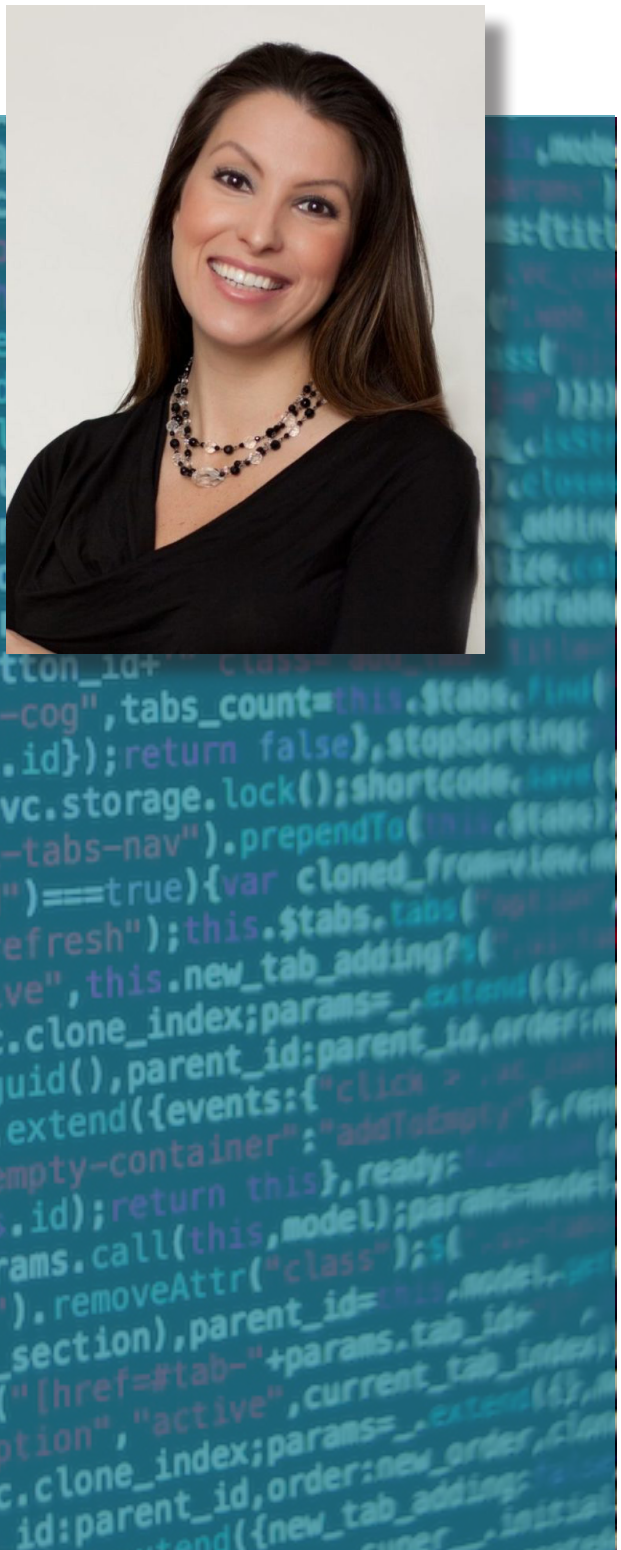
Read entire article on the ISS National Lab website:

https://www.issnationallab.org/upward63-ring-sheared-drop/

Young Women Want to Build More Than Cars & Rockets

What STEM Programs Are Doing Now To Attract More Young Women

By JJ DiGeronimo



I recently read an article entitled Paving the Way for Women in Technology and learned some interesting adjustments that are attracting more young women to college STEM programs. I was surprised, yet thrilled, to learn that these are some of the lessons I share with High School STEM Program Leaders. With some simple yet relevant updates, women are eagerly joining these programs.

In my work, I have the opportunity to meet with a variety of STEM programs leaders in 3rd-12th grades around the country; many that are struggling to engage girls. My first question, after our initial discussion, is:

"What are your projects within your STEM programs?"

They are often surprised when I share that girls are not as interested in building cars, or rockets or 3D telephone booths as seen in Superman. In my interviews and exchanges with girls

and women, they often express interest in solving real problems, building things that have an extended value or creating something new. It seems that women and girls want to know that their efforts can create additional value beyond the task at hand.

What comes to mind is: Know your audience.

I think it is brilliant that Harvey Mudd College has connected these dots. From the article, I learned more about the impact of their program updates:

Changing the approach of the courses or major can increase the enrollment of women. For instance, Harvey Mudd College changed technical computer classes such as "Introduction to Programming in Java" to include words like creative and problem solving.

The new name was "Creative approaches to problem-solving in science and engineering using Python." By aligning their computer courses to outcomes, the number of graduating female computer science engineers increased from 12% to 40% in 4 years. Besides changing the approach, other factors that contributed to the rise in enrollment included:

(1) "dividing the course up into two levels based on experience,

(2) encouraging female students to attend the Grace Hopper Celebration of Women in Computing conference, and

(3) allowing students to take on research projects after their freshmen year."

UC Berkeley, Duke, and Northwestern have also implemented similar updates. However, it was Harvey Mudd College that started the process. The experiment began in 2006 when Maria Klawe, a computer scientist and mathematician herself, was appointed college president.

The project was a three-step process, one which is detailed in the article How One College Went from 10% Women Computer Science Graduates to 40%. It all started with adding the aligning the value you could create with these new computer-based courses:

Harvey Mudd's introductory CS course went from being the most despised required course to the absolute favorite, says Klawe.
That is a powerful result. I go back to the fact that it is important we know our audience. What motivates them to explore particular interests? What career path do they hope to traverse?

What value can they bring to the world with these skills, knowledge and career?

Have you heard for Eden Full? She is the inventor of the SunSaluter: a solar panel rotator designed for the developing world. She is an aspiring product designer interested in human-centered appropriate technology, having tinkered with solar technologies since age ten.

I had the pleasure of interviewing Eden in a YouTube video while she was in Germany (the power of technology). She is changing the world – listen to how she uses solar power to bring light and power to the middle of African villages.

It excites me to think what is possible!

About the author:
JJ DiGeronimo, President of Tech Savvy Women, is one of the most highly regarded speakers, authors, and executive strategists to attract, retain and advance professional women. Through her keynotes and executive sessions, JJ shares effective leadership, influence, and inclusion strategies to accelerate professional women.

JJ is a featured columnist for Smart Business Magazine and has been quoted in numerous publications including Forbes, The Wall Street Journal, Fox Business, The Glass Hammer, Working Women Magazine, The Grindstone, IT-World, Career-Intelligence, and Rescue a CEO. Tapping Into Your Inner Power" and hosts regular videos on Tech SavvyWomen.TV.

Share this issue with your students, peers, parents and industry professionals you know. Make this a new monthly connection for curiosity, interaction, college prep and career development.

Many parents really enjoy this content as they too pursue their personal life-long learning goals.

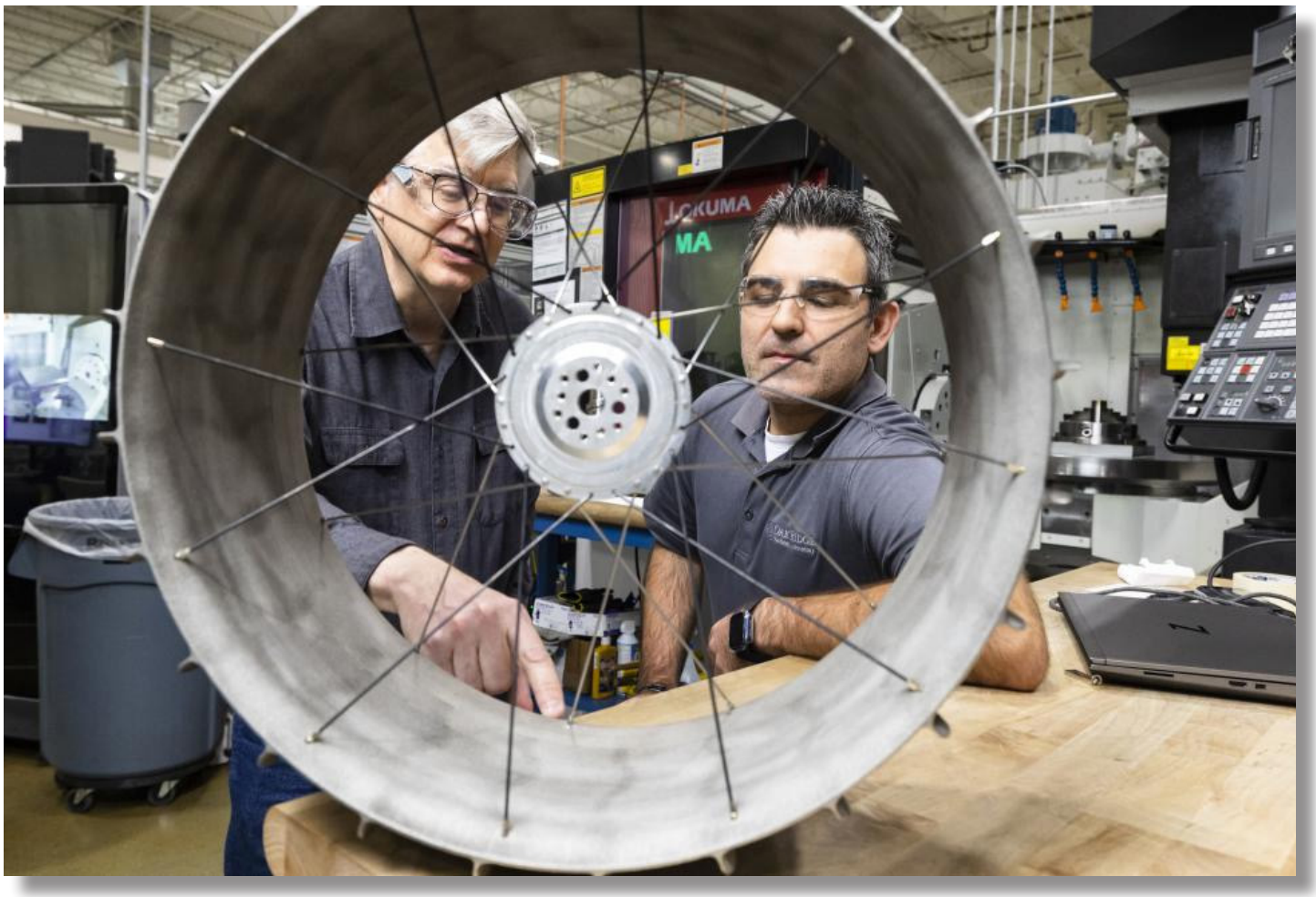
International industry and government leaders need to know about this resource as their future employees decide and prepare how to spend their careers.

OAK RIDGE National Laboratory

Researchers 3D print moon rover wheel prototype with NASA

By Heather Duncan / ORNL

Researchers at the Department of Energy's Oak Ridge National Laboratory, in collaboration with NASA, are taking additive manufacturing to the final frontier by 3D printing the same kind of wheel as the design used by NASA for its robotic lunar rover, demonstrating the technology for specialized parts needed for space exploration.



NASA mechanical design engineer Richard Hagen, left, and ORNL researcher Michael Borish inspect a lunar rover wheel prototype that was 3D printed at the Manufacturing Demonstration Facility. Credit: Carlos Jones/ORNL, U.S. Dept. of Energy

- ORNL collaborated with NASA to 3D print a lunar rover wheel based on a NASA design.

- The project demonstrated the potential of additive manufacturing for creating highly specialized parts needed for space exploration.

- NASA plans to test the printed wheel's performance to compare with a traditionally manufactured wheel that will be used on the moon next year.

- The ORNL-printed wheel prototype was able to incorporate more design features and complexity into a single piece, while taking less time and manpower to make.

The additively manufactured wheel was modeled on the existing, light-weight wheels of the Volatiles Investigating Polar Exploration Rover, or VIPER, a mobile robot NASA plans to send in 2024 to map ice and other potential resources at the south pole of the moon. The mission is intended to help determine the origin and distribution of the moon's water and whether enough could be harvested from the moon's surface to support people living there.

While the prototype wheel printed at DOE's Manufacturing Demonstration Facility, or MDF, at ORNL will not actually be used on the NASA Moon mission, it was created to meet the same design specifications as the wheels made for NASA's VIPER. Additional testing is planned to validate the design and fabrication method before using this technology for future lunar or Mars rovers or considering it for other space applications, such as large structural components.

Additive manufacturing can reduce energy use, material waste and lead time, while enabling design complexity and the tailoring of material properties. MDF is at the forefront of this effort, developing the technology for over a decade for a wide range of applications in the clean energy, transportation and manufacturing sectors. MDF researchers printed the rover wheel prototype at ORNL in Fall 2022. A specialized 3D printer used two coordinated lasers and a rotating build plate to selectively melt metal powder into the designed shape.

Typical metal powder bed systems operate in steps: In a machine the size of a cabinet, they rake a layer of powder over a stationary plate. Then a laser selectively melts a layer before the plate lowers slightly and the process repeats. The printer used for the rover wheel

Additive manufacturing allows fine design details, such as wavy thread on a domed shape, to be incorporated into the prototype lunar wheel. Credit: Carlos Jones / ORNL, U.S. Dept. of Energy

prototype is large enough for a person to enter and is unique in its ability to print large objects while the steps occur simultaneously and continuously, said Peter Wang, who leads MDF development of new laser powder bed fusion systems.

"This dramatically increases the production rate with the same amount of laser power," he said, adding that deposition occurs 50% faster. "We're only scratching the surface of what the system can do. I really think this is going to be the future of laser powder bed printing, especially at large scale and in mass production." Wang and project team members recently published a study, found here, analyzing the scalability of the technology for printing components like electric motors.

Although the machine is unique, a key to the success of the project was researchers' expertise in process automation and machine control. They used software developed at ORNL to "slice" the wheel design into vertical layers, then balance the workload between the two lasers to print evenly, achieving a high production rate, leveraging a computational technique recently submitted for patent protection.

The prototype wheel, one of the first parts produced by the system, demon-

strates the value of interagency collaboration. "The project with NASA really propelled the technology forward," said Brian Gibson, the researcher who led the rover wheel project for ORNL, calling it a milestone. "It was great to connect a capability with a developing need, and the team was excited to be making a prototype component with space exploration applications."

The prototype wheel, one of the first parts produced by the system, demonstrates the value of interagency collaboration. "The project with NASA really propelled the technology forward," said Brian Gibson, the researcher who led the rover wheel project for ORNL, calling it a milestone. "It was great to connect a capability with a developing need, and the team was excited to be making a prototype component with space exploration applications."

Made of a nickel-based alloy, the prototype wheel is about 8 inches wide and 20 inches in diameter – much larger than typical parts printed with metal powder bed systems. Making it required the ability to print small geometric features spread over a large work area. Additive manufacturing enabled greater complexity in the rim design without added cost or manufacturing difficulty, Gibson said.

In comparison, the four VIPER wheels that will churn through moon dust next year required multiple manufacturing processes and assembly steps. VIPER's 50-piece wheel rim is held together with 360 riveted joints. The manufacturing process required complicated and time-intensive machining in order to meet the mission's rigorous requirements.

If NASA testing proves the 3D-printed prototype to be as robust as conventionally built wheels, future rovers could instead use a single printed wheel rim, which took ORNL 40 hours to manufacture. Through the project, ORNL and NASA engineers also explored printing precise design features, such as angled sidewalls, a domed shape and wavy tread to increase the wheel's stiffness. These characteristics are difficult to incorporate in the current VIPER wheel design using traditional fabrication methods.

In just a few days, ORNL researchers used powder bed printing to create this lunar rover wheel based on a NASA design. Credit: Carlos Jones / ORNL, U.S. Dept. of Energy

ORNL researchers at the MDF monitored the printing of the prototype lunar wheel as two lasers melted metal powder to build it up, layer by layer. Credit: Carlos Jones / ORNL, U.S. Dept. of Energy

Despite enabling a more complex spoke pattern and spoke locking features to the wheel, 3D printing simplified and reduced the cost of the wheel design and made final assembly easier.

"A lot of these wheel features were put in just to highlight what you can do with additive manufacturing," said Richard Hagen, a mechanical design engineer for NASA and additive manufacturing lab manager at NASA's Johnson Space Center in Houston. "It lets you easily implement design features that are hard to implement with traditional tooling or even a traditionally machined part." ORNL's ability to print large objects demonstrates the potential of additive manufacturing technology for producing much larger rover wheels for both lunar and Martian missions, Hagen said.

A challenge is that the specialized printer only builds with certain materials – in this case, a nickel-based alloy – so the 3D-printed wheel is 50% heavier than the aluminum VIPER wheel, while printed at a similar thickness.

NASA plans to test the 3D-printed wheel's performance on a rover either

in the rock yard at NASA's Johnson Space Center or in a giant "sandbox" of simulated lunar rocks and soil at a contracted test facility. Evaluators will assess the wheel's maneuverability, pivoting resistance, sideways slippage, slope climbing and other performance metrics.

Hagen said additive manufacturing offers the advantage of rapid design updates in response to testing. It can also incorporate more complexity, such as a suspension system, without adding weak points.

Hagen said crewed research stations placed on the moon as part of the agency's Artemis Program will need off-planet manufacturing capability. "Being able to build parts in space for repairs will be important, because you just can't take enough spares," he said. "Powder, pellets or filament for printing are a lot easier to pack and would allow for more flexibility."

"Additive manufacturing offers the flexibility that if you have the feedstock, you could make any replacement part you need, whether in space or on Earth," Gibson said. This is a reason additive manufacturing has generated significant interest for a range of replacement needs, from rapidly manufactured tooling to hard-to-source castings and forgings.

For space exploration and habitation, 3D printers could eventually use local material from the moon or Mars as a feedstock.

Other ORNL researchers involved in the project include Jay Reynolds, Gordon Robertson, Greg Larsen, Jamie Stump, Michael Borish, Chris Ledford, Ryan Dehoff and former ORNL staff member Charles Wade, with technical support from Ryan Duncan and Jeremy Malmstead. The research was funded by NASA and DOE's Advanced Materials and Manufacturing Technologies Office, or AMMTO, and took place at DOE's Manufacturing Demonstration Facility at ORNL. The facility is home to the MDF Consortium, a nationwide group of collaborators working with ORNL to advance state-of-the-art manufacturing technologies in the U.S. under the guidance of AMMTO.

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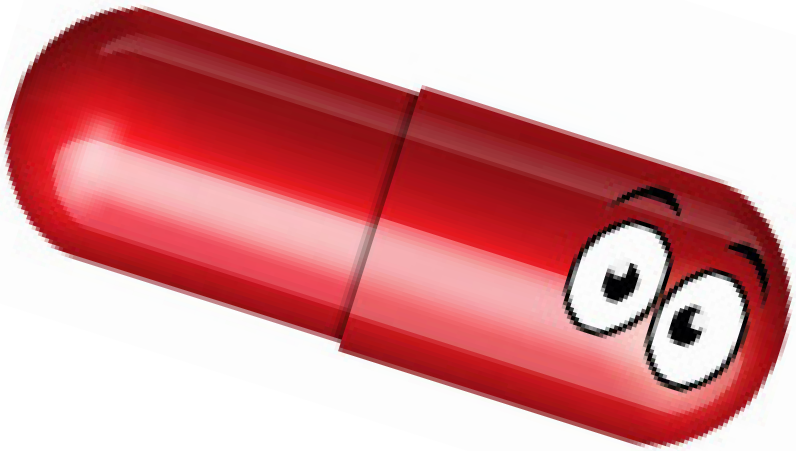
How Does Ibuprofen Know Where My Pain Is?

By Shoshana Steinmetz, PharmD / Touro College of Pharmacy



Medications exert their therapeutic effect in a variety of ways. Once absorbed into the body, every medication goes through a unique pathway that enables it to have the desired impact on the complex biological systems that are causing an unwanted symptom or illness. The way a particular medication interacts with the biochemical pathways in the body is called the medication's mechanism of action.

Some mechanisms of action are very well understood and have undergone a tremendous amount of scientific research to enable a comprehensive understanding of how they impact the intricate systems of the human body. Others, are more poorly understood. These medications are often utilized based on their ability to improve symptoms or successfully treat a disease even though scientists and physicians do not fully understand exactly how they work. A medication's mechanism of action often involves interrupting the way a chemical pathway in the body is working. Generally, the goal of a medication is to either induce or inhibit a particular pathway. Inducing a pathway can result in increased production of molecules or enzymes necessary for biologic functioning, while inhibiting a pathway causes the natural processes to slow down or stop completely.

For example, patients with diabetes do not produce enough insulin which is necessary for glucose absorption. When a patient receives an insulin injection, they are inducing the process of glucose absorption that would not have happened efficiently without the help of the medication. As another example, clinical depression is known to be linked with decreased levels of a neurotransmitter called serotonin.

Therefore, many medications used to treat depression, inhibit the removal of serotonin from the neurologic pathways. This results in an increase in the amount of serotonin available and helps decrease the symptoms of depression. Based on understanding how various medications work in the body, and understanding the cause of a specific symptom or illness, health care providers can appropriately determine what medications can best resolve an unwanted symptom or a harmful disease.

Medications that are known to work in the body through the same or similar mechanism of action are usually organized into a single category called a medication class. This way, if a patient comes to the doctor with a specific symptom they want to control or an illness they want to treat, the doctor can assess the issue, and choose from the class of medications that will most appropriately resolve the problem based on the medication's mechanism of action. Ibuprofen, also known by the common brand names Motrin or Advil, is classified as a non-steroidal anti-inflammatory (NSAID) drug. As the name suggests, these medications are used to reduce inflammation in the body. According to the labeling from the Food and Drug Administration (FDA), ibuprofen is indicated to relieve signs and symptoms of rheumatoid arthritis and osteoarthritis, relieve mild to moderate pain, fever, and to treat pain associated with menstruation.[1,2] Off label, ibuprofen is also used to treat gout, an inflammatory condition characterized by an increase in uric acid crystallization resulting in severe pain and swelling often localized in the big toe; as well as pericarditis, a condition where inflammation is present in the membrane surrounding the heart.[2, 3, 4]

How is ibuprofen able to treat pain and inflammation?

Pain is the result of a complex set of physiologic systems and can be influenced by biologic changes as well as social and psychological factors. The type of pain that is experienced as a result of a harmful stimulus such as extreme temperatures, a physical trauma, or a toxic chemical is called nociceptive pain.[5]

Once the nociceptors sense the presence of a substance that can be harmful to the body, that message must be passed on to the central nervous system (CNS) namely, the brain and spinal cord.

This pathway is referred to as the ascending pathway since the sensory information is being carried from the periphery up to the brain.6 The message is sent through the release of neurotransmitters and then undergoes further processing in the brain itself. These processes involve intricate interactions between many types of neurotransmitters and receptors. Once the sensory information is processed, a message is sent along the descending pathway and ends in a conscious perception of the pain by the individual. While the process of pain perception is not well understood, it is known that psychological functioning plays a role in pain perception. For example, activities that are relaxing like meditation, or engaging in a distracting activity may reduce pain. In contrast, anxiety or depression can often amplify the patient's perception of pain.[5]

Not all types of pain are nociceptive in nature. Some types of pain are not induced by an external stimulus. Pain can result from peripheral nerve damage or an issue with the pain processing system in the CNS. These types of pain are sometimes classified as neuropathic, maladaptive, or pathologic and can be extremely debilitating for a patient despite the lack of physical injury or harm.[5,6]

The processing of nociceptive pain starts when specialized nerve fibers are activated by the recognition that a particular stimulus may be harmful to the body. The nerve fibers that detect these changes are called nociceptors. Nociceptors recognize a harmful stimulus by sensing changes that take place when the external stimulus induces the internal inflammatory process.[5]

Inflammation in the human body occurs as a result of immune system activation. When there is tissue injury from bacteria, excessive heat, trauma, toxins, or other foreign substances, the cells that are damaged will release inflammatory mediators. The release of these chemicals causes fluid from the local blood vessels to leak into the tissue and results in swelling of the injured area. This is an important part of the immune response because the foreign substance is now "trapped" in the injured part of the body and is hopefully blocked from doing further damage to the rest of the body.[7]

In addition to limiting the progression of damage, the body's inflammatory response is also what begins the process of tissue repair. It is important to note

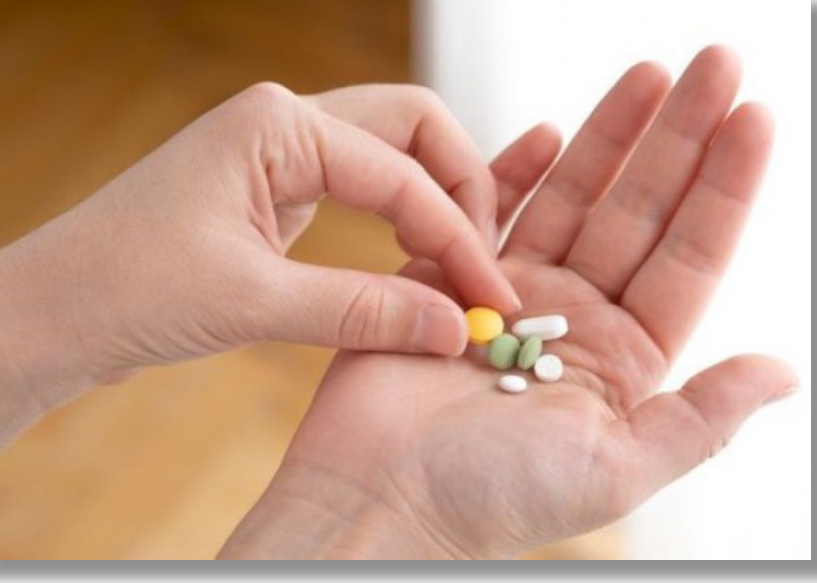
that inflammation is a crucial component of the healing process. Inflammation also leads to an increased sensitivity to pain, and can lead to feeling pain from a stimulus that would not normally cause pain, like a soft touch. This phenomenon is called allodynia.

As part of the inflammatory process, many chemical mediators are released from the bloodstream and gather at the site of injury. These chemical mediators are what signal to the pain receptors that the body was exposed to harmful stimulus.

One of the important molecules active in this pathway is arachidonic acid. Arachidonic acid is converted into prostaglandins through a chemical reaction involving the cyclooxygenase enzymes.[7,6]

The formation of prostaglandins is associated with increased sensitization and tenderness. Prostaglandins activate the nociceptors and they in turn relay the message of pain and injury to the brain.[6] Additionally, prostaglandins play a role in the development of fever by impacting the signal sent to the hypothalamus which is the area of the brain that regulates core body temperature.[8] The primary mechanism of action resulting in the reduction in fever, pain, and inflammation seen with NSAIDs is inhibition of prostaglandin formation.2 NSAIDs are able to stop the production of prostaglandins by inhibiting, or blocking the effect of the cyclooxygenase enzymes which normally enable the conversion of arachidonic acid to prostaglandins.

This inhibitions decreases the inflammation and can minimize pain. When ibuprofen is ingested, it does not only travel to the site of injury or pain. The inhibition of cyclooxygenase will happen throughout the body. While the inhibition of the cyclooxygenase enzyme is an important part of minimizing pain, fever, and inflammation, cyclooxygenase has other roles in the body aside from modulating pain. These other processes also get inhibited through the use of NSAIDs like ibuprofen. The inhibition of cyclooxygenase relates to some of the significant side effects associated with excessive NSAID use.



There are two forms of the cyclooxygenase enzyme called COX-1 and COX-2. COX-2 is the form that is primarily increased with the activation of the inflammatory pathway. COX-1 on the other hand, is involved in maintaining the protective mucosal lining of the stomach, as well as regulating platelet aggregation and kidney function. Ibuprofen, like most NSAIDs is considered non-selective. This means, ibuprofen inhibits both forms of cyclooxygenase equally. The result of this non-selective blocking is that along with the decreased inflammation and pain, patients taking NSAIDs often also experience reduced protection of the stomach wall and impaired blood clotting processes or kidney damage.[9]

These effects can sometimes be severe and dangerous. The FDA has included some of these side effects in a Boxed Warning included in the official labeling of ibuprofen. One warning is for the risk of clotting events that can lead to heart attack or stroke and the second is the increased risk for developing stomach ulcers.[1]

Taking ibuprofen every so often to reduce fever, inflammation, or pain as needed is unlikely to lead to these significant adverse effects. However, taking ibuprofen daily for many years or taking ibuprofen along with other medications that can impact bleeding, clotting, risk of stomach ulcers or kidney function is not recommended unless under the direct supervision of a healthcare provider.

Within the NSAID class of medications, each medication has particular characteristics that make it unique. These characteristics result from the different chemical structures of the medications and their various dosage forms (immediate release, sustained release, injectable etc).

Ibuprofen can be administered orally and intravenously. Orally, ibuprofen is available in tablet and capsule form as well as chewable and liquid formulations.

This can be important for patients like young children who may be unable to swallow pills. The oral formulation will generally provide a reduction in pain symptoms within 30-60 minutes and the effect should last four to eight hours depending on the dose administered.

Once absorbed into the body, medications function in a variety of ways. While the mechanisms of action of some medications are very well understood, others are poorly understood but are still utilized because of the positive effect they are known to have on symptom and disease management.

Medications generally work by either inducing or inhibiting a particular biochemical pathway. In the case of ibuprofen for reduction of pain, symptoms are thought to be primarily reduced by the inhibition of cyclooxygenase which effectively blocks the formation of prostaglandins.

While this reduces fever, pain, and inflammation, it also can reduce protection of the stomach wall, impair kidney function and cause changes in the normal bleeding and clotting processes. It is important to be aware of the ***proper dosing*** guidelines for ibuprofen and to consult a healthcare provider with any concerns related to potential adverse effects.

Shoshana Steinmetz is currently the Drug Information Fellow at Touro College of Pharmacy. She completed her PharmD at Creighton University School of Pharmacy and Health Professions. Shoshana's professional interests include drug information, pharmacogenomics, academia, and education. She resides in New York City with her husband and three children.

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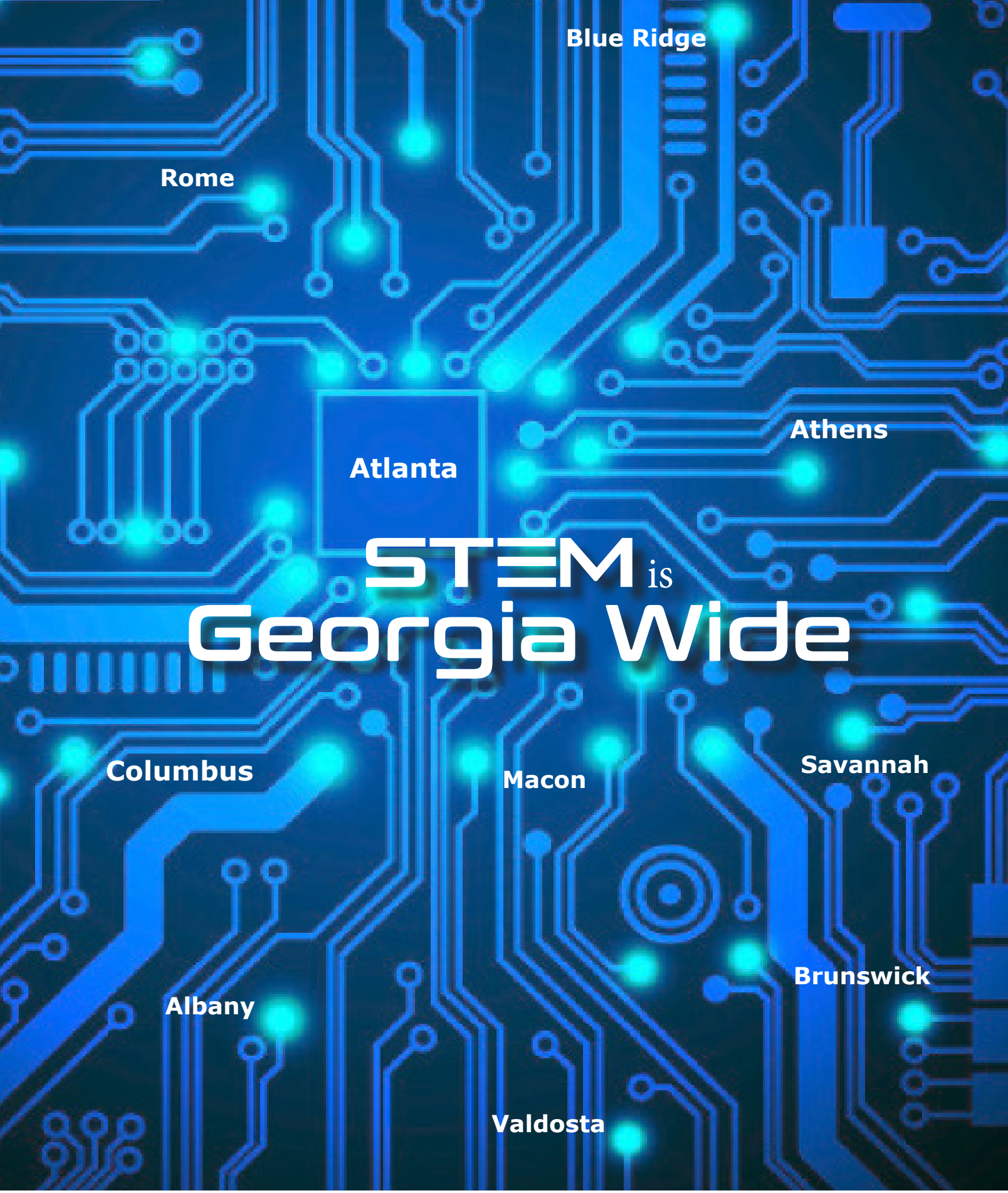

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