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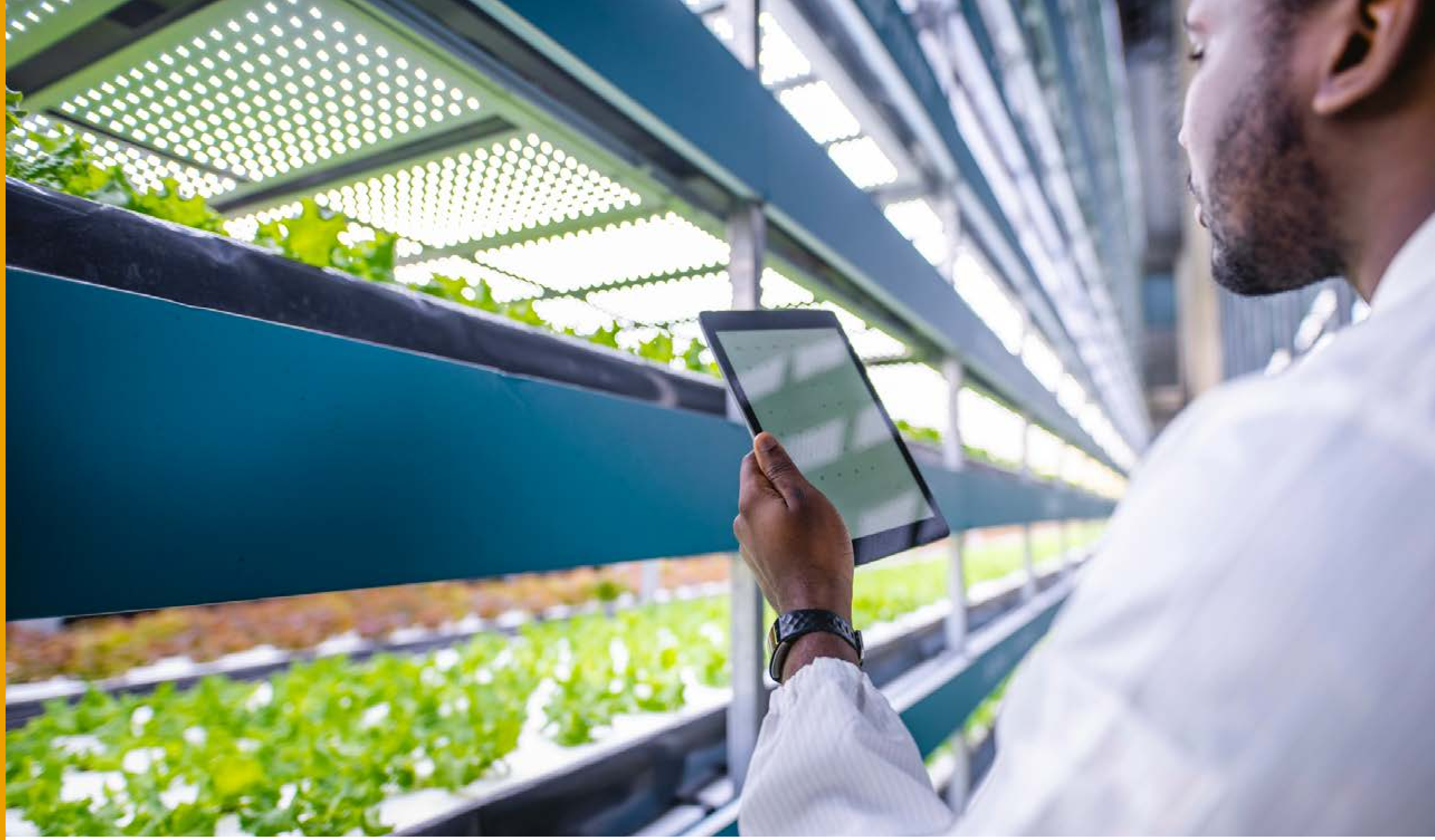
Day of Light

SUSTAINABLE FARMING



Cather Simpson
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The devastating effects of the COVID-19 pandemic threaten to continue well past the end of the virus's spread in the form of a global food crisis. Food-supply chains have been disrupted by production cuts from farmers and distributors, as major customers like restaurants, hotels, schools, and airlines cease operation. And with nearly half of the world's workforce at risk of losing their livelihoods, countless poor households will find themselves unable to buy food and going hungry.

The food-assistance branch of the United Nations, the World Food Programme, recently warned of a forthcoming "hunger pandemic."

While 821 million people already go to bed hungry every night, an additional 265 million could be pushed to the brink of starvation due to COVID-19 by the end of 2020.

In the short term, we can lessen the damaging repercussions of this crisis by allowing humanitarian goods and commercial trade to continue flowing across borders. But the pandemic has also reinforced the need for sustainable farming that uses our precious land and water resources more efficiently with less food waste and a reduced environmental footprint.

Agriculture has been an essential, life-sustaining industry for thousands of years — and its resilience during tough times can be boosted by innovation and technology.

Light-based technologies like solid-state lighting for indoor farms and optical sensors that measure plant characteristics have the power to improve the cultivation of plants and livestock.

Farmers now fly drones equipped with cameras and other imaging sensors over their fields to scan for signs of drought, pests and disease. In addition, my own lab at the University of Auckland in New Zealand has developed a technique that uses lasers to better sort bovine sperm by sex for the dairy industry.

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THE POWER OF PHOTONICS

While “photonics” has yet to become a household word, it certainly should be, as examples of it abound in our everyday lives. Photonics is the science of using light as a tool through its creation, manipulation, and detection. Research in photonics has contributed to cheaper lighting, fast telecommunications and the internet, flat-panel displays, better cameras, and so much more.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) recognized the importance of photonics by naming 2015 the International Year of Light. We now have an International Day of Light, May 16th, and this year it falls on the 60th anniversary of the laser.
The invention of the laser is the single most important event that allowed humankind to take advantage of and utilize light to its greatest potential. I might be a little biased, but I think of the laser's creation as important as the invention of the wheel.

So how can photonics and laser-based technologies help our farmers? For one, light-emitting diodes (LEDs) have become an integral part of indoor farming, which has the potential to increase our ability to feed the world sustainably. Indoor or vertical farming is the practice of growing plants in vertically stacked layers inside of an enclosed, controlled environment. Farms can produce the same amount of food in a much smaller footprint — a crucial advantage on a planet with dwindling amounts of arable land.

The cost of indoor farming has dropped significantly over the last 10 to 15 years, partially due to the availability of cheaper, more efficient LED lighting. LEDs can also be tuned to the precise colors that crops will best absorb. Adjusting the “light recipe” for each type of plant can improve productivity or enhance desirable traits. For instance, adding a period of supplemental red LED light may increase the antioxidant content of some vegetables. LED lighting also can serve as the major source of tunable light for crop gardening in urban buildings and even in outer space.

Since artificial lighting and climate control require a lot of energy, many indoor farms harvest energy from the sun with solar panels. And solar energy has dropped in price as well, from over $100 per watt in 1975 to 61 cents per watt in 2015, due to improvements in efficiency and materials cost. As a shining example, Sundrop Farms in the Australian desert grows 17,000 metric tons of vegetables with just seawater and sun. Its solar plant has 23,000 mirrors reflecting sunlight onto a solar tower that transform 1,000 liters of seawater each day into fresh water for their crops.

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MONITORING CROP HEALTH WITH LIGHT

In the last three decades, farming has witnessed a technological revolution that began with GPS guidance for tractors. Using location data from satellites, a controller in a tractor could automatically steer based on the coordinates of a field and prevent the vehicle from going over the same area twice. This made the farmer's job much easier, of course, but also wasted less seed, fertilizer, and fuel.

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The use of technology to increase crop yields while lowering the levels of inputs like land, water, and fertilizer has been dubbed "precision agriculture." Light-based technologies have contributed in the form of optical sensors that allow farmers to better understand variation in soils, plants, insects, disease, and other factors. These sensors can be handheld, attach to farm equipment, or even work remotely from drones and satellites.

For example, some farmers equip drones with cameras that capture near-infrared light, which is invisible to the human eye. By measuring the type of light that gets reflected or absorbed, these sensors can differentiate a healthy plant from a sick plant. A farmer can detect the slightest crop stress with this type of drone and take action to improve crop health before it's too late. Drones have successfully detected early signs of fungal diseases like cotton root rot in cotton and leaf rust in maize, the spread of invasive weed species, and areas of drought.

Light-based technologies also play a role in quickly measuring the physical characteristics of plants, Plant breeding requires knowledge of not only a plant's DNA, but also how parts of that genetic code connect to its physical traits. In this way, plants can be produced with a higher growth rate and greater resistance to disease, drought, and pests.

Researchers at the University of California, Davis, USA developed a robot that uses rapid, non-destructive sensing technology to measure plant features in the field (a process called high-throughput phenotyping). The device uses multiple optical sensors to create a 3D reconstruction of a single plant, from which a set of physical characteristics like number of leaves, plant height, and leaf size can later be extracted by a computer algorithm.

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LASERS, MILK, AND SPERM

CRV Ambreed

In 2011, a dairy investor took me out for coffee and said, "There are five problems facing the dairy industry. Can you help?" At the time, my research had everything to do with short laser pulses and nothing to do with cows or milk. But I thought, why not try my hand at tackling one of these problems: sperm sorting.

Sex-sorting of sperm is important to the productivity of dairy and beef industries worldwide. Dairy farms want mostly female-only sperm for obvious reasons, while beef farms want mostly male-only sperm to raise cows that will produce more meat. Methods for sex-sorting sperm do exist, but the network of dairy investors we were working with said that many farmers really wanted another option.

After talking some thought and literature research, my team started working on a device that could non-destructively sort sperm by sex with microfluidics and laser light. Microfluidics involves flowing liquid through tiny channels the width of a human hair. The DNA content of the sperm cells is stained with a dye before being injected into the microfluidic chip. It turns out that the X chromosome is a little bit bigger than the Y chromosome, which means that female cells have more DNA content than male cells – in optics terms, the females glow a bit "brighter" than the males.

The technology is based on the fact that light exerts a force. Once the sperm cells enter the chip, a laser is used to make the dye glow. Then, a light sensor detects how brightly the cell glows to determine whether it is male or female. Right before the channel forks off, another laser nudges the male cells towards one branch and the female cells towards the other.

We got some seed funding to from investors and our university to start a spin-off company called Engender Technologies and to do our initial "proof of concept" research. In the next several stages, we came up with a prototype microfluidic chip that could effectively sort sperm by sex, while at the same time being gentle on the cells to help preserve the sperm's fertility.

The big goal for Engender was to commercialize the device and bring it to farms around the world, and in 2018, Engender was acquired by global animal genetics company CRV. We hope that access to a low-cost sex selection technology for livestock would enable farmers to increase their productivity while reducing the impact of dairy and beef on the environment.

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TOWARDS A MORE SUSTAINABLE FUTURE

Mark Pasveer

In 2015, the United Nations General Assembly created a set of seventeen goals as part of its 2030 Agenda for Sustainable Development, designed to stimulate action in areas of critical importance for humanity and the planet. Light-based technologies have contributed to progress towards many these goals, but the innovations discussed above are highly relevant to Goal 2: “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.”

Increased agricultural productivity has led to a steep decline in the number of undernourished people in the past two decades. But regions in Africa and South America still suffer from severe food insecurity — and due to the COVID-19 pandemic, poor populations everywhere are more likely to experience hunger and malnutrition.

The applications of photonics in agriculture is a small window into the amazing capabilities of light and its boundless ability to solve humanity's problems. It can be harnessed as an energy source, a sensor, and a tool to increase food production and the sustainability of farming. Including the birth of the laser 60 years ago, history has shown time and time again that light can be used to make the world a better place, one innovation at a time. It's up to us to see that science — and the science of light, specifically — is a source of hope for us to inspire future innovations.