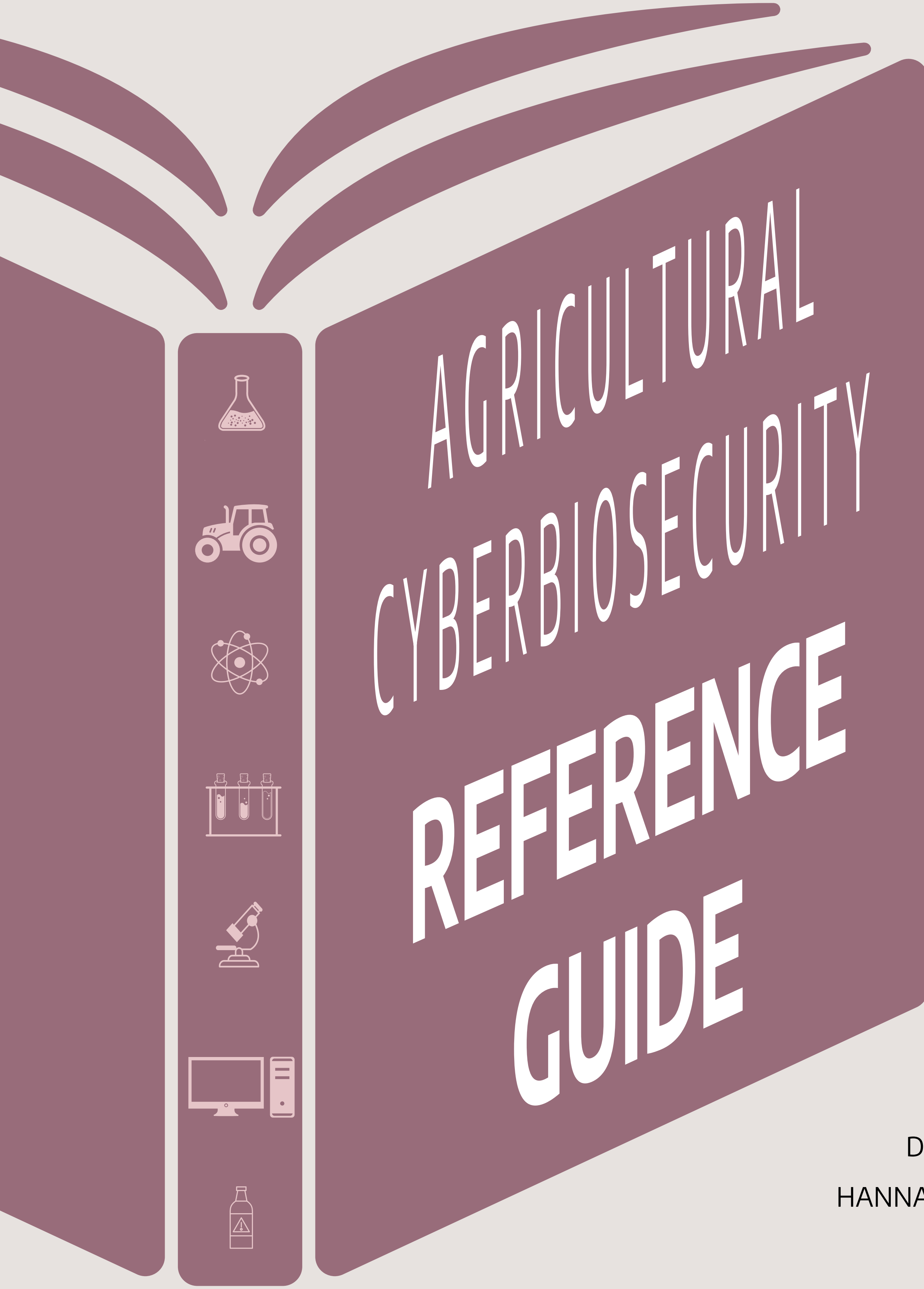

AGRICULTURAL CYBERBIOSECURITY REFERENCE GUIDE

EDITED BY

DAVID SMILNAK

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THIS WORK IS PUBLISHED BY CAIA, THE CENTER FOR ADVANCED INNOVATION IN AGRICULTURE AT THE VIRGINIA TECH COLLEGE OF AGRICULTURE AND LIFE SCIENCES IN ASSOCIATION WITH THE OPEN EDUCATION INITIATIVE, A PROGRAM OF THE UNIVERSITY LIBRARIES AT VIRGINIA TECH.

Agricultural Cyberbiosecurity Reference Guide

Edited by

DAVID SMILNAK

AND

HANNAH H. SCHERER

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CENTER FOR ADVANCED INNOVATION IN AGRICULTURE AT THE VIRGINIA TECH COLLEGE OF AGRICULTURE AND LIFE SCIENCES
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Dedication

Dr. Susan E. Duncan was a lot of things to a lot of people. At Virginia Tech, she was a trailblazer, a mentor, a futurist, and a friend to name a few. Sue has the distinct honor of being the first woman hired at Virginia Tech's Food Science Department as an assistant professor. Since then, she went on to do amazing work at Virginia Tech and in the surrounding communities. She was instrumental in developing a new strain of soybean called VT Sweet Soybean, took on leadership roles in the Virginia Cooperative Extension and Agricultural Research Centers; and she developed a university center, the Center for Advanced Innovation in Agriculture (CAIA).

Throughout her work and achievements, Sue prioritized students. She was inspired by adventurous learners and continued to be one herself in every role she held. She took time to listen to and talk with students, and then opened doors for their success. Sue understood that agriculture is changing. She understood that issues including climate change, cyberbiosecurity, and gender gaps, were problems her students would have to solve, and she had every faith they would. She encouraged and trusted her students to stay curious and rise to the occasion. She worked to prepare her students for the future of agriculture, and to change the way we all view and experience agriculture and its related disciplines.

This reference guide is dedicated to Sue to acknowledge her substantial contribution to this project and to ensure that her spirit lives on in this work.

Contents

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Project Team

Implementation of the grant project titled Initiating the rural cyberbiosecurity workforce pipeline through empowering agricultural educators and supporting middle school girls included an interdisciplinary team from Virginia Tech's Department of Agricultural, Leadership, and Community Education (ALCE), Integrated Security Education and Research Center (ISERC), and Center for Advanced Innovation in Agriculture (CAIA), and Virginia Cooperative Extension (VCE).

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Resource Development and Review

Several groups of people contributed significant efforts to developing and reviewing the Open Educational Resources published here and online.

Cyberbiosecurity Education Ambassadors

Virginia middle school agriscience teachers, 4-H youth development agents, and agriculture and natural resources agents who work with youth developed and piloted hands-on activities and reviewed resources. They provided feedback to improve the final resources. The following people served in this role:

Ambrosia Church	Peter Muhlenberg Middle School
Sally Farrell	Craig County Cooperative Extension
Kate Hawkins	James Wood Middle School
Morgan Paulette	Pulaski County Cooperative Extension
Daniel Sturgill	Marion Middle School
Cindy Vance	Stuarts Draft Middle School
Amy Whitten	Bluestone Middle School

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Virginia Tech researchers provided subject matter expertise to the project and contributed to the development and review of activities and fact sheets. The following people served in this role:

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Virginia Tech graduate and undergraduate students contributed to fact sheets in this resource collection:

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[1] OER definition adapted from the Hewlett Foundation

About this Project

Cyberbiosecurity is an emerging field that focuses on securing life sciences data, including in food and agriculture systems. This simply means creating security measures for digital aspects of our food and agriculture systems, creating a structure and opportunity for a safe food system that can meet the large needs of a growing population and world. The US domestic agriculture and food system accounts for $6.7 trillion dollars of the economy. This industry relies on biological data, technology, and computerized systems and software for making decisions to be able to meet the agriculture demands of society. Smaller businesses and farms tend to have the least amount of protection around cyberbiosecurity because of scale and resources. This leaves our seed and plant/crop agribusinesses, animal breeding and production enterprises, food processing, retail industries, and the associated supply chain vulnerable to cyber-attack as the weakest links within the food system. Our agriculture and food system needs a workforce that is trained in cyberbiosecurity. Simultaneously, while the number of women in cybersecurity is growing, women only represent 20% of the cybersecurity workforce. We have a unique opportunity to address gender parity as the emerging cyberbiosecurity workforce is developed.

Agricultural education, through 4-H and secondary classes, helps create interest and a "pipeline" into agricultural careers, but cybersecurity is not a topic that most programs have focused on currently or in the past. Within rural communities, contextualizing cybersecurity within the agriculture and food system represents a unique opportunity to spark interest in the emerging field of cyberbiosecurity. In this project, we have partnered with scientists, middle school teachers, and Extension agents to develop educational resources to help middle-school aged youth learn about the opportunities that exist in cyberbiosecurity. These resources incorporate strategies specifically designed to engage middle school girls, focusing on specific key concepts of learning for STEM that appeal to females and create a learning environment that draws them to the subject even in mixed groups or classes. Our long-term aim is to use this novel disciplinary space to spark STEM career interest of middle school-aged youth in rural communities, with an emphasis on girls, to build new pipelines into cyberbiosecurity careers.

The development of resources in this project was guided by the following design elements:

1. Support competencies outlined in the Virginia Department of Education's Curriculum Framework for Cybersecurity in Food and Agriculture (8074).
2. Showcase connections to research and career opportunities supported within the Virginia Tech College of Agriculture and Life Sciences.
3. Be age appropriate and engaging for a Middle School aged audience.
4. Align with the principles of equity within the 4-H Thriving Model framework.
5. Implement developmental strategies to target middle school girls' STEM interest.

About this Guide and Available Resources

This guide serves as a reference for facilitators using materials in the Agricultural Cyberbiosecurity Education Resource Collection. It includes background information on key topics in agricultural cyberbiosecurity (Fact Sheets), a glossary, and context for the overall project and contributors. A list of resources and how they align is provided in the table below, followed by descriptions of all resources.

Published as Open Educational Resources, all resources described here are provided in durable (pdf) and customizable (MS Word) formats downloadable at:
https://doi.org/10.21061/cyberbiosecurity

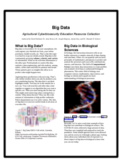
Resource Collection Alignment

Activity Topic

Fact Sheet Topic

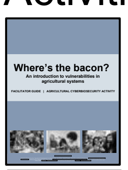
		Food system vulnerabilities	Soil nutrient automation	Hydroponics	Livestock tracking
1	Cyberbiosecurity	x	x	x	x
2	Data Literacy		x		x
3	Big Data				
4	Biotechnology				
5	Biomanufacturing				
6	Bioeconomy			x	
7	Precision Agriculture		x		
8	Sensors		x	x	x
9	Biosecurity	x		x	

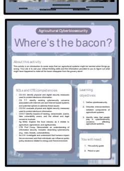
Fact Sheets



A series of fact sheets covering nine topics related to agricultural cyberbiosecurity (see table above) are designed to support facilitators in incorporating these ideas into their programming. First, there is a set of fact sheets that were written at an adult reading level to help facilitators understand these new concepts. These were written by experts who conduct research in these areas. These facilitator versions of the fact sheets are the main content included in this reference guide, and they are also available as standalone resources. Second, there is a set of fact sheets on the same topics that present the content at a 6th Grade reading level on a template that was designed to be engaging for middle school youth.

Activities





There are four activities that were developed as part of this collection. They were developed for a middle school youth audience, can be used in formal or non-formal educational settings, and are aligned with Virginia Standards of Learning for science and computer science and Career and Technical Education Competencies for agricultural education. Each activity has a Facilitator Guide and a Youth Activity Guide. A brief description of each activity is provided below.

Where's the bacon? An introduction to vulnerabilities in agricultural systems

This activity guides participants through a "Clue" style problem where they will have to critically assess the given information and determine the most likely cause of the problem in the scenario. The purpose of this activity is to facilitate problem-solving, critical reflection, and systems thinking. It prompts participants to draw connections between agriculture, cyberbiosecurity, and complex systems. The scenario is set up to introduce the foundational concept of an interconnected agricultural system and the role of cyberbiosecurity in ensuring that agricultural systems function effectively and safely.

Learning Objectives:

- Define cyberbiosecurity.
- Describe interconnections between components of agricultural systems.
- Identify roles that people play in cyberbiosecurity concerns affecting agricultural systems.

Traceability in Hydroponic Greens

The purpose of this activity is to enhance interest in STEM fields through an activity designed to facilitate problem-solving, critical thinking, and scientific observation. Using the lens of cyberbiosecurity concerns in fresh produce, specifically leafy greens, participants encounter a real-life problem where they will have to observe, document, and critically evaluate the problem, given the collected information to make science-informed decision(s). **Important Note:** This hands-on activity is designed to be implemented using an existing hydroponic unit. You can also build your own hydroponic system to utilize in this activity by following existing guidance. Throughout the growing cycle in this activity, follow the directions from your hydroponics system's manufacturer.

Learning Objectives:

- Describe the role of monitoring water pH, water temperature, amount of water, and amount of nutrients in hydroponic systems.
- Describe the importance of biosecurity in hydroponic growing systems.
- Explain the role of traceability in the food system.

Cybersecurity to Solve the Mystery of the Kentucky Derby Disappearance!

In this activity, youth act as private investigators trying to figure out what happened to a prized Kentucky Derby racehorse that has gone missing. The facilitator provides them with the introductory scenario and as they work to figure out who was responsible, they continue to receive additional clues until they solve the mystery. The scenario is set up to contain cybersecurity concerns with technologies commonly used in the livestock industry. Youth are introduced to technologies including GPS, RFID chips, and online databases that could be vulnerable to cyber attacks. This includes the Equine Microchip Lookup Tool ™ (https://equinemicrochiplookup.org/) that was introduced in 2017 and is now common practice.

Learning Objective:

- Describe the importance of cybersecurity in ensuring accuracy, security, and storage of data in agricultural systems.

Data quality in automation of food production: A soil nutrient experiment

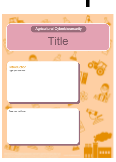
The overall goal of this activity is to emphasize the role of data quality to inform programming of automated systems in agriculture, while engaging participants in planning and conducting a scientific experiment on the effects of nutrient application on plant growth. This activity can be implemented using simple gardening equipment in a controlled environment.

Important Note: This guide is intended to provide an overarching structure for the activity, with an emphasis on situating the plant science experiment in the context of cyberbiosecurity. Facilitators unfamiliar with fertilizer application, growing plants from seed and/or experimental design are encouraged to utilize outside resources for these aspects. You should **choose a seed variety** that best matches plants that are locally grown or can be easily grown given local laboratory conditions. The variety should be something that readily shows the effects of fertilizer application; corn, tomatoes, and pennycress (cover crop) are recommended (as appropriate for your conditions). Please consult a local gardening store or Cooperative Extension resources for guidance on 1) selecting an appropriate seed variety, fertilizer, and growing conditions and 2) plant characteristics that are sensitive to fertilizer for that variety (e.g., plant height, time to bolt).

Learning Objectives:

- Determine through experimentation, observation and data collection, and data analysis the effects of nutrient application(s) on plant growth.
- Explain the role of data quality in ensuring food safety and security in automation of food production.
- Describe techniques for ensuring validity and reliability of data in experimental design.

Templates



The templates used to create the Youth Fact Sheets, Facilitator Guides, and Youth Activity Guides are available for download and use for creating new resources at https://doi.org/10.21061/cyberbiosecurity. Additional resources are available in the Ag Cyberbiosecurity Collection at https://goopenva.org/curated-collections/130.

1: Cyberbiosecurity

Authored by David Smilnak, Rebekah Miller, Jaylan Day, and Dr. Hannah H. Scherer

What is Cyberbiosecurity?

Technological advancement is happening everywhere. The products we buy are becoming more digital and advanced every day. With **digitization** comes a new set of concerns. While doorbells still ring, they also have a camera. These cameras can often be accessed through the owner's cell phone. Can other people access that camera? How would we know? What are the risks if I access the camera footage using public Wi-Fi? As technology becomes more advanced, we as consumers need to recognize and understand the risks of unwanted surveillance or harmful activities in the everyday things we do.

Technological advancement is also bringing connections among people, information, and devices. Bluetooth, Wi-Fi, and 5G, among others, are all avenues where devices can connect with each other and interact with people, products, and processes in the real world. As digital connections become more common, the need to protect our data and information, secure remotely controlled processes, and safeguard biological material makes cyberbiosecurity more important. Cyberbiosecurity aims to understand and act on these concerns. We can do this by developing measures to prevent, protect, mitigate, and investigate threats that intersect with cybersecurity, biosecurity, and cyber-physical security.

> Cybersecurity: Protection of computer systems and networks from the theft of or damage to their hardware, software, or electronic data, as well as from the disruption or misdirection of the services they provide.
>
> Biosecurity: Procedures intended to prevent the introduction and/or spread of harmful organisms in order to minimize the risk of transmission of infectious diseases to people, animals, plants, and the environment caused by viruses, bacteria, or other microorganisms.
>
> Cyber-Physical Security: Protection of physical and engineered systems whose operations are monitored, controlled, coordinated, and integrated by a computing core. Examples of cyber-physical systems include modern automobiles and medical devices.

Cybersecurity, biosecurity, and cyber-physical security are three areas of security that used to be separate from each other. As digital connections become more common, the line between them has started to blur. The digitization of industries, our personal lives, and how we interact enables us to do amazing things, but it also increases the risk of someone abusing that ability. The more technology present in any particular setting, the more pathways there are for people, like hackers, to find weaknesses in those connections to exploit. Cyberbiosecurity works to identify the weak spots between biosecurity, cybersecurity, and cyber-physical security to help safeguard our data and our systems, including our doorbells.

Cyberbiosecurity in Agriculture

Agriculture is a unique industry with great variety and complexity. It is a focal point for food systems, textiles, government research, and biofuels. It also has a large carbon footprint, requiring many resources, including land. Because of how important agriculture is and how much land is required, agriculture benefits from digital technology. Modern agriculture is more technologically advanced than we might imagine. The use of sensors to monitor soil conditions, irrigation systems that can be controlled through smartphones, and tractors with GPS and self-driving options are just a few of the many ways technology is being utilized in agriculture. Using these types of technology helps reduce the labor-intensive practices relied on in traditional farming but also brings new security considerations.

Figure 1. An autonomous tractor by John Deere. "Our Future" by adamthelibrarian is licensed under CC BY-NC-SA 2.0.

Figure 2. Sita Kumari, a farmer, uses mobile phone apps to enhance her yields and get access to markets and labor" by CGIAR System Organization is licensed under CC BY-NC-SA 2.0."

Cyberbiosecurity threats in agriculture can come in many different forms. The simplest example is a **phishing scam**. In 2017, ransomware called WannaCry hacked millions of computers, including those of many farmers. This type of attack makes a computer useless until the hacker removes the ransomware, which they often won't do until they receive money. These kinds of attacks can be devastating to smaller-scale farmers who rely on their computers to run their farms and may not have the means to pay the ransom.

The more technologically dependent agriculture gets, the more advanced the cyberbiosecurity threats can be. In the livestock industry, herd genetics are a crucial part of a successful ranch. As more data is stored digitally, it could be at risk of manipulation if a hacker got access to it. If this happened, a herd's true genetic data could be lost, causing ranchers to miss breeding windows or leaving genetic records unknowingly inaccurate. This is also a matter of national security. Agricultural data is incredibly important for the economy and for food systems. If a foreign government dominates a budding industry and stores that data exclusively within their country, they can control access to that data. While security concerns have always been present on the farm, **precision agriculture**, the **Internet of Things**, **artificial intelligence**, and **big data** make security gaps harder to find, harder to manage, and potentially more detrimental.

Cyberbiosecurity tries to consider the relationships between cyber, biological, and physical concerns to make security as strong as needed. Farms aren't the only place where cyberbiosecurity concerns can impact agriculture. Cyberbiosecurity can include safeguarding the food supply system, protecting financial and personal data stored in cooperatives, securing intellectual property, processes that produce seed varieties, genealogical and veterinary information on livestock, and securing potentially harmful pathogens and pests at research facilities.

Conclusion

As technology evolves, cyber threats will change as well. Cyberbiosecurity aims to keep up with cyber threats that pose a risk to our cybersecurity, biosecurity, and cyber-physical security. The largest intersection in those areas is you. Human error or negligence is a big weakness in cyberbiosecurity. Often, we might not even be aware of the risk we pose. While the security measures we decide to use may depend on the situation, below are some common security measures we can implement.

1. Check automated systems frequently to make sure they are operating as intended.
2. Secure data with multiple factors: passwords and two-factor authentication.
3. Provide training to employees; do not assume people know the risks.
4. Control access to systems and keep devices secured.
5. Update systems frequently; system updates often include security patches.
6. Backup and secure critical data.

Glossary

Artificial Intelligence: Advanced algorithms that receive input and alter their behavior similar to the way the human brain works.

Big Data: Data sets that are increasingly large and complex, in which we can find helpful trends that would not otherwise be apparent.

Digitization: Adaptation of a system, process, etc. to be operated with the use of computers and the internet.

Internet of Things (IoT): The connectivity between different computers, sensors, products, and processes via the internet.

Phishing Scam: A type of online scam that targets consumers by sending them an e-mail that appears to be from a well-known source—an internet service provider, a bank, or a mortgage company.

Precision Agriculture: A farm management technique that uses observations and measurements to optimize production.

Additional Resources

Phishing Attacks in the Agricultural Industry
https://resources.infosecinstitute.com/category/enterprise/phishing/the-phishing-landscape/phishing-attacks-by-demographic/phishing-attacks-in-the-agriculture-industry/#gref

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This resource was developed by faculty and students at Virginia Tech: David Smilnak, Ph.D. Candidate in the Department of Agricultural, Leadership, and Community Education; Rebekah Miller, Ph.D. Student in the Department of Food Science and Technology; Jaylan Day, Undergraduate Student in the Department of Chemistry; and Dr. Hannah Scherer, Associate Professor and Extension Specialist in the Department of Agricultural, Leadership, and Community Education, Virginia Tech.

2: Data Literacy

Authored by David Smilnak, Jordan Allen, Jaylan Day, and Dr. Hannah H. Scherer

What is Data?

Data is everywhere and revolves around everything we do. It is used anywhere from choosing the best time to grow crops to finding the cure for a rare disease or even creating personalized Spotify playlists just for you. Data is information gathered by the observation of people, things, or objects and can measure quantities, traits, or characteristics. There are two forms of data: numerical and descriptive. For example, the number of grapes in a bunch is numerical data. In contrast, the color of the grapes is an example of descriptive data. Data is created from information that can be gathered from almost anything, so understanding how to measure data correctly is essential.

Data in Agriculture

Farmers have been relying on data for years to understand and predict environmental conditions such as weather and climate. Over time, farmers use their observations about their land, the local weather, and the time of year to make management decisions for their farms. Recently, the use of technology in agriculture has meant that farmers can collect more data than ever. GPS-equipped tractors and weather tracking are examples of technology that allow agribusinesses to understand when and where to grow crops and if their crops are growing well. Growers can use data and new technologies to increase the efficiency of their processes, which can also boost production and profitability. One of the main reasons is the urgent need to produce more food for the world's growing population. Using data is one of the ways farmers and **agronomists** are working to solve this problem.

Figure 1: Conservationists recording data on corn. "Conservation agriculture in Chiapas: Data time" by CIMMYT is licensed under CC BY-NC-SA 2.0.

What is Data Literacy?

Data literacy is the ability to understand, read (graphs and charts), create, and communicate data effectively as information. An important component of data literacy is finding value in data. Data analysis is done after data collection to look for information that could explain trends or characteristics. It is frequently used to make important judgments, so it's critical to understand when data is misleading or presenting false information. Since data is commonly shared for public use, it's critical to handle it ethically.

What is Ethical Data?

Did you know that one out of every three sheep has two tails? Did that statistic surprise you? If so, it's likely because this fact is not true. This is an example of unethical data. Data is considered ethical when it is reliable, accurate, and honest. With many resources available online, it's important to always consider the ethics of the content you read. Three main types of research misconduct are related to unethical data:

Fabrication: when data is changed or left out to help support a hypothesis.

Falsification: the addition of data or observations that never happened.

Plagiarism: when you represent other work as your own.

False information has the potential to misinform individuals about critical issues that may have a direct influence on them. It is crucial to gather ethical data, but it is also crucial to recognize when data may be false or unethical.

Data Collection

Have you ever wondered where our data comes from? We've discussed some places already, but data is collected in many different ways. Data can be collected through surveys, interviews, personal interactions, mobile devices, sensors, computers, the internet, and observations, among others.

Mobile devices such as cell phones collect an enormous amount of data because of the many apps and additions that can be added to the device. Sometimes this is referred to as **Big Data**. TikTok, a popular social media app, is an example of an app that collects large amounts of data. One way TikTok collects data is by counting the number of likes someone's post receives. The app also uses data to collect information about the person using it, such as their ages, gender, and usernames. TikTok also uses data analytics to show the most popular videos on the main screen, known as the "For You" page, and control the content users observe based on their most visited posts.

Big data refers to data that is very large and complex and cannot be summarized using traditional data analysis methods. Instead, big data utilizes different types of software for people to understand the data being collected. Big data makes information on rainfall patterns, soil health, fertilizer needs, and other topics available to farmers. They can use this information to make decisions about when to harvest, what crops to grow, and where to grow specific crops to maximize crop yield.

Types of Data

Traditional forms of data are handwritten, audio, images, videos, or prints. Data can also be converted into a digital format so that a computer can recognize it. Digitized data is also easier to access and share. Cybersecurity and cyberbiosecurity focus on the protection of digitized data and information.

Some digitized data doesn't exist on a physical object, such as a USB flash drive. Digital data not stored on a physical device is usually held on software called a cloud. Google Drive, OneDrive, and iCloud are examples of cloud data storage. Cloud data storage allows for a quick way to transfer data between devices; however, it can compromise security and access to the data.

Connection to Cyberbiosecurity

Data literacy is a universal concept that isn't restricted to the field of cyberbiosecurity. In the agricultural industry, understanding and interpreting data is a very marketable skill and one that is vital to the success of a farm or agribusiness. Being able to understand the data and reliably decide if what you're seeing is trustworthy is going to become more important as digital technology progresses. Data crimes like **phishing scams** and **ransomware** can be incredibly harmful. As industries like agriculture become more reliant on digital technology, the opportunity for data crimes to happen increases. Being up-to-date on data literacy also makes sure you know how to protect and use your data.

Glossary

Agronomist: an expert in the science of soil management and crop production.

Big Data: Data sets that are increasingly large and complex, in which we can find helpful trends that would otherwise not be apparent.

Phishing Scam: A type of online scam that targets consumers by sending them an e-mail that appears to be from a well-known source—an internet service provider, a bank, or a mortgage company.

Ransomware: a type of malicious software designed to block access to a computer system until a sum of money is paid.

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This resource was developed by faculty and students at Virginia Tech: David Smilnak, Ph.D. Candidate in the Department of Agricultural, Leadership, and Community Education; Jordan Allen, Ph.D. Student in the Department of Food Science and Technology; Jaylan Day, Undergraduate Student in the Department of Chemistry; Dr. Hannah H. Scherer, Associate Professor and Extension Specialist in the Department of Agricultural, Leadership, and Community Education.

3: Big Data

Authored by David Smilnak, Dr. Anne Brown, Dr. Joseph Simpson, Jaylan Day, and Dr. Hannah H. Scherer

What is Big Data?

Big data is everywhere. It's in your smartphone, the cash register you checked out from, your online purchases, health records, etc. That's why this topic is so hard to wrap our minds around. Big data is the continuously growing **volume, velocity, and variety** of information. What we do with that information is the other part. Professionals in careers like data analytics, data engineering, and risk analysis, among others, collect data and look for patterns and trends. Those patterns give us insights that allow us to predict what might happen next.

Applying those predictions is the next step. That's why online retailers show you ads for products you are considering buying. The data that is out there highlights trends. You may be in the market for a new car. Your web searches and other data come together to suggest to an algorithm that you want a specific car. Then you start seeing ads for that car. This might seem unnerving when coming from a retailer. What about doctors? They use this wide amount of information to help predict outbreaks. Police departments use it to solve crimes. The idea of big data is to uncover useful trends in all areas of everyday life.

Figure 1. Big Data 2267x1146 white, Camelia, Boban, https://commons.wikimedia.org/wiki/File:BigData_2267x1146_white.png, Creative Commons Attribution-Share Alike 3.0 Unported License

Big Data in Biological Sciences

In biology, the interactions between cells in our bodies represent a complex network of data sharing and outcomes. Often, we can quantify and use basic principles of mathematics and physics to predict and analyze the processes and ways cells communicate, interact, and function. The field of **Computational Science** uses these data interactions to create profiles and atomistic-level data to understand biological phenomena. This entire field of biology uses computer science, mathematics, data science, and biology to inform and expand our basic understanding of biological processes.

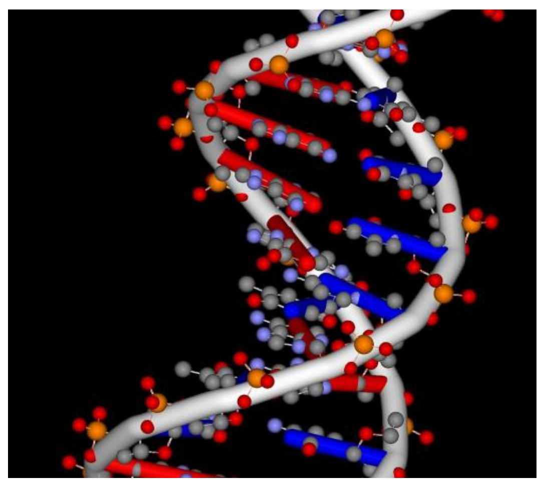

Figure 2. "DNA" by ghutchis is licensed under CC BY-ND 2.0.

Recently, we've seen a real-time example of how big data can contribute to biological science. The COVID-19 crisis collected a huge amount of data. That data was compiled and analyzed to track the pandemic. Some health agencies have even allowed you and me access to it through a phone app. Getting alerts about your individual risk of exposure is a direct impact of big data in biological science that you can see today.

Big Data in Agriculture

Agriculture today is far more advanced than you may realize. Big data is used throughout the industry. Farmers and ranchers use computers for everyday tasks, including ordering supplies, tracking crop and irrigation schedules, checking commodity prices, and keeping an eye on weather conditions. Farmers and ranchers have a history of observing changes on their farms and tracking them. Digitizing this data allows us to predict future changes and collaborate more quickly with others.

On the farm, **precision agriculture** is becoming more common. Precision agriculture uses measurements such as **LiDAR** maps of fields, soil moisture, crop stress, and nutrient levels to efficiently manage a field. These measurements are used to apply herbicides, pesticides, and fertilizers on a plant-by-plant basis. This can increase food production and decrease waste. In addition, we can use satellite networks to guide tractors, cell phones to run irrigation systems, and computer programs to tell us the best time to harvest. Big data in agriculture is going to become increasingly important as the global population increases and climate change progresses.

Figure 3. Sita Kumari, a farmer, uses mobile phone apps to enhance her yields and get access to markets and labor" by CGIAR System Organization is licensed under CC BY-NC-SA 2.0."

Figure 4. An autonomous tractor by John Deere. "Our Future" by adamthelibrarian is licensed under CC BY-NC-SA 2.0.

Connection to Cyberbiosecurity

Cyberbiosecurity is concerned with protecting the infrastructure, data, and products of biologically dependent sectors of industry. This includes things like proprietary seeds, health records, irrigation systems, and much more. Sectors including agriculture, biomedicine, and defense are generating and using more data than ever before. That data allows these sectors to work more effectively and do amazing things. However, it also provides a new target for attack and abuse. What makes this different from other computer attacks is the direct impact on people, animals, and plants.

One area where cyberbiosecurity and big data intersect is food security. In developing countries, famine is a major concern. The United Nations has used big data to create projects like the Global Pulse Initiative. This initiative uses a wide variety of data to predict famine and direct resources to curb the impact on human life.

Glossary

Computational Science: The art of creating mathematical models of a scientific process.

Precision Agriculture: Technology that maximizes the efficiency of a farm but is not critical to farming operations.

LiDAR: A detection system that works on the same principle as radar, recording the amount of time between an emitted electromagnetic wavelength and receiving its reflection to measure distance, but uses light from a laser.

The 3 V's of Big Data:

- **Volume:** The amount of data produced and/or available for analysis.
- **Velocity:** The speed at which we create, process, and receive data.
- **Variety:** The different types of data, i.e. spatial, temporal, discrete, and continuous.

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4: Biotechnology

Authored by David Smilnak, Sabrina Amorim, Jaylan Day, and Dr. Hannah H. Scherer

What is Biotechnology?

Biotechnology is already a part of our daily lives. We can find it in pharmacies, on our phones, and in supermarkets, among many other places. Despite having existed for millennia, the term “biotechnology” was created only in the last century by Hungarian engineer Karl Ereky. Great discoveries of humanity include fermentation to produce beverages, the manufacture of bread, cheeses, vinegar, and yogurts, the discovery of medicines such as penicillin, and more recently, the cloning of animals associated with biotechnology. With so many technological advances over the years, we ask ourselves, What is the limit? And if that limit exists, where can this type of technology take us in the future?

Biotechnology can be best defined as technology based on biology. Biotechnology utilizes biological processes to develop products and can fall into three main focuses: agriculture, manufacturing, and medicine. Biotechnology is widely used in agriculture and in the medical field. In these fields, biotechnology primarily focuses on **gene** editing. This includes manipulating the genes of organisms for a beneficial trait, marking genes so they are visible in experiments, and the identification and potential treatment of genetic diseases. Each of the three domains mentioned approach biotechnology differently.

Agricultural Biotechnology

For centuries, farmers have been selectively breeding crops for specific traits. Now, with biotechnology, scientists can make precise changes to genes in a short amount of time. Biotechnology in the agricultural industry is synonymous with genetically modified organisms (GMOs). Starting in the 1990s, advancements in DNA and computer technology allowed scientists to select specific genes to edit in crops. Changes to genes can provide tolerance to adverse weather conditions, resistance to herbicides and insects, and increased nutritional value. These changes can help provide more consistent or larger harvests, decreased environmental risk, and benefits to public health.

One example of genetic modification is the papaya. In the 1990s, the papaya ringspot virus was threatening to destroy the papaya industry in Hawaii. The virus stunts tree growth and leaves a distinctive black ring on the fruit. Researchers at the University of Hawaii and Cornell University developed a GMO papaya that had total immunity to the ringspot virus. After introducing GMO papaya, the industry rebounded. GMOs are not without criticism. The safety of these crops needs to be evaluated on a case-by-case basis to ensure there are no side effects from the gene modification. Additionally, efforts are being made to protect heritage or wild varieties of these crops to maintain **genetic diversity**.

Industrial Biotechnology

Industrial biotechnology, sometimes called **biomanufacturing,** is the use of biological processes to produce chemicals, energy, and materials for industrial use. Biomanufacturing on its own has agricultural, industrial, and medicinal applications. Organisms such as bacteria, fungi, microorganisms, and plants are utilized to create biofuels, biogas, textiles, paper, and more. Industrial biotechnology is beneficial for the environment by lowering greenhouse gases and conserving resources. For more information on biomanufacturing, please refer to its specific factsheet.

Medical Biotechnology

This is the use of living cells to develop technologies for the improvement of human health. Production of pharmaceutical products, vaccines, antibiotics, genetic testing, and drug treatments are benefits of medical biotechnology. A recent example of this is CRISPR-cas9. CRISPR-cas9 is a naturally occurring enzyme that modifies DNA. Its natural purpose is to remove damaged pieces of DNA to prevent harm to a person. Dr. Jennifer Doudna and Emmanuelle Charpentier found a way to “train” CRISPR-cas9 to target specific abnormalities. Now genetic modification can happen with a high degree of precision, making treatments and cures for Alzheimer's, Huntington’s disease, and HIV, among others.

"Emmanuelle Charpentier and Jennifer Doudna" by For Emmanuelle Charpentier’s portrait credit: Bianca Fioretti of Hallbauer & Fioretti. For Jennifer Doudna’s portrait credit: User: Duncan Hull and The Royal Society is licensed under CC BY-SA 4.0.

Connection to Cyberbiosecurity

The protection of biotechnology is one of the top priorities in cyberbiosecurity. Changing genetic codes for agriculture, storing medical information, and creating industrial products all pose serious security risks. Protecting data and intellectual property is a primary focus. Medical data and data describing a company’s specific seed variant are important to protect customer privacy as well as provide a competitive advantage in the marketplace. Secondly, protecting access to biotechnology can protect processes and products from cyber-physical attacks. Relying on automation and computers to carry out these tasks increases efficiency but also opens up potential pathways for hackers, terrorists, and foreign governments to intervene.

Glossary

Biomanufacturing: A process that produces commercially relevant biological materials.

Gene: A collection of DNA found in chromosomes that controls what characteristics are passed on to a person, animal, or plant.

Genetic diversity: The total number of genetic traits possible in a population of organisms.

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5: Biomanufacturing

Authored by David Smilnak, Dr. Anne Brown, Dr. Laura Strawn, Jaylan Day, and Dr. Hannah H. Scherer

What is Biomanufacturing?

Biomanufacturing is where science, nature, and business collide. Are you curious about how algae can make rocket fuel? Are you interested in how farming could help fight climate change? These and many more careers come together in biomanufacturing. There is an effort by industries to explore naturally occurring processes to produce the products we all use. Everything from medicine to plastics and, yes, rocket fuel, could have a naturally occurring process to help us make it.

For example, penicillin was one of the most important discoveries in modern medicine. In 1928, Dr. Alexander Fleming discovered penicillin. Using microscopes and Petri dishes, Dr. Fleming recognized that this common and natural mold could destroy harmful bacteria. Penicillin has since drastically lowered the death rate for bacterial infections. This discovery has all the characteristics of a biomanufacturing success: Penicillin is a naturally occurring substance, technology (microscopes and Petri dishes) was used to unlock its potential, and it had an economic impact on the medical industry (as well as others since it increased life expectancy).

A Brief History of Biomanufacturing

The history of biomanufacturing can be broken up into stages: biomanufacturing 1.0, 2.0, 3.0, and 4.0. The stages describe a variety of technological advances and understandings of the natural world.

Biomanufacturing 1.0

Certain biomanufacturing processes, like brewing beer, have been around for as long as civilization itself. Our ancestors may not have understood completely what was happening when they introduced sugar, yeast, and malt to water, but they soon realized that the processes that occurred allowed them to safely "brew" and consume the otherwise dangerous water. Biomanufacturing 1.0 is characterized by a refinement of this "brewing," or as it is technically called, fermentation.

In the 1910s, Chaim Weizmann, known as the father of industrial fermentation, started to experiment with a process called **acetone, butanol, and ethanol** ("ABE") fermentation. In this process, acetone, butanol, and ethanol are metabolites, natural products of a cell's function like the ethanol our ancestors produced while brewing beer. Weizmann used fermentation to produce acetone and butanol in a large-scale and more commercially viable way. The industrialization of ABE fermentation helped to produce products like synthetic rubber, smokeless gunpowder, paint lacquer for cars, and most recently, biofuels.

Figure 1. Dr. Chaim Weizmann (1874–1952), Professor of Chemistry at the University of Geneva and then the University of Manchester before becoming the first president of Israel. "President Chaim Weizmann" by the Government Press Office (GPO) is licensed under CC BY-NC-SA 2.0.

Biomanufacturing 2.0

Where biomanufacturing 1.0 utilized the everyday functions of cells to produce products, biomanufacturing 2.0 uses secondary processes. Secondary processes include chemicals that cells can create when they are under attack.

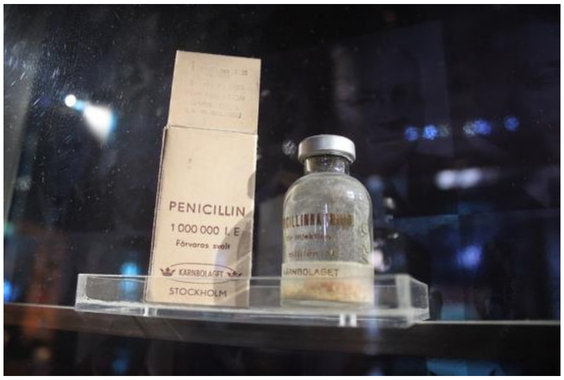

Figure 2. An original bottle of penicillin. "The Discovery of Penicillin" by Solis Invicti is licensed under CC BY 2.0.

The most famous example is the Penicillin story. Because so many of these secondary processes are used by cells for defense, they are ideal for **antibiotics.** However, they have also been used for flavorings and perfumes. Technological advancements about 20 years after Dr. Fleming's discovery allowed the production of penicillin, as well as other products, to grow and become cheaper.

Biomanufacturing 3.0

Large biological molecules like insulin and different enzymes were too complex to create using typical chemistry methods. In the 1970s, that started to change. Stanley Cohen and Herbert Boyer pioneered a new method of creating complex molecules like proteins. Their process tricks a bacteria called E. coli into making insulin. This method was so successful that it was used to mass-produce insulin for patients with diabetes.

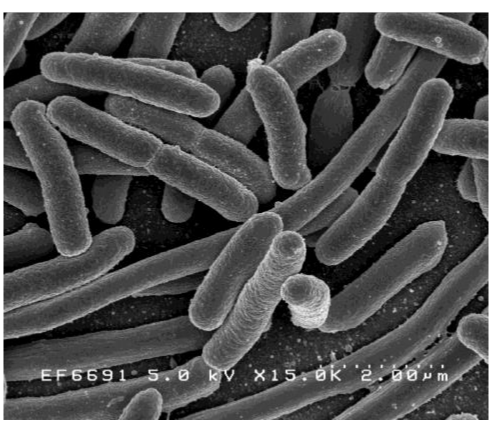

Figure 3. A picture of E. coli taken from an electron microscope. "E. coli Bacteria" by NIAID is licensed under CC BY 2.0.

Recently, this process has allowed for the development of anti-cancer technologies and other **enzymes** used in the agricultural, clothing, and chemical industries. To continue improving enzyme production, scientists started using plants such as tobacco or the soybean plant rather than E. coli to make these products. Plants are bigger than bacteria, so using these plants means they can make more enzymes and proteins quicker.

Biomanufacturing 4.0

If biomanufacturing 3.0 was about recreating complicated, naturally occurring molecules, biomanufacturing 4.0 will mean creating our own molecules. The future of biomanufacturing is still being shaped by the scientists of today and tomorrow, but it is motivated by finding answers to seemingly impossible questions and by making current processes more efficient. This will likely include the use of Artificial Intelligence (AI) to explore potential combinations and see what works. We haven't found the limits of biomanufacturing 4.0, and there are some budding areas pushing those limits.

Artificial food

Lab-grown meat, sometimes referred to as cellular agriculture, is a top priority of biomanufacturing 4.0. You may have heard of Impossible Foods and Beyond Meat. These companies are currently in biomanufacturing 3.0, where they mimic meat. In biomanufacturing 4.0, companies are trying to grow it. The ability to grow meat products in a lab has a large variety of societal, environmental, and health benefits namely, the ability to have a source of protein without injuring or killing animals.

Regenerative medicines

Rather than trying to replace human tissues, what if the body could just grow its own? Researchers are exploring the possibility of using **stem cells** to grow tissue and organs specific to the patient in need. Currently, a patient who receives a transplanted organ will need to take medicine to prevent rejection of the donor organ. If researchers are successful, this will be a thing of the past. In a similar application, biomaterials provide scaffolding on which cells can grow. These materials can then be applied to an injury, allowing tissues and bones to grow back naturally. Research into stem cells and biomaterials is the beginning point of this field, but the future is still being determined.

Connection to Agriculture

Examples of manufactured products in the field of agriculture include genetically modified organisms (GMOs) and agrichemicals. GMO produce and livestock are huge aspects of American agriculture. For example, gene editing has been used to create gray-patched cattle to reduce the amount of heat they absorb. Produce such as corn, apples, cotton, and potatoes are genetically engineered. Most crops have their genes edited to resist pests and diseases. However, some crops, like apples and potatoes, are modified to be more visually appealing to consumers. Some GMO potatoes have been developed to prevent the bruising and browning that occur when potatoes are packaged, stored, and transported. GMO apples were made to prevent browning since browning is often mistaken as a sign of an apple spoiling. Furthermore, many processes that other industries use have a connection to agriculture. Cellular processes in wheat, tobacco, and soy have proven to be useful for scientists exploring DNA technology.

Figure 4. Growing salt-resistant crops. "Polyploidal Plants" by jurvetson is licensed under CC BY 2.0.

Lastly, biomanufacturing has implications for agriculture. While lab-grown meat is beneficial for the environment and animal welfare, the social implications for ranchers and farmers are often ignored. How will lab-grown meat affect the farmers who raise cattle or grow food for those cattle?

Connection to Cyberbiosecurity

Biomanufacturing is one of the fields that cyberbiosecurity is focused on protecting. Biomanufacturing 4.0 coincides with the digitization of industry. As you can imagine, the work that scientists are doing and will do in the future will require a lot of computing power. As such, biomanufacturing businesses are a prime target for cyberattacks.

Agricultural and industrial biomanufacturing attacks are usually limited to a single business. These attacks target the intellectual property those businesses are working on. Also, cyberattacks in biomanufacturing are likely to be **cyber-physical** instead of data-based. An example would be the disruption of an assembly line compared to stolen data about the monthly production report of a business.

Glossary

Acetone: A chemical solvent often found in nail polish remover.

Butanol: A chemical solvent often used with paint, lacquer, and other coatings.

Ethanol: Chemical responsible for drinking alcohol. It is also used as an antiseptic, medicinal solvent, and fuel for transportation.

Antibiotic: A medicine that kills or prevents the growth of pathogens.

Mutant strains: A naturally occurring variation of a cell, pathogen, or virus.

Gene: A collection of DNA found in chromosomes that controls what characteristics are passed on to a person, animal, or plant.

Enzyme: A molecule that speeds up a chemical reaction.

Stem Cells: Cells in people, plants, and animals that go on to become specialized cells in the organism like skin cells, liver cells, reproductive cells, blood cells, etc. They are the first stage of cell production.

Biotechnology: The application of biology to an industrial process.

Cyber-physical Attack: A cyberattack that results in the physical interruption of a non-cyber process.

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6: Bioeconomy

Authored by David Smilnak, Dr. Tiffany Drape, Jaylan Day, and Dr. Hannah H. Scherer

What is the Bioeconomy?

How much money are all the apples in the United States worth? Have you ever had a thought like this? When you eat an apple, you might know how much it costs but how much do all the apples grown in the United States cost? Let's think about it. There are fresh apples, dried apples, preserved apples, apples used for juice, jams, and pie fillings. If we check USDA sales reports, all of these forms of apples equal almost 1 billion dollars! That's a lot of money, but do we stop there? What about the benefits we got from researching apples? What about new jobs in agriculture because of the apple industry? When we consider the economic impact of agriculture, biotechnology, computer science, and engineering, we're talking about the bioeconomy.

While there are a lot of engineers, scientists, and researchers working on apples, it's far from the only crop. The bioeconomy takes all the hard work scientists, farmers, and computer engineers put into their innovations and technology that go along with producing plants, animals, and microbes. Finding where the bioeconomy stops can be a little tricky because scientists using plants, animals, and microbes fit into all different types of careers. Generally, we can think of the bioeconomy as fitting within three domains: agriculture, bioindustry, and biomedicine. Within these domains, we can have people from all over helping. For example, the process that developed the COVID-19 vaccine is part of the bioeconomy. Many of the COVID-19 vaccines are mRNA vaccines. This means the cells in the human body are given a piece of messenger RNA from the virus so the immune system can identify it. Developing this vaccine took people from the federal government, universities, and medicine manufacturers to work together. Because COVID-19 is a virus (a microbe), we can count all of that work toward the bioeconomy.

Bioeconomy Domains

Agriculture

Agriculture as an industry has always been an innovative part of the bioeconomy. Agriculture's role in the bioeconomy is rooted in genetic engineering, data processing, food production, and the harvesting of raw resources. While selective breeding for beneficial crop varieties has been around as long as agriculture, our ability to genetically modify crops and livestock streamlines this process. Now scientists can develop drought-resistant crops and cattle that are more heat-tolerant.

As agricultural processes become more advanced and technologically driven, agricultural data is becoming a bigger part of the bioeconomy. Tractors and soil sensors are actively collecting data from the fields in which they operate. This data is used to inform manufacturers of farmers' needs and give farmers additional perspectives on their land. Future projects in food production and land management have even led the industry to explore lab-grown meat. This involves using muscle cells from livestock to produce livestock products without the use of resources, pharmaceuticals, or the loss of animal life.

Bioindustry

The bioindustrial domain relies on transitioning away from chemical processes in favor of natural and sustainable processes. For example, chemicals can be used to break down sugar into specific molecules used in other products. However, a strain of bacteria can do the same thing. Rather than producing and handling those chemicals, a company can decide to grow those bacteria to produce their desired molecules. Using a biological process rather than a chemical one can make a company less dependent on fossil fuels, use less water, and reduce energy use.

Biomedicine

The biomedical domain involves medicine that is developed from biological materials. The medicine produced from biological materials is called **biopharmaceuticals** or biologics. The COVID-19 vaccine was developed in the biomedical domain. This is because it uses a cell's ability to decode mRNA to produce a product, rather than an artificial or chemical process. Increasingly, new medicines are being developed through computer models to determine an appropriate molecular structure. While beginning on a computer, the testing process for these pharmaceuticals still requires significant biological research and development. Additionally, new products like brain-controlled prosthetics are slowly being developed. This intersection between technology, biology, and engineering is a great example of the bioeconomy.

Relating the Bioeconomy to Cyberbiosecurity

The need for cyberbiosecurity evolves from the larger objective of "Safeguarding the Bioeconomy." "Safeguarding the Bioeconomy" is an idea proposed by the National Academies of Sciences, Engineering, and Medicine (NASEM) in 2014. This idea recognizes that computers make it easy for people to access many different parts of the bioeconomy. The increased use of computers, sensors, and data in agriculture, economics, and medicine introduces more opportunities for cyberbiosecurity threats to cause harm. To make sure financial information, research, and personal information stay protected, the bioeconomy will need professionals trained in computer science and cybersecurity. As agriculture, bioindustry, and biomedicine become more dependent on technology, the need for cyberbiosecurity systems will continue to grow.

Glossary

Biotechnology: The application of biology to an industrial process.

Stakeholders: A group of people or entities that affect the success or failure of a business.

Intellectual property: A unique idea that someone could apply for protected rights.

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Additional Resources

https://research.cnr.ncsu.edu/sustainablebioproducts/resources/bioeconomy-careers/

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7: Precision Agriculture

Authored by David Smilnak, Shannon Bradley, and Dr. Hannah Scherer

Introduction

Have you ever considered a job as a drone pilot? Do you enjoy turning your house into a smart house? Have you thought about trying to protect the data and programs involved with both? Have you ever considered combining that with farming? It might sound funny at first, but farming is quickly becoming very high-tech. Farmers aren't just planting crops or tending to their cows. Now they use drone-mounted thermal cameras to see how healthy crops are, GPS trackers to keep tabs on cows, and phone apps to drive tractors. All of this is being done to make farming more cost-effective and environmentally friendly.

Figure 1. A cow with a GPS and health sensor on its collar. "20110429acp115sp008p" by ukagriculture is licensed under CC BY-NC-ND 2.0.

A Brief History of Precision Agriculture

Precision agriculture gets its name from farmers trying to be "precise" with the amount of fertilizer, pesticides, and water used. While it might seem like a new idea, precision agriculture can trace its roots back to the 1980s. In its most basic form, precision agriculture means changing the amount of fertilizer, pesticide, water, etc. put on a field based on the needs of the particular plant or piece of land. This can be done by hand by changing the equipment. Quickly, though, this started to become more automated. In fact, the first remote-controlled agricultural drone was used in the 1980s to spray rice paddies.

Figure 2. Drone pilots testing their agricultural drone. "Drone test flight" by millstastic is licensed under CC BY 2.0.

Modern Precision Agriculture

Since the 1980s, precision agriculture has become more technological. Companies like John Deere and New Holland among others have tried to automate as much farm work as possible. While this helps farmers make precise adjustments to their equipment, it also makes the equipment more computer-driven. Today, with internet connectivity and **the Internet of Things (IoT)**, all of these processes are becoming interconnected. Farmers do not even need to be on the tractor anymore. They can set a tractor's path on the computer, and with a combination of sensors in the field and GPS, the tractor knows where to go and what to do. Oftentimes, a farmer can make management decisions from their phone. From moving digital fences that corral their cows to turning on their irrigation system, farmers have a wide range of technological farming equipment at their disposal.

Figure 3. An autonomous tractor produced by John Deere. "Our Future" by adamthelibrarian is licensed under CC BY-NC-SA 2.0.

Figure 4. A center pivot irrigation system. "Center Pivot Irrigation System" by eutrophication&hypoxia is licensed under CC BY 2.0.

Connection to Cyberbiosecurity

With all of this technology, however, there are some risks. When you are online, you need to be careful about the sites you visit and who you talk to. If not, you open yourself up to **phishing scams, ransomware**, and other risks. Farmers have the same issue now. There are many aspects that farmers today have to be careful with, including the data they create, their internet connectivity, and computer updates for tractors. This overlap between security, agriculture, and technology is referred to as cyberbiosecurity. Cyberbiosecurity is quickly becoming a large part of agriculture. For example, while drones are helpful, they can produce images like the one below that often need to be analyzed by a specialist. Being able to understand what sites and services are trustworthy will become increasingly important for farmers in the future.

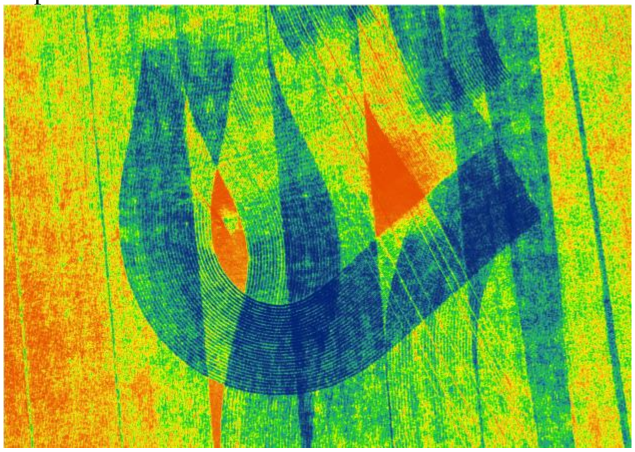

Figure 5. A NDVI "Normalized Difference Vegetative Index" image taken by a drone to show crops that are stressed versus ones that are healthy. "Agricultural art" by Antarsih is licensed under CC BY 4.0

Conclusion

Agriculture has become much more technologically advanced in recent years. Farming relies on **Big Data**, the Internet of Things, and **data literacy** to operate large-scale farms today. The average age of a farmer in Virginia is 58. While farmers are learning the basics of digital farming, they did not grow up with the internet like the younger generations. This means that something that comes naturally to those in middle school now, like flying drones, setting up smart devices, and being safe on the internet, may not be as easy for some farmers. So, careers in agricultural data analytics, remote sensing, and tractor technicians need professionals skilled in computer science and agricultural science to help our farmers keep their farms safe and food on our tables.

Glossary

Big Data: Data sets that are increasingly large and complex, in which we can find helpful trends that would otherwise not be apparent.

Data Literacy: The ability to read, work with, analyze, and communicate measures or records in context.

Internet of Things: The connectivity between different computers, sensors, products, and processes via the internet.

Phishing Scam: A type of online scam that targets consumers by sending them an e-mail that appears to be from a well-known source—an internet service provider, a bank, or a mortgage company.

Ransomware: a type of malicious software designed to block access to a computer system until a sum of money is paid.

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8: Sensors

Authored by David Smilnak, Dr. Robin White, Jaylan Day, and Dr. Hannah Scherer,

Sensors in Society

Sensors are prevalent throughout our society. For example, when you use a fingerprint to log into a smartphone, a **biometric** sensor is used. Similarly, "clap-on" lights use audio sensing to detect a clap signal to change the status of a light from off to on, or vice versa. In agriculture, sensors are used to measure things like soil moisture, nutrient concentrations, or animal activity. The breadth of applications for sensors within society demonstrates their importance in the modern world. As societies move faster and faster, sensors provide rapid measurements of important parameters.

Sensors are devices that measure some sort of physical property. For example, a lot of smartwatches can measure physical properties like heart rate or the number of steps taken. The measurement of physical properties is important because those measurements drive information or action. For example, wearers of those smartwatches may use those measurements to make decisions about their fitness routines. In agriculture, sensors measure various physical properties of a farm, field, or animal that help drive management decisions. Sensors are critical to the advancement of **precision agriculture** because they allow: 1) more measurements to be taken; 2) at a faster time scale; and 3) at a lower cost. These attributes of sensors are also what has made their expansion into society so prevalent.

One of the major advantages of sensors is that their measurement time is nearly instantaneous. Agricultural sensors like moisture monitors can continuously report on soil moisture measured in milliseconds, whereas traditional measurement of soil moisture requires time and labor to collect, weigh, and dry a sample. Providing data instantaneously, or in "real-time", allows a more precise capacity to respond to measurements

Types of Sensors

Within agricultural systems, a variety of sensing approaches are used. These approaches, in turn, drive a variety of decision-making options that have not historically been possible. Although not an exhaustive list, an example of some types of sensors, the types of measurements they collect, and how they inform decisions is provided below:

Location Sensors use GPS data to determine the exact locations of equipment, crops, animals, etc. Location sensors on equipment like drones and tractors allow for autonomous operation. Location sensors on animals can provide useful data about the animal's motion or behavior.

Figure 1: A tractor's GPS readout and controls "GPS Steers The Tractor" by cogdogblog is marked with CC0 1.0.

Optical Sensors use light to measure soil properties. Soil's ability to reflect light provides data about the moisture, texture, and organic matter of the soil.

Electrochemical Sensors use electrodes, like those found on the ends of batteries and starter battery cables, to determine pH and soil nutrient levels. Soil pH measures how acidic or alkaline the soil is, an important metric because plants can prefer different soil environments.

Figure 2: Ground penetrating radar measuring soil composition. "Ground Penetrating Radar" by Travis S. is licensed under CC BY-NC 2.0.

Mechanical Sensors measure soil compaction by determining the **resistive force** of the soil. A high resistive force means that the soil is compacted. Compacted soil means that less oxygen passes into the soil, less water drains into the soil, and the roots of crops must exert a larger force to penetrate the ground. Similarly, mechanical sensors are used to determine the pulling requirements of ground equipment like plows, harrows, and spreaders.

Airflow Sensors measure how well air can spread through soil. Airflow sensors produce information about soil compaction, moisture levels, and soil type.

Agricultural Weather Stations are usually a combination of sensors that provide information about ambient temperature, relative humidity, indicators of rainfall, wind speed, wind direction, etc. Several of these stations are placed throughout a growing field, and the data is compiled and sent to one central program. Agricultural Weather Stations are the most practical sensors for farms due to their low cost and mobility.

Figure 3: An agricultural technician checking weather data. "Weather Stations Synthesize Data for Individual's Needs" by USAID_IMAGES is licensed under CC BY-NC 2.0.

Sensors in Systems

Although sensors are an important component of precision agricultural systems, their job is primarily measurement. That means that sensors must work as part of a broader system to support decision-making. Specifically, the data from a sensor must be communicated to the device (or human) responsible for making decisions. In the example of the "clap-on" light, the audio sensor must send the audio data detected to the light switch. The light switch then responds to that data by changing from off to on. Similarly, in an agricultural application, a soil moisture sensor must send the data to the farmer, who then makes a decision about irrigation needs for that field. As a result, sensors are critical team players in technology systems, but they are not responsible for actions within those systems.

Sending data from a sensor to a decision-maker requires connectivity. There are lots of different types of connectivity. For example, data from sensors can be sent via the internet. Similarly, communication technologies such as cellular networks or Bluetooth can be used to send data from sensors. In practice, this connectivity means that a manager can know the status of the land, animals, buildings, etc. from anywhere in the world.

One major challenge with sensor-based decision-making is related to the reliance of sensors on connectivity. Specifically, sensing data over the internet or connectivity technologies like cell phones and Bluetooth provides greater vulnerabilities within the system. Imagine that the data coming from a soil moisture sensor was hacked to show adequate moisture during a period of drought.

Connection to Cyberbiosecurity

Sensors can provide a lot of data about a farm's operation. However, **data literacy** and a little research are required to use the data productively. For example, a sensor could reveal that the soil compaction in an area is high. It is up to the farmer to decide what to do with that information. They could conclude that the area is unsuitable for farming, or they could use a different farming technique to decrease soil compaction.

The data produced from sensors could be used to harm a farm, so it should be protected. For example, let's suppose that an autonomous drone was hacked. The hacker could use the drone to determine the size and location of everything in your farming operation, information that is valuable to competing farms. Also, that hacker could use the drone to disrupt other processes around the farm, such as disturbing animals when they are sleeping. If the drone was doing a task like spreading fertilizer, the hacker could use the drone to commit **bioterrorism** in the local area. These are just a few examples of a sensor cyberattack. Innovators in the cyberbiosecurity field will be challenged with trying to protect a farm's entire technological space.

Glossary

Biometric: Involving the automated recognition of individuals by means of unique physical characteristics, typically for the purposes of security.

Bioterrorism: The intentional release or dissemination of biological agents, typically to cause fear or violence, for political purposes.

Data Literacy: The ability to read, understand, and communicate data.

Precision Agriculture: Technology that maximizes the efficiency of a farm but is not critical to farm operations.

Resistive force: A physics term used to describe a force that is in the opposite direction of motion. Gravity pulling a thrown ball back down and the friction of sliding a box are two examples of resistive force.

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9: Biosecurity

Authored by David Smilnak, Rebekah Miller, Jaylan Day, and Dr. Hannah H. Scherer

What is Biosecurity?

Have you considered that plants and animals can get sick? Just like humans can get sick and feel unwell, there are viruses, bacteria, fungi, and toxins that can make plants and animals sick in their natural environment and on the farm. Fortunately, there is a field of study focused on protecting those plants, animals, and humans from viruses, bacteria, fungi, and toxins to keep everything and everyone healthy in the process. Biosecurity refers to the prevention of the spreading of harmful pathogens and pests to humans, animals, plants, and the environment. Generally, biosecurity focuses on bacteria, viruses, fungi, and toxins, but in agriculture, it can also include pests and **invasive plants and animals**.

What do you do to avoid getting sick? You'll probably say things like washing your hands or wearing masks. This is biosecurity! Since plants and animals can't wash their hands or wear masks, we need to get a little more creative. Biosecurity measures can fit into three areas: physical security, personnel reliability, and information security. Committing to washing your hands when you visit a farm is an act of biosecurity, just like wearing a hazmat suit is a biosecurity measure to prevent contamination at a lab.

Biosecurity in Animal Science

Raising animals for agriculture often includes housing a large number of the same type of animal in the same area. Examples can include a chicken coop, a horse stable, or a dairy farm. When a group of the same animal shares a common space, there is a higher chance for disease to spread. This chance is further increased if living conditions for those animals become unsanitary. We can prevent hazardous conditions by using structural and operational strategies to limit the ability of pathogens that are introduced and spread.

Figure 1. Chickens in a poultry habitat. mcf-poultry-farming-2 by Mully Children's Family is licensed under CC BY-NC-ND 2.0.

Examples of structural biosecurity include the proper cleaning and maintenance of animal pens and equipment. Regular cleaning and maintenance of stables, coops, fences, milking equipment, and feeding areas, among other examples, help protect the animals. Maintaining the facilities protects the animals by keeping them free of injuries and removing potential **vectors** that could spread disease.

Creating standard procedures for personnel and livestock activities also helps secure the farm. Bacteria, viruses, parasites, and fungi can be easily transported to and from the farm by the people who work there and the animals that live there. New additions to the herd or flock may already be sick, and employees may unknowingly have some sort of pathogen hidden in the mud on their boots. This is why procedures like quarantines for new animals and washing stations for visitors are important. Depending on the farm, there may be special protocols to follow. For example, poultry farms are particularly susceptible to diseases like **strains** of the bird flu. So visitors and employees may be asked to wear booties on their shoes and a sanitation suit like you would see in a laboratory.

Figure 2. A woman in a clean suit. "Dress like a scientist in our clean suits (19889555815)" by Science and Technology Facilities Council is licensed under CC BY-SA 2.0.

Biosecurity in Plant Science

Like people and animals, plants can catch diseases. For example, cedar-apple rust is a common fungus that can cause damage to apple trees. Cedar-apple rust is spread by the wind from tree to tree. However, other diseases, including blights and rots, which can also be caused by bacteria or fungi, can be spread through insects, soil, animals, and water. While animals can be moved away from areas infected with pathogens or pests, plants usually cannot. This means pests like nematodes and insects like armyworms need to be managed carefully.

Farms often use similar structural and operational strategies to ensure biological risks are managed. Structural strategies may include using a fence, greenhouse, or barn to separate fields, herds, or equipment. Operational strategies may include cleaning equipment between uses to prevent the spread of soil carrying diseases and pests.

Plant biosecurity needs to consider invasive species as well. Invasive species, which use the same methods of transmission as native species, may have fewer natural enemies or resistance to standard control measures. Japanese cedar-apple rust, for example, is a disease caused by an invasive fungus. The disease behaves very similarly to the native cedar-apple rust, but it spreads easier on different trees. Controlling Japanese cedar-apple rust requires different procedures than previously needed, such as changing what trees should be planted near each other.

Figure 3. Apple rust-infected leaf. "Rose apple rust caused by Puccinia psidii" by Plant pests and diseases is marked with CC0 1.0.

Another example of a biosecurity procedure in plant science is the effort to combat the spotted lanternfly. The spotted lanternfly is an invasive insect species from China and is a serious threat to Virginia’s fruit and tree industries. The Virginia Department of Agriculture and Consumer Services has been implementing procedures like quarantines to limit the spread. Other measures include setting up a monitoring program and encouraging everyone to kill the insect if they see it.

Figure 4. A flying spotted lanternfly. "Spotted Lanternfly, back_2017-06-16-16.50" by Sam Droege is marked with Public Domain Mark 1.0.

Laboratory Biosecurity

Laboratory biosecurity is focused on preventing the release of biomaterials in a laboratory setting. Laboratories all around the world work with pathogens to better understand how to combat them. This includes viruses like the flu, Japanese cedar-apple rust, and even national security interests like anthrax.

While some threats are worse than others, laboratories introduce structural and procedural measures to prevent the spread of these pathogens. Structural measures may include fences, limited access areas, data encryption, and a variety of passwords and key codes to enter the facility. Procedural biosecurity efforts include using personal protective equipment like gloves, hazmat suits and goggles, clearance and approval processes, and appropriate storage of dangerous chemicals. All of these biosecurity measures will vary in importance depending on the type of work completed in the laboratory.

Link to Cyberbiosecurity

As the world becomes more digital, the gap between biosecurity and cybersecurity is becoming narrower. Tasks that were once conducted by a technician in a lab are now automated and run by computers. The use of computers, **artificial intelligence**, and advanced algorithms in labs means that there is more data than ever to protect and more points for **cyber-physical attacks.** The same is true on the farm. As automation and digital processes become more common, there is a greater chance for errors to go unnoticed or for malicious actors to disrupt operations. Considering cyberattacks and their impacts on biosecurity is an important approach to strengthening security. Cyberbiosecurity can help fill the small gap between biosecurity, cybersecurity, and cyber-physical security.

Glossary

Artificial intelligence: Advanced computer systems that can perform tasks equally well or surpass that of human intelligence.

Cyber-physical attacks: A security breach that occurs in cyberspace but has influence in the real world, e.g., a hacker turning off a machine.

Invasive plants and animals: A nonnative organism, such as a plant or insect, that causes ecological or economic harm to a region.

Strains: A variety of bacteria. A recent example is the COVID-19 strains, which include Omicron, Delta, and Alpha, among others.

Vectors: An organism that spreads disease, parasites, or other harmful pathogens to another organism.

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Glossary

Acetone: A chemical solvent often found in nail polish remover.

Agricultural system: A set of interacting and interdependent components that work together to achieve the overall purpose of producing crops and raising livestock to produce food, fiber, and energy.

Agronomist: an expert in the science of soil management and crop production.

Antibiotic: A medicine that kills or prevents the growth of pathogens.

Artificial Intelligence: Advanced algorithms that receive input and alter their behavior similar to the way the human brain works.

Automated: carried out by machines or computers without needing human control.

Automated: carried out by machines or computers without needing human control.

Big Data: Data sets that are increasingly large and complex, in which we can find helpful trends that would not otherwise be apparent.

Biomanufacturing: A process that produces commercially relevant biological materials.

Biometric: Involving the automated recognition of individuals by means of unique physical characteristics, typically for the purposes of security.

Biosecurity: Procedures intended to prevent the introduction and/or spread of harmful organisms in order to minimize the risk of transmission of infectious diseases to people, animals, plants, and the environment caused by viruses, bacteria, or other microorganisms.

Biotechnology: The application of biology to an industrial process.

Bioterrorism: The intentional release or dissemination of biological agents, typically to cause fear or violence, for political purposes.

Bolting: when a plant grows flower stalks and produces seeds too early to produce a good harvest.

Butanol: A chemical solvent often used with paint, lacquer, and other coatings.

Computational Science: The art of creating mathematical models of a scientific process.

Controlled variable: a variable that is not changed (held constant) in a study.

Cyber-physical attacks: A security breach that occurs in cyberspace but has influence in the real world, e.g., a hacker turning off a machine.

Cyber-Physical Security: Protection of physical and engineered systems whose operations are monitored, controlled, coordinated, and integrated by a computing core. Examples of cyber-physical systems include modern automobiles and medical devices.

Cyberbiosecurity works to identify the weak spots between biosecurity, cybersecurity, and cyber-physical security to help safeguard our data and our systems

Cyberbiosecurity: Efforts to identify and minimize the weak spots between biosecurity, cybersecurity, and cyber-physical security to help safeguard our data and our systems.

Cybersecurity: Protection of computer systems and networks from the theft of or damage to their hardware, software, or electronic data, as well as from the disruption or misdirection of the services they provide.

Data Literacy: The ability to read, work with, analyze, and communicate measures or records in context.

Data security: Protection of data from theft or manipulation.

Data storage: use of technology to keep data using computers or other devices.

Data: information gathered by the observation of people, things, or objects and can measure quantities, traits, or characteristics.

Dependent variable: the variable that responds to changes and is measured by the researcher

Digitization: Adaptation of a system, process, etc. to be operated with the use of computers and the internet.

DNA testing: use of DNA profiles to determine parental relationships. Commonly used in the livestock industry for documenting pedigree.

Enzyme: A molecule that speeds up a chemical reaction.

Ethanol: Chemical responsible for drinking alcohol. It is also used as an antiseptic, medicinal solvent, and fuel for transportation.

Fertilizer: a substance added to soil to increase its fertility.

Foliage: leaves of a plant, typically a mass of leaves

Food safety: the practices and conditions and that ensure the quality of food to prevent contamination and food-borne illnesses.

Gene: A collection of DNA found in chromosomes that controls what characteristics are passed on to a person, animal, or plant.

Genetic diversity: The total number of genetic traits possible in a population of organisms.

Germinate: to begin to grow from a seed.

Growing medium: the substance that plants are grown in.

Hydroponics: the process of growing plants in sand, gravel, or liquid.

Hydroponics: the process of growing plants in sand, gravel, or liquid.

Independent variable: the variable that is changed by the researcher.

Intellectual property: A unique idea that someone could apply for protected rights.

Internet of Things (IoT): The connectivity between different computers, sensors, products, and processes via the internet.

Invasive plants and animals: A nonnative organism, such as a plant or insect, that causes ecological or economic harm to a region.

Leaf: flat green blade growing out from the stem; main site of photosynthesis.

LiDAR: A detection system that works on the same principle as radar, recording the amount of time between an emitted electromagnetic wavelength and receiving its reflection to measure distance, but uses light from a laser.

Macronutrients: elements that are essential for plants that are needed in large amounts.

Microchipping: implanting a microchip under the skin of an animal as a means of identification. Microchips store electronic information such as identification numbers.

Micronutrients: elements that are essential for plants that are needed in small amounts.

Mutant strains: A naturally occurring variation of a cell, pathogen, or virus.

Nitrogen cycle: the processes that move nitrogen through the atmosphere, soil, water, plants, animals and bacteria in a repeating cycle.

pH: a number representing how acidic or alkaline a solution is.

Phishing Scam: A type of online scam that targets consumers by sending them an e-mail that appears to be from a well-known source—an internet service provider, a bank, or a mortgage company.

Precision Agriculture: A farm management technique that uses observations and measurements to optimize production.

Ransomware: a type of malicious software designed to block access to a computer system until a sum of money is paid.

Reliability: consistency of a measure; if you measure the same thing in the same way, do you get the same result?

Resistive force: A physics term used to describe a force that is in the opposite direction of motion. Gravity pulling a thrown ball back down and the friction of sliding a box are two examples of resistive force.

Stakeholders: A group of people or entities that affect the success or failure of a business.

Stem Cells: Cells in people, plants, and animals that go on to become specialized cells in the organism like skin cells, liver cells, reproductive cells, blood cells, etc. They are the first stage of cell production.

Strains: A variety of bacteria. A recent example is the COVID-19 strains, which include Omicron, Delta, and Alpha, among others.

Traceability: the ability to find information about where and how a product was made.

Validity: accuracy of a measure; do the results actually represent what they are supposed to?

Variety of data: The different types of data, i.e. spatial, temporal, discrete, and continuous.

Vectors: An organism that spreads disease, parasites, or other harmful pathogens to another organism.

Velocity of data: The speed at which we create, process, and receive data.

Volume of data: The amount of data produced and/or available for analysis.

Water soluble: able to be dissolved in water.

About the Contributors

My name is ***Jordan Allen*** and I am from New Jersey. I hold a bachelors and master's degree in food science and technology. I am currently a Senior Chemist at Ingredion and my research specializes in plant protein characterization. With a strong commitment to data accuracy, my work is vital for understanding plant protein properties and applications. Recognizing the risks of compromised data, my research contributes to both cyberbiosecurity and the field of sustainable food technology while merging scientific insight with data integrity for a more secure and informed future.

My name is ***Sabrina Amorim*** and I am an Animal Scientist with MSc in Genetics and Animal Breeding, and currently a Ph.D. Student in the School of Animal Sciences at Virginia Tech. My research interest includes quantitative genetics and image analyses of high-throughput phenotyping data. I am interested in better understanding the genetic architecture of economically important traits in livestock and applying and developing statistical methods for prediction in the multi-omics era.

My name is ***Erika Bonnett*** and I am a 4-H Program Development Specialist with Virginia Cooperative Extension. I am passionate about creating STEM learning experiences that create career pathways into STEM careers. I started this work during my Ph.D. in Technology with my Dissertation on *"The use of sustained experiences in 4-H Fluid Power Education to Influence STEM Perception of Middle School Youth."* Other areas of research and engagement focuses are on vulnerable populations, girls in STEM, learner centered curriculum development, and educational technologies.

My name is ***Shannon Bradley*** and I am a drone pilot with a master's degree in entomology. I use precision technology, like drones, to monitor agricultural and urban landscapes. The use of precision technology needs cyber security for the data that is collected and how it is used. I am excited to use precision technology to highlight potential pollinator habitats in unexpected places.

My name is ***Anne Brown*** and I'm an Assistant Professor at Virginia Tech. I have a PhD in Biochemistry and work in the field of computational biology and applied biological data science. My work involves working with big data sets to understand how atoms move, how biological mechanisms happen, and how trends impact data impact systems. I work with faculty from all over the Virginia Tech campus for their data needs and with partners at other universities. I work with lots of students and like to teach about how to work with data and make it useful for your life, no matter what discipline. I enjoy teaching others about data, technology, and problem-solving. I hope my contribution to this project encourages students and teachers to bring more data into their classroom and use it to make agricultural decisions.

I am ***Ambrosia Church*** and currently teach Agriculture Science at a middle school in Shenandoah County, VA. I currently have more female students than males and while I still see many rural students, more and more students are looking at how they can be part of the agricultural community while not on a farm. I am excited to see what creative sparks the resources developed in this project can create in my students and hope to see an increase in program involvement because of it.

My name is ***Susan Campbell*** and I am an Assistant Professor in the School of Animal Sciences at Virginia Tech. As a Neurophysiologist, the focus of my research is to understand mechanisms involved in abnormal communication between brain cells that causes neurological disorders in agricultural and biomedically-relevant animal models. In particular, I am interested in neurological disorders in animal models of epilepsy. The goal of my research is to define novel molecular mechanisms and identify potential therapeutic targets to treat epilepsy. One of my current endeavors is to understand how the bacteria in our gut can contribute to seizures. The most fascinating technique used in the lab involves recording the electrical activity in live brain cells.

My name is ***Jaylen Day*** and I studied Polymer Chemistry and Chemical Engineering during my time at Virginia Tech. I'm currently a Cyber Warfare Technician for the United States Navy. I'm undergoing training at the Information Warfare Training Command in Pensacola Florida.

My name is ***Tiffany Drape*** and I am an Assistant Professor in Agricultural, Leadership, and Community Education at Virginia Tech. I investigate issues of equity and access in agriculture and the life sciences. My research revolves around formal and informal education, cyberbiosecurity in agriculture and the life sciences, and inclusive pedagogy.

My name is ***Sally Farrell*** and I'm a 4-H Extension Agent in Craig County. I work with many of the kids in my county. Some of my job activities are teaching science to 4th and 5th graders, helping run my 4-H clubs, helping coach a FFA stockman's team, taking about 60 kids to 4-H camp every year, and teaching archery in the schools. I raise sheep so I try to encourage kids to show sheep, I even have 3 of my lambs at 4-H Camp for the summer!

My name is ***Alexis Hamilton*** and I'm an assistant professor at Virginia Tech. I work on research projects and extension activities across Virginia, including projects that blend science with education - like this educational activity you're reading about! My work in the lab focuses on keeping the foods we eat safe from contamination from bacteria that make us sick after eating them. These are called foodborne pathogens. When I am not in the lab, I am educating people about food safety practices, helping food companies make safer food, and collaborating with food safety professionals across the country to develop research ideas and educational materials. I hope my work on this project helps you see that science is for everyone, and you can use the science you've learned here to be a smarter consumer!

My name is ***Kate Hawkins*** and I am a middle school agriscience teacher at James Wood Middle School in Frederick County Virginia. I teach 6th through 8th grade students and am the advisor for the FFA chapter. I have worked on *Initiating the Rural Cyberbiosecurity Workforce Pipeline Through Empowering Agricultural Educators and Supporting Middle School Girls* as a voice to guide the curriculum to meet the needs of middle school students and teachers. The best part of my job as a middle school agriculture teacher is working with 6th graders and experiencing the excitement and enthusiasm they have with their first experiences in a CTE classroom. I joined the project to help connect my non-traditional diverse students with the opportunities that agriculture can provide.

My name is ***Rebekah Miller*** and I have always had a strong interest in food including cooking, eating, and learning about all types of food. My interests led me to food science where I have continued to learn and grow in a variety of topics including food defense, biosecurity, and cyberbiosecurity due to their growing importance in the food industry. I currently work as a food scientist with my research focus being flavor and aroma of edamame, also known as vegetable soybean. I am looking forward to a career that combines my various interests and skills connecting to food science and the food system.

My name is ***Claire Murphy*** and I am a graduate student at Virginia Tech in the department of Food Science and Technology. My research projects focus on improving the safety of the environment that fruits and vegetables are grown in, including soil and water. I also enjoy analyzing data in order to interpret and communicate meaningful patterns that exist in data in order to help others in decision-making. I firmly believe that science is for everyone!

My name is ***Morgan Paulette*** and I'm the Agriculture and Natural Resources Extension Agent in Pulaski County. I work with farmers, landowner, homeowners, and youth; providing them with evidence-based information that will help them in their operations. With a needs-based approach, I focus much of time and efforts on livestock and forage production, as these are important parts of our local agricultural economy.

My name is ***Hannah H. Scherer*** and I am an Associate Professor and Extension Specialist at Virginia Tech. I am interested in how to make education more interesting and relevant to learners. In this role, I get to work with teachers, students, 4-H agents, and lots of other folks to try out new ideas for lessons and collect information to understand what works and what doesn't. As part of this work, I was fortunate to be able to direct the *Initiating the Rural Cyberbiosecurity Workforce Pipeline Through Empowering Agricultural Educators and Supporting Middle School Girls* project and help make everything happen.

My name is ***Joe Simpson*** and I am the Director of the Integrated Security Education and Research Center (ISERC). I study how security affects decision-making in corporations and among executives. Basically, I look at how organizations focus their efforts around protecting their assets and whether doing so makes them engage in more or less risk-taking. I also examine how certain types of knowledge problems (like uncertainty) affect organizational outcomes (like acquisition success). Fun fact about me: I had fun once, it was the worst experience of my life. Kidding! I enjoy watching my daughter play soccer and my New Orleans Saints winning the Super Bowl for the 1,229th time! I hope that the resources developed in this project make this topic one that appeals to anyone and everyone. It isn't just all boring stuff.

My name is ***David Smilnak*** and I'm a Ph.D. student at Virginia Tech. I work as a graduate assistant working on a couple of projects one of which is the Initiating the Rural Cyberbiosecurity Workforce Pipeline Through Empowering Agricultural Educators and Supporting Middle School Girls. My work involves individual research towards my dissertation as well as writing papers, giving presentations, and coordinating groups of people for those projects. Generally, I'm working with graduate students and faculty members at Virginia Tech, or agricultural professionals including teachers, Extension Agents, and farmers. I enjoy the different types of people I get to work with and occasionally I get to go to a farm as well!

My name is ***Laura Strawn*** and I'm an Associate Professor and Extension Specialist in the Food Science and Technology Department at Virginia Tech. My research and extension program focuses on reducing foodborne pathogen contamination throughout the supply chain. To do this, I use both field and laboratory experiments in my program. Discovery from these projects is disseminated directly to the public through different education and outreach activities. My program empowers individuals to make risk-based decisions for their operations by providing them with science-based information and practical solutions to limit contamination events. Fun facts about me: I am a Mom of two boys and three dogs. I also love to play tennis, video games, and binge watch TV shows. I hope you find the outcomes of this work interesting… You too can wear many hats and do so many fun things from being a scientist, animal lover, super friend, TV-hobbyist, recreational tennis player, among others (endless possibilities)!

My name is ***Dan Sturgill*** and I am an Agricultural Education Instructor at Marion Middle School in Marion, VA. I teach 6th, 7th, and 8th grade students. I am very passionate about the subject that I teach.

I am ***Cindy Vance*** and currently a middle school Agriscience teacher in Augusta County, VA. I have a large percentage of female students and am excited for them to learn about what may be available for them after graduation in the field of Agriculture.

My name is ***Karen Vines*** and I worked on this project as an Assistant Professor and Continuing Education Specialist in Agricultural, Leadership, and Community Education at Virginia Tech. My role was to work with the Advisory Board to ensure that their expertise and experience helped make this project and the resources we developed are effective.

My name is ***Donna Westfall-Rudd*** and I am an Associate Professor at Virginia Tech. My passion is supporting pre-service teachers and extension educators, secondary agricultural teachers, and future university faculty in developing their student-centered teaching practices in the context of agriculture and community development. My contribution to this project was my leadership in developing the summit for participating secondary, postsecondary, and extension educators to engage in collaborative curriculum design initiatives. I am excited to see where these curriculum resources will be utilized and the middle school students who will experience instruction in cyberbiosecurity!

My name is ***Robin White*** and I am an Associate Professor in the School of Animal Science and the Associate Director of the Center for Advanced Innovation in Agriculture. I conduct research at the interface of animal agriculture, sustainable food production, technology, and data analytics. In my work, I use sensors and animal monitoring technologies to improve efficiency and sustainability of animals-source food production.

My name is ***Amy Whitten*** and I am a middle school agriscience teacher in Mecklenburg County Virginia. Working on the *Initiating the Rural Cyberbiosecurity Workforce Pipeline Through Empowering Agricultural Educators and Supporting Middle School Girls* has been a wonderful experience. My job in this project is to collaborate with the scientists and researchers to create relatable and enjoyable classroom resources for other teachers to use. All students learn best when they are interested in the subject matter. This project has allowed me to connect with fellow agriculture teachers, scientists, and researchers to create engaging lessons for educators to use in their classrooms.

	Classroom Activities			
SOL Area/Course	**Food System Vulnerabilities**	**Hydroponics Food Chain Safety**	**Livestock Tracking**	**Soil Nutrient Automation**
Computer Science (6th)	1) 6.6 The student will identify physical and digital security measures used to protect electronic information.	1) 6.6 The student will identify physical and digital security measures used to protect electronic information.	1) 6.6 The student will identify physical and digital security measures used to protect electronic information.	1) 6.10 The student will use models and simulations to formulate, refine, and test hypotheses.
Computer Science (7th)	1) 7.7 The student will identify existing cybersecurity concerns associated with Internet use and Internet-based systems and potential options to address these issues.	1) 7.7 The student will identify existing cybersecurity concerns associated with Internet use and Internet-based systems and potential options to address these issues.	1) 7.7 The student will identify existing cybersecurity concerns associated with Internet use and Internet-based systems and potential options to address these issues.	1) 7.8 The student will discuss the correctness of a model representing a system by comparing the model's generated results with data that were observed in the system being modeled.
Computer Science (8th)	1) 8.6 The student will evaluate physical and digital security measures used to protect electronic information. 2) 8.7 The student will identify impacts of hacking, ransomware, scams, fake vulnerability scans, and the ethical and legal concerns involved. Exclusion: Students do not need to implement solutions.	1) 8.6 The student will evaluate physical and digital security measures used to protect electronic information.	8.6 The student will evaluate physical and digital security measures used to protect electronic information.	8.10 The student will evaluate online and print sources for appropriateness and credibility.
Science (6th)	6.9 The student will investigate and understand that humans impact the environment and that individuals can influence public policy decisions related to energy and the environment.	1) 6.6 The student will investigate and understand that water has unique physical properties and has a role in the natural and human-made environment	6.9 The student will investigate and understand that humans impact the environment and that individuals can influence public policy decisions related to energy and the environment.	6.1 The student will demonstrate an understanding of scientific and engineering practices by asking questions and defining problems; planning and carrying out investigations; interpreting, analyzing, and evaluating data; constructing and critiquing conclusions and explanations; developing and using models; obtaining, evaluating, and communicating information.
CTE Professional Competencies	Demonstrate an understanding of information security. Includes: describing cybersecurity (e.g., risks, threats, vulnerabilities).	Demonstrate an understanding of information security. Includes: describing cybersecurity (e.g., risks, threats, vulnerabilities).	Demonstrate an understanding of information security. Includes: identifying various information types/formats (e.g., paper, electronic)	Demonstrate proficiency with technologies, tools, and machines common to a specific occupation.
8002-Intro. to Agriscience		1) 41. Describe the interdependency of agriculture and other segments of society, includes: tracing the flow of an agricultural product from the farm to the table (i.e., production, processing, distribution, and marketing) 2) 44. Identify basic requirements for plant growth and development.	1) 50. New agricultural engineering technologies (i.e., development, impact, application) 2) 45. Economic significance of various animals to the community	1) 44. Identify basic requirements for plant growth and development.

8003-Agriscience Exploration		1) 60. Explain the use of hydroponics and aquaponics in growing plants. 2) 39. Describe the relationship of agriculture to other segments of society.	1) 39. Describe the relationship of agriculure to other segments of society 2) 65. Describe new technologies in animal science	1) 39. Describe the relationship of agriculture to other segments of society. 2) 42. Identify soil compositions.
8004- Agriscience & Technology (36 weeks)	1) 77. Explore the food industry as it relates to agriculture, agriscience, and agribusiness.	1) 70. Discuss the importance of water to agriculture.	1) 37. Explore new and emerging technologies in agriculture and agriscience	1) 37. Explore new and emerging technologies in agriculture and agriscience. 2) 40. Perform an agriculture/agriscience experiment.
8074-Cybersecurity in Food and Agriculture	1) 45. Analyze the interdependence among the commercial facilities, financial services, and food and agriculture (FA) sectors. 2) 61. Compare food defense, food safety, and food security. 3) 52. Identify cybersecurity vulnerabilities and threats in animal production systems. 4) 53. Explain cybersecurity vulnerabilities and threats in animal systems related to health. 5) 78. Identify methods of distribution disruption.	1) 57. Identify cybersecurity threats and risks in water sources. 2) 58. Identify cybersecurity threats and risks related to power. 3) 61. Identify cybersecurity threats related to equipment. 4) 62. Propose methods to ensure equipment (e.g., drones) is resistant to cyberattacks.	1) 52. Identify cybersecurity vulnerabilities and threats in animal production systems 2) 53. Explain cybersecurity vulnerablilities and threats in animal systems related to health 3) 66. Describe the technologies used in precision agriculture and precision agronomics	1) 25. Examine aspects of financial responsibility within an industry/organization. 2) 56. Explain cybersecurity vulnerabilities in plant production systems.