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HUMAN HEALTH
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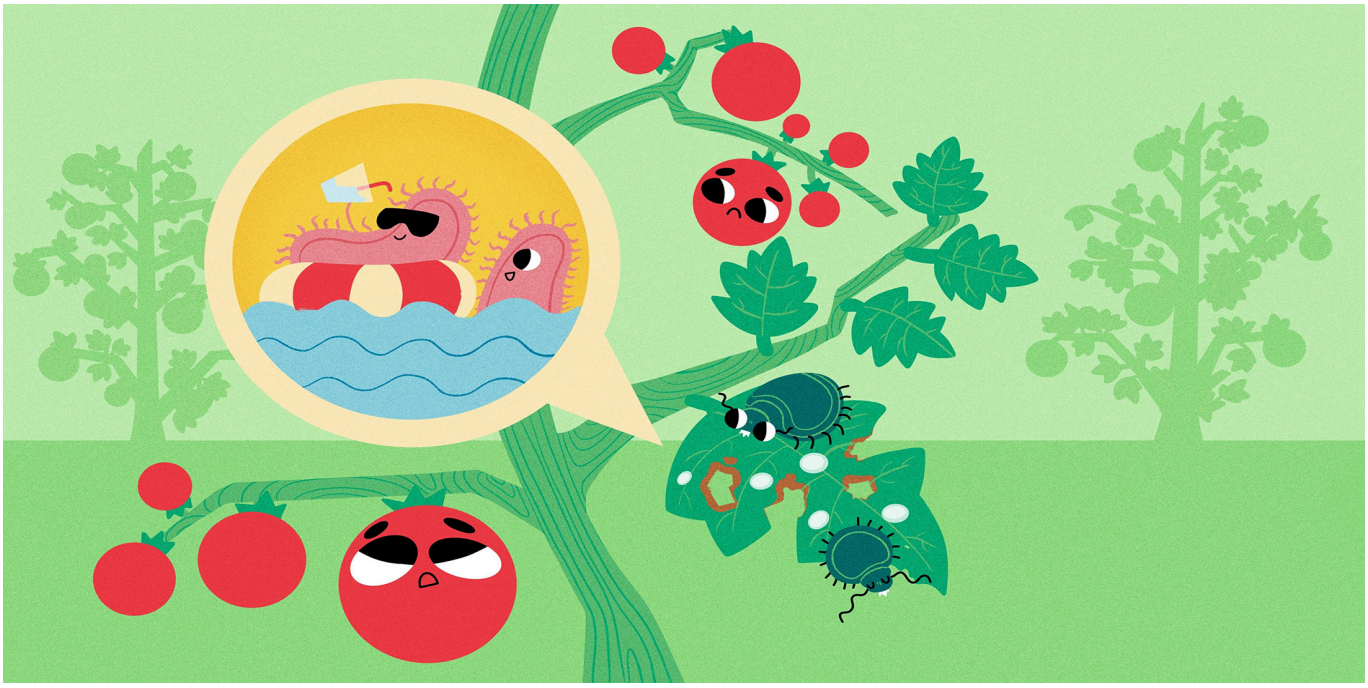

THE "FRIENDS" THAT HELP DANGEROUS BACTERIA GET INTO YOUR SALAD

Megan H. Dixon [1,2]***, Victoria L. Harrod*** [1,3,4]***, Russell L. Groves*** [4] ***and Jeri D. Barak*** [1*]

[1] *Department of Plant Pathology, Barak Lab, University of Wisconsin-Madison, Madison, WI, United States*
[2] *Microbiology Doctoral Training Program, University of Wisconsin-Madison, Madison, WI, United States*
[3] *Department of Entomology, Groves Lab, University of Wisconsin-Madison, Madison, WI, United States*
[4] *Entomology Department, University of Wisconsin-Madison, Madison, WI, United States*

YOUNG REVIEWERS:

IC-DE FILIPPO VICO, CLASS 1C

AGES: 11–12

IC-DE FILIPPO VICO, CLASS 1D

AGES: 11–12

SATYA

AGE: 15

Salmonella enterica is a type of bacteria that can cause vomiting and diarrhea in humans. Normally, *Salmonella* dies when it is on the surface of healthy plant leaves. However, *Salmonella* has "friends" on plants that can help it survive. Plant-eating insects and phytobacteria that cause plant diseases can help *Salmonella* reach new places and access new food sources. Plant-eating insects can move *Salmonella* from one plant to another and provide *Salmonella* with valuable nutrients through their poop. Phytobacteria can cause sicken leaves, creating an environment that helps *Salmonella* enter the leaf and access protection. Both plant-eating insects and phytobacteria can cause leaves to release nutrients that can nourish dangerous bacteria like *Salmonella*. Together, the combination of *Salmonella* and insects or phytobacteria on crops may create the perfect recipe for contaminated produce that leads to disease in humans when they eat their healthy fruit or veggies.

WHAT IS A FOODBORNE PATHOGEN?

FOODBORNE ILLNESS

Sickness caused by eating food that has been contaminated by a harmful pathogen.

PATHOGEN

Microorganism that sickens its host; different types can cause harm to humans, animals, and plants.

MICROORGANISM

Tiny organism such as bacteria, fungi, archaea, and viruses that can often be seen only with a powerful microscope.

GASTROENTERITIS

Illness of the stomach and intestines characterized by vomiting and diarrhea; can be caused by foodborne bacteria and viruses.

Have you ever gotten really, *really* sick from eating food? If you had vomiting, stomach pain, and diarrhea, it is likely that you have had **foodborne illness**. Foodborne **pathogens**, which are **microorganisms** that contaminate food, cause these illnesses and make us sick after we ingest them. Just to be clear, not all microorganisms are harmful. There are many microorganisms, including some bacteria within our bodies, that do not cause harm and are necessary for our health. However, some bacteria can cause humans to get sick. In this article, we focus on a type of bacteria called *Salmonella enterica* (*Salmonella*), which causes an intestinal infection called **gastroenteritis**. Several foodborne pathogens can cause gastroenteritis; the specific disease caused by *Salmonella* is called salmonellosis.

So how does *Salmonella* end up in the foods we eat? *Salmonella* commonly lives in the guts of animals such as cows, pigs, and chickens. Unlike us, these animals do not get sick from *Salmonella*. *Salmonella* can be transferred from the guts of animals to the parts we eat as food, such as hamburger patties, porkchops, and eggs. Most people are familiar with the connection between salmonellosis and animal products. However, it has become a lot more common nowadays for people to get foodborne illness from fresh produce like tomatoes, sprouts, and leafy greens [1]. Produce like tomatoes are grown in large fields, where *Salmonella* can exist naturally in the environment. All the steps between the farm field and your dinner plate—including growing in the field, crop harvesting, food processing, and meal preparation—can be chances for *Salmonella* to get into your food. In the worst situations, major outbreaks of foodborne illness can result in many people ill with salmonellosis. But how does *Salmonella* first arrive in agricultural fields where our fresh produce is grown and harvested?

Salmonella can live in lots of places; it is naturally found in water and soil and can linger in the environment for a long time without eating. *Salmonella* directly reaches our crop plants by leaving an animal's gut through poop, and it can then be transported by water. Contaminated irrigation water (the water used to grow crop plants) has been linked to outbreaks of foodborne illness [2]. During irrigation, water can spray or splash onto leaves and/or fruits, leaving *Salmonella* bacteria stranded on plants. Surviving on plants is hard for *Salmonella*, but the bacteria has "friends" that help it cope.

WHO ARE *SALMONELLA'S* FRIENDS ON PLANTS?

When *Salmonella* arrives on plants, life is stressful because there is no food. Imagine a stray cat wandering around. The cat is likely hungry, thirsty, and uncomfortable, and desperately wants food, water, and shade. Believe it or not, *Salmonella* has similar problems. Food is

scarce for bacteria on plants—the environment is dry, and the bacteria are bombarded by dangerous ultraviolet light from the sun [3]. Stray cats get help from human friends that offer food, water, and shelter. What kinds of friends will drop food scraps for *Salmonella*?

PHYTOBACTERIA

Microorganisms that live on plants; some types can be pathogenic to plants, causing disease.

Insects and **phytobacteria**, which are bacteria that live on plants, are commonly found in fields where our fruits and vegetables are grown (Figure 1). When insects or phytobacteria attack plants, they transform them into *Salmonella*-friendly environments. These plant attackers help *Salmonella* reach new locations and access nutrients. Without its "friends," *Salmonella* on plants would slowly die. Let us dive a little deeper into how these friends help *Salmonella*.

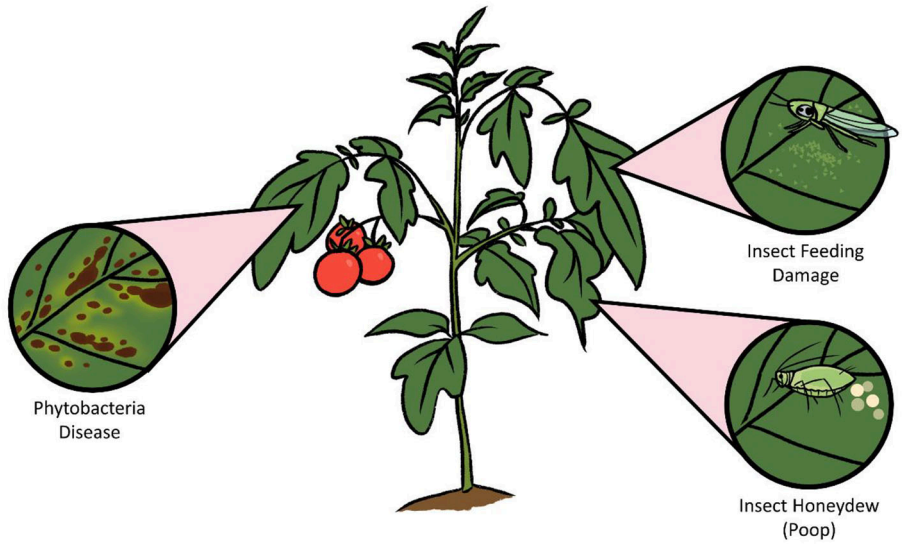

Figure 1

The crops we grow can be affected by insects and phytobacteria in the field. Insect feeding can result in visible damage to leaves, and honeydew (poop) left behind can make leaves sticky. Phytobacteria can cause brown spots and yellowing on leaves.

REACHING NEW PLACES

From those that pollinate to those that sting, insects are ever-present in our food systems. Insects move around easily and are capable of spreading bacteria. An insect that walks across a leaf contaminated with *Salmonella* can then walk over to new leaves, moving the bacteria from one leaf to another (Figure 2)—just like someone tracking mud all over your home after playing outside [4]! In addition to walking between leaves, insects can fly over wide distances, dispersing bacteria as they go. Imagine a field heavily infested by insects and recently irrigated with *Salmonella*-contaminated water. After the insects have explored and fed upon these *Salmonella*-contaminated plants, some may fly to a faraway field and spread *Salmonella* there, too.

The other "friends" of *Salmonella*, phytobacteria, are very common. Although many phytobacteria are not dangerous to plants, every plant has at least one phytobacteria that can sicken it (plants get sick too!). The diseases caused by phytobacteria can result in brown/dark green

Figure 2

Insects and phytobacteria help *Salmonella* move to new locations, and they create conditions on the leaf surface that help *Salmonella* to multiply. For example, *Salmonella* can eat nutrients present in honeydew and nutrients within a leaf water-soaked by phytobacterial disease. Image shows the cross-section (or side-view) of a leaf. Note that objects are not drawn to scale.

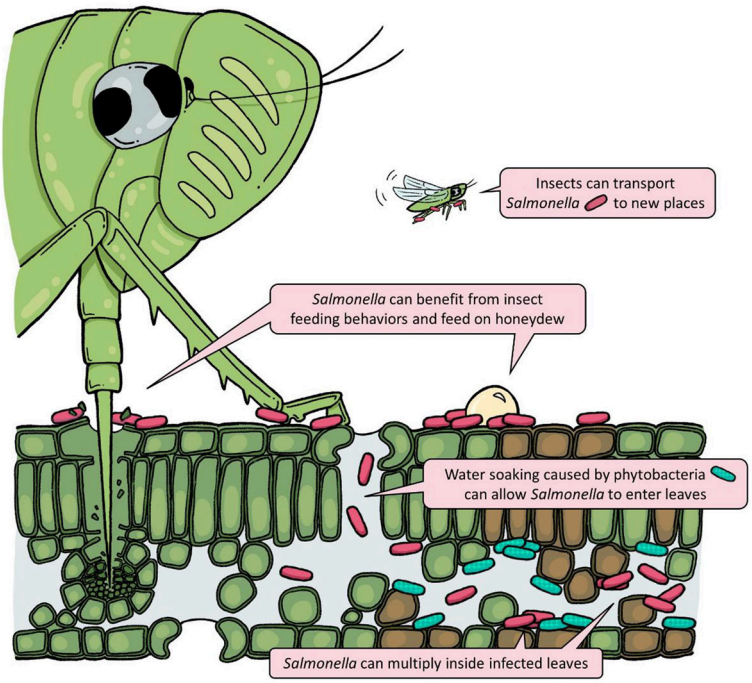

Figure 2

spots and yellowing on the surface of leaves, which are visible signs that phytobacteria may be causing a plant to be sick. Phytobacteria are very small—about 100 times smaller than the width of a human hair. However, despite their size, phytobacteria can cause big problems to crop plant, and they can help *Salmonella* move around by dramatically transforming a leaf into a wet environment (Figure 2) [5].

When some phytobacteria infect leaves, they cause water from the inside of the plant's cells to leak, creating a wet environment within the leaf interior—you can think of this as plant diarrhea! The water soaking caused by phytobacteria allows bacteria on the outside of the leaf to slide inside through natural openings in the leaf surface called **stomata**. These stomata serve as the entrance to a sort of "waterslide" that leads to an "indoor pool" created by the water soaking produced by phytobacteria. The distance that *Salmonella* can travel from the outside of a water-soaked leaf to the inside is quite small compared to the large distances that insects can carry bacteria. However, this change in scenery for *Salmonella* can make a huge difference. When *Salmonella* boards the waterslide and rides it into the fabulous, indoor pool, they are protected from harmful dryness and UV light and find a buffet of food.

STOMATA

Microscopic openings in the surface of leaves that are necessary for water vapor, carbon dioxide, and other gasses to enter and exit leaves; can utilized by bacteria to enter leaves.

SNACKS FOR *SALMONELLA*

How do insects and phytobacteria provide food for *Salmonella*? For some insects, it begins with feeding on the contents of

VASCULATURE

Network of tubes that carries water, minerals, and food through a plant's stems, roots, and leaves so it can grow.

a plant's **vasculature**, which includes the plant stem and veins that carry nutrients throughout a plant. Scientists have identified over a million insect species with all kinds of unique mouthparts. Leafhoppers use piercing-sucking mouthparts to reach into the plant's vasculature—think of pushing a straw through a juice box. Thrips, on the other hand, use their ripping-sucking mouthparts to destroy the surface of leaves and then feed on plant cell contents. With the inside of the leaf exposed, food is now available to bacteria that could not access it on their own (Figure 2). This opening in the leaf and cornucopia of available food gives *Salmonella* protection and a chance to grow, which increases the likelihood of outbreaks of foodborne illness [6].

HONEYDEW

Poop produced by insects that feed on the vasculature of plants; contains high amounts of sugar and looks like a clear droplet.

With eating comes pooping, and insects are no exception. **Honeydew** (not to be confused with the delicious melon) describes the watery poop produced by insects such as aphids and leafhoppers which only feed on the vasculature of plants. While feeding on the vasculature, insects filter out most of the sugars but some passes through them [7], making their poop as sweet as honey. It even looks like a morning dew drop. Unlike our own poop, insect honeydew does not go to waste. As it is high in sugars, insects (such as ants and bees) and bacteria like *Salmonella* consume it for food, which helps them to survive on leaves (Figure 2).

Phytobacteria do not leave sugary poop behind like insects do. Instead, they create a nutrient-rich environment. As phytobacteria make plants sick, along with creating a wet environment, they cause plant cells to leak nutrients everywhere! The phytobacteria lounging inside a leaf feast on the sugars and nutrients they caused to leak into the "indoor pool" they created for themselves. *Salmonella* does not cause plants to get sick, and it cannot construct a sugary, watery pool within leaves by itself. But if phytobacteria have already done that hard work and they are holding open the VIP door (stomata), *Salmonella* can enjoy all the benefits. When *Salmonella* reach the sugary insides of phytobacteria-infected leaves, they use the food to multiply, making more and more bacteria (Figure 2) [5]. More *Salmonella* can mean big problems...

HOW MIGHT THESE FRIENDS OF SALMONELLA AFFECT US?

Leaves infested with insects or infected by phytobacteria can support higher *Salmonella* populations compared to healthy plants (Figure 3). Higher *Salmonella* populations on produce increase the likelihood of foodborne illnesses. *Salmonella's* friends on plants—insects and phytobacteria—directly harm food production by reducing a farmer's harvest, and indirectly harm consumers by increasing the risk of salmonellosis.

Figure 3

Higher *Salmonella* populations increase the risk of salmonellosis outbreaks. Insect behaviors (such as feeding and pooping) and phytobacteria disease allow *Salmonella* populations to increase on plant leaves.

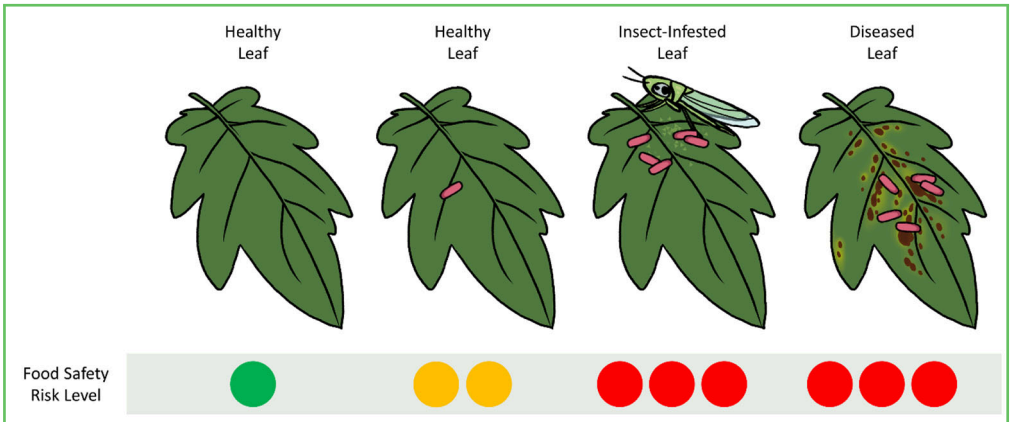

Figure 3

There is more than meets the eye when it comes to agricultural fields. Depending on where an insect lands or where a water droplet containing bacteria splashes, the perfect storm for outbreaks of foodborne illnesses can brew. Remember that outbreaks are rare compared to the tons of veggies that are harvested and show up on your plate, so we hope you continue to enjoy your favorite fresh fruits and veggies!

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

IC-DE FILIPPO VICO, CLASS 1C, AGES: 11–12
We are the students of the 1st C. Our class is composed of 18 pupils (seven girls and eleven boys). We all have different characters but we love each other. We are all very good friends, and in case of any problems, we always try to help each other. In class, we usually focus on the lessons, but sometimes we are a bit noisy! We like spending time together both at school and at home.

IC-DE FILIPPO VICO, CLASS 1D, AGES: 11–12
Class 1D is made up of Sixteen: 4 girls and 12 boys, who are between eleven and twelve years old. It is a living classroom but sometimes they can also be very kind and lovely. They study a lot of subjects and are very good at English. These pupils study a lot and they are always interested in new topics. They help each other whenever possible!

SATYA, AGE: 15

Satya is 15 years old and currently a sophomore in high school. She enjoys participating in Speech and Debate tournaments and playing Indian classical violin. From a young age, Satya has been interested in medicine and is always looking for new opportunities to gain experience in the health science field.

AUTHORS

MEGAN H. DIXON

Megan Dixon is a Ph.D. student studying microbiology. She enjoys learning about life sciences and examining how tiny things cause big problems. As someone who is passionate about food and public health, Megan hopes to use her microbiology knowledge to help improve food safety. She regularly makes time to knit, crochet, play guitar, and create artwork.

VICTORIA L. HARROD

Dr. Victoria Lason Harrod is a food safety consultant who specializes in insect's impact on foodborne outbreaks. Through her passion for agriculture and commitment to food safety, she is able to provide informed recommendations to farmers and food-related businesses for ways to improve their food safety practices. When she's not in the field or touring food processing facilities, you can find her exploring the local farmers market, playing video games, and baking cakes!

RUSSELL L. GROVES

Russell L. Groves is a Professor and Department Chairperson in the Department of Entomology at the University of Wisconsin-Madison. He has responsibilities for insect pests affecting commercial, organic, and fresh market vegetables. Research focuses on the development of integrated pest management solutions for vegetable crops emphasizing insect vector-borne disease, insect dispersal and movement, and insecticide resistance management. Elements of his research and extension program are available at the Vegetable Crop Entomology web-page and insect and disease risk for the State of Wisconsin is available through the Vegetable Disease and Insect Forecasting Network.

JERI D. BARAK

Dr. Jeri Barak studied several disciplines in biology and chose plant pathology for her career. She is intrigued by the complicated system that feeds us. She loves visiting farms and taking her observations back to the lab to tease apart food safety risk factors. She is a lifelong learner with a mind full of questions about the biology she sees in nature. Jeri is eager to share her knowledge with farmers to offer them real-world solutions and with consumers to help them make informed decisions. *barak@plantpath.wisc.edu