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HUMAN HEALTH
Published: 08 January 2024
doi: 10.3389/frym.2023.1182510

SALMONELLA: A STAR AMONG DISEASE-CAUSING BACTERIA TRANSMITTED BY FOOD

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AGES: 12–13

JACKSON
AGE: 12

Salmonella is an important type of bacteria capable of infecting humans and animals. These bacteria were discovered over 100 years ago, and thousands of types have now been identified. *Salmonella* can be found in many sources, and its pathway to causing disease in humans is a complex web. *Salmonella* can live in farm, wild, and domesticated animals; the environment; and water sources—all of which can contaminate food items and, in consequence, humans. The most frequent illness in humans is called salmonellosis, which is characterized by diarrhea, stomach cramps, fever, nausea, vomiting, and headache. Although most people have mild symptoms, a few cases may evolve into a more severe illness that may need medicines called antibiotics to treat. In this article, you will learn about the importance of *Salmonella*, as well as the challenges it poses for the future and promising scientific advances that will improve our knowledge of these bacteria.

WHAT IS *SALMONELLA*?

Salmonella are important bacteria that can cause illness in humans and can also infect wild and domesticated animals [1]. They belong to a large family of bacteria called *Enterobacteriaceae*, which is very important in the medical field due to its ability to infect humans. Under the microscope, *Salmonella* strains have a rod-like shape (Figure 1). They can survive and grow in the presence or absence of oxygen, and they use sugars as their energy source.

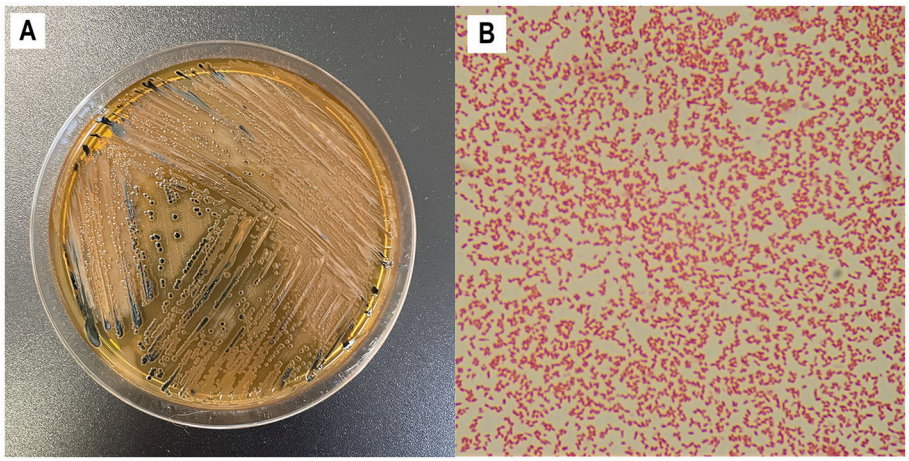

Figure 1

Figure 1

Growing and examining *Salmonella*. **(A)** *Salmonella* forms growth dots, called colonies, when it is grown on Jello-like substances, called agar plates. In this figure, you can see how *Salmonella* grows in *Salmonella-Shigella* agar. **(B)** Dyes can be used in a method, called Gram staining, to give *Salmonella* a pink/red color and allow it to be seen under a microscope. If you look closely, you can see the rod-like shape of each *Salmonella* cell.

Salmonella were first described back in 1884 by two scientists, Daniel Elmer Salmon and Theobald Smith, while they were studying the effects of a severe infection in the intestines of pigs. But it was not until 1900 that another scientist, Joseph Lignières, named these bacteria "*Salmonella,*" as a way to honor the studies of Daniel Salmon.

THE COMPLICATED CLASSIFICATION OF *SALMONELLA*

Salmonella have a really extensive and complex classification system [1]. They are divided into two species, called *S. bongori* and *S. enterica*. Both are commonly found in cold-blooded animals (such as reptiles) and in the environment. However, one of the six subspecies of *S. enterica* (which is *also* called *S. enterica*) is particularly important, as it can infect several warm-blooded animals, such as birds and mammals, including humans (Figure 2).

Scientists classify *Salmonella* using a method called **serotyping**. In the laboratory, we get a small scoop of the growing *Salmonella* bacteria and mix them with small drops of a substance called **serum**. These serums come from animals, and their molecules can bind to different structures present in the bacterial cell outer membrane. If the *Salmonella* react to specific combinations of serums, the bacteria are classified into a group called a **serovar** (Figure 2). Using this method,

SEROTYPING

A laboratory technique that uses serums that bind to surface structures of the bacterial cell to identify them. *Salmonella* are classified in serovars if they react to specific serum combinations.

SERUM

Liquid obtained from the blood of animals, which is rich in antibodies (molecules that protect against infectious and non-infectious agents).

SEROVAR

A group of bacteria classified as belonging to a specific type through the serotyping method, these types are called "serotype" or "serovar".

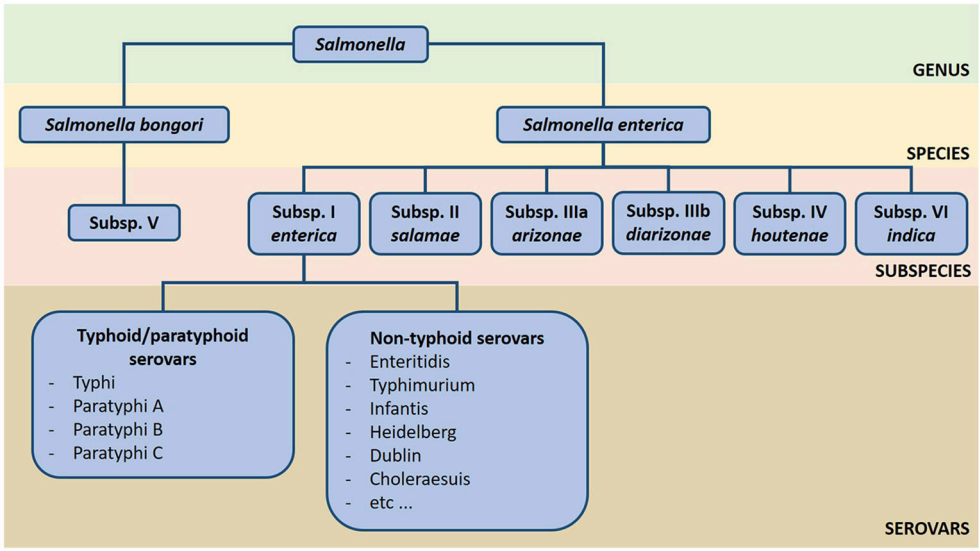

Figure 2

Figure 2

An overview of the extensive classification system of *Salmonella*. The genus *Salmonella* has two species, *S. bongori* and *S. enterica*, that can also be divided in seven distinct subspecies. *S. enterica* subspecies *enterica* is commonly found in warm-blooded animals (such as mammals and birds), while the other subspecies are more present in the environment and cold-blooded animals (such as reptiles). Subspecies *enterica* currently has more than 1.5 thousand serovars identified, which can be classified as typhoid/paratyphoid and non-typhoid serovars according to the two types of diseases they cause in humans: typhoid/paratyphoid fever and salmonellosis, respectively.

SALMONELLOSIS

Disease caused by non-typhoid *Salmonella*. The main symptoms are diarrhea, stomach cramps, fever, and sometimes nausea, vomiting, and headache.

scientists have identified and named more than 2.6 thousand serovars of *Salmonella* so far [1].

We can also categorize *Salmonella* serovars according to what illnesses they cause in humans: typhoid/paratyphoid *Salmonella* cause diseases called typhoid or paratyphoid fever, while non-typhoid *Salmonella* cause **salmonellosis** (Figure 2) [1]. The rest of this article will focus on the importance of non-typhoid *Salmonella*.

HOW ANIMALS AND FOODS ARE LINKED TO TRANSMISSION OF *SALMONELLA*

If you knew about *Salmonella* before reading this article, you most likely related it to eating contaminated raw meat or eggs. However, the dangerous relationship of *Salmonella* and food is bigger than we imagine, and it begins long before we are eating or cooking our food (Figure 3) [2].

Chickens are the main source of non-typhoid *Salmonella* among farm animals. However, pigs, cows, and turkeys have also been important animal sources of non-typhoid *Salmonella*. Their meat and related food products (such as ham, sausages, milk, and cheese) can be potential sources of the bacteria [2].

But how do these farm animals get contaminated with non-typhoid *Salmonella*? There are a number of ways. One of them is through the environment—but not only the natural environment. Farm environments and industry settings where meat and food items are produced can be sources of **contamination**, too. Some studies also show that animal feed (including the foods we give to pets) can be

CONTAMINATION

Undesirable elements or impurities that infect or corrupt materials, organisms, environments, etc.

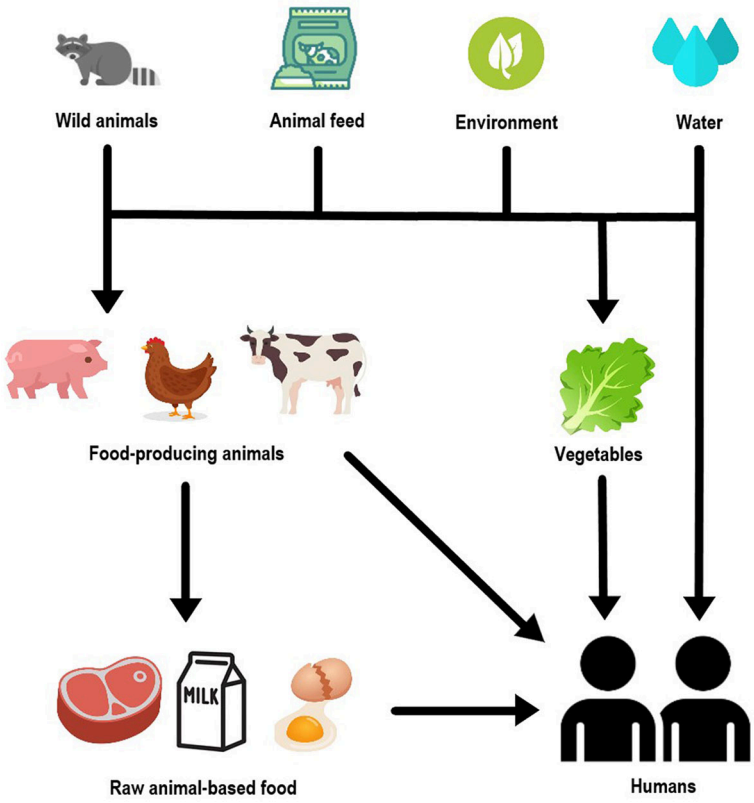

Figure 3

Non-typhoid *Salmonella* can move among humans, animals, and foods in various ways. *Salmonella* is mainly transmitted to humans by contaminated food, especially those of animal origin, but also vegetables and water. Food-producing animals can become contaminated with *Salmonella* through diverse sources, such as contact with wild animals, the environment, and contaminated water or feed given to these animals. Finally, it is also worth to mention that humans can get *Salmonella* after having contact with contaminated animals.

contaminated with non-typhoid *Salmonella* because some types of feed are produced with animal meat. In addition, contact with wild animals can also be a potential route by which farm animals can become contaminated. Wild animals and even insects have also been found to carry non-typhoid *Salmonella* [2].

We usually eat vegetables fresh, but if they are not carefully washed, vegetables can also be sources of non-typhoid *Salmonella*. Vegetables usually get contaminated water contaminated with bacteria is used to water crops, or they can get contaminated from the water used to clean them, if adequate cleaners are not used [2]. Farm animals (and people) can also get non-typhoid *Salmonella* by drinking contaminated water, and people can also get it through handling infected farm animals.

To prevent people from getting sick due to *Salmonella* in food, simple measures can be used. The U.S. Centers for Disease Control and Prevention (CDC) suggests that food be cooked to a minimum temperature of 145–165°F (~62–74°C), depending of the type. Eating raw or undercooked ("runny") eggs should be avoided. Perishable foods should be stored in the fridge, at temperatures under 40°F (~4°C). It is also important to use adequate cleaning methods for food and cooking instruments, and to practice good hand washing habits. You can find these and other useful information about *Salmonella*

and food at the CDC website, at https://www.cdc.gov/foodsafety/communication/salmonella-food.html.

SALMONELLOSIS: WHAT IT IS AND HOW TO TREAT IT

Salmonellosis is the main human illness caused by non-typhoid *Salmonella*. In the United States alone, the CDC estimates that 1.35 million infections, 26,500 hospitalizations, and 420 deaths occur every year. The World Health Organization (WHO) considers non-typhoid *Salmonella* to be one of the four main bacteria that cause diarrhea in humans.

The first symptoms usually appear 12–36 h after eating contaminated food, but this period may vary from as short as 6 h up to 6 days. The most classic symptom of salmonellosis is diarrhea, which is a watery, loose stool (poop), usually accompanied by stomach cramps and fever. In more severe cases, blood can also be present in the diarrhea. Nausea, vomiting, and headaches can also happen sometimes.

The symptoms are usually fairly mild and they generally last 4–7 days. Some people have cases with such mild symptoms that the infection even goes unnoticed. However, these bacteria can be found in the feces of infected individuals for several weeks after symptoms end. Most patients naturally recover by simply drinking a lot of fluids, which prevents dehydration caused by diarrhea.

Severe cases of dehydration can be especially concerning for children under 2 years old and for elderly patients. These cases can result in symptoms such as long-lasting diarrhea and vomiting, high fever (above 102°F/38.5°C), bloody stool, and dehydration indicators such as very little urine, dry mouth, and dizziness. In these severe cases, people should get medical treatment. They might need to receive fluids directly into their veins to become rehydrated.

A very small number of patients develop severe cases of what is called invasive salmonellosis. In these situations, the bacterial infection is not limited to the gut. Instead, *Salmonella* may infect the blood, the membranes surrounding the brain and spinal cord, and the bones and joints. Severe illnesses are more common in people with weakened immune systems, such as children under the age of 2 years, elderly people, people living with HIV, cancer, or autoimmune diseases, or people who take certain medications. In these cases, hydration alone is not enough to treat salmonellosis. Instead, **antibiotics** are needed to ensure a patient's survival.

ANTIBIOTICS

Drugs developed to kill or prevent the multiplication of bacteria in the human body.

You can find these and more information about the burden, disease, symptoms and treatment of *Salmonella* infections at the CDC (https://www.cdc.gov/salmonella/general/index.html) and WHO

[https://www.who.int/news-room/fact-sheets/detail/salmonella-(non-typhoidal)] websites.

THE FUTURE OF *SALMONELLA* STUDIES

The future of *Salmonella* studies may bring great advances but serious challenges [3, 4]. For example, as reported by the WHO and CDC, a growing number of bacteria now have **antibiotic resistance**, including *Salmonella*. Imagine this: a patient infected with *Salmonella* develops a serious illness, so doctors start treatment with antibiotics. However, the patient's condition does not improve, and suddenly their life is at risk. Sad and worrying, right? That is why antibiotic resistance is so concerning and must be prevented. New ways to understand and prevent the spread of bacteria causing disease in humans, as well as hard work to discover new antibiotics, are goals for the future [3].

ANTIBIOTIC RESISTANCE

The ability of bacteria to survive in the presence of antibiotics. Bacteria usually become resistant through changes in their DNA.

There is reason to hope that we will have ways to respond to dangerous *Salmonella* infections. Over the years, the study of bacterial DNA has taught scientists a huge amount about *Salmonella*, and even faster techniques are now available. Imagine how many questions might be quickly answerable when the entire DNA sequences of certain bacteria are in a computer file. Scientists could see whether a sample of bacteria is related to others already identified in other countries or time periods. They could investigate whether the bacteria have any genes that might make them resistant to antibiotic, or genes that might indicate the severity of the illness they will cause [4]. Such information will be very helpful to scientists and doctors.

FINAL REMARKS

Now you know why non-typhoid *Salmonella* are such important bacteria. Thousands of serovars capable of infecting humans and farm animals have already been identified. You also learned about the impact of *Salmonella* in food, and its spider web of transmission routes that includes humans, several types of food items, farm and wild animals, and various environments. Salmonellosis in humans is an illness with global impact, and it can vary from mild to severe. However, treatment of salmonellosis may be at risk due to increasing antibiotic resistance. Finally, we also briefly examined how new DNA technologies are helping scientist to understand *Salmonella*.

We hope that this article provided you with useful information about *Salmonella* that you can use in your daily life. Our even greater hope is that this information awakens your curiosity and inspires you to learn more about these bacteria. The challenges of the future are already happening, and we will need more curious and smart minds to help in our battle against *Salmonella*!

ACKNOWLEDGMENTS

This study was supported by a research grant from the São Paulo Research Foundation (Proc. 22/07013-0) under the supervision of JF. During the course of this work, FV was supported by a PhD student scholarship (Proc. 141017/2021-0) and JF by a Productive fellowship (Proc. 304399/2018-3 and 304803/2021-9) from the National Council for Scientific and Technological Development. This study was financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil—Finance Code 001.

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SUBMITTED: 08 March 2023; **ACCEPTED:** 19 December 2023;
PUBLISHED ONLINE: 08 January 2024.

EDITOR: Bergithe Eikeland Oftedal, University of Bergen, Norway

SCIENCE MENTORS: Marlene Santos and Alina Nico West

CITATION: Vilela FP and Falcão JP (2024) *Salmonella*: A Star Among Disease-Causing Bacteria Transmitted by Food. Front. Young Minds 11:1182510. doi: 10.3389/frym.2023.1182510

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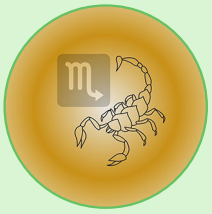
YOUNG REVIEWERS

FOUR INCREDIBLE MINDS, AGES: 12–13

We are called the ≪Four Incredible Minds≫, two of us are 12 and the other two are 13. In our free time, we like reading, going to the cinema, and hanging out with our friends. We are curious about the world and what is happening around it. We like being creative and we express it by having theater, music, and dance lessons. Adventure is our middle name, so we are always waiting for a new challenge.



JACKSON, AGE: 12

The beloved prince of his family, Jackson, is all about action! He loves to take on new, challenging, and exciting ventures. Jackson is an expansive thinker, interested in scientific inquiry and discoveries ranging from the solar system to human behavior to genealogy. He plays the trombone, listens to music, performs calisthenics, and enjoys the outdoors in his spare time

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Felipe Pinheiro Vilela is a Brazilian dental surgeon, with master's in sciences degree, and is currently a Ph.D. student at the School of Pharmaceutical Sciences of Ribeirão Preto, at the University of São Paulo. As a science lover since childhood, Felipe decided to graduate as a dental surgeon to fulfill his wish to take care of people's health. During the way, another passion showed up: microbiology. Since then, his research has mainly been based on the characterization of the genetic diversity, antimicrobial resistance, and virulence of serotypes of *Salmonella* in Brazil.

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Juliana Pfrimer Falcão is a Brazilian pharmacist with a master's and Ph.D. in sciences. She currently works as an associate professor at the School of Pharmaceutical Sciences of Ribeirão Preto, at the University of São Paulo. Since she graduated, Juliana has been working on research to better understand bacteria causing gut infections in humans. For over 17 years, following the steps of her dear scientist aunt, Juliana has been teaching microbiology for dentistry and pharmacy students. Also, in this period, her research mainly focused on the study of bacteria causing gut infections, such as *Salmonella*, *Campylobacter, Yersinia,* and *Shigella*.
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