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Experience and Science: A Brief History of Food Safety. The Role of Empirical Knowledge in the Development of Food Safety. Part I: Prehistory and Antiquity

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1. Summary

How did our ancestors know not to eat raw pork? Why have the Japanese been wary of eating fugu fish for centuries? Why are certain plants, such as yew berries, prevented from being eaten by both children and horses? How did the Ancient Greeks know that they were deliberately poisoning the fruit of the hemlock tree, for example by executing Socrates? Epidemic diseases caused by mouldy cereals have been a part of history for centuries. They are and have been frequently caused by mycotoxins produced by cereal fungi. Why was it only at the end of the 20th century that the continued presence of mycotoxins was discovered? Fire, the most important food safety discovery of prehistory? It is safe to say yes! The prehistoric heat treatment of foods, especially meat, as a result of increased protein consumption also fundamentally changed the pace of human evolution. The knowledge gained through observation played a decisive role in enabling mankind to avoid death by poisonous plants and other toxins, pathogenic bacteria, and viruses, which caused fatal diseases, before the development of scientific methods and tools. Empirical knowledge has played an enormous role in the development of food safety. In the course of human evolution, empirical observations first and then conscious, experiment-based findings have provided the basis for the establishment of food safety rules. However, empirical knowledge, supported by targeted scientific experiments, is still of great importance today.

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2. The Prehistoric Era

The prehistoric era is the longest period in human history, yet we have the least information about it. It began with the emergence of humans about 6 million years ago and dates back to the appearance of written history, that is, 3000 BC. The prehistoric human had to walk up to 14 km a day to get food and had to endure the extreme weather conditions of the time. On average, they had to provide a daily intake of 4000-4500 calories from hunting and gathering (Lee, 2021). The average lifespan of prehistoric humans did not reach 25-30 years **[2]**, while the expected lifespan of people born in the European Union today is 80.1 years on average **[8]**.

Unfortunately, we have very little information on the dietary habits of prehistoric humans. Thanks to the works of scientists studying the life of prehistoric humans (archaeology, paleontology, cultural anthropology, art history, geology, paleontology), there is still some information about what our ancestors might have eaten thousands of years ago **[13]**. The prehistoric human diet was extremely varied; the popular Paleo diet of today is similar to that. At that time, depending on natural conditions, seasonal changes, and weather, prehistoric humans had the opportunity to consume fruits and vegetables. The role of environmental factors is not negligible in the basic storage of fruits and vegetables. In cooler, less sunny periods, the ripening and decay of vegetables and fruits started more slowly.

Prehistoric man had to pay attention to the growth of plants and the habits of animals. They needed to know which foods were nutritious, which could make them sick, and possibly which plants had healing properties. Toxic plants have been known to mankind since ancient times. Therefore, after a while, they realized which plants were edible and which were poisonous. They had experience-based knowledge about the consequences of consuming certain foods. The colour of the food was important because it could easily help identify whether a plant was edible or poisonous.

The taste of food also played an important role because the pleasant sweet taste brought pleasure, and the human body perceives sweet taste as a sign of a pleasant and energy-rich food, making it beneficial for our body to consume. In addition, it helps to move quickly, escape if necessary, because if something is sweet, it contains sugar, which is a good source of energy **[6]**.

Prehistoric men ate delicious sweet fruits until their bodies could no longer take it. Of course, pleasure caused by the sweet taste was not the only reason for their greediness, but they were aware that they did not have the opportunity to eat such pleasant food every day, so they maximized their stomach capacity **[12]**.

In contrast, bitter taste is associated with danger, as the majority of toxic substances is bitter and it takes the smallest amount of bitterness to recognise it **[6]**. Salty taste signals good news, as our body can obtain natrium and potassium, which are essential for our body's nerve processes and the transmission of stimuli. Our ancestors in the Stone Age also needed to constantly replenish their salt intake to survive, so we can confidently say that the craving for salt may be an evolutionary support for maintaining electrolyte balance **[6]**.

The aroma and smell of the desired food were also influential factors. There is still no consensus on this claim, as some scientists have concluded that our ancestors did not consume fruits that tasted bad and had an unpleasant smell. After all, even today, disgust towards certain foods prevents us from consuming them, such as edible insects or balut, which is a popular dish in the Philippines made from a duck embryo inside an egg **[15]**. However, many Asian and African countries have a thousand-year-old tradition of eating insects and they have been an excellent source of protein.

It is certain that one of the most important observations of the Stone Age was the recognition of the significance of fire. We can confidently state that our ancestors also consumed heat-treated foods. While examining the presumed habitats of our ancestors, archaeologists observed that the soil absorbed a certain amount of dripping fat, thus proving that they had found an area once used as a "hearth" **[13]**. The use of fire was already commonplace among *Homo erectus,* Neanderthals, and *Homo sapiens*. The discovery of Stone Age meat consumption was greatly aided by the cave paintings left behind. The well-known view is that with stone-carved weapons and skillful tactics, our ancestors hunted various large animals. It is also believed that the first humans consumed raw meat from the carcasses of dead animals. They only began to hunt when their physical status strengthened, but even then they were only able to kill injured or sick animals. Due to the physiqual capabilities of our ancestors at the time and the lack of appropriate tools, they could only feed on the remains of wild animals that had been preyed upon by predators. Raw meat from sick animals and dead carcasses carries an extremely high level of food safety risks **[15]**. Anthrax caused by *Bacillus anthracis, Clostridium botulinum,* as a source of botulism, salmonellosis, or other pathogens, could cause fatal illnesses. Not to mention the presence of parasites, such as the tapeworm *Taenia saginata* or *Trichinella* spiralis **[3]**.

The real breakthrough in food safety for early humans occurred about 800,000 years ago with the discovery, understanding, and appropriate use of fire **[11]**. Fire marks the beginning of a period in which our ancestors had access to safer and longer-lasting food. The main motivation for this was that they noticed that fire and

various tubers and plants were much tastier and more easily consumable **[12]**. The importance of consuming meat increased due to its taste, safety, and nutritional value.

Increased protein consumption caused significant changes. *Australopithecus africanus,* which lived three million years ago, was only about 120 cm tall and weighed around 35-40 kg. In contrast, *Homo erectus,* with its muscular 68 kg body and 185 cm height, made a huge leap on the ladder of evolutionary history **[14]**.

Due to increased protein intake, the size of our ancestors' brain began to grow significantly, with the brain volume of the so-called first humans, *Australopithecus africanus,* being 500 cm3, compared to the average brain volume of modern humans, which is 1500 cm^3 **[14]**. The change is simply staggering. The massive development of brain size also resulted in the development of social skills and the emergence of primitive speech.

After a while, early humans became aware that they would not become sick from eating cooked meat and gained important experience in terms of food safety. The biggest advantage of fire was the heat treatment of food with fire, which destroyed pathogens. Natural foods that were indigestible to humans in their raw form, such as wheat, rice, or potatoes, became consumable, enjoyable, and digestible through heat treatment. Harari states that the taming of fire was a precursor to the coming development. The varied collecting-hunting diet developed by our ancestors through numerous sensory experiences was healthier than the relatively uniform and less diverse diet developed through subsequent agricultural development **[12]**.

In terms of food safety, the role of smell and taste is outstanding. Today, the same receptors are activated when we sense a smell, scent, or taste and when we also see the appearance of the food. These valuable observations have become millennia of experience and transformed into valuable knowledge. Perception is the basis for all complex learning and experiential processes. Based on the experience of our ancestors, we know that visibly contaminated water is not suitable for consumption and that dangerous pathogens may be present in malodorous and unpleasant-smelling food.

Our legacy includes taste memories, which became our strongest associative memories because the lives of our ancestors literally depended on them. Prehistoric humans often became ill after eating certain foods. Through conditioning, our ancestors learned which foods should not be consumed. Taste aversion developed, which helped preserve negative experiences in their memories and provided guidance for avoiding illnesses transmitted through food **[6]**.

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Figure 1.: Farming in antiquity (Source: worldhistory.org/image/170/threshing-of-grain-in-egypt/)

3. Antiquity

Prehistoric man lived for 2.5 million years gathering plants, fishing, and hunting. He often changed his habitat, searching for areas abundant in food. Everything changed about 10,000 years ago. They started to cultivate land and attempted to domesticate animals. "This was a revolution in human lifestyle, the agricultural revolution" **[12] (Figure 1.)**.

Wheat, rice, and cereal crops played the most important role in the development of agriculture worldwide. Based on experience applied and with increasingly favorable weather conditions, there was a growing yield of crops. The agricultural revolution significantly multiplied the amount of food available to people, and with that, the population grew directly **[15]**. French historian Fernand Braudel calls these cereal crops "civilizational plants" or "plants that carry civilization" that laid the foundation for the culture of a given population **[4]**.

The development of agriculture was a huge step for humanity, but it significantly increased food safety risks. With the cultivation of cereals the potential for health risks caused by mycotoxins produced by molds was very high. The grain-based diet was monotonous and poor in vitamins and minerals as compared to the previously followed diverse diet.

Children consumed breast milk for much shorter period of time and were given porridge made of some type of cereal crops, instead. Therefore, different types of mycotoxins produced by various molds caused serious illnesses and death, primarily among young children **[15]**. Common mold species found in damp grain storage areas include *Fusarium, Penicillium, Aspergillus,* and wheat rust, *Gibellina cerealis* **[15]**. Early cereal porridge feeding is still a common practice in several poor African countries **(Figure 2.)**.

Figure 2.: Feeding by cereal porridge in Ethiopia in 2021 (Photo credit: Diána Bánáti)

Alongside agriculture, various craftspeople practicing different professions emerged and significant scientific, artistic and religious transformations took place. Technological development was quite spectacular, as exemplified by the water supply system used in ancient Rome, the art of ancient Greek warfare, architectural masterpieces, and the progress of medicine. The different fields of science and arts resulted in long-lasting achievements that were precursors of modern science. However, technological innovations and engineering masterpieces were particularly spectacular in terms of development, while knowledge in the field of life sciences was limited and often based on (mis)beliefs.

In ancient times, one of the greatest food safety risks was lack of hygiene. The ancient Greeks and Romans were extremely modest in terms of cleanliness, especially when it came to washing their hands. Since no ancient Mediterranean culture used utensils for meals, people ate food with their bare hands **[13]**. Due to the lack of basic scientific knowledge about bacteria and viruses, contamination, infection, illness, and death were attributed to curses or intentional poisoning.

Rulers and wealthy people could afford to employ food tasters who tasted the food before the feast. This was only effective in cases of acute poisoning; other hazards were not eliminated. Throughout history, this phenomenon was a landmark example of empirical experience, since the toxicity of food (whether due to intentional poisoning or contamination) could not be otherwise measured.

Despite the hygienic shortcomings of the time, significant progress was made in food preparation and preservation. Compared to previous millennia, the knowledge gathered through experience helped people store the food they produced as economically as possible and consume it in a safe way.

In ancient times, various methods of food preservation were already known. Heat treatment (boiling, cooking, baking, roasting), heat extraction (cooling with ice), water removal (salting, drying), and lactic acid fermentation were used in numerous ways.

Heat treatment – boiling. In ancient China, boiling water and the ritual of making tea became a significant part of culture. According to a Chinese legend, in 2737 BC, Emperor Shen Nong of China boiled water in the open air in the hope that he would become healthier. Suddenly, a nearby Camellia (*Camellia sinensis*) was immersed in the emperor's pot of hot water and he drank the brew. He found that it gave energy to his body, contentment to his mind, and determination to his will. Tea was initially considered a medicine and was used for healing. At first, tea was only popular among the rulers, but around 907 AD it became widely consumed. This was because the water was quite polluted and of poor quality in ancient China. Making tea, which improved the taste and quality of water, became an age-old tradition **[5]**. Another legend says that Buddha, the ancient philosopher, discovered tea when a tea leaf fell into his cup during meditation, flavoring his drink. Legend has it that the spread of tea in Europe was due to Portuguese explorers who started the tea trade and brought it to different continents.

Heat treatment – frying and storing in fat. The method of preserving food in salt and fat known as confiture was inherited from ancient times and is still a commonly used method of food preservation today. During domestic pig slaughter, meat is often fried and stored in lard, an airtight layer of saturated fat solid at room temperature, and preserved without refrigeration for a longer period of time.

Heat treatment – roasting. During the development of agriculture and the cultivation of cereal crops, various methods were used to process the cereals. It was observed that roasting mature cereal grains made it easier to remove the hulls, creating an immediately consumable, relatively easily digestible food. Roasting also prevents germination.

In both the Roman and Chinese empires, it was discovered that various herbs have medicinal and antibiotic properties. For example, mandrake *(Mandragora autumnalis),* brewed from the plant, has a calming and anxiety-reducing effect, and its leaves can be used externally for pain relief. The fruit of myrtle *(Myrtus communis)* used for the production of a delicious jam, was shown to be a great solution for treating bronchitis **[9]**.

Heat extraction – cooling. The ancient Persians invented the ice tower, which was an 11-12 meter high cone-shaped structure made of sand, clay, goat hair and egg whites. The ice was stored in a pit approximately 3 meters deep at the bottom of the ice tower, and the cool air flowing into the bottom of the tower pulled the ice down into the deep ice pit, while the conical shape of the building helped to expel warm air. The temperature inside such a structure remained below the freezing point, even on hot summer days. Ancient Persians thus created the predecessor of today's refrigerated warehouses. At the cold temperature, fruits and meats could be stored safely **[10]**.

Ancient Greeks and Romans stored ice in underground pits. In the ancient cultures that developed around the Mediterranean Sea, ice was considered a luxurious trade item. Japan, too, has a centuries-old tradition of the Ice Festival, which is held on the 1 June.

Water extraction – salting. Humans have been using salt, sodium chloride or table salt for a very long time. Prehistoric man did not need to search for and acquire salt because their mixed diet provided them with enough salt for survival. Most of it consisted of the meat of wild animals and it contained a sufficient amount of salt. Almost every plant also contains salt, so they had access to the required amount in this form as well. Salt was not significant in terms of food safety at the time **[18]**.

Prehistoric men consumed meat raw or cooked, but ancient humans often cooked meat, which significantly reduced the salt content. This was noticeable in the form of altered taste sensation when consuming cooked meat. They also observed that salted meat could be stored longer, it did not have the repugnant smell of rotting raw meat, and did not cause illness after consumption. Therefore, they found out through experience that salt, by removing the water content of the cells and "binding" water, prevents the decay, growth and survival of pathogenic microorganisms.

Water extraction – drying. Drying has been used for millennia, and it is still a popular preservation method today. In ancient times – especially during warm seasons – there was no other way to preserve fruits, than drying. They observed, that the water content of fruits decreases in warm, dry air and makes them longer lasting. Today, we know that several valuable nutrients and minerals are preserved in dried fruits due to water extraction, and the number of harmful microorganisms is significantly reduced.

Lactic acid fermentation, acidification. The consumption of vegetables throughout all four seasons became possible due to acidification. Fresh milk, especially in Mediterranean and tropical areas, deteriorates rapidly without being refrigerated. It was observed empirically, that spontaneous lactic acid fermentation occurs

in milk due to the natural presence of lactic acid bacteria, resulting in a product that can be stored for a longer period of time. It was also discovered through empirical observation that during long journeys or transportation in hot weather, the shaking caused butter to form in leather pouches on the back of horses or camels.

The production of cheese was also based on empirical knowledge. To make cheese, salt and a suitable starter culture (enzyme) are necessary. Nowadays, there is a wide selection of starter cultures available, but in ancient times, Fráter **[9]** suggests that white liquid from fig trees (*Ficus carica*) was primarily used as a starter for cheese production. Additionally, the potential use of lamb or calf stomach was also recognised. When animals were slaughtered, the so-called rennet stomach was chopped up, salted and dried, and used to "inoculate" fresh milk.

The fruits and oil of olive trees are still staple foods for Mediterranean people. Easily cultivable and long-lasting, it became the main ingredient of fish preservation **[10]**. In ancient times, olive oil was more important than butter, at least in areas with a suitable climate.

Ancient Romans and Chinese discovered that certain herbs have medicinal and antibiotic properties. Spices are known for a long time and were already an integral part of our diet, used for various purposes as a food ingredient. Spices not only served as food flavoring agents, but were also used to mask the odor of meat as well. The Bible mentions numerous medicinal plants, the importance of which is still significant today. Some of them are primarily used as food, spice or smoking plants, but their medicinal properties are also known.

The shelf life of food, besides its preservation, is determined by the way it is stored and transported. Incorrect storage of grain contaminated with molds poses a serious risk in terms of food safety. In ancient times, in the Near East, approx. 10-15 m^2 grain storages were built, by which they were able to eliminate the constant presence of grain molds. In the Roman Empire, it was quickly recognized, that vegetables and fruits could be stored for a long time in cold places, to maintain their quality and flavor. They stored their various crops in cellars and abandoned caves. Written records mention that wild asparagus was stored in the coldest caves of the Alps, in large quantities **[7]**. Root vegetables grown in small gardens are still buried in sand, stored in cellars. In ancient times, wine, oil, figs, fish, and dried fruits were stored airtight in ceramic containers. In this period, important food preservation methods, food production practices, and storage methods that are still used today were developed through empirical experience, successfully surviving the harsh times ahead. In ancient times, food safety, improved significantly.

Interestingly, one of the influential philosophers of the Golden Age of philosophy, that is the 5th century BC, Socrates was executed with a decoction of a poisonous plant. People of the time knew a lot about poisonous plants, and in this case, they intentionally used their experience (toxicological knowledge).

The hemlock plant (*Conium maculatum*) and its fruits contain the toxic alkaloid coniine. Its decoction was used for executions by both Greeks and Romans **[20]**. It was frequently used in making arrow poison, and there were cases of mass hemlock poisoning when some part of the hemlock plant was mixed with the plants used as food. For instance, biblical stories often end tragically from a layperson's perspective, but without exception, every story and its outcome is thought-provoking. The Bible can be viewed from various scientific perspectives, but we must always respect its theological teachings. The Book of Exodus contains several different stories related to food safety. One of the most interesting one is when numerous people died after consuming quails. Suddenly, a multitude of weary quails appeared on the path of the exodus, sent by the Lord. The capturing of exhausted birds, crossing the Mediterranean Sea, was not a challenge. According to the Bible, after consuming the flesh of the quails one after the other, people died one by one. Scientists have conducted various experiments to unravel the underlying cause of this story. The accepted theory suggests, that the quails ate poisonous spotted hemlock seeds during their migration. While the toxic effects of the consumed seeds did not harm the birds, the people who consumed the birds presumably lost their lives due to hemlock poisoning **[17]**.

It can be concluded that the improvement of food safety related and nutritional observations, experience and knowledge gained in ancient times and in the prehistoric era was continuous. The blossoming of science, the emergence of intellectual development, and the growing importance of human thinking helped to utilize the experience gained. Ancient scholars, such as Plato and Aristotle, believed that science cannot exist without different opinions, contradictions, and disputes. This way of thinking resulted in a very important element of science, namely, that there can be multiple appropriate explanations for an event or phenomenon.

Our next example, a well-known principle of food safety today, but unknown toxicological knowledge in ancient Rome, led to serious illnesses, and as some suggest, even to the intellectual deterioration of the population and the downfall of an empire (which was obviously a much more complex phenomenon).

Lead (Pb) was one of the first metals discovered and used because it can be easily extracted from various lead-containing ores, it is soft and has a low melting point, which makes it easy to process, and it is also durable and does not rust. In addition to be a part of metal tools, it was mixed into cosmetic preparations in ancient Egypt, used as a stimulant and contraceptive in China, and consumed as a sugar substitute in Rome **[1]**. When lead enters the human body, most of it is not excreted naturally, which alters enzyme function and the connection between neurons and causes serious symptoms and complications ranging from diarrhea to renal dysfunction and developmental disorders to cerebral function deterioration. The phenomenon was already present among contemporary doctors at the level of speculation, based on observations. Moreover, Hippocrates, in the 4th century BC, presented the first occupational disease by describing a lead poisoning case of a miner suffering from severe diarrhea **[16]**. However, despite the warnings of eminent physicians, there were no noticeable consequences, and the true volume of heavy metal contamination was only revealed by modern archaeology using scientific tools.

In its heyday, the Roman Empire produced at least 80,000 tons of lead annually, primarily as a byproduct of silver extraction. By analyzing plant samples, archaeologists have shown that during this era, the air's lead content quadrupled. However, it was the extensive and widespread use of lead that caused systematic and multigenerational lead poisoning in the population. Coins' noble metals were alloyed with lead, and red lead oxide was included in the glaze of ceramic vessels. Lead was also widely used in construction, such as as a sealant or mixed into interior wall paints. Lead sheets were also hammered onto ships' spines for reinforcement, which in some ports, such as Alexandria, a center of Mediterranean trade, along with lead ballast detached from fishing nets, poisoned the water and its inhabitants for centuries and eventually made its way into the local residents' bodies through fish and mollusks caught around the ports. Due to its advantageous properties, lead was also commonly used in the construction of water supply systems. The most prevalent theory is that lead input was primarily due to the lining of Roman aqueduct networks, which preceded their era by two thousand years. Today, the main source of lead poisoning is considered lead-containing cookware and processed lead derivatives used as food flavorings and preservatives **[19]**.

Among the 450 recipes from the Roman cookbook of Apicius, a great gourmet, one in five has lead listed among the ingredients **[16]**. Lead acetate was used as a popular sweetener, added to diluted-and-spiced wines consumed at the time. Based on ancient descriptions, the Roman aristocracy consumed a minimum of 1-1.5 liters of wine per day, which, taking into account other types of intake, would mean that a thirsty Roman would saturate their body with 150-200 micrograms of lead per day. Lead poisoning has been a serious problem from ancient times to the present day. It was only in the 1920s that lead-containing paints were banned and so were leaded soft drinks and canned foods in the 1980s, while leaded anti-knock gasoline additives were only phased out of circulation in 2000.

Part II.

In Part II, we are about to discuss the role of food safety-related observations and empirical experiences in the development of food safety knowledge in the Middle Ages and modern times. We will also highlight that the appearance and development of scientific tools and methods has led to a dramatic improvement in food safety.

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