Chapter 2
A Brief History of Food, Food Safety, and Hygiene

Since food and water are such central physiological needs for life, humans must have had early in the evolution's path, probably through a combination of instinct behavior and trial and errors, some sort of adaptive strategy to avoid, as much as possible, foodborne diseases. Most likely, they were obtained through a combination of instinctual behavior and trial and errors. For instance, in the archeological and paleontological site of the Arago Cave in Tautavel in the department of Pyrénées-Orientales in southern France, scientists found that "sometime between 450,000 and 550,000 years ago," prehistoric humans (*Homo erectus*) successfully hunted several large herbivores ("elk, reindeer, and fallow deer"; "bison, musk ox, argali, and tahr"; "chamois"; and "horses and rhinoceroses"). It was discovered that the bone remains "show markings made by prehistoric tools" not only to remove the flesh from the bones but also that "all of the bones have been fractured" to extract the "bone marrow" [9]. We now know through our current scientific knowledge that the bone marrow, until it is extracted from its bone cover and matrix, remains naturally protected from contamination caused by spoilage and/or pathogenic microorganisms. This activity can therefore be viewed as a rudimentary form of food conservation.

The subsequent step of the "control of fire by early humans" is still rather controversial. While many scholars agree that *Homo erectus* began to domesticate fire some 400,000 years ago, claims of much earlier control of fire through different findings in Africa, Middle East, and Asia are gaining "increasing scientific support" [10]. Nevertheless, in the archeological site of Terra Amata near Nice by the Mediterranean Sea, archeologist found that hominids 380,000 BCE lived in huts by the beach and that those "habitations included vestiges which suggested that in the center of each hut" there "was a fireplace, with ashes showing that the inhabitants had domesticated fire." "These signs of fire," along with other archeological sites, "are the earliest evidence of the domestication of fire known in Europe" [11]. No one knows, however, if fire was only used for warmth and protection, or it was also used for some sort of rudimentary roasting or cooking. Ward Nicholson, citing the

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works of Wu and Lin in 1983, Rowley-Conwy in 1993, and Megarry in 1995, "it does seem likely that at least by 230,000–460,000 years ago humans were using fire in the cave, and given scorching patterns around the teeth and skulls of some animal remains, it does appear the hominids may have done this to cook the brains (not an uncommon practice among hunting-gathering peoples today)" [12].

According to the "cooking hypothesis" by primatologist Richard Wrangham, "cooking had profound evolutionary effect because it increased food efficiency which allowed human ancestors to spend less time foraging, chewing, and digesting." He also claims that *Homo erectus* "developed via a smaller, more efficient digestive tract which freed up energy to enable larger brain growth" [13]. Critics of this hypothesis however argue that our "human ancestors scavenged carcasses for high-quality food that preceded the evolutionary shift to smaller guts and larger brains" [14]. Notwithstanding, it might be worth pointing out, in regard to the possible dietary habits of the gathering and hunting hominid societies during the Pleistocene, many scholars now feel that "early researchers in cultural anthropology overemphasized the importance of hunting to the group's survival, giving the impression that hunting provided most of their food and stressing the male's vital job as hunter." In this respect, Lee and De Vore (1968), cited by Weiss and Mann, remind us that "we have found that hunting might not have been that important, and that the fruits, vegetables, nuts, birds and bird's eggs, insects and insect grubs, frogs and other small vertebrates, and small mammals gathered were the main part of their diet" [15].

These cultural anthropological observations prompt us at least to two considerations: the first is that these practices seem to be consistent with what we now observe with the few isolated and "primitive" societies we have left today in this world. The second is that given what we now know to be true about the probable microbiological and parasite profiles of those foods of animal origin (wild birds, small vertebrate, and small mammals (including rodents)), we can easily speculate that thorough heating (or cooking) must have been a necessary and an almost indispensable adaptive behavior early on, in order to allow the perpetuation of these eating habits over such a long period of time.

From an historical point of view, "it is extremely difficult to pinpoint the precise beginning of human awareness of the presence and role of microorganisms in foods, the available evidence indicates that this knowledge preceded the establishment of bacteriology or microbiology as a science" [16]. Our knowledge is not only limited to what we can understand but especially to what we can see. It is therefore not surprising that the first organisms that we could easily identify as "parasites" were worms, since many parasitic worms can be big enough to be seen with the naked eye. The first written records on parasitic worms come to us from the "Ebers Papyrus" of ancient Egypt (ca. 1500 BCE), where medical practitioners gave great importance to parasitic worms, against which they described several recipes and exorcisms for their attenuation or eradication. Interestingly, their etiological concept was similar to the theory "spontaneous generation" in ancient Greece, which can be described as the "diseases generate worms and not worms generate diseases" [17].

The transition from gathering and hunting societies of the Paleolithic to the new stones or “food-producing period” of the Neolithic is generally believed to have begun—based on the known archeological and paleontological records—about 8,000–10,000 years ago. There seems to be an agreement that “the problems of spoilage and food poisoning were encountered early in this period. With the advent of prepared foods, the problems of disease transmission by foods and of faster spoilage caused by improper storage made their appearance” [16]. This concept seems to be reasonable, not only because of the greater complexities which are necessary for food-producing activities as opposed to gathering and hunting but also because the size of human groups tends to grow in accordance to the availability of food resources. Consequently, the establishment of permanent settlements and the resulting greater proximities and densities of populations would also make it more likely for pests, pathogens, and parasites to contaminate and infect humans.

Human domestication of food plants and cereals in particular, began approximately 17,000 years ago and naturally preceded the domestication of large herbivores. Around 9,000–10,000 years ago, important plant and animal species such as sheep (*Ovis aries*), goats (*Capra aegagrus*), cattle (*Bos taurus*), and wild boar (*Sus scrofa*) (~7,000 years ago) were domesticated by humans. Despite their obvious contributions in the production of milk, meat, wool, and skins, sheep and goats were also traditionally used in ritual or religious sacrifices [18]. Ritualistic sacrificial offering of animals or animal products (such as clarified butter) is well documented in most traditions and religions, and they are designed to appease the Deities and for protection of the group against natural disasters, famines, diseases, and other adverse natural effects [19]. Historically, tradition and religious beliefs seem to provide the first line of teachings to humans about hygiene and epidemics, long before any true scientific approach was ever developed.

For instance, in the ancient Hebraic religious writings, there are many references that describe the paramount importance that the Israelites must have given to the roles of insects as propagators or agents of diseases. Flies were seen as the physical expression of the prince of the devil Beelzebub (*Ba' al zebûb*), and intestinal worms, rodents, and other pests were all considered dangerous because of their inherent “impure” nature. Plagues and diseases were believed to be “divine castigations.” However, one important principle of disease prevention was already recognized at time, which was to actively isolate the sick or “impure” from the healthy to prevent transmission and to require a “purifying bath” before a patient could return to the community [20]. The religious teachings of the Torah or Pentateuch not only recognized the risks of contagion of pests to human and between humans but also warned against the inherent dangers caused by the sick to the crops. In Numbers V, 1–3: “the LORD said to Moses: Order the Israelites to expel from camp every leper, and everyone suffering from a discharge, and everyone who has become unclean by contact with a corpse. Male and female alike, you shall compel them to go out of the camp; they are not to defile the camp in which I dwell” [21].

In India, in the sacred Hindu book of the Atharvaveda (1200–1000 BCE), diseases are also believed to be the “actions of demons or by foreign malefic substances which produced some sort of, not personified, fluid or ether that penetrates the human and prostrates him." We can thereby state that "in the ancient Indian medicine, we are faced, for the first time, with a rational concept: the one of an external etiology for contagious diseases" [22]. Also in the far East, ancient Chinese "not only understood that certain diseases, like smallpox, are contagious but realized that the ones who had been able to overcome smallpox itself would no longer be susceptible, so they thought to purposely contaminate the children in order to provoke in them a disease that would protect them as adults." This technique known as *variolation* consists in utilizing the "dried infective crust of smallpox patients and inoculate it in small quantities in the nostrils of children by means of a stick or blown through a small bamboo twig." This can be considered to be the very "first immunological practice that for centuries has remained unfortunately circumscribed only to the far East" [23]. In addition, in China, ca. 1000 BCE, some of the earliest records of modern food preservation are also documented including "drying, smoking, salting, and spicing." Interestingly, "wine, converted to vinegar, is also used for food preservation" [24].

Spontaneous fermentations have probably been observed since the beginning of the first stable human settlements in their first attempts to store fermentable food. It seems like Neolithic humans might have somehow managed to make some sort of beer and wine very early; however, archeological evidence in this regard seems only to appear around 4000 BCE [18]. The first alcoholic fermentation was probably spontaneous or accidental, and it certainly involved wild yeasts typically occurring on the surface of the vegetable materials and in the environment. "The term fermentation is derived from the Latin verb *fervere*, to boil, thus describing the appearance of the action of yeasts on extracts of fruits or malted grains" [25]. Mature grapes, fruits, must, and juices have very complex microflora, including "yeasts, lactic and acetic acid bacteria, and molds" [26]. Once the alcohol is converted from simple sugars, unless care is taken to prevent oxidation, acetic acid bacteria will eventually oxidize ethanol to acetic acid, thereby producing vinegar. A similar sequential process can also be observed in the fermentation of malted cereals and fermented rice.

Other very old microbial food processes are the production of sour milk, yogurt, and sour cream. These products may have originated from some successful attempts to conserve dairy products in stable human settlements around 5000 BCE [18]. Although, at least "theoretically, milk that is secreted to the udder of a healthy cow (or other healthy mammal) should be free of microorganisms." "Freshly drawn milk is generally not free of microorganisms. Numbers of several hundred to several thousand colony forming units per mL are often found in freshly drawn milk, and they represent the movement up the teat canal of some and the presence of others at the lower ends of teats" [27]. It can therefore be assumed that in the early stages, the naturally present microbes and the lactic acid bacteria, usually present in fresh milk, when stored in the warmer dwellings of the Neolithic, initiated spontaneous lactic acid fermentation, thereby catabolizing "lactose to lactic acid and lesser amounts of acetic acid in the critical step of lowering the pH" of the substrate [28].

One must realize that by "spontaneous," we usually mean now the natural evolution of any endogenous microbes in a substrate, as opposed to the inoculation of a substrate with microbes. It should not be confused with the theory of "spontaneous generation." This theory, which was considered axiomatic since ancient Egypt, remained a doctrine for millennia, causing many polemical debates, until it was finally abandoned by modern microbiology. During the ancient Greek civilization, one of the most respected Western philosophers of all times, Aristotle, believed "there are animals that grow spontaneously inside other animals" [29]. The theory of spontaneous generation was based on what people could see with their own eyes: usually "maggots originate from rotting meat." Notwithstanding to the fact that during the Roman civilization, unlike during Greeks times, Roman scholars had "perfectly understood some aspects of the contagious nature of some diseases," "describing pests and pestilent sites, contaminations of herds, diseases that would affect contemporarily group of people and their dogs, infections of wounds from fly's maggots, and the diffusion of scabies among animals." In general, however, in most concepts of infective pathology, Romans "limited themselves to repeat" and to "translate from Greek to Latin" what "Greeks had already written before them" [30].

Although the nature and especially the origin of the microbial world would not be understood for many years to come, by recognizing the existence of pestilent sites (like swamps) and by understanding somehow the causal relationship between disease and contagion, some effective preventive measures were taken long before the "germ theory of the diseases" could be understood and accepted. Around the year 900 AC, "the leader of the Byzantine Empire, Emperor Leo VI, forbids the eating of blood sausage because of its association with a fatal food poisoning now presumed to be botulism." Interestingly, the actual term "botulism," which originates from the Latin word for sausage *botulus*, will "come into use at the beginning of the nineteenth century because of the association of the disease with eating sausage." Also in 1403, as the "bubonic plague strikes Venice, in an attempt to protect its citizens, the city establishes a policy that no one can enter the city until a certain waiting period has passed." The waiting period is 40 days (in Italian *quaranta*) giving origin to the term still used today: *quarantine* [24].

Microorganisms are separate living entities, and they are not the by-product of decaying higher organisms. Many more scientists than the ones mentioned here contributed over centuries to this gradual conceptual understanding. Generally, the most cited is Girolamo Fracastoro who in 1546 in the *De contagione* suggests that "infections and epidemics are caused by *seminaria*, or seeds of disease." Seminaria were considered living or "exhalations from onions that causes tearing." Fracastoro also "suggests three modes of transmission: direct contact, fomites (inanimate objects), and contagion at a distance (through the air)." In 1658, Athanasius Kircher in *Scrutinium Physico-Medicum Contagiosae Luis, quae dicitur Pestis* proposes that "small, imperceptible living bodies are the sources of contagion and penetrate clothing, ropes, linen, sheets, and anything else that has small pores." However, "because Kircher's writings are ambiguous, often incomprehensible, most students of his work regard them as being of little if any value." In 1668, Francesco Redi "places meat into two dishes, leaving one open to the air and the other one covered. He repeats the experiment leaving one dish open and the other covered with gauze. In both experiments, maggots appear only in the uncovered dishes." Not surprisingly, however, "few people believe that life cannot be spontaneously generated" [24].

The first documented record of any direct observation of the microbial world comes from Antonie van Leeuwenhoek, who observes and measures in his microscope molds (1673); protozoa, green algae, and red blood cells (1674); bacteria (1676); spermatozoa (1677); yeasts (1680); and oral bacteria (1683). These observations can be assigned with a high degree of historical precision because van Leeuwenhoek systematically "sends more than 200 letters describing many observations with the use of his microscopes" to the Royal Society of London. As the debates on the theory of spontaneous generation continues, Lazzaro Spallanzani, in 1765, repeats the experiments of John Turberville Needham in which "meat infusions were boiled in corked glass tubes but improves upon them by melting the tops in a flame to seal the tubes. He concludes that microorganisms do not arise spontaneously if the infusions are heated for a sufficiently long time." He is credited to have been the first person to "suggests that food can be preserved by sealing in airtight containers" [24].

Spallanzani's observations are not only important to the advances of pure science but also to the advancement of food technology. His experiments are replicated by a very dynamic confectioner with no formal scientific training, Francois Nicolas Appert, who in 1804, "after several years of experimentation, opens a factory for preserving food in glass bottles using a heating process that he invents." Then in 1808, "he reports experiments performed over two decades that show food can be successfully preserved through a heating process." In 1810, he publishes *Le livre de tous les ménages, ou l'art de conserver, pendant plusieurs années, toutes les substances animales et végétales*, where he explains "his method for preserving food in bottles" during many years [24]. Appert is credited to be the "inventor of airtight food preservation" and the "father of canning" [31]. However, it should be pointed out that Appert's "canning" was carried out only in glass containers until 1819, when "Peter Durant replaces Nicolas Appert's glass containers with steel cans," and in 1839, when Charles Mitchell adds "a thin layer of tin to line steel cans" [24]. Although Appert's discoveries provide the basic rationale for subsequent findings in food preservation by heat, "appertization" should not be confused with pasteurization, which comes later in time, because pasteurization employs a gentler heating process than "appertization" [31].

In 1838, Charles Cagniard de la Tour, "based on microscopic observations of budding and growing brewer's yeast, concludes that yeast is a living organism that might cause fermentation." His findings are in agreement with the colleagues Pierre Turpin, Theodor Schwann, and Friedrich Kützing, who are however ridiculed in 1839, in "a humorous article" which appear in a "journal edited by Friedrich Wohler, Justus von Liebig, Jean-Baptiste Dumas, and Thomas Graham." Since these editors were eminent chemists at the time, "this article may have significantly delayed the acceptance of Cagniard de la Tour's conclusions about fermentation." In 1840, as part of the long debate surrounding the germ theory of disease versus spontaneous generation, Friedrich Gustav Jakob Henle, who was "one of Robert Koch's teachers at the University of Göttingen," proposes in his book *Pathologische Untersuchungen* the existence of "living entity that reproduces itself and possibly could be grown outside the body" [24].

In 1846, "cholera pandemic in India spreads across Europe, reaching England," and in 1849, "John Snow presents his first observations on the transmission of the disease cholera through drinking water." "Snow is awarded a prize of 30,000 francs." In 1854, "Filippo Pacini describes the cholera bacillus and names it *Vibrio cholera*," and 1 year later, John Snow publishes *On the Communication of Cholera by Impure Thames Water* and "provides quantitative data on the spread of the disease through water contaminated by sewage. In one of the earliest thorough epidemiological studies, he traces one outbreak in London to the Broad Street water pump (now Broadwick Street in Soho), showing it to be contaminated by raw sewage." In 1856, William Budd suggests that the fecal-water route is also responsible for the transmission of typhoid fever through contaminated drinking water. Although William Budd rightly recommends the use of different disinfectants in water to control the infection, "chlorine water, chloride of lime, and carbolic acid," the first suggestion to use chlorine (formerly called oxymuriatic acid) "for the sanitation of drinking water" is however assigned independently to Guyton de Morveau and William Cruikshank in 1800 [24]. In this regard, it must be pointed out that presently in most developing countries, "chlorination is the principal disinfectant used in water treatment, with risks associated with chlorination byproducts being considered far less significant compared to consequences of waterborne disease" [32].

Louis Pasteur's contribution to the advancement of microbiology and to the development of modern food processes cannot be underestimated. The process named after this French scientist differs from appertization. During the pasteurization of canned food, the perishable food items contained in the cans are subjected to a much milder "process which permits a limited shelf-life if kept cold," while in the process of appertization, one achieves "commercial sterility," thus obtaining "shelf stable" products which can be stored at room temperature [33]. Louis Pasteur's contributions to science are not limited to his most famous experiments with swan neck flasks to disprove the theory of spontaneous generation but largely mark "the birth of industrial microbiology," when in 1860 and on his subsequent work, he elegantly and "finally demonstrates beyond doubt that alcoholic fermentation in beer and wine production was the result of microbial activity, rather than being a chemical process" [34].

Pasteur makes many fundamental ingenious observations in many areas of microbiology. He is credited to be the first scientist to describe some important aspects of "butyric acid fermentation" such as the "fermenting bacteria live without free oxygen" and that in this process "oxygen inhibits fermentation," thereby being the first to apply the term *anaérobies* for anaerobes. Pasteur confirms Friedrich Kützing observations in 1837 that aerobic bacteria are the "microscopic organisms smaller than yeast" that live on "the film known as the mother of vinegar," which is "responsible for the conversion of ethanol to acetic acid." Pasteur also demonstrated that lactic acid bacteria convert lactose to lactic acid. Despite his many contributions and brilliant achievements, there are also some controversies surrounding some of his premature recognitions, which remain in the historical records. For instance, when in 1861, Pasteur is awarded by the Paris Academy of Sciences the "Alhumpert Prize" with a premium of 2,500 francs, for "throwing new light on the question of spontaneous generation," "the actual conclusion of the controversy" will only come later with the experiments of John Tyndall (1876) and Ferdinand Cohn (1875, 1876), who elucidate the important survival mechanism of "heat resistance endospores," in endospore-forming bacteria [24].

Bacterial endospores still can represent a serious threat to the safety of food items today because they are able to survive most conventional cooking and heat treatments. The first drawings of bacterial endospores are attributed to Maximilian Perty in 1852, but he did not assign any function to them. In 1872, Henry Charlton Bastian "revives the argument about spontaneous generation of life" by reporting an experiment where "he boils acid urine for several minutes and then neutralizes it with a potash solution prepared with distilled water he believes to be sterile, but possibly introducing contaminating bacteria." We can assume that most probably these contaminants were endospore-forming bacteria of the genus *Bacillus*. In response, between the years 1876 and 1877, after many trials and many errors with boiled hay infusions (which naturally contains bacterial endospores), John Tyndall "develops a procedure of several cycles of heating, incubating, and reheating his culture tubes that results in sterilization even of the heat-stable phase. This technique, known as "tyndallization," is used as a means to achieve sterility without using steam under pressure." Ferdinand Cohn confirms in 1877 "that *Bacillus* species found in hay have heat-resistant endospores." Surprisingly, however, in 1869 while studying the silkworm disease, Louis Pasteur had already noted that "some bacteria have dormant stages, refractile bodies" which are "more resistant to heat than actively growing cells" but failed to recognize them as bacterial endospores [24].

Louis Pasteur should also be remembered not only for his discoveries in microbiology and immunology but also for having positively inspired other key scientists. Among others were Joseph Lister, who is considered to be the father of the "practice of antiseptic surgery," and Robert Koch, proponent of the first experimental demonstration to identify an infective agent. The rationale behind the "Koch's postulate" actually relies on the logical criteria, originally proposed but not experimented by Edwin Klebs in 1877 [24]. The experimental evidences leading to the formulations of the Koch's postulates were "presented in 1883 by renown German bacteriologist, Robert Koch," with a later addition of a fourth rule, by American phytopathologist Erwin Frink Smith, in 1905 [35].

These rules can be summarized as follows:

1. "The suspected causal organism must be constantly associated with the disease" [35].
2. "The suspected causal organism must be isolated from an infected plant and grown in pure culture" [35].
3. "When a healthy susceptible host is inoculated with the pathogen from pure culture, symptoms of the original disease must develop" [35].
4. "The same pathogen must be re-isolated from plants infected under experimental conditions" [35].

With our current knowledge, it must be pointed out that the Koch and Smith protocols for the determination of the causal relationship between pathogen and disease are only applicable to viable and culturable microorganisms. Some bacteria, for instance, are able to go in a sort of "dormant state" thereby remaining "viable and potentially virulent but nonculturable by standard methods" [24]. Currently, with more advanced understandings and technological methods in virology and molecular microbiology, we are able to go "beyond the Koch's postulates" and understand some of the "false-negative" conclusions we might have obtained in the past in the lab [36].

In this modern era, in what we consider to be the most "developed parts of the world," we generally take for granted our very high standards of living and our complex norms and regulations regarding housing, personal, and manufacturing sanitation and hygiene. As we have seen, in the prescientific era, tradition and religions provided some sets of rules and commonly accepted practices, which were promoting some basic hygiene criteria. Soaps or soap-like substances and vinegar [37], for instance, have been known and used for cleaning for several thousand years and all over the world [38]. Disinfectants, however, have been an important aspect of our good hygienic practices for a much shorter time. Surprisingly, although alcohol distillation has been a practice by Arab chemists since 900 AC, and in vogue the late eleventh century by Europeans, the beginning of alcohol being used as disinfectant does not seem to appear until much more recent times. Hand disinfection techniques we use in food production today originate from the earliest medical antiseptic practices, which were first "met with strong opposition" from the medical community at the time [24].

Historically, when in 1842, Oliver Wendell Holmes suggests to disinfect the hands after "postmortem examinations or attending patients with puerperal fever," his ideas were generally discarded by most scholars at the time, with the notable exception of Ignaz Philipp Semmelweis, who, in 1846, "introduces the use of antiseptic (hypochlorite solution) in his work on prevention of the spread of puerperal fever" [24]. Hypochlorite solutions like common bleach are still considered, along with alcohol, as some of the most classical and most commonly used disinfectants, which are still effective against most pathogenic microorganisms today [38]. Unfortunately, however, when as early as 1861, Semmelweis "publishes *Die Aetiologie, der Begriff und die Prophylaxis des Kindbettfiebers*" which "requires medical students to wash their hands in chloride of lime upon leaving the autopsy room and before examining patients in the maternity ward," his ideas are not only refused but are strongly "opposed by the director of the hospital and other physicians," leading him to eventually become so "disturbed because his work goes unrecognized," to die insane, in 1865 at the aged 47, after being forcibly recovered in a mental asylum. Sadly and ironically, "his careful work survives and is recognized as an important contribution to antiseptic medical practice" [24].

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