

Chapter 1

Introduction

Introduction

Food safety is a relatively recent 'invention'. It was introduced in the developed world to increase confidence in food. In our modern world it simply is not acceptable to have food that might make us ill. Sadly even now a good proportion of the world's people are very much more concerned about getting food and stemming their unrelenting hunger than they are about whether they might get a stomach upset as a result of eating the food. We must always remember these horrifying facts when we study food safety. Food safety and the legislation emanating from it are for the relatively rich countries that have the luxury of having sufficient food to allow them to make rules about what is safe to eat.

A brief history of food safety

Prehistoric times

The risk of eating in prehistoric times was very much more an issue of the dangers of catching the beast to eat than the ill effects suffered after eating it. To survive, cavemen had to eat and their animal instincts dominated their behaviour with respect to food. These instincts, no doubt, made them avoid food they had learned made them sick, but their overriding instinct was 'eat to live'. Some foods, however, might have been so toxic that they threatened the early man's survival. Behaviour that minimised consumption of toxic food would have been selected in because individuals that succumbed to toxins in their food simply did not survive. This is the raw material of Darwinian evolution and could be considered a very early manifestation of food safety issues! Whether this happened or not thousands of years ago is impossible to know, but we do know that modern-day animals avoid toxic plants in their diet. This might be because some of the toxins (e.g. alkaloids) have a bitter taste that warns the would-be consumer of the risk. Prehistoric man probably behaved in exactly this way which is why he was able to survive in such a harsh environment in which every day posed new and unknown food challenges.

This is hardly prehistoric food safety policy, but it illustrates our inborn survival instinct that extends to the food we eat. We have an innate desire not to eat something that will make us ill. This has not changed over the millennia.

Evolution of cellular protection mechanisms

It is important to remember too that our metabolic systems (and avoidance strategies) evolved during the tens of thousands of years of prehistoric times. Metabolism of toxins from food in order to reduce their toxicity and so make the food 'good' developed over millions of years. There are highly complex metabolic systems 'designed' to detoxify ingested toxins that evolved long before man, but the enzyme systems from the primitive cells

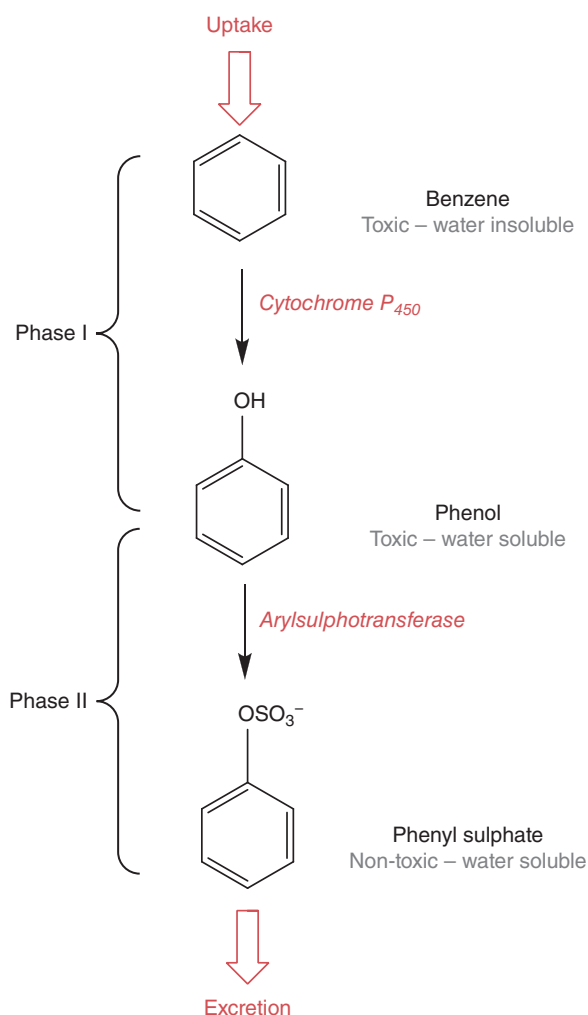


Figure 1.1 Phase I and II metabolism for a simple compound, benzene, showing how the molecule is detoxified, made water soluble and excreted (e.g. in urine).

in which they evolved were selected into the human genome through the evolutionary process and were inevitably expressed by the earliest hominids. These detoxification systems gave man an advantage because he could eat food that contained chemicals which if not detoxified would make the food too toxic to eat. These enzyme systems are now very well understood; they include the cytochromes P_{450} mixed function oxidases (termed Phase I metabolism) and the conjugating enzymes (termed Phase II metabolism) (Figure 1.1).

There are many food toxins that are detoxified by these systems, so making the food safe to eat (this will be discussed further in Chapters 7 and 8); for example, parsnips contain bergapten, a photosensitising toxin that also causes cancer (see Chapter 8, *Furocoumarins in parsnips, parsley and celery*); bergapten is detoxified by Phase I and II metabolism (Figure 1.2)

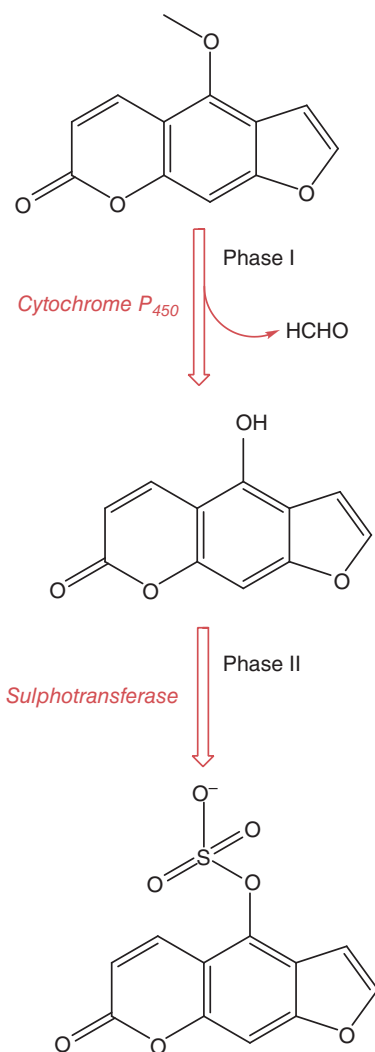


Figure 1.2 A proposed metabolic pathway for bergapten.

thus making parsnips safe to eat. These metabolic processes are the cell's internal food safety mechanisms and broaden the range of foods we can eat without suffering the ill effects that some of their components would cause.

There are significant differences in the susceptibility of different animal species to toxic chemicals; these are due to the evolutionary selective pressures under which the particular species developed. This means that safe foods for some species might be highly toxic to others. For example, the toxin in the swan plant (*Asclepias fruticosa*), labriformidin, is very toxic to birds but harmless to the monarch butterfly (*Danaus plexippus*) (see Chapter 8, *Why produce natural toxins?*).

The monarch butterfly uses this differential toxicity as a means of protection. Its caterpillar eats swan plant leaves and incorporates labriformidin into its body; this makes it toxic and unpalatable to predatory birds. This interesting means of survival is by no means unique amongst animals. Indeed, some plants that are eaten by animals are very toxic to humans. For example, it would only take a few leaves of hemlock (*Conium maculatum*) to kill a person, but the skylark (*Alauda arvensis*) is unaffected by its toxin (Figure 1.3). Indeed, there have been cases of human poisoning in Italy following consumption of skylarks which (strange as it may seem) are a delicacy in that country. The toxin in hemlock is coniine (Figure 1.3) – it is very toxic; about 200 mg would be fatal to a human. Hemlock was the poison used to execute Socrates in 399 BC for speaking his mind in the restrictive environment of ancient Greece.

Tudor England (1485–1603)

In the 1500s I doubt whether many people thought about illness being linked to what they had eaten, but I imagine food-borne illness was prevalent in that rather unhygienic society. In fact spices were introduced into Tudor England to mask the putrid taste of some foods particularly meat – this is a 'head in the sand' approach where masking the bad taste was thought to take away the bad effects. Whether the Tudors thought that masking the taste of putrefying meat stopped them getting ill I cannot know, but they certainly thought that masking the terrible smells of putrid plague-ridden London prevented them catching fatal diseases like the Plague. The gentry used, amongst other things, oranges stuck with cloves, and ornate necklaces with receptacles for sweet-smelling spices and resins (pomanders – derived from the French *pomme d'ambre* meaning apple of amber; ambergris, a sweet-smelling substance produced by sperm whales was often used to scent pomanders) to waft in front of them to take away the evil smells as they walked the streets. This is hardly food safety legislation, but it might just be the beginning of people connecting off-food with illness – a key step in making food safe.

The times of King George III of England (1760–1820)

The Georgian era was a time of great social division. The rich ate well, if not exuberantly, and the poor just about found enough food to keep them alive. The idea that bad smells were associated with disease prevailed as

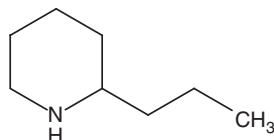
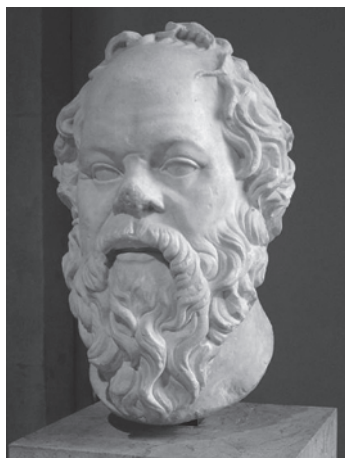


Figure 1.3 Socrates (469–399 BC), coniine, the poison from hemlock used to execute him, and the skylark (*Alauda arvensis*) which is unaffected by coniine. (Pictures from http://en.wikipedia.org/wiki/File:Socrates_Louvre.jpg, © Sting; http://en.wikipedia.org/wiki/File:Alauda_arvensis_2.jpg, © Daniel Pettersson; photograph of hemlock taken by the author.)

did the naïve thought that if the smell was masked, putrid food was good to eat. Susannah Carter, an American cookery author, described a 'method of destroying the putrid smell which meat acquires during Hot Weather' in her book *The Frugal Housewife, or, Complete Woman Cook*, published in New York in 1803. Some people must have been very ill after eating food prepared under this rather naïve food safety philosophy; i.e. bad smell means high risk and hiding the smell minimises the risk. I wonder if they connected their stomach upset with the food they had eaten? Probably not because such illness would be the norm in the 1700s and people probably simply took it for granted.



Figure 1.4 Louis Pasteur (1822–1895). (Picture from http://en.wikipedia.org/wiki/File:Louis_Pasteur.jpg.)

The 1800s – Pasteur’s Germ Theory, Lister’s antiseptics and the first refrigerators

In the mid 1800s in Europe there was a significant improvement in the understanding of disease and, in particular, public health. This was the time that the connection between microorganisms and disease was beginning to be understood. Louis Pasteur (1822–1895; Figure 1.4) proposed the Germ Theory of Disease while he was working at the University of Strasbourg in France in the 1860s. He later extended his understanding of ‘germs’ to propose that heating contaminated broths to a high temperature for a short time would kill the ‘germs’. This is the basis of one of today’s most important methods of assuring safe food – pasteurisation.

Disinfectants

Joseph Lister (1827–1912) followed Pasteur’s work with his discovery of antiseptics. He showed that carbolic acid (phenol; Figure 1.5) killed germs and reduced post-operative infection. This revolutionised surgery, which was often a sentence of death pre-Lister. The people of Victorian England embraced scientific development – they were fascinated by science and were keen to understand and use it. Lister’s antiseptics were modified and developed and became the carbolic and creosote disinfectants that were used to keep Victorian (1837–1901) homes free of germs. There is no doubt that this ‘clean’ approach to living reduced food-borne illnesses in the kitchens of the Victorian upper classes. The lower classes were still scrambling to get enough food to feed their large families and probably knew nothing of the new-fangled theories of germs and antiseptics. A disinfectant fluid was

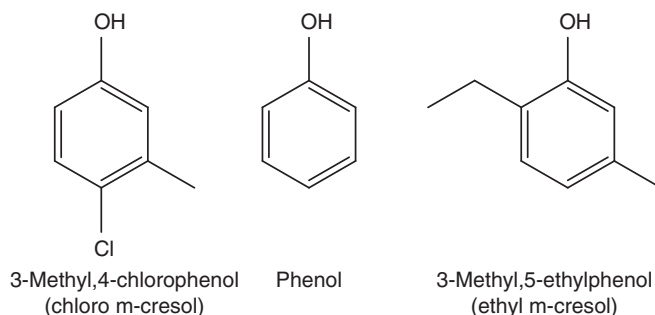


Figure 1.5 Molecular structures of some of the components of Jeyes' Fluid, a very effective disinfectant introduced in Victorian times.

patented by John Jeyes in 1877 in London which was a product of the increased interest in 'germs' and antiseptics and was based on Lister's phenol. Jeyes' Fluid comprises 5% 3-methyl,4-chlorophenol (chloro m-cresol) and 5% alkylphenol fraction of tar acids (these were a by-product of the coal industry; Figure 1.5); it is still used today.

Refrigeration

It has been known for a long time that food keeps better when it is cooled. The Victorians equated this with suppression of the growth of spoilage germs and introduced complicated means of keeping their food cool. Refrigerators, as we know them now, were not introduced until the 1860s, but before then 'iceboxes' were used in which large chunks of ice kept the food cool. The production of ice was not an easy task either – this is a circular problem; without refrigeration it is difficult to produce ice. In the early days, ice was collected during the winter and packed into ice houses, then the ice houses were used for storage of perishable food. With good insulation the ice could be maintained for a good proportion of the year in temperate climates. Later ice was made using cooling chemicals and water. For example, when diethylether evaporates it takes in heat, thus cooling its surroundings; the cooling property of ether was used to freeze water for iceboxes. There is no doubt that the increased availability of iceboxes increased the safety of mid-1800s' food. In the 1860s, the Industrial Revolution was under way; the developed world was enthralled by mechanical devices and commercial, large-scale manufacture. Long-haul transport became important as a means of moving products, including food, around and between nations; this led to a renewed interest in cooling devices both to keep food cold at home, and, perhaps more importantly, to allow food to be transported long distances without spoiling. Since the problem of food spoilage was more acute in hot countries, it is perhaps not surprising that it was a man from Scotland living in Australia who appreciated the need to cool food. This man was James Harrison (1816–1893) and he developed one of the first mechanical cooling devices based on the compression and expansion of a volatile liquid (when liquids evaporate – remember the ether example above – they take up heat). Harrison was granted a patent for the vapour-compression refrigerator in 1855. He used



Figure 1.6 A cow creamer. (Photographed with permission from the collection of Mrs S. Drew, Christchurch, New Zealand.)

this device to manufacture ice for the first attempt to transport meat from Australia to England in 1873. Unfortunately the ice melted before the ship arrived in England and the meat spoiled. It was not until 1882 that the first successful shipment of cooled meat was made from the antipodes to England and it went from New Zealand not Australia.

Refrigeration revolutionised food safety and continues to be used as one of the main ways we keep our food safe in the 21st century.

It is clear that the Victorians were aware of hygiene and its link to health. Mrs Beeton's *Book of Household Management* (published 1861) has many tips on hygiene; she advises suspending chloride of lime (calcium hypochlorite – $\text{Ca}(\text{ClO})_2$)-soaked cloths across the room. Chloride of lime slowly liberates chlorine gas which is a powerful antiseptic. Such methods would have killed bacteria and therefore made food preparation more hygienic.

There are some good examples of the Victorians' concern about food hygiene. For example, they loved intricate, delicate china to accompany afternoon tea. Milk was served from creamers (small jugs) sometimes shaped like cows. Cow creamers (Figure 1.6) disappeared in the late 1800s because of concerns about hygiene – it was very difficult to clean them properly because of their intricate design.

Chemical preservatives

Food spoilage and food-borne illness can also be prevented by using naturally produced chemicals to kill bacteria or significantly reduce their growth rate. Some of these methods are very old. For example, fermentation; here 'good' microorganisms are used to produce natural preservatives in the fermented food. Salami manufacture relies upon fermentation. The acid products of the fermentation process (e.g. lactic acid) preserve the meat by inhibiting the growth of pathogens and spoilage bacteria which do not thrive in acid conditions (see Chapter 11, *Antimicrobial food preservatives*). On the

other hand, yoghurt is simply milk infected with good bacteria (traditionally *Lactobacillus bulgaricus* and *Streptococcus thermophilus* and more recently *L. acidophilus*); these bacteria colonise the milk so effectively that they prevent harmful bacteria growing. Yogurt production, as a means of preserving milk, has been known for at least 4,500 years and probably began in Bulgaria.

Some chemical preservatives are added to food to prevent food spoilage. Some of these preservatives have been used for thousands of years. Vinegar (acetic acid; ethanoic acid) produced by fermenting ethanol (originally from wine) is a good example; traces have been found in Egyptian urns from 3,000 BC and it is still used today to pickle vegetables (e.g. onions) and make chutneys, etc. The acidity of vinegar inhibits most bacterial and fungal growth, thus preventing food spoilage – the principle is the same as described above for food preserved by fermentation, but, in this case, the acid is added to the food rather than being produced by fermentation of the food (see Chapter 11, *Other organic acids*).

Sugar is also used as a preservative. If the concentration is high enough it too prevents bacterial and fungal growth by scavenging the water that microbes need to survive (sugars form hydrogen bonds with water, thus effectively removing the water from the system). Sugar, either in the form of refined sugar (sucrose) or honey (mainly fructose), has also been used for thousands of years to preserve food. Jam is simply fruit boiled with sugar and bottled aseptically. Sugar can also be used to bottle or can fruit which involves heating the fruit in a strong sugar solution in jars and sealing the jars aseptically. Both bottled fruits and jams will keep for years.

There are also many modern means of preserving food using gases (e.g. nitrogen) and chemicals (e.g. sodium benzoate) to inhibit microorganism growth, or using irradiation (see Chapter 12) to kill them. These techniques are associated with risks to the consumer and therefore are often controversial; we must not forget, however, that the risk of harm following exposure to a food pathogen is likely to be greater than the risk of the method of preserving the food (this will be covered in detail in Chapter 11). However, there is no doubt that pickling with vinegar and preserving in sugar represent a negligible risk to the consumer ... unless, of course, you eat too much of the sugar-preserved food and your teeth decay and you become obese!

Sodium benzoate itself has a very low toxicity – no adverse effects have been seen in humans dosed up to 850 mg/kg body weight/day. However, in the presence of ascorbic acid (vitamin C) sodium benzoate can react to form benzene (Figure 1.7) which is a carcinogen. Since many foods that sodium benzoate might be used to preserve might also contain ascorbic acid, perhaps the risk is not worth the benefit. On the other hand, benzoic acid is present at low concentrations naturally in some fruits (e.g. cranberries) and they contain ascorbic acid too, so you cannot avoid the risk if you choose to eat these foods. Sometimes 'natural' is not good (See Chapter 8 for many more examples), but whichever way you look at it the risk is very low indeed (see Chapter 2).

For cats, the risk of cancer following benzene exposure via foods preserved with benzoate is significant because cats have very different routes of metabolism to humans and are unable to detoxify benzoate efficiently and so benzoate itself is toxic to cats. For this reason, the allowable level of sodium

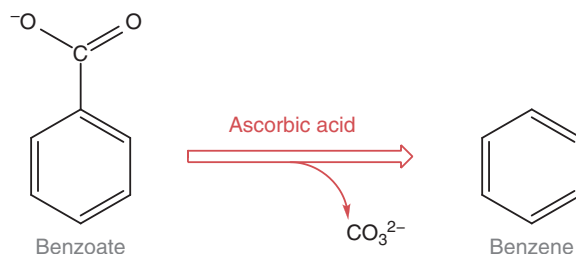


Figure 1.7 The oxidation of benzoate by ascorbic acid to form highly toxic benzene.

benzoate in proprietary cat foods is significantly lower than the corresponding level for foods intended for human consumption.

The influence of religion on food safety

Many religions are strict about what foods can be eaten and how they should be prepared. There is often little rationale for this except that it was decreed thousands, or more, years ago by the prophets or gods of the religion concerned. It is tempting to speculate that the reason that the food rules were originally introduced was because they constituted a simple means by which food was made safer to eat. There are good examples that illustrate this from Judaism and Islam.

The *Old Testament* prohibits the Jews from eating pork:

And the swine, because it divideth the hoof, yet cheweth not the cud, it is unclean unto you: ye shall not eat of their flesh, nor touch their dead carcase. (*Deuteronomy* 14:8)

Similarly the Koran forbids pork consumption:

He has only forbidden you dead meat, and blood, and the flesh of swine ...'

Banning pork was a very sensible food safety rule for a warm climate thousands of years ago. Pigs can be infected by the parasite *Trichinella* (see Chapter 5, *Trichinella* sp.) and it is likely that many more pigs were infected then than are infected now.

Trichinella is a roundworm (nematode) that infects pigs and spreads quickly via its eggs in infected animals' faeces. Consumption of undercooked *Trichinella*-infected pork can lead to human infection which leads to severe fever, myalgia, malaise and oedema as the *Trichinella* larvae infest the host's muscles. Modern meat production hygiene operated in most developed countries has reduced the incidence of human trichinellosis to very low levels – in the USA there were only 25 cases between 1991 and 1996, whereas in Asia and parts of eastern Europe there are still thousands of cases annually. Since the animal husbandry and meat production hygiene were primitive in the times of Christ and Allah it is very likely that most pigs were *Trichinella*-infected and therefore the risk of disease from eating pork was great. So what better food safety legislation than to ban pork consumption through the religious statutes?

The impact of space travel on food safety

The biggest impetus to make absolutely certain that food is safe was the introduction of space travel in 1960s USA. Astronauts must eat, but they simply cannot become ill while floating around in space, primarily because they usually do not have a doctor on board to treat them, and if they did the 'hospital' facilities would be rudimentary at best. There is a rather more pressing and pragmatic reason for not getting food-borne illness in the confines of a space craft orbiting the earth – most food-borne illnesses are associated with diarrhoea and vomiting and this is out of the question in a spaceship at zero gravity for obvious reasons. The developers of the US space programme realised the potential problems associated with unsafe food in space and therefore they formulated a series of extremely strict rules to ensure that the food consumed by astronauts would not make them ill. Producers of food for space travel had to ensure that it was sourced from reliable producers, that it was prepared under ultra-hygienic conditions, that it was cooked properly (to kill any pathogenic organisms that might be present) and packaged in a way that prevented later contamination (Figure 1.8). In addition, they developed a testing regime to check that astronauts' food was not contaminated with potential human pathogens. The system worked – as far as I am aware there has not been a serious incident of food-borne illness on any space mission so far.



Figure 1.8 Space food used by US astronauts. It is sterilised and vacuum packed to prevent food-borne illness in space. (Picture from <http://en.wikipedia.org/wiki/File:ISSSpaceFoodOnATray.jpg>.)

The system that the US Space Agency formulated is the basis of modern food safety principles and has been adopted as the Hazard Analysis and Critical Control Point (HACCP) approach to minimising food-associated risk.

It is clear that making food safe by preventing the growth of spoilage and pathogenic organisms has been practised for a very long time. This is important because it allows food to be stored for times when it is less plentiful. We still use ancient food preservation techniques today to make some of our finest delicacies, including salami, yoghurt and cheeses. The idea that 'germs' in food might make the consumer ill is a much more recent (within the last 150 years) leap in understanding and the concept of chemical contamination causing illness is even more recent; these two facets of food safety form the basis of food legislation (see Chapter 16) in most countries.

In the following chapters we will explore what makes food unsafe, the processes that are used to make food safe and the laws that are in place to make it an offence to sell unsafe food. Food is safer now than it has ever been. Read on and you'll find out why.