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The changing face of disease: implications for society

Brian J Ford

Introduction

The papers presented at the meeting have offered us challenging insights into the development of the study of diseases and their impact on human health. For this final presentation I wish to adopt a contemplative stance, and to air some thoughts on the new age that awaits us. For fifty years, microbiology has dwindled to become a 'Cinderella' science (Ford, 2000a). Young biologists have been discouraged from entering the discipline, since it has been tacitly assumed that the major infections were known and relatively little work remained to be accomplished. Virologists, when retired, found they were not replaced (Slade, 2001).

Much microbiology became subsumed into molecular biology, and the topic generally became regarded as unfashionable and passé. The levels of immunisation among the young fell to dangerously low totals, and when the BCG vaccine was proving difficult to source in Britain, wholesale vaccination of the teenage population was relegated to a matter of low priority. This is at variance with the realities of the subject, since the new millennium, arbitrary as the demarcation might be, seems to me to herald an entirely new era of infection.

We are encountering new diseases that may have implications for human health (such as BSE); recently identified pathogens (including *Helicobacter pylori* and *Campylobacter*); new types of well-known pathogens (for example, *E. coli* O157 H7); and a range of new means of transmission. From cling-film wrapped sandwiches, that offer a secure medium for cryophilic organisms like *Listeria*, to international transportation, which can bring people into contact with new diseases and can offer pathogens a unique channel through which to propagate an epidemic (in addition to global dissemination of the consequences) the new problems are largely undivined and widely ignored. In this closing paper I wish to review a selection of the new problems, emphasising the grounds for my belief that a radically changed proactive stance to novel infection risks will be a necessary concomitant to a secure and civilised lifestyle in the future. Microorganisms are great opportunists, and the channels for transmission that are available in the modern world add greatly to the problems we will encounter in the west.

Foodstuffs, traditional and novel

Disease has long been spread through food. Some of the earliest dietary strictures were based upon an ancient understanding of infections spread through our daily diet. The parasitic nematode *Trichinella spiralis*, spread by inadequately cooked pork, causes serious lesions and the fact has been known for thousands of years. It is to avoid such infections that the proscription of eating pig-meat amongst semitic and other races was first introduced.

Infections with the beef tapeworm *Taeniarhynchus saginatis* are now rare. The primary host is mankind, while cattle are the secondary host. Current agricultural practices in the west make the closing of the cycle improbable, but plans to reuse human excrement as a soil conditioner and fertilizing agent raise the possibility that infestations could reappear.

The storage of chilled food allows some pathogenic organisms (like *Listeria*) to flourish; similarly, stored peanuts show a high incidence of growths of fungal organisms that are sources of aflatoxins. Although health and safety regulations for food workers have been widely advanced, the recorded incidence of food poisoning is steadily increasing throughout the western world. We are all aware, from personal experience, that casual gastroenteritis is rarely reported to the public health authorities; thus the true extent of this problem is far greater than statistical evidence suggests. Much of the problem can be related to modern methods of food preparation and packaging, and it can be argued that insufficient emphasis is placed upon the health implications of newly introduced forms of food.

Notions of naturalness

There are some prevalent ideas on the supposed naturalness of foodstuffs that may predispose western populations to harm. Nothing could be envisaged as more 'natural' than a hunk of bread and butter and a slab of cheese. In fact, these are the products of technology - traditional technologies, indeed, but profoundly unnatural processes none the less. The grinding of grains of the common bread wheat *Triticum aestivum* (= *T. vulgare*) to form a paste, which is then fermented through the action of the ascomycete yeast fungus *Saccharomyces cerevisiae* and baked in an oven, is far from a natural process. *T. aestivum* is itself a man-made species, unknown in nature; *Saccharomyces* is confined to the skin of fruit in its natural environment.

Similarly, cheese is a product of a wholly unnatural set of processes: cow's milk is a natural food only for calves, and the fermented products we know as cheeses are products of considerable technical refinement. Goat's-milk is widely regarded as a more wholesome alternative, heedless of the fact that it is subject to fewer health controls and may be more frequently infected with pathogens. Health food fanatics are prominent consumers of synthesised meat substitutes such as Quorn, even though these are the products of extensive technological processing and has no counterpart in nature. Notions of 'naturalness' need objective reassessment.

Sexual behaviour

Since the 1960s the increased emphasis on sexual freedom has encouraged promiscuous behaviour. The western world is characterised by a widespread acceptability of multiple sexual partners, and the fashionable nature of such attitudes means that the term 'promiscuity' is rarely encountered. This must be viewed in contrast to traditional societies, in which complex rituals to guard against promiscuity are widespread. The notion that the contraceptive pill enabled women to conduct relationships without fear of pregnancy circumvents the concern posed by a rising incidence of sexually transmitted disease. In consequence, a rising incidence of organisms such as *Chlamydia* is now apparent in young women. Female human anatomy makes it less likely that characteristic symptoms, such as a discharge, will be noticed. In consequence, we are witnessing a rise in the incidence of STDs. Although this applies to traditional diseases such as syphilis and gonorrhoea, it is in the newer conditions (including chlamydia and HIV) that the increase is most marked. The

erosion of sub-Saharan societies by AIDS is particularly noteworthy: the very viability of many ancient communities is threatened by the widespread incidence of this tragic new disease.

Xenotransplantation

There is something so simplistic about the notion of xenotransplantation. A donor animal, customarily a pig, because of the anatomical similarity of its internal organs to those of humankind, is genetically modified so that surface markers on the cell surface will be recognised by the host (the human recipient) as self rather than non-self. The rearing of a pig as a source of a heart, kidneys, pancreas, etc., seems to offer hope for extensive organ transplantation without the complications of immunosuppression. In practice, it is not so simple, for mammalian species harbour viruses that may be symptomless and non-infective in the host, but potentially harmful to the recipient.

A greater awareness of the extent of the risk of infectious disease in the course of this research might have prevented unduly optimistic forecasts of the progress of the research. A list of viruses known to be transmissible from pigs to humans in xenotransplantation is given below; the same authors list over 60 species of microorganisms that could be transmitted to humans via the same route. The occurrence of these potential pathogens does not inevitably lead to an inference that they will prove to be unavoidable hazards in practice; current research into the use of porcine stem cells in humans with nerve trauma is currently under way, and some indications of the safety of xenotransplantation will inevitably accrue from this line of investigation.

TABLE 1: Porcine Viruses Capable of Transmission to Humans Following Xenotransplantation

Porcine adenovirus
Porcine cytomegalovirus
Porcine rotavirus
Porcine endogenous and exogenous retroviruses
Aujeszky's disease virus
Japanese encephalitis virus
Encephalomyocarditis virus
Vesicular stomatitis virus
Swine vesicular disease virus
Foot-and-mouth disease virus
Rabies virus
Swine influenza virus
Swine parainfluenza-1 virus
[Malaysian Nipah virus, vide infra]
[Australian Paramyxovirus, vide infra]

(Borie *et al*, 1998)

Potable water supply

There is a global shortage of potable water. In some arid nations, such as Saudi Arabia, reverse-osmosis desalination is used to produce potable water, but in other areas, extending from the Spanish coast to the western USA, the invasion of sea-water into subterranean strata is already causing water supplies to contain unacceptably high levels of ionic sodium. The introduction of breast milk formula into tropical countries is posing problems of its own, for the water used to reconstitute the product is often contaminated with waterborne pathogens.

Many areas are suffering a loss of forest cover, as wood is burned for fuel, and thus water is less often boiled. Waterborne diseases are posing an increased international problem. As we shall see, in Britain we have witnessed some outbreaks of *Cryptosporidium* infections and these may pose an important risk to the financial viability of privatised water-supply industry.

Suprahygiene

A curious side-effect of our hygienic mode of living in the west has been a tendency for us to indulge in routine hand-washing, bathing and showering until we avoid exposure to so many antigens that we may challenge our immune systems too little. It can be argued that regular antigenic stimuli maximise the immune responses of the body, so that a highly sophisticated and ultra-clean community is at greater risk from opportunistic infection.

There are several areas here that we need to address. One is that there are clearly communities of health-potentiating microorganisms that inhabit the skin, a lack of which might allow easier access to potential pathogens. Another is that early infections with microorganisms like *Cryptosporidium* traditionally produced a fleeting enteritis which conferred lifelong immunity. Keeping such challenges at bay may leave us increasingly liable to infection in the ultra-clean world of the future. Should this encourage us to reinvest in the old saying that a 'bit of dirt does no harm'? I doubt it. Some of the current pathogens are well adapted to routes of transmission left open through poor hygiene, and in future we may need to maximise a systematic antimicrobial stance.

Internet Marketing

Although some totalitarian regimes have tried to control the internet, and others (like China) attempt strictly to limit access to the world wide web, global access to the net is now the norm. The claim made for the internet is that it frees people to access global awareness. True as this is, it is less rarely recognised that it also offers opportunities for people to mail prohibited imports around the world and for customers to order potentially infected foodstuffs. Bush meats that are potentially contaminated with foot and mouth virus are widely exported in unlabelled packages.

It may prove to be the case that the current epidemic of foot and mouth in the UK originated in unlawful imports of infected meat from the Far East. There cannot be a single terrorist group anywhere in the world that has not watched the reports of the decimation of British agriculture with interest. Rather than expend large sums on missiles, extremists in future know that to close down a large portion of a national economy, all one need to do is to arrive with a virus-contaminated cloth in a pocket. The misuse of microbiological knowledge will open up unforeseen avenues of terrorism.

Commercial globalization

Western economies traditionally functioned with a large reservoir of poorly paid workers; once on farms and in homes, as domestic servants, and more recently in factories and mines. The opening up of global markets means that the subservient classes exist as they did before, but are now geographically remote from those who benefit from their labours. The resulting global patterns of trade mean that potentially infected goods and products are sent worldwide as a matter of routine.

The provisions of the UK health and safety legislation since the 1970s has bequeathed to us a framework that serves to reduce health risks from materials we purchase. Globalisation implies that products are imported from countries in which comparable safety regulations do not exist, and pose real hazards to public health. A recent outbreak of *Salmonella* in Australia was traced to imported halva (a paste made from sesame seeds).

Mass air transportation

A generation ago, air travel was still something of a luxury. The modern trend towards increasingly efficient and inexpensive air transportation encourages people from western nations to travel to areas of the world where exotic diseases are endemic. At the same time, immunisation against infections is on the wane. The routine vaccination of schoolchildren using the BCG vaccine is not practiced in the USA, and has been lacking in the UK for some decades due to 'problems of supply' with the vaccine itself. This leaves large populations at risk from the disease.

Worse still, the confinement of passengers within aircraft at altitude offers new opportunities for organisms to spread. Economies imposed by the air companies have led to a reduction in the rate at which fresh air is introduced into the cabin of an aircraft, which further increase the rate of contact between host and pathogen. Air transport, which has become a hallmark of the late twentieth century, could pose problems of interest to epidemiologists.

Reviewing the diseases

Many of the papers prepared for this important meeting have examined specific areas of research and it would not be appropriate here to attempt a comprehensive review of the hazards we may face. A contemplative stance does lend itself to a representative review, and we can select some examples for special consideration.

Chlamydia

For many decades, genito-urinary infections with *Chlamydia pneumoniae* were hidden under the generic categorisation of NSU (non-specific urethritis). In 1985 I proposed that the term chlamydia be adopted to identify the widespread incidence of the organism (Ford, 1985). Between 1985 and 1990 the incidence of this condition increased five-fold in young American women. The incubation period is between two days and two months, and the symptoms may include a slight itching or burning which is often dismissed as 'mere cystitis'. A urethral discharge is frequently overlooked among normal vaginal discharges.

The organism causes an inflammation of the fallopian tubes, and sterility is a common consequence of infection. The extensive pathology that results is promulgated by the vogue for sexual freedom. Although the infection is amenable to antibiotic therapy, infections may

be relatively asymptomatic and thus damage may be considerable without the sufferer being aware of the existence of a potentially serious condition. Barrier contraception, which can militate against the transfer of pathogens as much as spermatozoa, needs to be seen as a crucial safeguard of personal health.

Campylobacter

The genus *Campylobacter* has only been recognised in recent years. These are microaerophilic gram-negative organisms measuring 1.5-5 µm in length. Because of their unusual environmental preferences, the organisms did not appear in routine monitoring until the 1980s. Since studies began in the 1980s it has now emerged as the leading cause of enteritis in the USA, and is known to be widespread throughout the western world. Three species are of significance, *Campylobacter jejuni* is implicated in ninety per cent of outbreaks, while *C. coli* and *C. lari*, account for nine of the remaining ten per cent (Blaser et al, 1995. Butzler, 1984. Nachamkin, 1992).

The organisms are highly infectious; as few as 500 bacteria may provide an inoculum. The disease features watery stools sometimes followed by bloody diarrhoea. The species listed above are non-invasive organisms, though *C. fetus* is normally an invasive bacterium. Some strains of *Campylobacter jejuni* are occasionally invasive. These strains cause pneumonia, meningitis, spontaneous abortion and severe forms of Guillain-Barré syndrome. Three-quarters of the cases result from the consumption of food or water contaminated by animal waste, including fruit and vegetables, meat and poultry, shellfish and milk.

Listeria

Although the genus *Listeria* has been studied since the nineteenth century, it has recently attracted attention through its appearance in supermarket food products. *Listeria monocytogenes* is a gram-positive flagellated bacterium that has been isolated from a wide range of animal hosts and is found as a contaminant in soil. About 40 mammalian species have been shown to harbour *Listeria*, which can be isolated from intestinal samples of up to 10 per cent of the human population. *L. monocytogenes* has been contracted from unpasteurised (or ineffectively pasteurised) milk products such as soft cheeses, ice cream, raw vegetables, and all types of uncooked fish and meat, including uncooked sausages.

An inoculum of <1,000 cells is sufficient to induce infection. The symptoms are initially 'flu-like, progressing towards nausea, vomiting and diarrhoea. These typical forms of listeriosis can be followed by septicaemia and meningitis. *Listeria* provides a timely reminder of the exceptions to rules that we have to bear in mind. We know that phagocytic cells protect the body from pathogenic microorganisms, and that refrigeration is a front-line defence against the proliferation of pathogens in foodstuffs.

Neither is true in the case of *Listeria*. Here we have an organism that can penetrate phagocytes and multiply within them. This remarkable property allows the organism access to the cerebrospinal fluid, and may also pass the placental barrier to produce an intrauterine infection of the foetus. Furthermore, the organism is able to multiply at temperatures around 30C, and it is thus able to proliferate in a refrigerator.

Although it is the major outbreaks that attract attention (like the stillbirth epidemic of California in 1985, caused by soft Mexican style cheese) there is a growing number of casual

outbreaks. Currently there are around 2,000 cases of *L. monocytogenes* infection reported in the US each year. Testing relies on culturing the organism and takes up to a week, though recombinant DNA techniques currently under development may reduce that to two days (Anon, U.S. Food & Drug Administration Center for Food Safety & Applied Nutrition, 1999a).

Salmonella

Here we encounter a well-known organism that has been thoroughly documented. It has caused political repercussions, as when British parliamentarian Ms Edwina Currie MP was obliged to resign after claiming in the House of Commons that 'most chicken production' in the UK was infected. If 'most' is taken to mean 'more than 50 per cent' then it may be that the statement was technically inaccurate. This statement is not entirely misleading, since the incidence of *Salmonella infection* is steadily increasing throughout the Western world.

The genus includes several species of gram-negative rod-shaped organisms, all of which (excepting *S. gallinarum* and *S. pullorum*) are actively motile. *S. typhi* produces typhoid fever, but *S. paratyphi* can also produce a similar infection. As few as 15 cells may be sufficient to produce an infection with *S. typhi* and *S. paratyphi*. Although the initial symptoms include diarrhoea, cramping and headache, arthritis may supervene after a month. The sources of the bacteria include soil and water, factories and kitchen surfaces, and shellfish.

In the retail environment the organisms are particularly abundant in poultry and pork. *S. enteritidis* is particularly characteristic of poultry, and infected eggs are a hazard sufficient to have caused the general public health advice against the consumption of soft-boiled or poached eggs. It is now estimated that there may be half a million cases of salmonellosis in the UK each year, and up to 4 million in the USA. During the past decade, a six-fold increase has been recorded in the north-east United States. This is a potentially serious disease, and it is steadily on the increase.

Clostridium

Clostridium perfringens is a gram positive short rod-shaped non-motile sporing organism that is a common cause of food poisoning (Bean & Griffin, 1990). As few as 10 organisms per gram of food can result in an infection with an incubation period of around ten hours. There are several strains of *Clostridium perfringens* (= *C. welchii enteritis necroticans*): type A1 produces enteritis with marked colic and diarrhoea, though diarrhoea and vomiting are usually absent. Type A2 produces an enterotoxin, while type C cause a necrotising enteritis. The type A bacteria can also cause wound infections that can culminate in gas gangrene or gangrenous cholecystitis (Hatheway *et al*, 1980).

Currently, infections can be treated with penicillin, though some strains have been shown to have resistance to penicillin, tetracycline, erythromycin, chloramphenicol, metronidazole and clindamycin. The spores can survive for prolonged periods, and the bacteria have been shown to survive for up to a year in contaminated meat. Corned beef has sometimes been implicated in outbreaks. Recommendations include the storage of partly-used corned beef in a refrigerator, since the organism will not reproduce at or below 40°F (4.4°C) (Anon, Health Canada, 1994). *C. difficile* is of increasing importance in hospitals, and is often associated

with the over-use of antibiotics that disturbs the gut flora. In appropriate cases, metronidazole or vancomycin are used in therapy.

Bacillus cereus

This classical bacillus is widespread in nature and is one of the first organisms I cultured at the age of sixteen. So abundant is the organism that it is an inevitable contaminant of food, though only toxin-producing strains cause illness. The symptoms of disease are similar to those caused by *Staphylococcus aureus* and *Clostridium perfringens*. Various toxins may be produced by the various strains of *B. cereus*: those of high molecular weight tend to produce diarrhoea, whilst those of lower molecular weight produce nausea and vomiting.

The organisms produce toxins that reside in food, and thus trigger symptoms typically within 10 hours of consuming the contaminated food. Within 24 hours the symptoms typically subside. As is often the case in minor episodes of food poisoning, most cases are never reported to the authorities, so the accepted incidence (around two per cent of all outbreaks of food poisoning) is certainly an underestimate. Meat and fish have long been known to act as sources of the toxins, but in recent years rice has been more frequently incriminated (Anon, Centers for Disease Control and Prevention, 1994).

Vibrio parahaemolyticus

In Japan, this is the most frequently-encountered cause of casual gastro-enteritis. In the USA and Europe the organism is common in estuarine waters and can be accumulated by filter-feeding molluscs. Most vibrios pass through the gastrointestinal tract without causing problems for the host, but some organisms attach themselves to the intestinal wall and secrete a toxin. It is accepted that a dose of about 1 million organisms is needed to induce disease, though the number is greatly reduced in patients taking antacid preparations. The resulting disease manifests itself as diarrhoea and vomiting, abdominal cramps, headache and fever. In most cases the illness lasts for about three days and is mild to moderate, though some require hospitalisation. Related species can cause wound or ear infections, etc.

Table 2: Food-borne *Vibrio* species potentially pathogenic to mankind

Vibrio alginolyticus
Vibrio carchariae
Vibrio cincinnatiensis
Vibrio damsela
Vibrio fluvialis
Vibrio furnissii
Vibrio hollisae
Vibrio metschnikovii
Vibrio mimicus

(Anon, 2001)

Helicobacter pylori

The recognition of *Helicobacter pylori* in the human gastrointestinal tract was greeted with much interest, for it seemed to be the organism responsible for the great majority of duodenal ulcers. The discovery was made by Barry J Marshall, an Australian microbiologist, who drank a broth culture of the organism and contracted gastritis as a result (Marshall, 2001). It is said that a course of antibiotics resolved the illness, though colloquial reports suggest that the condition resolved spontaneously. Until *H. pylori* was recognised, the cause of ulcers was believed to be hyperacidity consequent upon emotional stress or spicy foods, etc., acting upon the gastric and/or duodenal mucosa. However, a number of small spiral gram-positive bacteria were regularly observed in histological preparations of ulcerated gastric tissues, and these proved to be the *Helicobacter pylori* that has since been isolated in 90 per cent of sufferers from duodenal ulcers and 70 per cent of those suffering gastric ulceration. Aspirin and ibuprofen are claimed to be causally related to the remaining cases.

There is also a close correlation with carcinoma, such that the WHO designated *H. pylori* as a 'Category 1' carcinogen in 1994. The causative relationship between the bacteria and disease can be questioned, since the majority of people infected with the bacterium worldwide do not become ill, and in some surveys the levels of ulcer patients positive for the bacteria is much below 50 per cent. It can also be argued that the organism confers health by protecting against oesophageal carcinoma: in the areas of the West where the use of antibiotics has reduced the incidence of *H. pylori*, levels of cancer of the oesophagus are steadily increasing. It may be that the organism is a familiar inhabitant of the human gastrointestinal tract, where it can help protect against cancer, but which can become pathogenic if its environment is disturbed. Certainly the effects of ulcers have been widespread. Among those who seem to have succumbed to the condition are Lorne Greene, Stonewall Jackson, Pope John Paul II, James Joyce, Ayatollah Khomeini and Imelda Marcos.

Cryptosporidium parvum

The type species of this genus is *C. muris* and it inhabits the gastric glands of several mammalian species (including laboratory rodents) but rarely infects humans. Although *C. muris* is frequently said to infect humans, the species involved is actually *Cryptosporidium parvum*. The genus is a member of the coccidia, and is a protozoan related to the gregarines. *Cryptosporidium* is a parasite of neonate mammals (Atwill, 1999). Human infants traditionally contracted the infection through contact with farm animals (de Graaf, 1999), the transient diarrhoea that ensued conferring lifelong immunity (Clavel, 1996). Interestingly, the human species is unusual in that we are able to contract the infection at any age. *C. parvum* enters the gut in the form of an oocyst containing four infective sporozoites that are liberated in the presence of digestive juices.

The main site of infection is the ileum, where the parasites may be observed apparently attached to the luminal surface of the mucosal cells. Electron microscopy reveals that the sporozoites are covered by cell membrane, and are actually intracellular parasites. Each subdivides to form eight merozoites which can colonise previously uninfected cells and thus perpetrate the infection. Cryptosporidia are not eliminated by chlorination of water, and large outbreaks have been reported from many parts of the western world (Cordell, 1997). It may be wondered why legal action for damages by business people has not been reported, but personal discussions suggest that the water companies resolve such disputes by out-of-court settlements, in which a non-disclosure clause is conditional.

VTEC (*E. coli* O157:H7)

Verotoxin-producing *Escherichia coli*, VTEC, is also known as *E. coli* O157:H7. This is a fast emerging pathogen that was first identified in 1982. It appears that a strain of *E. coli* acquired genes coding for toxin production in the related coliform genus *Shigella*. From being a relatively obscure organism in the 1990s, *E. coli* O157:H7 has spread to infect the majority of cattle in the UK and USA, and is increasingly widespread around the world. The bacterium produces a bloody diarrhoea that can worsen and lead to widespread damage to internal organs. Farm animals may be asymptomatic carriers, and infants can also excrete the organism for some weeks after recovering spontaneously from infection.

Older children (and adults) are much less likely to carry the organism and not show symptoms. Lavatory hygiene is important in preventing an outbreak, and so is the avoidance of raw or partly cooked beef. Although pasteurisation will kill *E. coli*, the organism has been spread through milk and fruit juice. Information is available through web sites including: Partnership for Food Safety Education information on *E. coli* O157:H7 - <http://www.fsis.usda.gov>

U.S. Department of Agriculture web site - <http://www.fsis.usda.gov/OA/topics>

Antibiotic-resistant cocci

The gram-positive coccus *Staphylococcus aureus* is a common skin commensal, and was one of the first bacteria to be defeated by the newly-introduced penicillin in the 1940s. Strains are now known that are resistant to conventional antibiotics and methicillin-resistant *Staphylococcus aureus* (MRSA, sometimes also known as 'multiple-resistant') are becoming common. Vancomycin, the antibiotic of last resort, is also now known to be ineffective in some cases, and vancomycin-resistant *Enterococcus faecalis* and *E. faecium* (VRE) are also becoming familiar.

These organisms compromise the health of patients at risk, for example through a weakened immune system, and can produce life-threatening infections. Barrier nursing and personal hygiene are all important in the management of sufferers, and here we are reminded of the need for new antimicrobial agents. Many of these organisms can survive for up to a week on dry surfaces. They are now commonly found in the hospital environment, and iatrogenic infections are an increasing threat to our future.

Mycobacterium

Among those who died of tuberculosis have been:

- Frederick Chopin (d 1849 aged 39) the composer
- Rene Laennec (d 1826) discoverer of the acid-fast bacillus
- John Keats (d 1821 aged 26) poet
- John Harvard (d 1638 aged 31) founder of Harvard University
- Robert Louis Stevenson (d 1894 aged 39) author
- Anton Chekhov (d 1904 aged 43) playwright
- Max Lurie Max Lurie (d 1966 aged 73) TB researcher
- Franz Kafka (d 1924, aged 40) the surrealist author.

It was not unusual for entire families to be killed by TB. The Brontë family, descendants of the reverend Patrick Brunty (who changed his name in order to make it more socially acceptable), succumbed to TB:

- Brontë's wife Maria Branwell (d 1821 aged 39) and their offspring:
- Maria (d 1825 aged 12)
- Elizabeth (d 1825 aged 11)
- Branwell (d 1848 aged 31)
- Emily (d 1848 aged 30) who wrote *Wuthering Heights*
- Anne (d 1849 aged 29) author of *Agnes Grey*
- Charlotte (d 1855 aged 39) who wrote *Jane Eyre*.

Tuberculosis was a daily part of life and begrudgingly accepted, often as part of an ascetic lifestyle. In a similar way, today we associate a virtual plague of coronary heart disease and strokes with over-stressed businessmen. In earlier eras TB was not recognised as having a single cause and colloquial names were given to its various manifestations; thus *lupus vulgaris* was the term used for TB occurring in the skin.

Table 3: Traditional terms for tubercular infections

Consumption - Pulmonary tuberculosis
King's evil - Tuberculosis of cervical lymph glands
Long (or Lung) sickness - Pulmonary tuberculosis
Lupus Vulgaris - Tubercular lesions of the skin
Mesenteric disease - Tuberculosis of abdominal lymph glands
Phthisis - Pulmonary tuberculosis
Pott's disease - Tubercular lesions of the spine
Scrofula - Tuberculosis of cervical lymph glands in young adults
White Plague - Pulmonary tuberculosis
White swelling - Tuberculosis of the bone

The organisms that cause TB are acid-fast bacilli with a waxy coat that serves to make the disease difficult to treat. Immunisation using the BCG vaccine has been widely used in many countries to reduce the spread of the infection. On 20 November 1944 streptomycin was first used to treat tuberculosis, yet by 1947 the first examples of resistance to streptomycin were being recorded. Since the introduction of streptomycin, many other antimicrobials have been brought into use. Para-aminosalicylic acid (PAS) was shown to have weak anti-tubercular effects in 1946, and from 1948 it was used with PAS to treat patients successfully. By 1951 the streptomycin was replaced by isoniazid, and then came pyrazinamide (1954), cycloserine (1955), ethambutol (1962) and rifampicin (1963).

Currently the aminoglycosides amikacin, capreomycin, viomycin and kanamycin are used with quinolones including ofloxacin and ciprofloxacin for resistant strains of the organism. The macrolides, which are also useful, await further clinical testing.

In spite of these strides taken at the research level, strains of tubercle are now found that are resistant to all available agents. A generation ago the purpose of the Temple of Peace in Cardiff, Wales, was subject to reappraisal. The building had been provided by a charity to support the war against TB, and in the 1970s it was felt that there was no further use for the

concept - TB was construed as having been beaten. In the global scenario, however, matters are unambiguously disturbing. One-third of the human population is infected with TB and on new individual is infected every second. An undetected victim will infect some 20 new people per year (Barnes *et al* 1996, Nardell *et al* 1986). metronidazole or vancomycin.

Those infected with drug-resistant tubercle suffer a 70 per cent risk of mortality, and rates of infection in the western world have been increasing since the mid-1980s. In the 1930s, levels of infection in the US were 175 per 100,000. By 1965 that had fallen to 2 per 100,000, but by 1992 the figure had risen to 52 per 100,000. The current invasion of resistant organisms is a cause for concern. In confined circumstances (such as an aeroplane, a subway or a conventional train) a large number of potential contacts could be involved, and in an era where the organisms are resistant to therapy the consequences could be serious.

Lyme disease

This debilitating chronic fever is caused by a tick-borne spirochaete named as recently as 1984 *Borrelia burgdorferi*. The bacteria can be cultured on Barbour-Stoenner-Kelly agar but have a slow rate of growth, often requiring 24 hours for fission to be completed (Nadelman, 1990). *B. burgdorferi* has been incriminated in Lyme Disease in the USA, but *B. afzelii* and *B. garinii* are the causative agents of the disease in Europe.

The syndromes produced by the species are somewhat at variance: arthritis seems to be more typical of the disease produced by *Borrelia burgdorferi*, and also cause Lyme disease in Europe. In Asia, only *B. garinii* and *B. afzelii* cause Lyme disease in humans. Evidence is accumulating that these closely related, but different, spirochetes are associated with somewhat different disease expressions.

Arthritis appears to occur more frequently following infection with *B. burgdorferi*, cutaneous symptoms are typical of *B. afzelii* while neurological manifestations are more typical of *B. garinii* infections (Steere, 2001).

Bartonella

Trench fever was the name given during the First World War to a louse-borne disease with symptoms including fever, rash splenomegaly and severe bone pain. It is caused by *Bartonella quintana*, and it is estimated that one million troops were infected between 1914-1918. In the 1980s the disease (which is also known as cat-fever) began to re-emerge (Relman, 1995), this time as an opportunistic infection in victims of AIDS in the USA, and later in France (Stein & Raoult, 1995). Meanwhile the tick *Ixodes pacificus* from California has been shown to carry a reservoir of infection, and it may be that this accounts for episodic outbreaks (Jackson *et al*, 1996).

Research in Sweden on orienteers between 1979-1992 showed that 16 suffered heart attacks in a sample where one might be anticipated. *Bartonella* was incriminated in these cases, and the organism is already known to cause cardiac damage in cats. Here we may have a disease that is more widely implicated in public health than is currently realised, and which appears to be increasing in its geographical spread. Antibiotic therapy with azithromycin, doxycycline, erythromycin or tetracycline is claimed to be effective.

Emergent viruses

We are experiencing the colonisation of human communities by organisms that we have not encountered before. *Campylobacter*, VTEC (E. coli O157:H7), MRSA, and multiple drug-resistant *Mycobacterium* are among the bacterial pathogens that have emerged within the last generation. Other current threats to human health are of more ancient lineage. *Bacillus anthracis*, recently used in mail-borne terrorism, is not infectious, person to person, but many of these recently-emerged organisms have the capacity to trigger epidemic outbreaks. It is when we consider virus outbreaks, however, that we may gain an impression of the magnitude of the potential problems that we face in a new era. We may contemplate a representative selection of these, including, as a finale, some viruses that have been identified within the last few years.

Hanta virus

Korean haemorrhagic fever, caused by Hantavirus, was first recognised by Western scientists during the Korean war. The disease is spread by rodents. In recent years, cases have been reported from Argentina and Chile, and now there have been reports from the USA, notably California. The strains of the virus cause different syndromes, including Hantavirus Pulmonary Syndrome (HPS) which has been found in the USA, and Haemorrhagic Fever with Renal Syndrome (HFRS) in which renal failure, haemorrhage, and shock occur in sequence. Levels of mortality are about 80 per cent in the USA.

In the last fifteen years there have been some 200 cases in Argentina, less than 30 in Chile, and a handful in Brazil and in California. The incubation period can be over a month, followed by the sudden onset of severe respiratory distress and likely death. On 23 May 2001 the Centers for Disease Control and Prevention (CDC) announced that they had begun to receive reports from authorities concerned over the fate of a stock clerk who became infected with Hantavirus while working in a storeroom. According to the e-mail message, the infection resulted from exposure to dried rodent droppings that were contaminated with Hantavirus. It was a hoax. As we have seen in more recent times, biological agents are peculiarly susceptible to misappropriation by hoaxers. A greater familiarity with the behaviour and nature of potential pathogens on the part of the public is our surest way of keeping such matters in perspective. Web site - <http://www.cdc.gov>

West Nile Virus

Here we have an emergent disease with a ten per cent mortality that is causing much interest in the USA since it has begun to cause infection on the East Coast in the last few years (Anon, CDC, 1999b). In 1999 there were 58 cases and seven deaths, with much attendant publicity in the press and broadcast media across the western world. We may contrast this with the position in 1997, when there were over 500 cases in Romania and little attention was paid by America or Britain.

The disease emerged in the New York City on 4 August 1999, and on 31 August an 80-year-old man died of encephalitis (Hubalek *et al*, 1999). This was the first time the virus had been detected in the Western Hemisphere. The secondary host for the virus is avian, and about 20 species - from the crow to the bald eagle - have been shown to harbour the virus. Mosquitos transmit the virus to the human host. The effect of global warming would encourage the

proliferation and geographic spread of the insect vector, which allows us to infer that such outbreaks may become more prominent in future decades.

Lassa fever

This disease was first described in the 1950s, though the virus, a member of the Arenavirus group, was not recognised until 1969. Human carriers may be entirely asymptomatic, but in others the disease exerts a powerful and devastating effect. A gradual onset of headache, nausea, cough, vomiting and diarrhoea progresses to shock, effusion and haemorrhage with encephalopathy. Fifteen per cent of hospitalised patients die, and those that survive may suffer deafness, alopecia and a loss of manual coordination. Ribavirin, an antiviral, may prove to be effective in therapy if administered within the first six days of onset.

The disease is found in Guinea, Liberia, Nigeria and Sierra Leone. The secondary host, recognised during the 1970s, is the multimammate rat *Mastomys natalensis*. There is no vector, the virus being acquired by inhalation of dried excreta, etc., from the rodents. Once established in the human host during the acute phase the disease is highly contagious, being spread easily to unprotected hospital personnel for instance. The incubation period is 1-3 weeks. A recent major outbreak was in Sierra Leone in 1996-97. A total 823 cases were reported with 153 deaths (18.6% mortality).

Ebola and Marburg haemorrhagic fevers

The existence of the highly dangerous Filoviridae emerged in 1967 when scientific staff in Belgrade, Yugoslavia and Marburg, Germany, became infected with a virus contracted from tissue samples from the African green monkey *Cercopithecus aethiops*. Of the 25 primary cases, seven died. Sporadic outbreaks have since occurred in Zimbabwe, Kenya and South Africa. Subsequently, the related Ebola virus gave rise to outbreaks in Zaire and Sudan in 1976. Over 500 cases were reported, with a mortality rate of 53 per cent in Sudan and 88 per cent in Zaire. In November 2000 an outbreak in Uganda of 280 cases of Ebola haemorrhagic fever resulted in 89 deaths, a mortality rate of 24.9 per cent. No association between Ebola and monkeys is known.

Further discoveries of Filoviridae have been made in the cynomolgus monkey *Macaca fascicularis* that is native to the Philippines. These are the Reston viruses which, though serologically similar to Marburg and apparently transmissible to humans, do not cause a disease in the human host. The symptoms and course of the diseases are legendarily unpleasant. After an incubation period of 4-16 days fever, headache and myalgia become manifest, soon followed by nausea, dehydration and diarrhoea. Haemorrhage appears from the orifices, lungs and into the abdomen from the gastro-intestinal tract.

It has been shown that Novalgin (Metamizol, Antipyrin) can reduce intravascular coagulation in Marburg disease. However, vaccination of experimental animals with antigen and with inactivated whole virus particles has shown no prophylactic benefit following a challenge with live virus. A vivid portrayal of an epidemic in the California hills in the Hollywood film 'Outbreak' was drawn to the conclusion that a nuclear attack on the district was the only way to curtail it. Clearly, in the minds of the public, such viruses pose serious threats.

Dengue fever

Here we encounter the most widespread of all haemorrhagic fevers across the world. Fortunately, most cases do not progress to this stage, but unfortunately this is the most rapidly spreading insect-borne disease known to us. The condition was first by Western medical science in 1780, though modern reports of epidemics date only from 1949. Over two billion people live in at-risk areas, and tens of millions of new cases occur each year. Haemorrhagic fever effects annually perhaps a quarter of a million people. No vaccine is available, though an experimental attenuated candidate vaccine has been investigated in Thailand.

There are four serotypes of Dengue fever, and an infection with one serotype, far from conferring resistance, seems to increase the likelihood of a haemorrhagic fever in any subsequent infections. The disease is widespread across large areas of Africa, Asia and South America (including the Caribbean). The vector is the mosquito *Aedes aegypti*, and the use of a reliable insect repellent is the most effective prophylactic measure travellers can take. Dengue fever is characterised by a sudden high fever, myalgia, nausea and retro-orbital pain often accompanied by bradycardia.

In most cases, symptoms persist for a week (hence a common name, 'seven-day fever'). In some cases the immune system collapses, with a further increase in temperature, shock convulsions and a fatal outcome. Haemorrhagic dengue manifests itself as prostration and bleeding from the gastro-intestinal tract and elsewhere, and has a five per cent mortality. In recent years the disease has been appearing in states in which it previously undetected, including Venezuela (1990), Brazil (1991), Djibouti (1992), and Pakistan, Saudi Arabia and Nicaragua (1994).

Nipah virus

In March 1999 an outbreak of a new virus from pigs was reported in Malaysia (and Singapore). The disease manifested itself as an acute encephalitis and respiratory illness that often resulted in death. The cause proved to be a hitherto unrecognised paramyxovirus that has been named Nipah virus. Once the connection with pigs was recognised, abattoirs were closed in Singapore, and no further examples of infection were reported.

In Malaysia, by 27 April 1999 there had been 257 cases of febrile encephalitis recorded the Malaysian Ministry of Health (MOH), 100 of which had a fatal outcome. Some further cases were reported in Negeri Sembilan and Selangor. The most likely source of the virus is pigs; in the Negeri Sembilan outbreak, almost 90 per cent of the victims reported they had recently been close to pigs; two-thirds of the patients reported that the pigs with which they had been in contact had appeared unwell. The virus has not been shown to be transmissible from person to person, and it was controlled by the slaughter of 900,000 pigs in the affected areas (Anon, CDC, 1999c).

Paramyxovirus

In 1994 a hitherto unknown equine morbillivirus (EMV) caused an outbreak of a severe disease in horses and humans. Levels of mortality appear to be high: of 21 horses found to be infected at Brisbane, 14 died (or were put down due to) severe respiratory distress; of the two

human contacts suffering a similar disease, one died (Selvey et al, 1995). The source of the virus appears to be the fruit bat or flying fox *Pteropus*.

Two outbreaks were reported with a month of each other: one at Brisbane, the other at Mackay; towns separated by 1000 km. In the Mackay incident two horses became ill and both died (Murray et al, 1995). One person also died of a relapsing encephalitis. The first case in both outbreaks appears to have been a mare late in pregnancy and grazing on open pasture, but no connection has been shown to exist between the two outbreaks. Serological examination of samples from 46 wildlife species showed that approximately 10 per cent of *Pteropus* carries antibody to the virus.

Other causative agents

We have thus looked at a range of new, re-emergent or emergent infections that are of growing importance in the field of public health. The examples discussed above are viral or bacterial diseases. There are others of interest in which causative agents are either non-genetic or still unknown. The general inference we must draw is that infectious disease, far from being a field in which most of the research has been accomplished, is one in which new challenges are arising. The examples that follow will exemplify some current problems.

vCJD (variant Creutzfeldt-Jacob Disease)

Following the recognition of bovine spongiform encephalopathy (BSE) in 1986, a novel spongiform encephalopathy was recognised in human patients in 1996. Although in symptomatic terms it has more in common with kuru than with classical Creutzfeldt-Jacob Disease, it was dubbed *nvCJD* (new variant Creutzfeldt-Jacob Disease), a term recently shorted to vCJD (variant CJD) (Tyrell, 1994).

The origin of both diseases remains problematical. It has been argued that a change in the rendering processes for meat and bone meal led to an escape into animal feed of the causative agent, a modified prion. The diagnosis of cases of the human spongiform encephalopathy a few years after surveillance began has led to the general acceptance that BSE in infected cattle led to vCJD in humans, although clearly no precise causal link has been demonstrated. The saga of vCJD posed many curious questions, and showed how official sources (from ministry to government) conspired to launder realities for short-term commercial expediency.

Although much was said of the government's determination not to make similar mistakes in future, the outbreak of foot and mouth (=hoof and mouth) in February 2001 showed a similar inability to grasp the realities of disease control. In October of the same year it was announced that the BSE-positive samples of sheep brain tissue were erroneously ascribed - bovine samples had mistakenly been analysed instead. It is examples of this sort that encourage me to feel that present-day governments are ill-equipped to handle disease outbreaks (Ford, 1996). A fundamental reappraisal of our criteria in cases like these is a matter of utmost urgency. Future outbreaks could have more far-reaching consequences.

Kawasaki syndrome

Academics and clinicians in public health will recall the claim that rheumatic fever is the leading cause of acquired cardiac disease in children across the Western world. This is no longer the case: Kawasaki disease, which was first described in Japan in 1967, has now taken

over the title. Eighty per cent of the cases occur in children aged under five years, and is characterised by pyrexia, redness of the eyes, lips, skin and extremities, and cervical lymphomegaly. After a week or more the skin of the peripheries may peel, and arthritic symptoms appear.

Although precautions against Reyes syndrome must be taken (e.g. offering influenza and chickenpox vaccine) therapy with aspirin is considered advantageous. Gamma-globulin, given in large doses within the first ten days of the disease, is believed to be important in aiding recovery. Crucially, a weakening of the coronary arteries is a consequence in some 20 per cent of sufferers. This can cause sudden collapse and death in later childhood. The mortality rate is 0.5 per cent (Shulman, 1995). What might be the cause? The erythroderma and peeling of the skin suggest some form of toxic shock syndrome, and research has been directed to eliciting signs of an infectious viral or bacterial pathogen. However, Kawasaki disease is a condition of growing importance and with a potentially tragic outcome, yet still lacks an identifiable cause.

Priorities for the Future

Human society has developed through the conquering, or at least the management, of disease. With occasional perturbations, like the bringing of measles to the Eskimo peoples, or the importation of syphilis into Europe, the graph of infectious disease has had a downward path, so that each generation has tended to have less to fear from infectious disease. Scourges of previous decades, from scarlet fever and poliomyelitis to mumps and measles, have faded within living memory.

At the beginning of a new millennium we are, for the first time, facing a significant change in that downward graph: now we are facing new threats, as hitherto unknown diseases emerge to threaten our complacency. In many cases this is due to human intervention, for microorganisms are quick to exploit the loopholes that our innovations (like supermarket food, or mass international travel) can offer. At a deeper level, this problem is exacerbated by a sense that the study of bacteriology was somehow unfashionable and *passé*, coupled with a dearth of understanding on the part of politicians and the public alike. Departments of microbiology are poorly funded, and public health services are being curtailed.

As this discursive presentation has shown, we are facing a series of novel problems that only a fundamental change of attitudes, and a reappraisal of our criteria, can ameliorate. There is a tendency to regard warnings of impending problems as scare-mongering, but such a criticism cannot apply to cases like these. Here are diseases which we are facing now, and in greater amounts than we once were. Millions of people are ill; urgent action is needed to prevent that number from dramatically increasing. Human behaviour must change, and change soon.

The Spread of Vectors

Global warming may have an effect on the spread of vectors. The anopheline mosquito is spreading northwards toward northern Europe, and other insect species are spreading further. The Asian Tiger Mosquito *Aedes albopictus* is becoming increasingly widespread in the USA, although it is not a native species. *A. albopictus* first appeared in Texas in 1982. Larvae were present in pools of water lying in used tyres that were being imported from the East. The mosquito has since spread to about 20 states in the USA. Among the diseases that it is capable of transmitting are dengue fever, yellow fever, Mayaro, Venezuelan and Eastern

Equine Encephalomyelitis. It is noteworthy that *A. albopictus* is somewhat hardier than *A. aegypti*, and may therefore extend the range of insect-borne infections.

Until the over-use of DDT led to its prohibition, extensive programmes of vector eradication had done much to reduce their extent, and vector distribution in the present day is far higher than it was. A notion that was prevalent in the USA in the post Second World War period was of a nation freed from all insects, which were seen at the time as nothing more than superfluous. Ill-informed as this might be, we do need to investigate means of controlling the insect transmission of human disease, and can anticipate that research can throw light on the most suitable means of limiting the spread of such potentially hazardous insect species without compromising the crucial importance of the insect world in the management of the global ecology.

Expert misinformation

The public are ill-equipped to comprehend microbiological matters. Little of relevance is taught at school, and many of the popular reference sources are inaccurate or misleading (Ford, 1975). At the Royal Society of London, the document for the public that set out to explain the background to spongiform encephalopathies stated that: 'The human form [of spongiform encephalopathy] is CJD', heedless of kuru, fatal familial insomnia, and Gerstmann-Sträußler-Scheinker syndrome.

A recent account by the medical columnist of a major Sunday newspaper in Britain described the agent of tuberculosis as 'a virus' (Henderson, 2001). The author (in a personal communication) has since informed me that this was an editorial error, which still indicates a level of ignorance of basic understanding among newspaper editors. Meanwhile a student textbook describes how viruses become 'accustomed to antibiotics' (Reynoldson, 1996). When the authorities write with such a disregard for elementary realities it is unreasonable to expect the public, or policy-makers, to have a detailed understanding of the issues involved.

Education – sexual and otherwise

From the earliest age, young people should be given a full understanding of the ubiquitous nature of microorganisms, their vital role in the cycles of the environment, and the sheer sense of wonder that watching life under a microscope can convey. A topic like 'public health' should feature in the syllabus along with current topics like 'environmental studies' and 'media and communication'. Teaching medicine to medical undergraduates is not enough: the subject should appear on the syllabus from the age of eleven. Hygiene should be a matter of course. Sexual education needs to pay far greater emphasis on the transmission of pathogenic microorganisms through promiscuity. Although the term is rarely encountered, being regarded as somehow judgemental and unfashionable, it remains a fact that the social acceptability of multiple sexual partners in short-term and uncommitted relationships provides many opportunities for the dissemination of pathogens.

The decimation of many African nations, and the tragic loss of so many young lives in the Western world and elsewhere, is testimony to the effectiveness of sexual transmission for HIV, and the bacterial diseases - syphilis, gonorrhoea - are proliferating once more as chlamydia is taking a hold on young lives. We have inculcated an acceptable notion of casual sex in the young, with no concomitant awareness of the hazards to health that this implies. The availability of the contraceptive pill was heralded as the key to an unfettered

sex-life for women. The development was hailed as a timely breakthrough for the drug companies, and a time for excitement in young men. To the microorganisms that rely upon sexual transmission, it was the most propitious development of all.

Immunisation

The widespread application of vaccination, promulgated by Edward Jenner, led to the eradication of smallpox. Subsequently, stocks of the virus became confined to three nations: Russia, USA and South Africa. South Africa was induced to give up her stocks in 1983, leaving two super-powers as holders of the virus in high-security establishments. On 30 June 1999 Russia and the USA destroyed their remaining stocks. However, research into the uses of smallpox virus as an agent of warfare were conducted by many nations in the 1960s, though in 1972 the Biological and Toxic Weapons Convention was signed and such research was halted.

However, it was claimed that Russia had equipped warheads with smallpox virus, and among the nations that have been claimed to hold clandestine stocks of the virus North Korea, China, Israel, India, Libya, Syria, Iraq and Iran. The evidence for such claims is slight, though the existence of related pox viruses that are amenable to genetic modification is sufficient for us to remain aware to the possibilities of bioterrorism using such agents. In the case of smallpox, the abandonment of routine vaccination was clearly justified at the time, although vaccine may be needed should an unauthorised source of the virus manifest itself and be released.

The failure to continue BCG vaccination in the UK, by contrast, has less scientific support, particularly in an era when antibiotic-resistant strains of tubercle are becoming widespread. If resistant strains become increasingly widespread in the USA, we may need to offer routine vaccination to Americans. In other cases lowered rates of protection are elective.

Concerns felt by parents over the safety of the triple MMR vaccine have led to greatly reduced levels of protection. Although unequivocal evidence for the relationship between MMR and subsequent brain damage is not available, it could be argued that the immune system is not ordinarily simultaneously challenged by disparate antigens, and an option for the administration of the vaccines in spaced doses should be available for parents who desire this. The British authorities have proscribed this method of administration, a form of heavy-handedness that is leading to dangerously low levels of protection. The recalcitrance of officialdom is leading children to remain unprotected when separate vaccinations would be acceptable to many of the families who reject the triple vaccine. In the present situation, we need to vaccinate the public with every available form of treatment for each prevalent disease. It is incumbent upon medical authorities to take every measure possible to maximise compliance.

Public Preoccupations

Today's public are concerned about safety. They read food labels, often incomprehendingly. They are perturbed by what are construed as 'scientific' ingredients. The E-number system, widely used in Europe during the 1980s, has been abandoned because it intimidated the public. The listing of ingredients by number intimidated the public, and people used to set out to avoid food 'full of E-numbers', heedless of the fact that wholly beneficial ingredients (vitamins, for example) were among those on the list. The current vogue is for 'organic' foods, however construed. Yet labelling of food products is often suspect. Although it is

widely assumed that the label tells the truth, there are companies in existence who replace labels, who re-label out-of-date food, and who falsify descriptions. It would be helpful if reporters began to investigate some of these.

A recent case in Britain that involved the public resale of chicken meat condemned as unfit for human consumption has been widely reported; such cases are unlikely to be the rarity that this isolated case implied. We could seek to involve the public far more in the realities of microbiology. I am certain such topics should be taught at school, for they would establish codes of behaviour of immeasurable benefit in adult life. The use of dilute hypochlorite, as a kitchen sterilant, would be valuable if it could be well understood, and elsewhere I have proposed that a sterilising bowl may become a feature of the kitchen facility in homes of the future (Ford, 2000b).

We need to understand that the use of washing machines that run at blood heat, <40°C, does not destroy pathogens. Although the surfactant properties of detergents may well act against pathogens, washing machines at such low temperatures are afflicted by a build-up of greasy waste. A high temperature wash may prove to be a useful safety precaution. Airline operators may have to reconsider the rate of atmosphere exchange within their aircraft if we are to ensure that the body of the plane does not become a re-infection chamber for healthy passengers travelling with an infectious individual (particularly those with a resistant strain of tubercle, for instance).

Governments need to adopt a more proactive stance, and need to be closer to science and to scientists if they are to make sense of future problems. Following the debacle of bovine spongiform encephalopathy in the UK, much was heard of governmental intentions to handle matters more effectively in the future, though their subsequent management of foot and mouth has been widely criticised for a failure to apply the lessons learned. In an era microbiological hazards are multiplying, we can no longer rely on the behaviour of governments that are ignorant of the principles of biology.

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