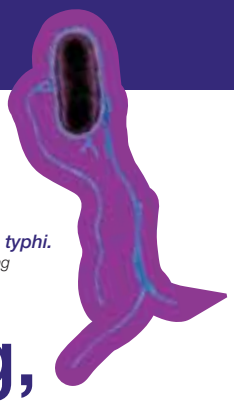
Big Picture on EPIDEMICS

ISSUE 6
SEPTEMBER
2007



Salmonella typhi.
David Goulding

Chatting in the morning, dead by the afternoon.

NEW THREATS: What is the best way to stop a disease spreading?

ML Antonelli/Rex Features

One of the reasons that **infections** are so frightening is the speed with which they can kill. Doctors dealing with human cases of avian flu in the Far East have seen their patients worsen dramatically and die within a day. Add to that the fear of the new and unknown, and **emerging infections** can seem truly terrifying.

In the West, we have had success in dealing with infectious diseases. With **vaccines** and **antibiotics**, we have had the tools to keep them at bay. In the case of **smallpox**, we even managed to **eliminate** one of them completely.

In fact, smallpox may come to be seen as the high-water mark of our campaign against infectious disease. It is now clear that we are constantly going to face new threats – and that old threats may return with a vengeance. Animals of all kinds remain the possible source of new human infections. This is the era of emerging and re-emerging infections: **HIV,** ever-deadlier forms of **TB**, **antibiotic-resistant bacteria**, **SARS** and **avian flu**.

The focus now is not so much on eradication as on control or **management**: how do we stop new diseases emerging or re-emerging infections getting out of hand? To add spice to the mix, how does this happen in a world of such **global economic imbalance**, where countries vary greatly in the resources they can put into fighting disease? And how do we balance **individual rights** with the need to protect **public health**?

FIND OUT MORE →

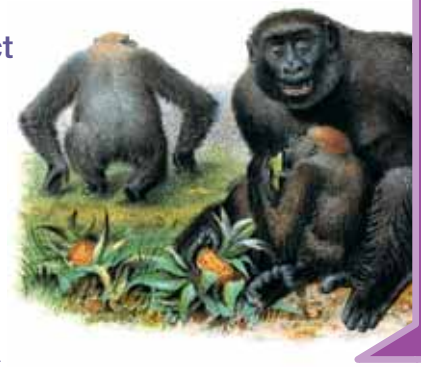
wellcome trust

THE NATURE OF THE THREAT

For many kinds of organism, the human body is a perfect environment in which to live. We have learned to cope with the presence of some; others are harmful or deadly.

Among the most deadly are organisms that have only recently made us their home. We generally have little or no **defence** against them.

The bad news is that we can expect one or two new human infections to appear every year.

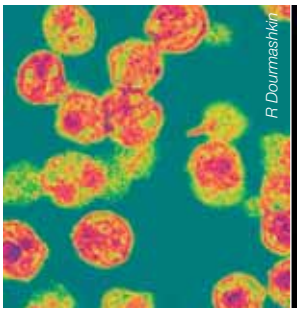


FAST FACT

5000

Estimated number of gorillas killed in Ebola outbreak in West Africa. Of 143 animals being studied by a Spanish group, 130 died – a 91% mortality rate.

New challenges

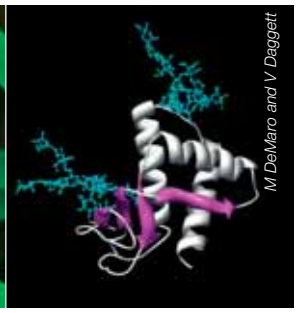


Virus
e.g. HIV (above): nearly 3 million deaths globally in 2006.

Bacterium
e.g. *Clostridium difficile* (above): in February 2007, it was reported that UK deaths involving *C. difficile* had risen by 69 per cent to 3800 from 2004 to 2005. Antibiotic-resistant bacteria such as *C. difficile* and MRSA are a growing threat in the UK and globally.

Parasite
e.g. *Cyclospora*, *Entamoeba* (above): although lower-profile, infections with some single-celled parasites are becoming more common.

Fungus
e.g. *Candida*, *Cryptoccocus*, *Aspergillus* (above): often a problem in specific populations – *Cryptococcus* in HIV-positive people, *Aspergillus* in transplant recipients.



Prion (protein, above)
e.g. vCJD: responsible for more than 150 deaths in the UK.

Education editor: Rachel Thomas
Editor: Ian Jones
Writers: Harriet Coles, Joanne McManus, Henry Nicholls.
Illustrator: Glen McBeth
Advisory board: Joe Brownlie, Nan Davies, Brian Duerden, Jeremy Farrar, Phil Luton, Jolyon Medlock, Andrew Read, Michael Reiss, Mark Woolhouse.

All images, unless otherwise indicated, are from Wellcome Images.

The Wellcome Trust is a charity whose mission is to foster and promote research with the aim of improving human and animal health (a charity registered in England, no. 210183).

Reflecting the profound impact today's research will have on society, the Wellcome Trust also seeks to raise awareness of the medical, ethical and social implications of research and promote dialogue between scientists, the public and policy makers.

MC-3836.p/20K/07–2007/MD

AN INTERNATIONAL ISSUE

New diseases may emerge in developing countries – but they won't stay there.

Most infectious diseases that pose a global threat, including severe acute respiratory syndrome (SARS), avian flu and HIV, originated in developing countries.

Living conditions are key factors. The poor often live in close contact with **animals**, creating opportunities for animal diseases to spread to humans.

In resource-poor countries, many aspects of healthcare may be inadequate – treatment, diagnosis, disease monitoring and disease control. With large numbers of people moving into crowded urban slums with insufficient sanitation, healthcare and clean water, new infections can soon become **endemic.**

International travel and trade can spread infections globally, as in the 2002–03 **SARS** epidemic, which spread to 31 countries before being contained. **HIV/AIDS** escaped detection and has grown into one of humankind's worst ever pandemics. HIV/AIDS accelerated the global re-emergence of **TB.** It may also increase the risk of **malaria** – while malaria worsens HIV infection.

Poor health hurts countries economically – and poverty has a huge impact on health. This vicious cycle will ensure that new diseases will constantly emerge and spread.

Home guard

The UK faces challenges from several emerging and re-emerging infections.

Although less threatened by infectious disease than developing countries, the UK does face significant challenges.

Following the **BSE** crisis, the UK has seen cases of variant **Creutzfeldt–Jakob disease (vCJD)**, a rare but fatal brain disease caused by an infectious protein particle (a **prion**). Since the first confirmed case in 1994, about 150 people in the UK have contracted vCJD. Although the annual death toll appears to be declining, it is too soon to rule out an epidemic completely as the **incubation period** – the time between infection and the appearance of symptoms – is still unknown.

A nasty strain of the common gut bacterium *Escherichia coli* – ***E. coli* O157** – has also become more common. Control focuses on **food safety** (the bacterium is found mainly in the intestine of cattle) and good hygiene. A very small number (perhaps just 100 bacteria) are enough to make people ill.

Of re-emerging infections, **TB** has been gradually making a comeback. It is strongly linked to poverty and is a major problem in deprived urban areas. Around 8000 new cases arise each year and numbers have increased by 20 per cent over the past ten years.

HIV/AIDS is on the rise in the UK. More than 7500 new cases were diagnosed in 2005 and **heterosexual sex** has become the primary route by which the virus is spread.

And other **sexually transmitted infections** (STIs) are also increasing. **Syphilis** has made the greatest advance, jumping from just over 100 cases in 1996 to more than 2500 in 2005 – though these figures are dwarfed by ***Chlamydia***, cases of which trebled to 110 000.


Sam Morgan Moore/Rex Features

Breaking barriers

Why do pathogens normally stick to their favourite host?

If your pet cat gets the flu, fear not – it will not pass it on to you. The cat flu virus does not infect human cells. And when foot and mouth disease hit the UK, there were no human health fears – the virus almost never infects humans.

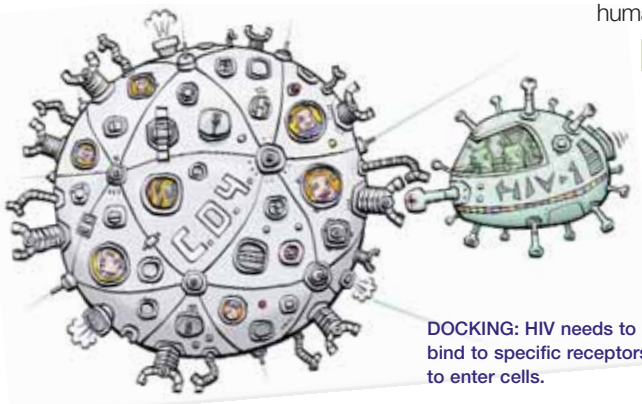
When infectious diseases do not spread from one species to another it is because of **species barriers**. These might be a strong immune response that repels an attempted attack, or a pathogen and potential host may be **incompatible**. When invading, infectious agents attach to host cells, usually through specific **receptors**.

Some pathogens are very fussy: viruses will only infect a narrow range of cells (the **cold-sore virus**, for example, will only invade **nerve cells**). Others are less so: some bacteria will colonise many locations.

Sometimes, a pathogen will vault the species barrier – with potentially disastrous consequences. It was thought that the species barrier would protect people from **mad cow disease** – that the infectious prion protein in cattle should not affect the human prion protein. But in some cases it did, leading to **vCJD**.

Jumping the species barrier can occur in stages. With **avian flu**, for example, some strains can infect people but are not transferred from person to person (only from bird to person). In the future, human-to-human transmission may evolve.

New infections that have jumped species can be particularly **deadly**. Many strains of avian flu, for example, are harmless to wild birds but deadly to captive birds such as chickens – and to humans. In part this may be because there has been no chance for hosts to evolve any form of resistance.



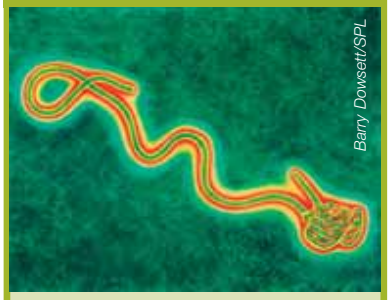
DOCKING: HIV needs to bind to specific receptors to enter cells.

WEIGHING UP THE RISKS: How should governments prepare for a possible new infection? How much effort should be put into preparation and prevention when there are so many competing priorities? And how do individuals decide what to do when faced with uncertainty and risk? Find out more at...


ON THE WEB

www.wellcome.ac.uk/bigpicture/epidemics

CASE STUDY
EBOLA VIRUS


Barry Dowsett/SPL

In late August 1976, Mabalo Lokela, a 44-year-old schoolteacher from Zaire (now the Democratic Republic of the Congo), was returning from a trip to the north of country when he fell ill with a serious fever. Over the next week, doctors suspected malaria, but then he started vomiting violently and eventually began bleeding from his mouth, nose and anus. Just two weeks after the onset of symptoms, he was dead. The cause, then unknown, was the Ebola virus.

Shortly after Lokela's death, others began to flood to the hospital with similar symptoms – in total more than 300. Almost all of them died, making Ebola one of the most virulent pathogens to infect humans.

Some 25 years on, its likely origin is still debated. Tests of over 1000 vertebrates, collected during outbreaks in Gabon and the Republic of the Congo in 2001 and 2003, found the virus in several species of fruit bat – but other reservoirs may exist.

NEED TO KNOW

Pathogen: A disease-causing organism.

Epidemic: Widespread outbreak of a disease, usually in a particular area and of limited duration.

Pandemic: A large-scale epidemic affecting many countries.

Endemic: A disease that has become established in a region.

Zoonosis: A disease of animals that can be transmitted to humans.

TACKLING NEW INFECTIONS

When the Black Death struck Europe, people were defenceless – they had no immunity to the disease and little knowledge of good hygiene and sanitation. Now, with our awareness of the causes of disease, good hygiene, drugs and vaccines, we are much better off.

Medical Art Service, Munich

FAST FACT

39.5 million

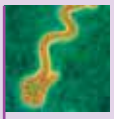
Estimated number of people living with HIV/AIDS at end of 2006. There were an estimated 2.9m deaths and 4.3m new infections in 2006.

But the threat of new infections will not go away. There is a constant danger of **zoonotic infections** – animal pathogens that become adapted to human hosts.

We can now anticipate many of the possible pandemic diseases and take steps to prevent them or lessen their impact. But enormous challenges remain – scientific and political.

NEW INFECTIONS IDENTIFIED SINCE 1918

NB: Dates are when the infectious agent was identified or an infectious disease first described. The agent may have been present earlier. HIV, for example, probably crossed into humans in the 1930s.



1918	1937	1956	1967	1968	1969	1976	1977	1981
Spanish flu	West Nile virus	Asian flu	Marburg virus	Hong Kong flu	Lassa fever	• Legionnaire's disease • Ebola virus	Lyme disease	HIV

Spread the word

In infectious disease, not everyone is equal.

Just as rumours get spread by a handful of gossip-prone people, so the spread of disease can be promoted by some people more than others. Such key individuals are known as **'superspreaders'**.

In **SARS**, for example, a Chinese physician spread the infection to several people at a hotel, who then seeded outbreaks in other Far East countries; he infected at least ten people from six countries. And the patient causing the Canadian outbreak was also a superspreader.

It is not yet known what makes a superspreader; perhaps they just cough more. Possible clues have come from scientists studying the spread of ***Escherichia coli* O157** in cattle, who have found that some 20 per cent of infected animals are responsible for around 80 per cent of transmission. *E. coli* mainly colonises a particular region of the lower intestinal tract, and in the superspreaders the O157 strain seems to dominate this niche.

As they play such an important role in disease transmission, understanding what makes someone (or some animal) a superspreader is a key question.

A DIRTY JOB: Studies of cowpats have revealed that some cows shed more *E. coli* O157 than others.

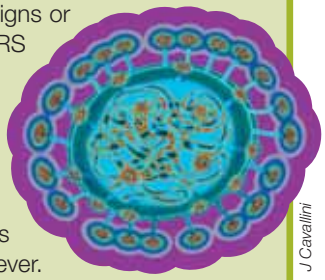
CASE STUDY SARS: A SUCCESS STORY

Tackling a newly emerging infectious disease requires global surveillance and a global response plan, but as was seen with SARS, success really depends on local action. SARS emerged in China in November 2002. By the time it was over in June 2003, there had been 8098 cases and 774 deaths in 32 countries.

As bad as that sounds, it could have been much, much worse. Outside China, local transmission (that is, non-travel-related infection) was limited to a handful of Asian cities plus Toronto and Vancouver. SARS was contained and stamped out because the public health authorities in the communities most affected mounted a rapid and effective response.

In Toronto, SARS spread to more than half of the city's acute care hospitals, but the disease was prevented from spreading throughout the general population. How? Because affected hospitals were closed to new patients and to all visitors and because draconian quarantine restrictions were imposed on anyone who had been in contact with a suspected SARS patient.

Between 13 February and 30 June 2003, health officials tracked down at least 15 000 people and ordered them to stay in their homes for ten days. Anyone who developed signs or symptoms of SARS was immediately taken to hospital to be treated in isolation.



J Cavallini

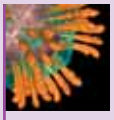
The severity of this response was questioned, however. And there is some evidence that quarantined individuals suffered psychological distress as a result.

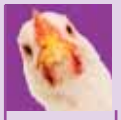
Today, the GOARN (see 'A global watch' above right) remains on the lookout for SARS but since June 2003 no suspected cases have been confirmed.

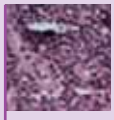
A PATHOGEN ON THE MARCH: Late in 2006, more than 2000 cases of bluetongue virus infection were seen in northern Europe – a region previously free of the virus. The disease, which kills around 30 per cent of infected animals, is transmitted by a species of midge that thrives in warm, wet areas.

Recent hot summers seem to have moved the midge's habitat northwards, the virus spreading with it. The spread of bluetongue illustrates how climate change could have a big impact on animal and human health.

Credits: *Barry Dowsett/SPL* (1976), *D Gregory and D Marshall* (1977), *Russell Kightley/SPL* (1987), *iStockphoto* (2003).







1986 BSE

1987 Hepatitis C virus

1993 Hantavirus pulmonary virus

1996 vCJD

2002 SARS

2003 Human H5N1 avian flu

2005 Chikungunya virus

2006 XDR-TB

A global watch

Pandemic control calls for international cooperation.

Since no one knows where the next major infectious disease will come from – or when it will emerge – **surveillance efforts** must be well coordinated and they must span the globe.

Leading this effort is the **Global Outbreak Alert and Response Network** (GOARN), which was set up by the World Health Organization (WHO) in 2000. GOARN coordinates a network of 120 institutions and partner agencies. It taps into other disease surveillance networks, such as those overseen by the UK's **Health Protection Agency** (HPA) and the USA's **Centers for Disease Control and Prevention** (CDC). Part of the work of these groups and others is to help developing countries to strengthen their disease surveillance systems.

These systems will only work if countries are willing to share timely and accurate information. Since the presence of disease might have **economic consequences** – interrupting trade or tourism, for example – or be seen as damaging to a **country's reputation**, some countries may be reluctant to be open about potential outbreaks.

Revised International Health Regulations should help to rectify this problem. Up until now countries have only been legally obliged to report cases of cholera, plague and yellow fever to the WHO. As of June 2007, countries will have 48 hours to notify the WHO of "all events that **may** constitute public health emergencies of international concern" – which means all outbreaks of life-threatening infections, whatever the cause.

ML Antonelli/Rex Features

Justin Briarty/Rex Features

THE HEAT IS ON: Screening air passengers for fever was used to try to contain SARS.

UNDER CONTROL

What can we do to prevent pandemics?

ELIMINATING INFECTED ANIMALS

Mass culling was used during the UK **foot and mouth disease** (FMD) epidemic in 2001. This has also been use to contain **H5N1 avian flu**. In 1997, after the first human cases, the Hong Kong authorities slaughtered their entire poultry population – 1.5 million birds – in just three days. The disease was contained but at huge cost. And the virus has reappeared and spread through wild birds and via the international poultry trade.

Though often effective, mass culling has its problems. In the UK FMD outbreak, the culling policy led to the slaughter of **4m animals**. A similar number of cattle were slaughtered to prevent BSE entering the food chain.

In the BSE outbreak, **inadequate compensation** led some farmers to break the rules. And in developing countries, something similar could happen – who will compensate poor farmers told to slaughter their chickens to prevent a global epidemic?

VACCINATION

Although vaccines often exist, **trade restrictions** may hinder their use – a vaccinated animal is hard to distinguish from an infected but healthy-looking animal, so countries may not admit them. In many places, it is not practical to vaccinate huge numbers of animals. And for diseases such as **flu**, a vaccine may protect against some strains but not others.

DRUGS

For bacterial infections, **antibiotics** are effective – but to varying degrees. The biggest challenge is from **antibiotic-resistant bacteria**, such as *Clostridium difficile*, which is rising alarmingly in the UK. **TB** is also a major problem, as it is very difficult to kill, and strains resistant to several antibiotics have appeared.

The medicine chest for viruses is less well stocked. After avian flu strain H5N1 was found in early 2007 in a British turkey farm, 320 workers were given the antiviral drug **Tamiflu (oseltamivir)**. This can prevent infection and improves survival of those already infected – but only if given early in infection. And resistant strains of virus have already been seen in South-east Asia. Most governments are stockpiling oseltamivir for use in a possible pandemic.

PUBLIC EDUCATION

It sounds simple, but teaching people about taking medicines properly and sanitary practices in the home and backyard can also have a big impact on disease control.

PASS IT ON

The discovery in Scotland of a dead swan infected with H5N1 avian flu in 2006 was headline news. Migrating birds may bring the virus to these shores. But a human epidemic is unlikely to be triggered by a bird. Chances are it will be brought in by an infected human.

H5N1 avian flu can infect people but cannot (yet) be transmitted between them. The evolution of human-to-human transmission would be catastrophic.

So transmission is crucial to the spread of infectious disease. And stopping the genie escaping from the bottle in the first place is key to the prevention of pandemics.

FAST FACT

Around 150 million birds have been destroyed to try to control H5N1 avian flu.

Rex Features

COMMUNITY CHALLENGE

In 2004 Richard Campbell-Smith, a fit 18-year-old Royal Marine recruit, grazed his leg on a training run. Within two days he had died, his wound having become infected with a 'community' (i.e. non-hospital) form of *Staphylococcus aureus* – Panton–Valentine leukocidin (PVL) *S. aureus*.

Identified in the 1930s and common until the 1960s, PVL *S. aureus* was almost wiped out by the antibiotic methicillin, but antibiotic-resistant forms have emerged in the past decade. It is now the most common skin and soft tissue infection seen in US hospitals. At one Los Angeles hospital, its prevalence more than doubled, to 64 per cent, between 2001 and 2004.

PVL is a toxin produced by the bacteria. Recent research has shown that it has a double whammy effect – attacking respiratory tissue and defence cells in the lungs. Tissue destruction is extensive and rapid – PVL *S. aureus* is one of the causes of necrotising fasciitis, the 'flesh-eating' infections that hit the headlines in the 1990s.

Worryingly, PVL community bacteria have begun to be seen in hospitals as well as in the general population. They seem to have acquired genes from a different species of *Staphylococcus*, which, although harmless, is better adapted to human skin. These genes seem to enable community strains to multiply more quickly in people.

The 'nightmare scenario' is that these rapidly growing strains take over from the 'ordinary' MRSA in healthcare settings.

The numbers game

Maths can be a key weapon in the war against infectious disease.

The spread of an infectious disease is a complex affair, affected by many factors. **Mathematical equations** modelling the spread of disease can help us to limit the impact of future infections.

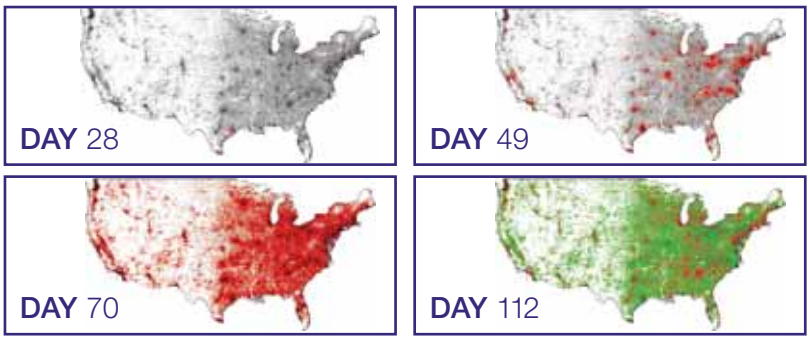
These mathematical models can be used to **simulate** or re-run outbreaks. Researchers can then test the impact of different control strategies.

Data from the 2001 foot and mouth epidemic in UK cattle, for example, has been used to test possible **vaccination strategies** in the event of another outbreak. (Vaccination of animals on neighbouring farms in a ring around an infected site would be the best bet.)

Mathematical models of **pandemic flu** have also produced some useful predictions: border and travel restrictions may delay but won't prevent an outbreak; closing schools would cut the peak attack rate in half but isolating the infected would have a bigger impact; and vaccines would help even if they are only partially effective.

However, the models make a number of **assumptions** about the nature of infection, so are inevitably **simplifications**. The main problem is that key information – how the disease spreads, how long it survives in the environment – may not be available.

Modelled spread of H5N1 flu in the USA: new infections (red) and immune survivors (green).



Understanding transmission

To halt the spread of a disease, you need to know how it is transmitted.

John Snow's success in stopping a **cholera** outbreak in London in 1854, by removal of the handle from a water pump, is well known. Most people believed that disease was contracted by breathing foul-smelling air, but Snow was convinced – rightly – that cholera was a water-borne disease.

Ignaz Semmelweis (1818–1865), a Hungarian who realised that doctors going straight from post mortems to delivery rooms were infecting women in labour, was similarly far-sighted. By making doctors disinfect their hands, he slashed the incidence of infection.

Sadly, this was before **germ theory**, and a combination of political factors and, perhaps, Semmelweis's own stubbornness meant that his ideas were not as widely accepted as they might have been. Thousands of young mothers died unnecessarily as a result.

Today, 150 years after Snow's death, there is still uncertainty about how certain diseases are spread, for example, how important **badgers** are for spreading bovine tuberculosis between cattle.

And although the importance of **good hygiene** is now well recognised, there are plenty of devils in the detail. Hospital cleanliness has been blamed for the rise in **hospital-acquired infections** such as MRSA, but the picture is not that simple. The ability to identify and **isolate** infected patients is more critical – and hard to achieve with the UK's high rates of bed occupancy.

CASE STUDY HEPATITIS C VIRUS

Hepatitis C virus is one of a family of viruses causing inflammation of the liver. In the 1970s, doctors in the USA discovered that most cases of hepatitis after blood transfusions were not caused by hepatitis A or B viruses. But it wasn't until the late 1980s that this newly discovered virus was identified and named hepatitis C.

About 170 million people are infected with the virus globally, with 3–4m new cases each year. The virus – spread by blood-to-blood contact – attacks the liver, causing chronic liver disease and liver cancer.

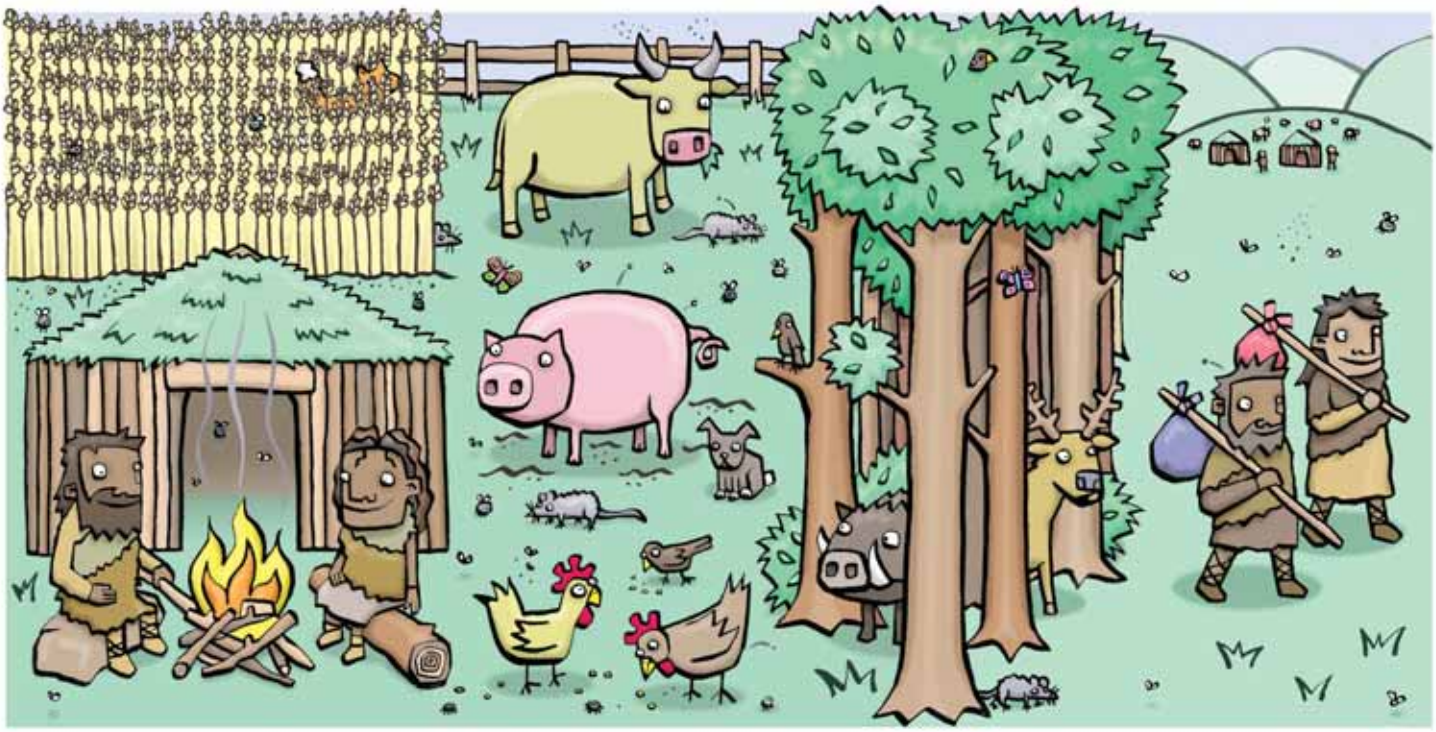
Hepatitis C is mainly spread by transfusions with unscreened blood products and the use of inadequately sterilised needles and syringes. In the UK and the USA, transmission is mainly between injecting drug users.

Although globally only about 3 per cent of people are infected with the virus, in Egypt about 12 per cent of the population have a chronic hepatitis C infection; it is one of the top five causes of death in Egypt. This anomaly is the tragic result of a medical intervention.

From the late 1950s to the 1980s, Egyptian health authorities ran a nationwide programme to eradicate a parasitic flatworm. People received up to 16 injections over three months. But the needles used were often not properly sterilised; and so in the fight against one disease, treatment inadvertently spread another.

Hepatitis C virus particle.

Humans and pathogens



LIVING CONDITIONS: The way humans live has had a huge impact on the spread of disease. Living in groups brings potential hosts close together; living with domesticated animals increases the risk of pathogens jumping species; migration spreads disease to new areas and exposes migrants to new risks; sanitation is a major problem; and vector species find attractive habitats around humans.

BEARING BAD NEWS: An animal species that carries a pathogen transmitted to people is a reservoir. An organism that transfers a pathogen is a vector. Clockwise from left: fruit bat, mosquito, castor bean tick.

INDUSTRIAL RELATIONS: What role do pharmaceutical companies have in disease control? Can drugs and vaccines reach those that need them in poor countries? Some progress is finally being made, especially through public–private partnerships. Read how at...

www.wellcome.ac.uk/bigpicture/epidemics

THE PERSONAL AND THE PUBLIC

Health is usually a private matter. But infectious diseases also have consequences for others, who may become infected because of our actions.

People have been prosecuted for deliberately infecting others with HIV, but should we go further? Should people have to take more responsibility for ensuring they do not pass on illnesses?

And how far should the state go in limiting individual freedoms to protect public health?

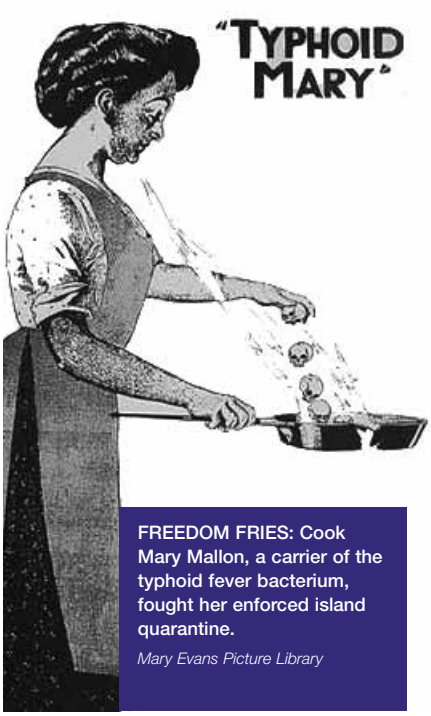
CIVIL LIBERTIES

To protect public health, individuals' freedoms may be restricted.

Bringing an outbreak under control requires public trust and cooperation. The degree to which individual liberty must be sacrificed in order to protect the public from harm depends on the nature of the threat. During the outbreak of SARS, for instance, thousands of people had to be forcibly quarantined.

TB is a different kind of example. In the standard treatment protocol (DOTS, directly observed therapy short-course), someone has to watch the person being treated swallow the required pills. The risk to the public comes from patients who stop treatment (a 'short course' lasts six months). In many countries, therefore, non-compliant patients can be jailed until they have completed treatment.

A particularly drastic case was that of cook Mary Mallon, 'Typhoid Mary', the first person to be identified as a 'healthy carrier' of the bacterium that causes typhoid fever. She refused to believe that she was infecting others. The authorities in New York eventually sent her against her will to live in isolation on an island for three years. She was 'freed' in 1910 on the condition that she never again work as a cook (typhoid can be spread through contaminated food). But Mary, who never believed the science, soon defied the court's order. When she was caught she was sent back to the island where she spent the last 23 years of her life in quarantine.



FREEDOM FRIES: Cook Mary Mallon, a carrier of the typhoid fever bacterium, fought her enforced island quarantine.

Mary Evans Picture Library

Herd mentality

Vaccination does not just benefit the vaccinated.

Childhood vaccination against infectious diseases has saved countless lives. The main beneficiary, of course, is the child who gets vaccinated. But those not given a vaccine also gain, thanks to **herd immunity**.

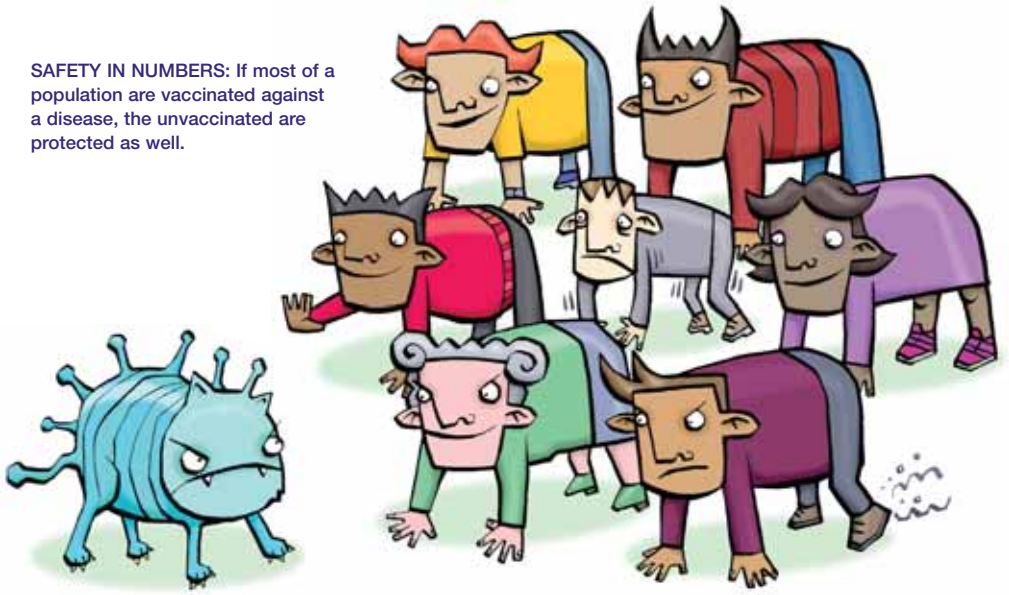
If most people in a population are vaccinated, a pathogen cannot spread – it cannot come into contact with enough susceptible hosts to sustain an infection. The degree of vaccine coverage needed to create herd immunity varies between infections, but is rarely more than 90 per cent.

If people choose not to vaccinate their children, there is often little risk that their child becomes ill. But they are freeloading on the majority – they gain the benefits without facing any risks.

And if lots of parents go down this route, the risk of an outbreak rises dramatically. This is a particular problem for children who for medical reasons cannot be vaccinated, and so have to rely on herd immunity.

Fears about a possible link between the **MMR vaccine and autism** (considered extremely unlikely by the overwhelming majority of experts) lowered vaccine coverage to danger levels, threatening herd immunity. As a refusal to vaccinate places others at risk, some have argued that vaccination should be compulsory. In the USA it is effectively compulsory – children cannot attend school unless they have had the MMR vaccine.

Others argue that individuals should have the right to decide for themselves whether to vaccinate their children, having made their own decision about the risks involved.



SAFETY IN NUMBERS: If most of a population are vaccinated against a disease, the unvaccinated are protected as well.

Border order

Can nations protect themselves from emerging infections?

In our globalised interdependent world, more people are crossing borders than ever before. But is there anything that a country can do to prevent the import of communicable diseases from foreign countries?

The answer is that it depends on the disease. During **SARS**, Singapore installed **thermal imaging scanners** at airport, seaports and land entry points. All passengers (both Singaporeans and foreigners) had their temperature checked before going through immigration, to see if any had a fever. It has plans to do the same in the event of an outbreak of avian flu. In this case a screening tool was used on large numbers of people without discrimination (though its actual value is debatable).

The same cannot be said for some other possible measures to control diseases at borders. In the UK and elsewhere there have been calls for the compulsory screening of all immigrants for **TB** and **HIV**. While this is an issue that makes headline news, there is little evidence to support such a policy on the grounds of protecting public health, and can easily feed anti-immigration sentiments.

Such a policy also raises several practical and ethical questions. For a start, which groups of immigrants get screened? Only asylum seekers? Foreign students? What about people from the expanded EU?

Keep out...

The big ethical issues include the possibility of **discrimination**, loss of **confidentiality** and **stigma**. In short, communicable disease control is not the same as immigration control. History also tells us that 'public health' has often been used as a smokescreen for politically motivated actions.

Australia, for example, has historically had strong border controls, partly for medical reasons. Yet in the 19th century, these controls were shot through with **class and race prejudice**.

In the **Sydney smallpox epidemic** of 1881, for example, a Quarantine Station was divided into the Hospital Ground (for the infected) and the Healthy Ground (for suspected carriers). The Healthy Ground was deliberately segregated by class, the Hospital Ground by race. And eight Chinese men, although healthy, were forcibly separated in tents and not allowed to mix with Caucasians.

A MATTER OF TRUST

In democratic societies, we place considerable emphasis on individual freedoms. But we also accept that these may need to be restricted 'for the greater good'. If everyone chose for themselves which side of the road to drive on, for example, there would be chaos.

"FREEDOM TO SWING YOUR FIST ENDS WHERE MY NOSE BEGINS."

A growing emphasis on the rights of individuals presents challenges to this balance. We may resent what we feel is unwanted state interference. Or we may question why we have to make sacrifices for the supposed benefits of others.

Compounding this challenge is the lack of trust we now have in authorities and, in particular, politicians. This is borne out by annual surveys of public opinion. We are unconvinced that politicians are always telling us the truth, and acting in our interests rather than their own.

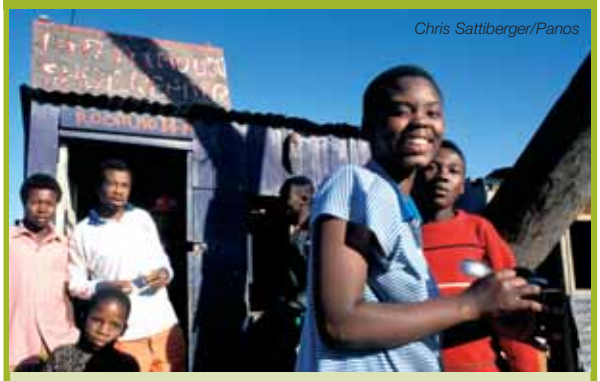
In turn, politicians may be reluctant to intervene for fear of alienating individuals or being seen to promote a 'nanny state'.

WHO GETS THE MEDICINE? If there is not enough medicine to go round, who should be first in line – and who should decide? For a look at the options, see...

ON THE WEB

www.wellcome.ac.uk/bigpicture/epidemics

CASE STUDY
XDR-TB – A DISASTER IN THE MAKING?



Chris Sattiberger/Panos

In September 2006, the WHO described an outbreak of TB in KwaZulu-Natal in South Africa. Of 544 patients studied, 53 had a new, even deadlier strain of TB – **'extensively drug-resistant TB' (XDR-TB)**, resistant not just to 'frontline' drugs, but also to at least three out of six backup drugs. Median survival time from lung sampling to death was just 16 days.

The WHO has called for a **global response** to XDR-TB similar to those for SARS and avian flu. Occasional cases have been seen in several countries recently, but it may already be endemic in South Africa. Not only is this a potential national disaster, but with South Africa an increasingly popular tourist attraction, XDR-TB could be poised to go global.

Why does South Africa have such a problem? **Poverty** is one reason, as is the extent of **HIV infection**. In addition, **non-compliance** is fuelling the spread of drug resistance – 15 per cent of patients default on frontline drugs and around 30 per cent on backup drugs. Overall cure rates are only about 50 per cent.

Drastic measures

While improving compliance and infection control could have an impact, some suggest that the situation is so serious that drastic **social measures** are needed. One option is to change the policy that hospitalised patients lose **social welfare benefits** – which encourages patients to discharge themselves and mix with the general population.

A more draconian suggestion is that people with drug-resistant TB should be **forcibly detained**. The WHO recommends that people with MDR-TB should voluntarily stop mixing with uninfected people. But what happens if they do not follow this advice?

The South African Government has been reluctant to use forcible detention, but **international law**, such as the European Convention for the Protection of Human Rights and Fundamental Freedoms, does allow for such action if other measures have failed. A case heard by the **European Court of Human Rights** in 2005 similarly supported Swedish public health officials' decision to detain an **HIV-infected man** who refused to alter his risky behaviour, which was endangering others.

It is a difficult decision to remove someone's freedoms in order to protect public health. Safeguards should ensure that it happens only when other avenues have been explored and the disease is serious enough to warrant such drastic action.

EPIDEMIC HISTORY

Only in the past 100 years (and only in the West) have human beings not been at the mercy of infectious disease.

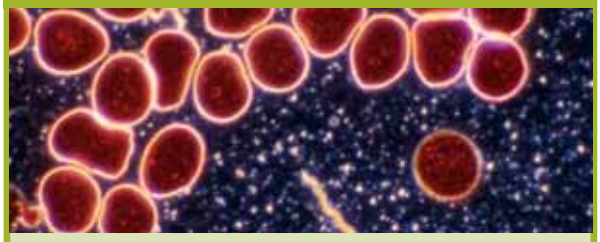
Pathogens have shaped human history profoundly, and their impact can still be seen in our genetic make-up.

What we learn from past pandemics may well help us to prepare for – or perhaps even prevent – the pandemics of the future.

SHAPING HUMAN HISTORY: The Plague of Justinian was a factor in the downfall of the Roman Empire. Some credit the Black Death with a profound social shift in England. After it subsided, labour was scarce, so the remaining serfs found themselves with far more power – landowners were now competing for their services. So the peasants that survived became a little more prosperous. And they also became more mobile, for the first time moving around the country for work.

Mary Evans Picture Library

CASE STUDY
LYME DISEASE



Lyme disease is the most common tick-borne disease in Europe and North America, yet one we still know little about. The problem is that it's hard to diagnose, with several stages to the infection and symptoms that mimic other diseases.

It was first identified in 1977, around the town of Lyme in Connecticut, though it is probably much older.

It is caused by bacteria of the genus *Borrelia*. If caught early on, while the infection is localised to the site of the tick bite, antibiotics do a good job at clearing it up. But if the bacteria spread to other sites in the body, an infection may become harder to detect and treat.

All this uncertainty means that nobody knows just how prevalent Lyme disease really is and how best to treat it. But all indications are that it's on the increase in both Europe and North America.

There are those that suspect climate change could have a hand in this increase, with milder winters increasing the abundance of ticks. The best advice remains to avoid getting bitten in the first place, for example by not exposing bare flesh when walking through woodland areas or bracken.

Death on the doorstep

The Black Death was the most severe pandemic ever recorded.

In 1348, the **Black Death** swept through Europe. It is estimated to have killed at least 75 million people, which probably makes it the most devastating pandemic in human history.

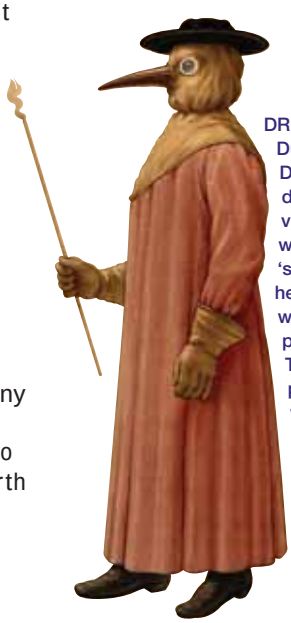
Its cause and origins are uncertain. Some have argued it was caused by the bacterium ***Yersinia pestis***, responsible for the bubonic plague that hit Europe in the 19th century. Others think the Black Death had the hallmarks of a viral infection.

Eyewitness accounts give us an idea how devastating it was: "Villages and hamlets became desolate, not a house being left in them, all having died who dwelt there." It spared neither young nor old: "I observe about me dying throngs of both young and old, and nowhere is there a refuge." It was so infectious that "in whatever household it took hold, whosoever took care of the sick, all the carers died of the same illness". It was so virulent that "almost nobody survived beyond the fourth day". There was no treatment, "neither doctors nor medicine proving of any avail". And the aftermath was bleak. "There were also those who were so sparsely covered with earth that the dogs dragged them forth and devoured many bodies throughout the city."

Three plague pandemics

The Black Death was the world's second pandemic. **The Plague of Justinian** of 541–42 CE is the first recorded pandemic. Named after Eastern Roman Emperor Justinian I, it killed around 25m people, including a quarter of the population of the Eastern Mediterranean and 40 per cent of the inhabitants of Constantinople.

The **Third Pandemic** began in China in 1855. It went on to kill 12m in China and India alone. Plague remains a threat in some parts of Asia, and there are fears that **global warming** may increase the risk of new outbreaks, by encouraging the spread of bacteria-infected fleas and the great gerbils they live on.



DRESSED TO KILL: During the Black Death, 'plague doctors' would visit victims to see if they were infected. The 'snout' contained herbs and spices that were supposed to prevent infection. The stick was to push away patients who got too close. Most plague doctors were not real doctors and could do nothing for victims.

Polygram/Kobal/Phillip Caruso

20th Century Fox/Kobal

FLESH-EATING ZOMBIES, ALIEN KILLERS AND GREY GOO: The cinema has drawn heavily on the dramatic potential of emerging infections. For some classic examples, see...

www.wellcome.ac.uk/bigpicture/epidemics

THE POSTWAR KILLER

Spanish flu ravaged a continent already devastated by World War I. More people succumbed to flu in 1918–19 than died at enemy hands.

An outbreak of flu in 1918 is estimated to have infected perhaps one in five of the world's population. In just one year, it killed more than 40 million people. Conditions at the end of World War I may have contributed to the spread of the virus and hence the scale of this pandemic. It became known as the 'Spanish flu' because of the attention given to it by the Spanish press, which was not censored as much as the papers in other countries.

Although flu had always been a risk to infants, the elderly or weak, Spanish flu was different: it also carried off the healthy in the prime of life.

Scientists have recently recovered isolates of this deadly strain from the preserved remains of an American serviceman and from a flu victim exhumed from a frosty mass grave in Alaska. The genetic sequences of these isolates suggest that the virus was of avian origin rather than a human variety.

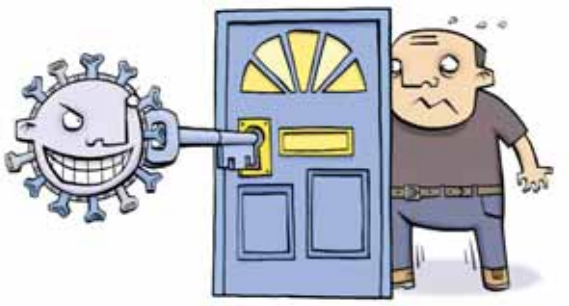
Although risky, researchers have re-created the 1918 virus and tested its effects on animals (oddly, **ferrets** are the best match for the human respiratory system). The virus triggers a massive immune response – a **'cytokine storm'** – that rapidly destroys the lungs.

And they may have discovered how a bird virus came to kill so many humans. By making just two amino acid changes in the outer **haemagglutinin** protein, researchers created a virus that was still lethal to ferrets but was not transmitted between them. The changes alter the type of **sugar molecules** to which the haemagglutinin binds. The fear is that these changes will happen in reverse in today's avian flu virus – turning it into a virus that can spread between people.

© Bettmann/Corbis

HOME HELP: Volunteers in Cincinnati feed children of familes affected by Spanish Flu.

Avian flu



STRAIN SPOTTING: Flu viruses have two key proteins on their surface: haemagglutinin (H) and neuraminidase (N). These come in different forms, given numbers (H1, H3, etc.). Different strains of virus have different combinations of H and N – hence H5N1. The H protein determines the type of cell that a virus will bind to (e.g. avian or human). The big problem will arise if a bird virus gains the ability to infect and spread between people.

Mary Evans/Edwin Wallace

THE END OF CIVILISATION: Once, great civilisations, the Aztecs and Incas, thrived in Central and South America. Then came the Europeans – and European germs. The catastrophe that followed is recounted in...

ON THE WEB

www.wellcome.ac.uk/bigpicture/epidemics

AVIAN FLU – THE ESSENTIALS

- H5N1 virus is endemic in East Asian wild bird populations.
- It rapidly kills most domesticated birds such as chickens.
- The virus has infected humans in 12 countries.
- In all, 306 people have been infected and 185 people have died.
- Almost all cases have been caught from birds. It is possible that one or two cases have been caused by transmission between people.
- The virus is spreading from Asia, either carried by migrating wild birds or through trade.
- By spring 2007, the virus had reached countries in east Europe.
- The virus may only bind to cells deep in the lungs – which would make human to human transmission less likely – but this is not certain.
- Anti-flu drugs are of some help, if given early, but cases of resistance have already been seen.
- Some new drugs are in development, and promising results are being obtained in animal models, but there is no sign of a wonder-drug just round the corner.
- Many different types of vaccine and adjuvant (a chemical given with vaccines to make them more potent) are being tested. But no vaccine is yet wholly effective.
- A new system is needed to make, quickly, large quantities of vaccine (flu vaccine is currently manufactured in eggs).
- The presence of H5N1 virus in European bird populations is important to the food industry, but is unlikely to be a threat to human health.
- The virus triggers a massive immune response (a cytokine storm), which destroys the lungs at devastating speed.

REAL VOICES

Emerging infectious diseases have the potential to affect us all. Here, three people from different backgrounds – an infection control nurse, a Vietnamese clinician and a patient who contracted MRSA – describe how their lives have been affected by new diseases.

Tran Tinh Hien is a clinician on ward D of the Hospital for Tropical Diseases in Ho Chi Minh City, which looks after avian flu patients in the southern provinces of Vietnam.

What happens when a suspected avian flu case is admitted?

TTH In addition to routine medical examination, laboratory tests will be performed to confirm infection of H5N1. However, the results of those tests are only available in 12–14 hours so we have to decide treatment based on epidemiological and clinical factors such as exposure to ill poultry, fever, cough and chest X-ray. The physician, based on this assessment, has to decide whether or not a patient should be sent to the isolation area and receive oseltamivir treatment.

How is avian flu perceived in Vietnam?

TTH In Vietnam the outbreak of H5N1 (2004) followed SARS (2003); therefore it was a great public concern. The national and regional governments have seen the overall problem. Unfortunately, people – particularly those who live in the remote areas who lack information about the disease, or think that ill or dead poultry is still edible – ignore the risk of de-feathering, gutting and preparing chicken or duck or handling fighting cocks. Poverty is another important factor: knowing that any infection in the poultry will have serious consequences for them, farmers try to escape culling poultry in outbreak areas by taking them to untouched places.

Is a pandemic likely?

TTH If the situation is not brought under control in the backyard farms in Asia, the virus will continue to spread country to country and year after year, and this continent will be the most dangerous focus for global public health. Having some degree of immunity after several exposures, Asia may not be the victim of a pandemic but it may occur in Europe and America.

How well prepared do you think the world is?

TTH I am afraid to say that the preparation is not enough in terms of controlling the outbreak in poultry. My personal impression is 'too many conferences'. We could use those funds to pay compensation for farmers' culled flocks or to encourage vaccination of poultry. How can we prevent the pandemic while the outbreaks in poultry and cases in humans still occur in Asia every year and farmers refuse to slaughter their poultry? The situation in Vietnam and Indonesia is an example. We overemphasise the threat but do not implement effective measures for control!

Do you ever fear you might contract avian flu?

TTH Yes, but that is the fear of getting avian flu from patients not from poultry, because I and my family have given up chicken and duck including eggs (the most delicious and my favourites) since 2004. I do hope that I am becoming immunised after four years of treating avian flu patients!

A PATIENT'S EXPERIENCE OF MRSA

When Alison went to a leading London hospital for an operation, she expected to be home in three weeks. But after contracting MRSA, it was a different story.

"Before I went in, I got a letter from the hospital saying it was high up in the anti-MRSA league tables. I thought: 'Oh good, that's one thing I don't need to worry about.'

After the second operation [there were two stages], I was suddenly moved to an isolated cubicle in the High Dependency Unit (HDU), where full isolation procedures were followed. Here, they told me my swab had shown that I had MRSA but said I had nothing to worry about because it was isolated in the bladder, and they had new antibiotics to treat it there.

At this stage I became very ill. An infection in my chest spread to my lungs and I needed oxygen, a chest drain and a tracheotomy to help me breathe. I was also put on a ventilator for a week. I was delirious during my time in HDU – 33 days in all – and remember very little of it. It was like a dream.

When I improved, I was taken from HDU to another isolation ward. When I asked why I wasn't going back to the open ward, the nurse hesitated slightly, then said I would find it easier to rest in a single cubicle.

Again in this ward, they followed isolation procedures. The hygiene was good, but they talked about MRSA very casually.

All in all I was in hospital for nearly ten weeks – although my operations and recovery period should have only taken three. When I left they gave me a letter for the district nurse. It said I'd had MRSA ('MRSA' was highlighted in big red letters).

Overall, although care and prevention was excellent, communication was poor. I have no knowledge of the course of the MRSA. No one was ever open or specific about it. Yet they were always very clear and precise about my operations."

N Durrell McKenna

N Durrell McKenna

HOW DOES YOUR JOB AFFECT YOUR HOME LIFE?

PF It hasn't made me any cleaner. I am hygienic but you still wouldn't want to operate on somebody on my dining table. When I was a front-line nurse directly responsible for patients on the wards, my life was a lot more stressful.

ARE YOU EVER WORRIED ABOUT CATCHING AN INFECTION?

PF No. Having a good knowledge of the infections out there and knowing how they spread makes me worry less. I've worked at the hospital for 17 years and I've never taken an infection home. The handrails on the tube or the bus are much more filthy than anything in the hospital.

Patricia Folan is lead nurse in infection control at University College London Hospital.

What are the most common infections you encounter?

PF I see a lot of MRSA. This bacterium can infect wounds and also where needles have been put under the skin. At the more severe end of the spectrum MRSA can cause infections of the bloodstream. We also see increasing numbers of patients infected with tuberculosis, and chicken pox, which spreads very easily, particularly on the children's wards. It's very dangerous in the neonatal unit.

Which ones do you think are becoming more common?

PF MRSA is becoming more common, mainly because the bacterium is becoming resistant to more and more antibiotics used in the community and in the hospital environment.

We are also seeing more TB, which has been on a steady increase for the last 20 years.

Which infection do you most fear?

PF Norovirus. It's the winter vomiting and diarrhoea bug. It's indiscriminate, causing symptoms in patients, staff and visitors. It's so infectious we've had to shut down wards. In the past we've even had to close entire hospitals. It takes up a lot of our time and a lot of staff are off sick with it. It's a logistical nightmare.

What is the key to infection control?

PF It's what you learned at nursery. In a word, hand-washing. You're not likely to transmit organisms between patients if you wash your hands. That involves patient input as well. If you've got dirty hands and scratch your wound, you're potentially going to infect it.

What are the main challenges now and in the future?

PF Up until about five years ago, the challenge was just to be taken seriously. Thankfully, the authorities now recognise the importance of infection control. A wound infection, for example, lengthens a patient's stay in hospital by an average of four days, which results in a major cost. Now we are getting the resources we need to collect and analyse data on different infections. In time, people are going to have a say in where they are treated. If you have high rates of infection people simply aren't going to come to your hospital for treatment. So the challenge for the future is to get everyone to improve on their hygiene to keep infection rates down. It's an ongoing battle and it involves everyone.

ONLINE ACTIVITY

Devil's Alliance

This issue's activity is based around a drama, *The Devil's Alliance,* which has been written by Radio 4 playwright Alastair Jessiman. It looks at themes of personal responsibility, isolation and the transmission of TB.

Students will have an opportunity to listen to the play and to learn about the complexities of decision making about infectious diseases. They will also gain insight into a specific bacterium, *Mycobacterium tuberculosis*.

The activity is supported by background material including the audio drama, which can be listened to on the website or through an MP3 player – plus support notes for teachers and students.

Full details can be found at **www.wellcome.ac.uk/bigpicture/epidemics**

OUTBREAK!

What would happen if a new infection emerged in the UK?

In the imaginary town of Chortlington-on-Sea, a man falls ill. Take part in our interactive epidemic scenario, and decide for yourself what you would do if you were a public health official or the editor of a local newspaper…

A patient is admitted to Chortlington District Hospital with high fever and strange red marks on his face. Doctors have seen nothing like it before and order some blood tests.

After a few days, the tests return from the hospital labs but have failed to identify an infectious organism. Meanwhile, five more patients are admitted with similar symptoms. All are put into isolation as a precaution. As a cluster of cases has appeared, the hospital alerts the Health Protection Agency (HPA).

YOU ARE A PUBLIC HEALTH OFFICIAL AT THE HPA.

News arrives of the outbreak at Chortlington. Do you:

(a) Put the message in your pending tray and make a mental note to sort it out later.

(b) Arrange for blood samples to be tested at HPA labs – they should be able to identify the infection.

(c) Ring the Department of Health pointing out there is a strange plague affecting Chortlington.

(d) Go on holiday and hope it goes away.

YOU ARE THE EDITOR OF THE LOCAL NEWSPAPER, THE CHORTLINGTON BUGLE.

Word spreads around Chortlington that people with a strange disease are quarantined at the hospital. A local anti-immigration group suspects that a recent influx of immigrants has brought a foreign disease in with them. They organise a public meeting and leafleting campaign. Do you:

(a) Run a factual account of the outbreak and the public meeting.

(b) Throw your weight behind the campaign – whipping up a bit of controversy is bound to sell a few more papers.

(c) Send your top newshound into the hospital to sniff out a personal interest story from the patient's family – 'Builder's son in face-eating killer bug horror'.

(d) Put the story at the bottom of page 5 as there's a great picture of Kate Moss for the front page.

Tests come back from the HPA labs, but are still inconclusive. The infection seems to be something entirely new. Meanwhile, ten new cases are diagnosed in Chortlington; two patients are dangerously ill. Do you:

(a) Request repeat and more extensive testing – they must have missed something first time around.

(b) Contact the Department of Health, passing on all the facts, and organise a local information campaign to calm fears, using press releases and the local radio station, Chortlington FM ('the sunny sound of the seaside').

(c) Ring Downing Street and insist that COBRA is mobilised immediately and Chortlington evacuated.

(d) Seriously consider the offer of early retirement made last year.

With the latest cases, the anti-immigration group has got more vocal, calling for all immigrants to be quarantined then deported straight away. There are rumours they plan to march on the hospital. Do you:

(a) Get your newshound to stir things up, making sure the cameraman is there to get some shots of rampage on the streets of Chortlington.

(b) Quietly report the facts but don't go over the top.

(c) Organise a 'Quarantine Them Now' campaign to show solidarity with the local population.

(d) Get a bright junior reporter to do some research on the links between immigrants and outbreaks of disease.

With 30 patients now affected, and ten in intensive care, the situation continues to deteriorate. Do you:

(a) Refuse to say anything and run all the tests again – there must be something in there.

(b) Continue to communicate with the local population and engage the help of microbiologists and epidemiologists at the renowned University of Chortlington.

(c) Send a series of panicked emails to the World Health Organization.

(d) Lock the door and refuse to answer the phone till it goes away.

HPA researchers and University of Chortlington scientists get together. It turns out that all the people affected walk on Chortlington Downs, next to the sea. Ecologists studying the Downs suggest a species of biting insect newly seen on the Downs, possibly because of global warming, might be involved.

Your ace reporter comes back to tell you that there is little evidence that immigrants ever bring in infections. Do you:

(a) Send him away to make something up anyway.

(b) Poke fun at the authorities for catching butterflies in the midst of a serious epidemic.

(c) Attack the Government for cutting support for environmental science when it's obviously essential.

(d) Re-use the picture of Kate Moss.

Further research reveals a bacterium normally seen only in the Chortlington Tree-creeper. A breakthrough: the insect contains the bacterium in its gut. And, surprisingly, the bacterium infects human cells in culture.

Things fall into place: the bacterium has mutated so it can infect humans; the new vector is transmitting it between reservoir and people. An experimental drug is given to the patients, all of whom recover.

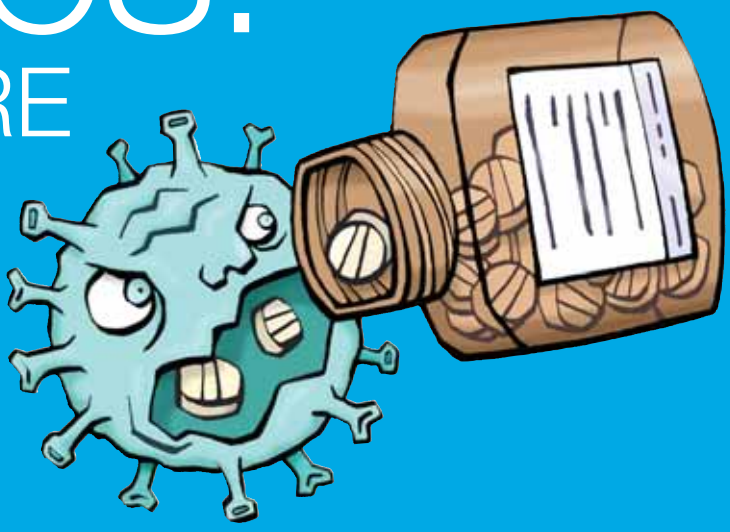
AND THE REALITY IS…

In fact, genuinely new infections are extremely rare in the UK. If a local or regional diagnostic service were unable to identify an infectious agent, it would be referred to the **HPA at Porton Down**, which can diagnose the vast majority of infections affecting people. If patients had travelled **overseas**, experts in centres such as the Hospital for Tropical Diseases in London might be involved.

All **clusters** of infections are automatically reported through NHS systems. Any unusual clusters might be a sign of a new **epidemic**, or possibly even **bioterrorist** activity. If the cluster were not brought under control, the problem would be escalated to the **Department of Health** and other Government departments. The highest level alert would involve **COBRA** (Cabinet Office Briefing Room A), which coordinates the response to a national emergency. COBRA meets rarely, but did so in response to the discovery of a swan infected with H5N1 avian flu in Scotland in 2006 and the outbreak of H5N1 in an East Anglian chicken factory in 2007.

In a serious outbreak or pandemic the Government would decide on steps to safeguard public health, such as closing schools, postponing major public events or imposing quarantine restrictions. One role of COBRA would be to coordinate the **public health response**, such as vaccination or drug treatment programmes. Periodic exercises simulate the impact of an outbreak, check preparedness and improve emergency plans.

EPIDEMICS:
THE BIG PICTURE

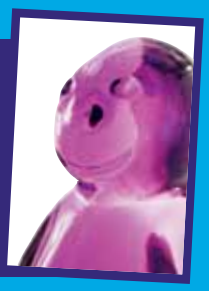


- Around **two new human infections** appear each year.
- With human populations often living in close contact with **animals**, infections may jump species into humans.
- **Rapid death** from infection is alarming, but organisms that take longer to kill a host have more opportunity to spread further.
- **Air travel** has made it more likely that new infections will be spread globally.
- **Species barriers** may restrict infections to particular species, but can be crossed.
- Understanding how infections are **transmitted** is central to their control.
- Disease control focuses particularly on **monitoring**, to identify new outbreaks and stop them becoming established.
- **Mathematical modelling** can be used to simulate the spread of infections and test control strategies.
- **Isolation** remains a key way to prevent transmission of an infection.
- **Vaccination** is a very powerful tool to prevent the spread of infections, but vaccines rarely exist for emerging infections.
- If vaccination levels fall too far, population benefits of **herd immunity** may be lost.

- Control of epidemics can lead to conflicts between **personal freedoms** and the **public good**.
- Balancing public health and personal freedom is a **politically controversial** area. Politicians may be reluctant to restrict freedoms because of fears of alienating voters. But governments may also use public health as a smokescreen to restrict freedoms.

Wellcome Collection, the Wellcome Trust's new free public venue, has opened at 183 Euston Road, London. Check out the website for details of its unique mix of exhibitions, events and attractions.

www.wellcomecollection.org



BIG PICTURE SUBSCRIPTIONS

Individual copies of each issue in the *Big Picture* series are available free for teachers and other education professionals, or anyone with a professional interest in the topic.

To order an individual copy of a specific issue, or subscribe to receive a copy of each issue in the series, sign up at **www.wellcome.ac.uk/bigpicture/order**

Additionally, teachers can order a class set of two copies or more for students.

Order sets of a specific issue or subscribe to receive copies of each issue until further notice.

Class-set prices
2–20 copies: £1.00 per copy per issue (inc. P&P in the UK)
>20 copies: £0.75 per copy per issue (inc. P&P in the UK)

Postage and packing charges
UK – free of charge
EU – £0.15 extra per copy ordered
Rest of world – £0.30 extra per copy ordered

Other interested groups can also order copies at these prices.

Payment methods
We accept cheques, and all major credit cards and debit cards.

Contact
See www.wellcome.ac.uk/bigpicture for full details, or:
T +44 (0)20 7611 8651
E publishing@wellcome.ac.uk

Or write to:
Big Picture series
The Wellcome Trust
FREEPOST
SCE 7446
Slough SL3 0BP

Previous issue

January 2007:
Big Picture on Evolution

www.wellcome.ac.uk/bigpicture/evolution

Next issue is due out in January 2008.

FEEDBACK
If you have any comments on the *Big Picture* series, please email **bigpicture@wellcome.ac.uk**.