Pathogens and Land Contamination

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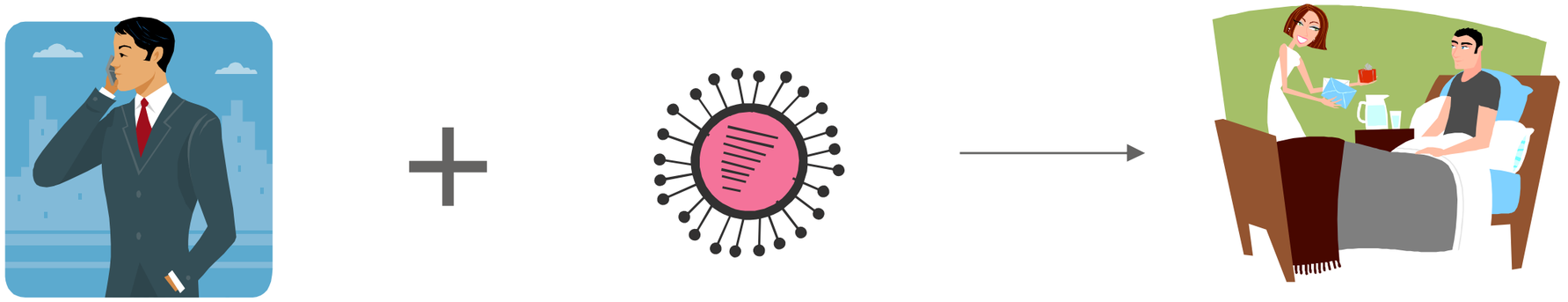
Microorganisms and Pathogens

- Microorganisms – are distributed throughout soil, air and water.
- Most don't pose a risk to healthy humans – many millions inhabit our bodies.
- Microorganisms able to inflict "damage" on host organisms are called pathogens.
- Likelihood of infection is dependent on many factors including:
  1. Standards of sanitation and hygiene;
  2. Quality of diet and drinking water;
  3. Health of the individual
     - Do they have pre-existing conditions/diseases (e.g. cystic fibrosis, diabetes);
     - Do they have a weakened immune system (very young or old, immuno-compromised);
     - Do they have cuts/grazes/burns to skin;
  4. Prevalence of local diseases and sources of infection; and
  5. Immunisation status.
- Factors 1,2,4 and 5 are generally not major issues in the UK.
- Most of the worst pathogens are not endemic or have been eradicated in the UK.

Likelihood of Infection

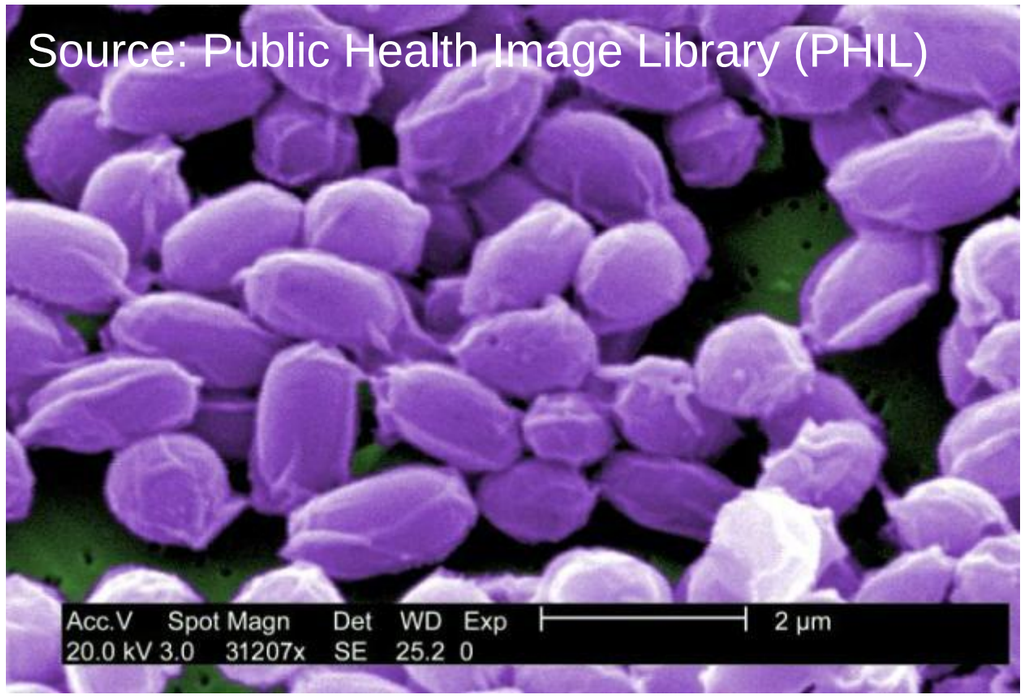
- Most people's interactions with pathogens are limited to common illnesses e.g.
  - Colds and flu;
  - Sickness and diarrhoea; and
  - Food poisoning.
- These are generally caused by viruses (e.g. influenza virus) and bacteria.
- Fungi and protozoans can also be pathogenic.
- Pathogens are mainly an issue for public health, but specific illnesses may relate to land and building.



- Exposure to certain pathogens may increase due to a person's living or working environment.
- For example, living or working on land potentially contaminated by pathogens.

Potential Pathogens

- Most pathogens are unlikely to be encountered in soils as they do not remain viable outside of a host organism for a significant length of time.
- Exceptions are certain types of spore-forming bacteria.
- Certain bacteria form spores, a resting (dormant) state in which they survive until conditions are suitable for them to return to their normal living (vegetative) state.



- The primary spore forming bacteria of concern are:
  - Spore forming *Clostridium Sp.* e.g. *Clostridium tetani and Clostridium perfringens*
  - *Bacillus anthracis,* the causative agent of anthrax

Left: An electron micrograph of anthrax spores

Other Potential Pathogens

- Other examples of pathogens which may be encountered are:
- Bacteria (non spore forming bacteria)
  - *Legionella pneumophila* – cause of Legionnaires disease.
  - *Leptospira* – cause of Weil's Disease.
  - *Pseudomonas sp.* – causes minor infections in healthy humans, but is more serious, possibly fatal in the immuno-compromised.
- Fungi
  - *Aspergillus sp.* - causes farmers lung and other diseases, mainly allergic responses to spores and conditions can become chronic. Particularly harmful to those who are immuno-compromised.
- Protozoans
  - *Cryptosporidium parvum* – causes cryptosporidiosis, the main symptom of which is very bad diarrhoea.
- Viruses
  - Variola major virus – caused the disease Smallpox.
- Prions
  - BSE/variant Creutzfeldt Jacob Disease.

Sites Potentially at Risk from Pathogens

Sites potentially affected	Processes undertaken/ Examples of potential pathogens
Slaughterhouses, abattoirs, knackers yards and fellmongers.	Animal slaughter and processing into various products incl. meat, hides etc. e.g. Spore forming bacteria, BSE/vCJD.
Rendering plants, glue works and bone processing sites.	Bones and inedible offal used to produce glue, gelatine, oils and fertilisers. e.g. Spore forming bacteria incl. *B.anthracis.*
Tanneries and related hide processing sites	Hides prepared for use in leather goods, e.g. jackets, gloves and shoes. e.g. Spore forming bacteria, incl. *B.anthracis.*
Meat processing and packaging factories	Processing and packaging of butchered meat. e.g. Spore forming bacteria, BSE.
Human burial sites, crypts, catacombs, graveyards etc.	Burial of infected bodies, particularly semi preserved infected bodies in lead coffins and coffin liquors. e.g. Smallpox, vCJD, *C. Tetani,* Leptospirosis.
Animal burial sites	Mass graves of buried animals from major outbreaks of disease. e.g. Spore forming bacteria, BSE, *C. Tetani,* Leptospirosis.
Woollen mills	Wool/hides contaminated by *B.anthracis* spores.
Old buildings	*B. anthracis* spores in horse hair plaster/building fabric
Water pipes in contaminated ground	Microorganisms can grow (in water pipes/tanks) on organic compounds diffusing into non chemically resistant pipes. e.g. *Pseudomonas sp.*
Air conditioning systems and stagnant water in pipes/tanks	Stagnant water in pipes and air conditioning systems at risk from *Legionella.*
Agricultural land and water courses	Risks from pathogens in food storage (*Aspergillus sp.*), slurry, bovine urine, rats and water course (*Cryptosporidium parvum* and Leptospirosis).

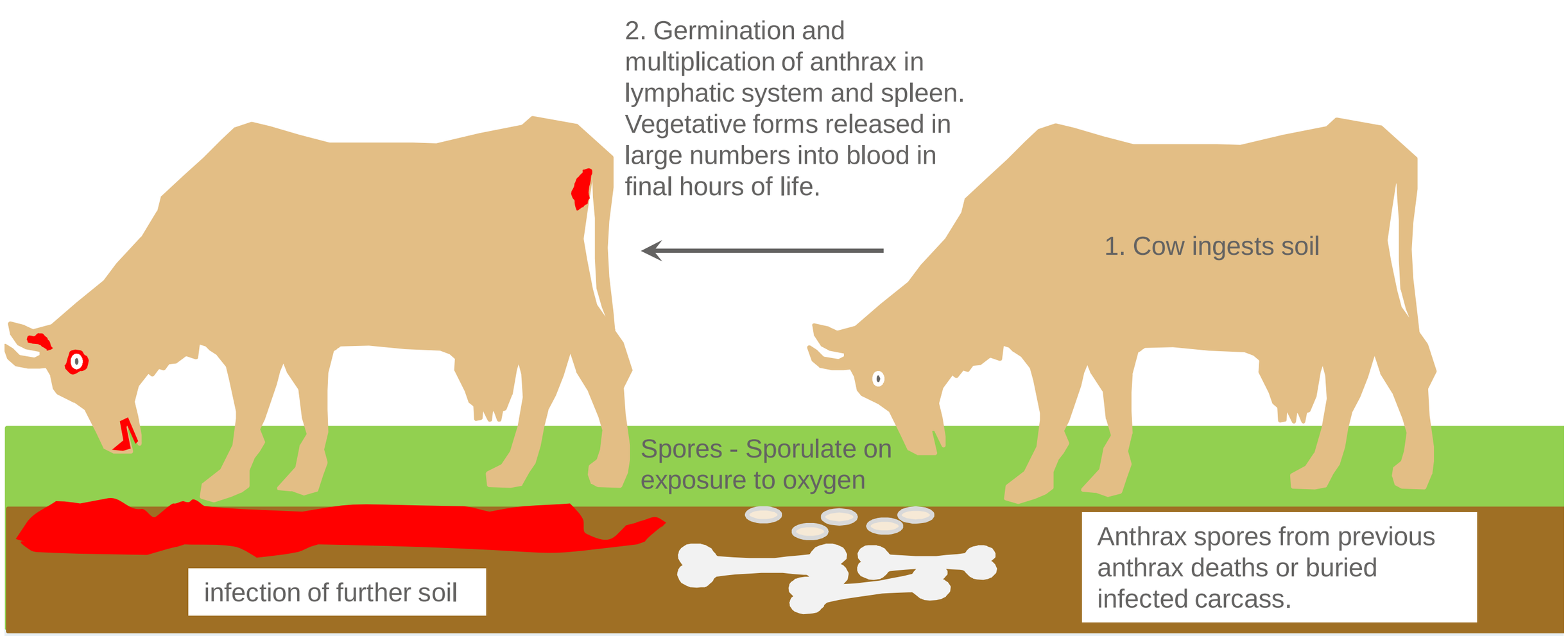
Examples of Pathogens – *Bacillus anthracis*

- *Bacillus anthracis* causes the potentially fatal disease anthrax.
- It is a zoonotic pathogen and predominantly infects herbivorous animals.
- Humans can be infected, but are relatively resistant.

Lungs of patient after 4 months of anthrax infection in the lung. Source: Public Health Image Library (PHIL)

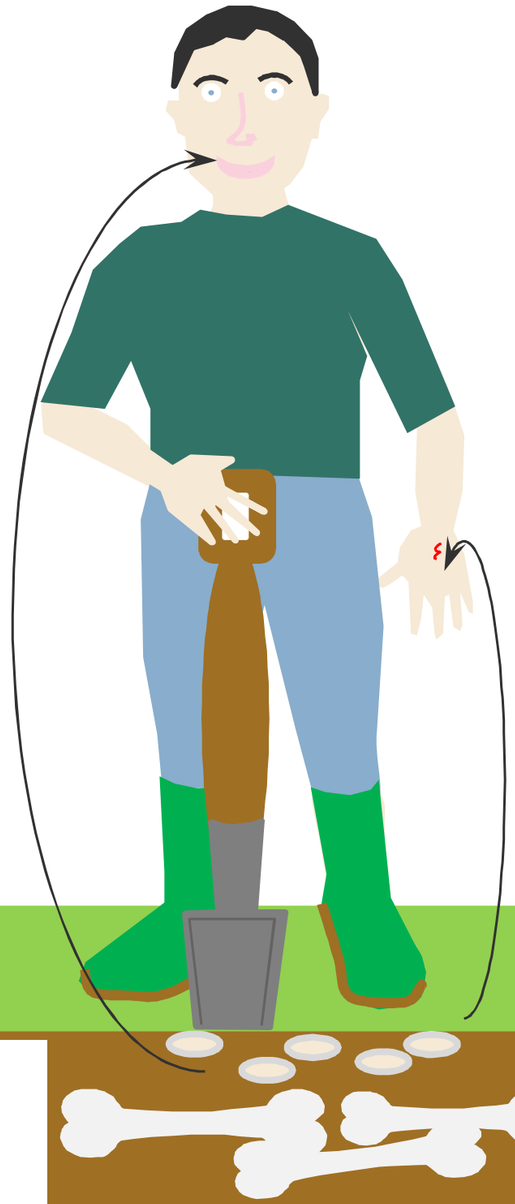
Dermal Anthrax lesion, source: Public Health Image Library (PHIL)

Anthrax Infections how do they Occur



Anthrax Infections how do they Occur

1. Pulmonary anthrax, inhalation of spore laden dust from the site, entering the lungs.



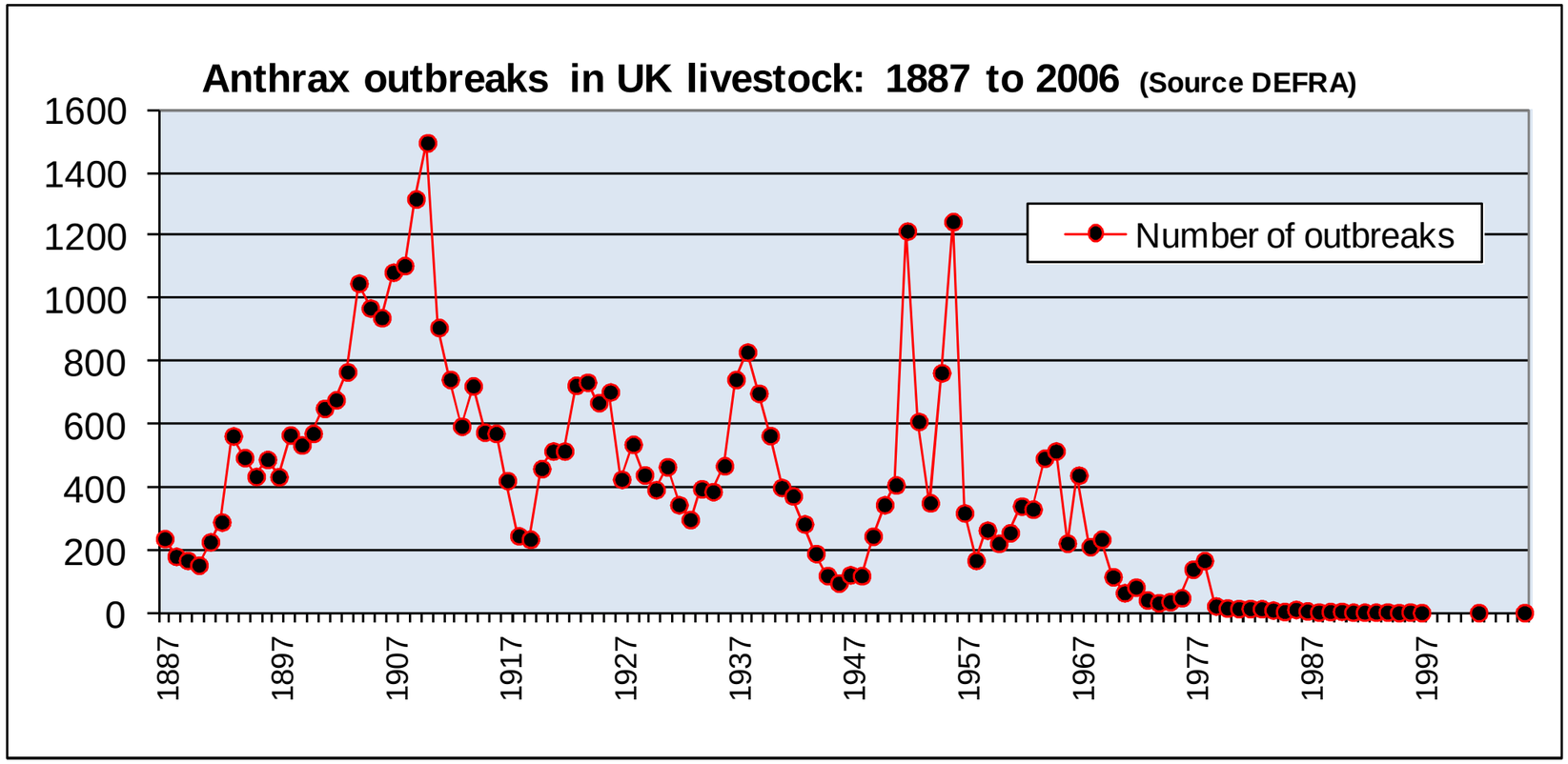
Source: Public Health Image Library (PHIL)

2. Cutaneous infection via a lesion or cut in the skin.

3. Gastrointestinal, only caused by eating infected meat or contaminated water. Has not occurred in the UK in past 100 years

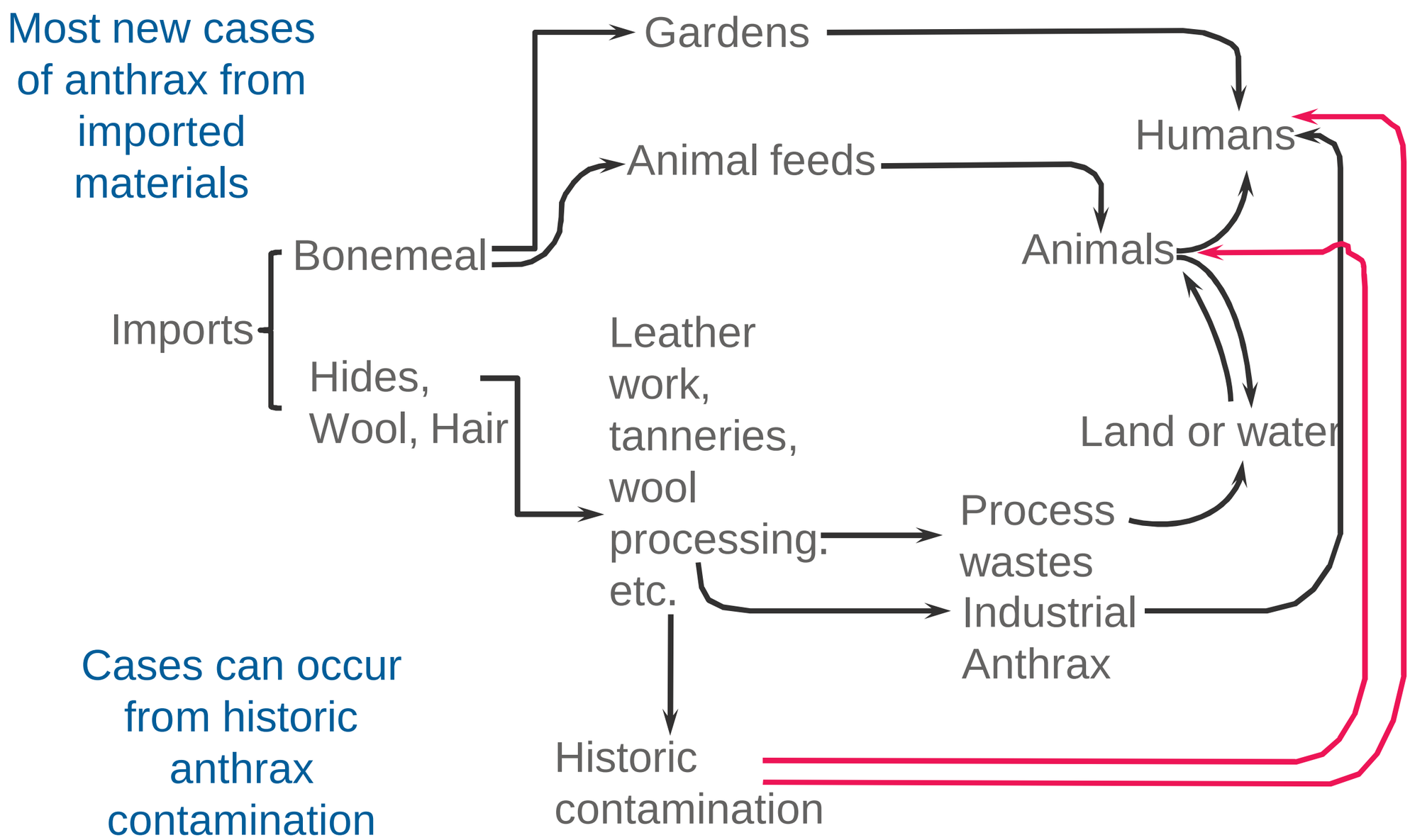
Anthrax spores from previous anthrax deaths or buried infected carcass.

Prevalence of *Bacillus anthracis* in the UK



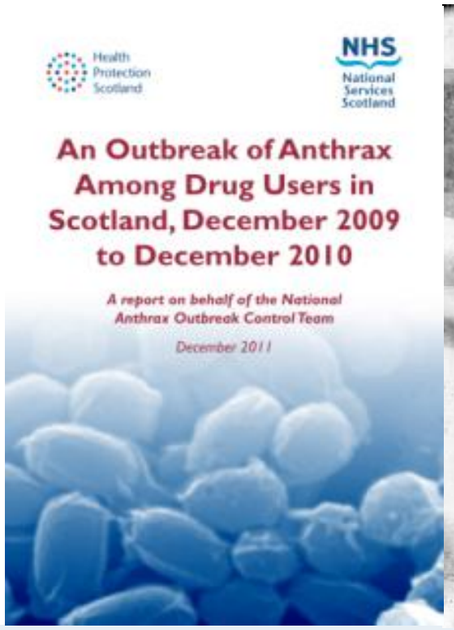
- Anthrax was more prevalent in humans in the UK due to a greater incidence in livestock and also greater workplace exposure (e.g. woollen mills).
- The number of human cases has dropped steadily over the years, with very few cases since the 1970's, workers in key industries vaccinated since 1965.

General routes of infection for Anthrax



Anthrax Infections

- Today anthrax occurs sporadically with isolated cases reported in humans.
- Cases have usually been dermal anthrax. Black boil-like lesions develop on the skin, readily diagnosed and easily treated.
- Rarely inhalation anthrax occurs, resulting in haemorrhagic pleural effusions, severe septicaemia, meningitis and high death rates. Recent case caused by imported hides contaminated with anthrax spores, used make into drums.
- In 2009-2010 a number of cases of death from anthrax occurred to the intravenous injection of Heroin cut with anthrax.



Viral Infection - Variola Major Virus

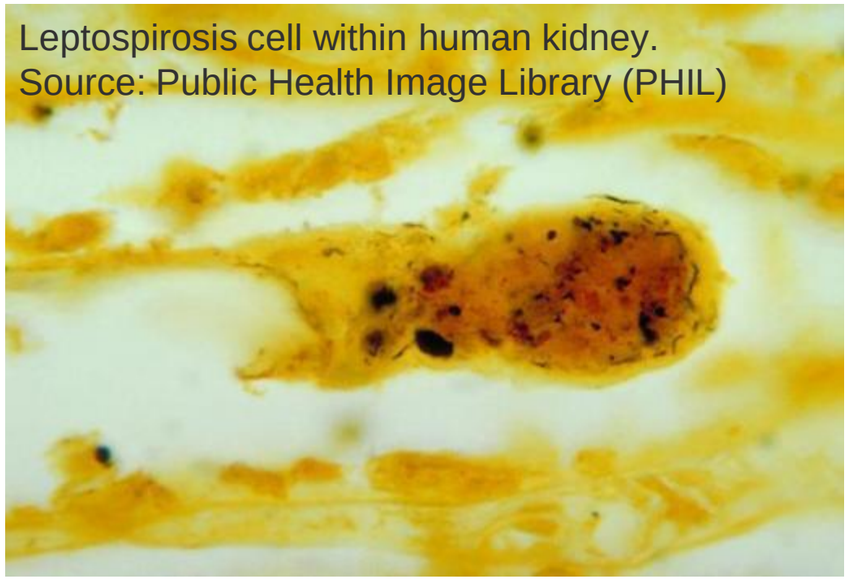
- Smallpox is caused by Variola major virus, which has since been eliminated from the world.
- There is no treatment and it has high mortality rates.
- The last outbreaks were mainly in the 1930s, some sporadic cases until the 1970's but none afterwards.
- Smallpox can survive for long periods of time in dry scabs (13 years has been documented).
- In normal conditions, it is unlikely to survive for more than 48 hours.

Smallpox infection. Source: Public Health Image Library (PHIL)

- Intact virus was recovered from an exhumed body (Spitalfields 1985), over 100 years old.
- The virus could not be grown in the laboratory and not considered infective.
- The risk that smallpox might re-emerge if the remains of smallpox victims are disturbed is remote, but clearly the impact would be very significant.

Leptospirosis – Weils Disease

- Leptospirosis, a bacterial disease passed from animals to humans (zoonoses).
- It can be caught from:
  - work on farms or handling animals (e.g. cows and rats);
  - contact with canals, rivers and other watercourses; and
  - work in drainage ditches and sewers;



Leptospirosis cell within human kidney.
Source: Public Health Image Library (PHIL)

- Infection via contact with infected animal (particularly rats) urine, fluids, tissue or indirect exposure through water, soil or animal foodstuffs.
- The bacteria enter the body through cuts in the skin, the skin lining the mouth and nose, and membrane at the front of the eye.
- Treated early the prognosis is good, if untreated it can cause liver and kidney failure and be fatal.

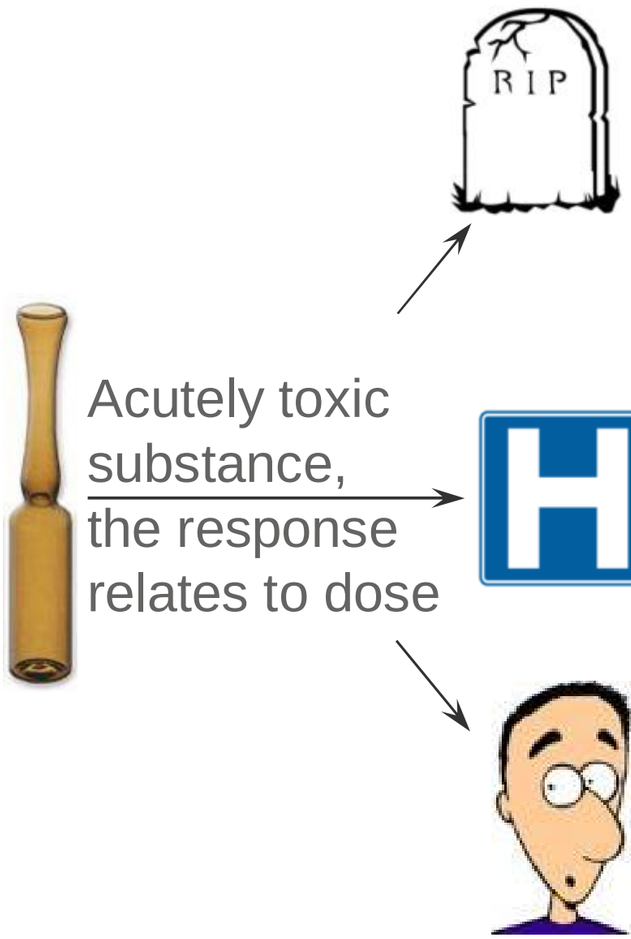
Assessing the Risk – What is Acceptable?

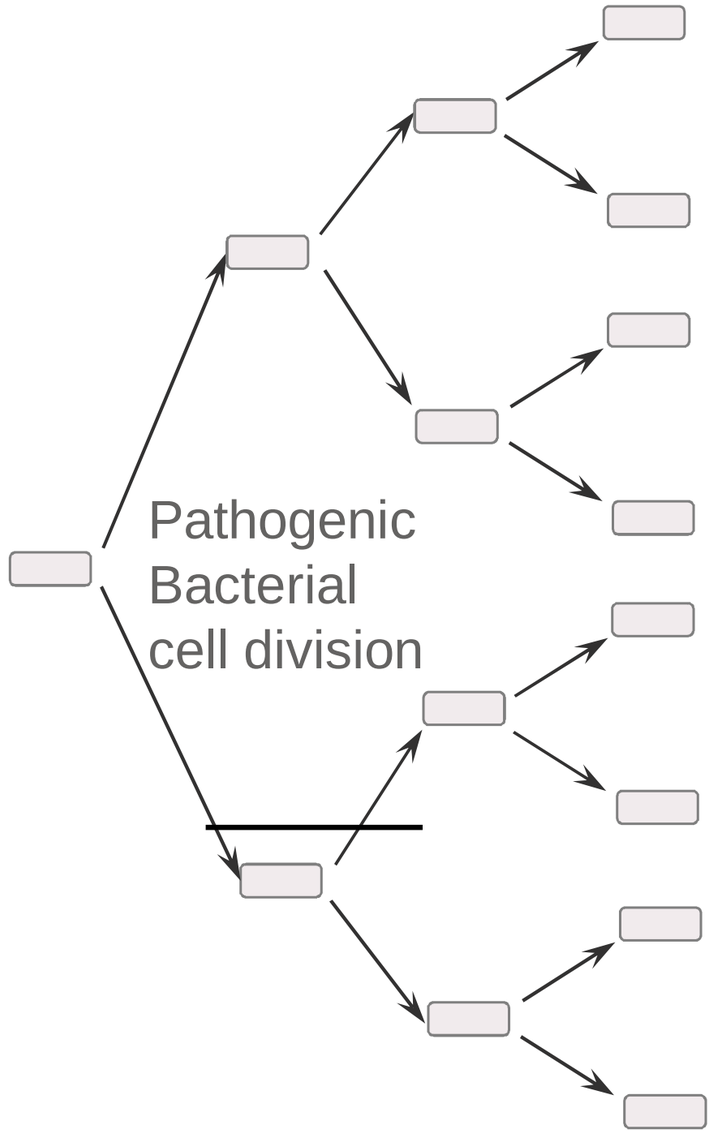
- Pathogens are present throughout the environment, but there are different risks posed by different pathogens.
- Humans assess the risks posed by pathogens everyday:
  - Should we go into work when our colleagues have a cold?
  - Gauging the cleanliness of eating establishments?
  - Wash your hands after using the toilet?
  - What is the water quality at a beach?

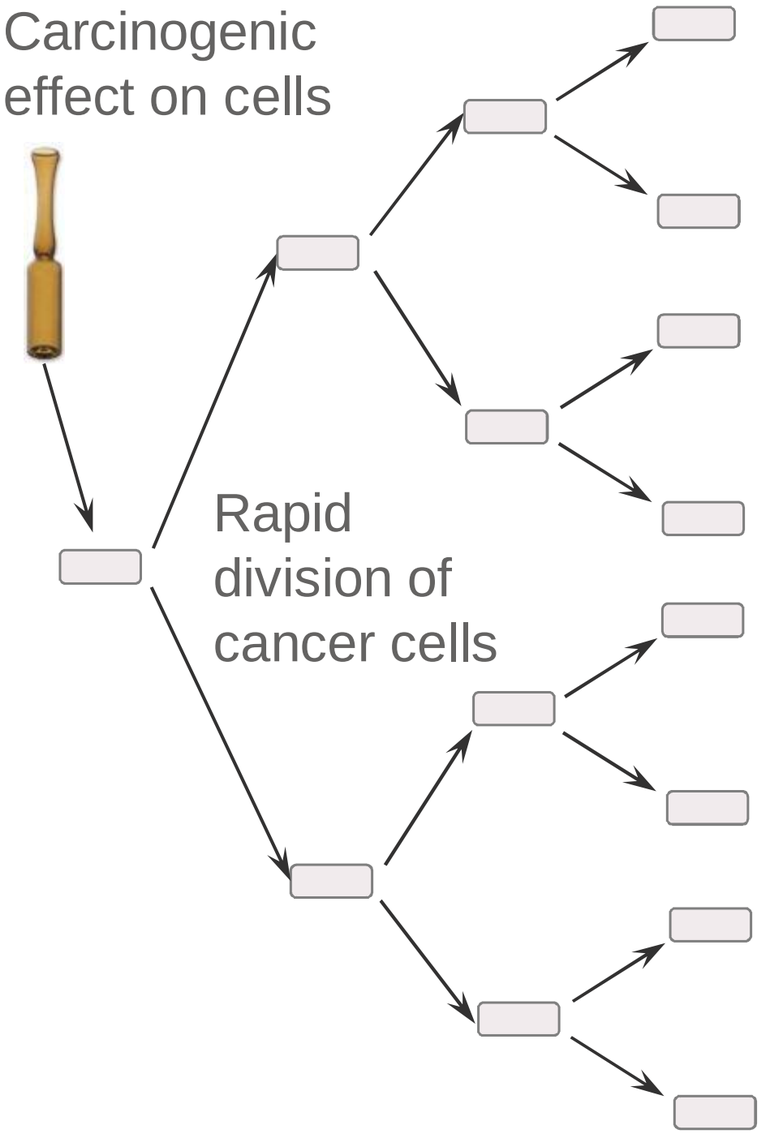
Source: Public Health Image Library (PHIL)

- Your bodies immune system is constantly battling against potential pathogens.
- When dealing with soils/buildings or water, the risks have to be taken in the context of the threat posed by the likely pathogens and their abundance.
  - e.g. Anthrax – Highly dangerous and major economic threat to agriculture. No risk is acceptable as only one organism may be required to cause infection; no detectable viable spores/cells is threshold.
  - e.g. *Leptospirosis/Clostridium* – potentially abundant in environment, minimise exposure to sensitive receptors as it is impossible to eradicate pathogen.

The Unique Problem of Pathogens



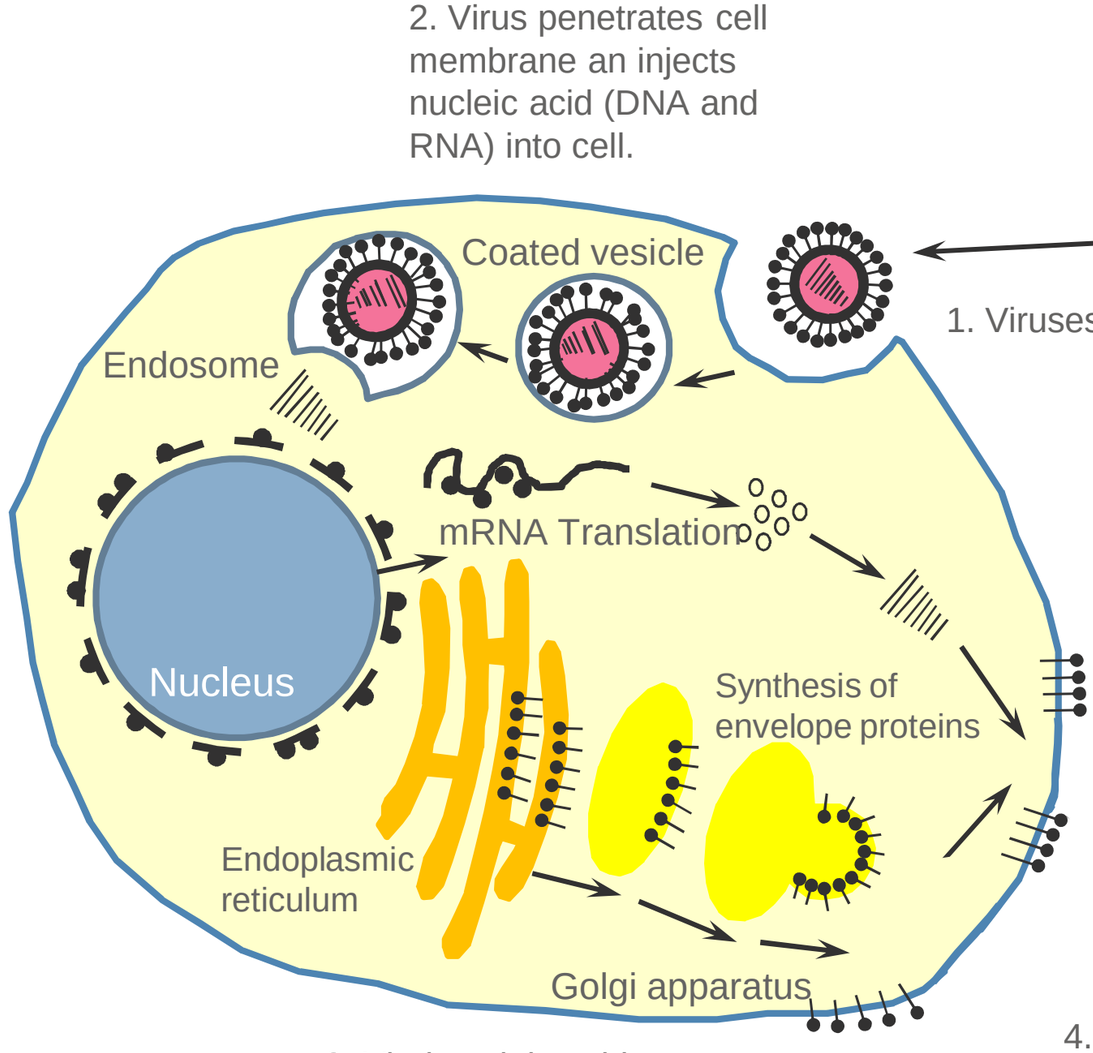




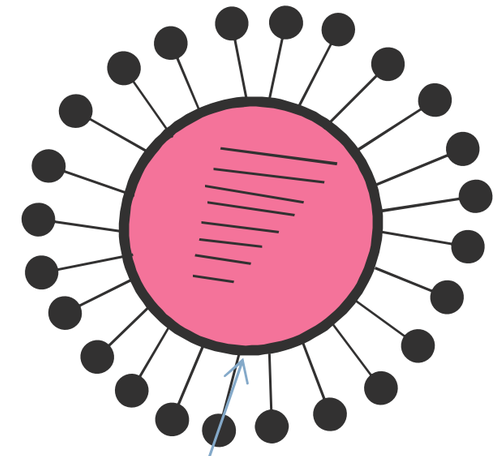
One cell divides into two, two cells into four, four cells into eight, this process continues leading to the growth millions of cells. This is analogous to cancer and the effect of carcinogens.

Viral Infection and Replication

2. Virus penetrates cell membrane an injects nucleic acid (DNA and RNA) into cell.

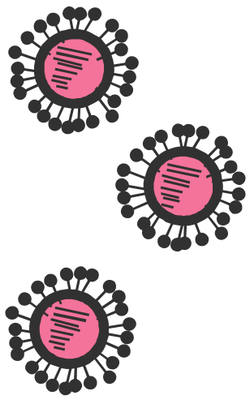


1. Viruses attach to cell



nucleic acid (DNA and RNA)

3. Viral nucleic acid replicates using host cellular machinery.



4. New viral nucleic acids are packaged into viral particles and released from the host cell, which may be destroyed in the process.

Risk Assessment – Sources of Contamination

- **Industrial Sites**
- The areas of sites that processed animals or products made from animals, posing the greatest risk of pathogen contamination are:
  - Areas where carcasses or hides/wool were received and stored;
  - Areas for the washing or early processing of the materials and associated drainage systems; or
  - Areas used for waste disposal, animal burial or where land raising has taken place.
  - Areas inhabited by pests (e.g. rodents) which are vectors of disease (applies below)
- Targeting these areas would be the most effective approach to detecting pathogens, if free of pathogens it is likely that others are also uninfected.
- **Agricultural Sites**
- Does information suggests previous disease outbreaks or animal burials on site, “Animal Health and Veterinary Laboratories Agency” should be contacted.
- If burial sites (due to notifiable diseases) are recorded it is unlikely that investigation/development of these areas would be allowed.
- Has blood, tissues or anaerobic digester waste been spread on the site.

Managing Risks from Gas Industry Construction in Contaminated Land

What/Who Might be at Risk

Surface Water Drainage

Inhalation, ingestion or dermal contact of soils/dusts, containing microorganisms or spores.

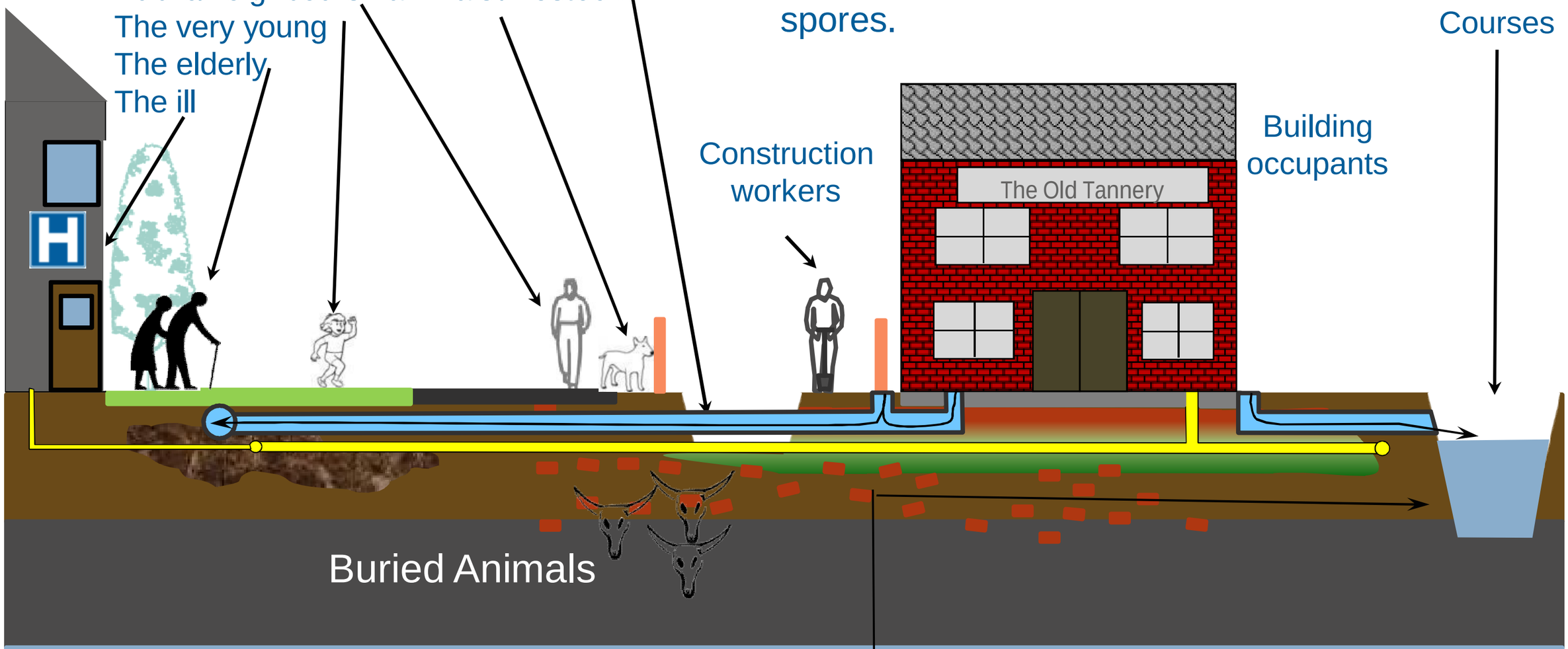
Surface Water Courses

Public/neighbours
The very young
The elderly
The ill

animals\livestock

Construction workers

Building occupants



Groundwater

Leaching of Microorganism and spores into, drains, surface water and groundwater.

Risks from Investigation and Construction

- The risks from pathogens may be overlooked through ignorance or because they are deemed outside the scope of a project (e.g. Part 2a).
- Risks may be higher on sites which are not potentially polluted by chemical pollutants and protection not offered by PPE.
- Health and Safety issues which may be overlooked include:
  - Not including the analysis of pathogens;
  - Not identifying the risk of potential pathogens;
  - Adopting suitable drilling methods that minimise waste, aerosols, and dust generation;
  - Provision of suitable PPE including, the covering of cuts and respiratory protection;
  - The safe handling, storage and disposal of waste materials;
  - Quarantining samples until cleared of expected pathogens; and
  - Good site hygiene practices.

Assessing the Risk – Other Considerations

- The three main routes of infection from pathogens are: dermal contact, inhalation and ingestion.
- However, the main route of infection varies between different pathogens; the severity of the disease may also change dependant on the route of infection.
- Zoonotic pathogens cause a greater risk to their target host animals, although they can still cause severe disease in humans.
- Children are at the greatest risk of infection and serious illness from environmentally transmitted pathogens because:
  - Absent or poor sanitation habits and more likely to ingest soil;
  - Immature immune system; and
  - Intestinal mucosa more permeable to water and reduced stomach acid and pepsin secretion
- The elderly and immuno-compromised are also at greater risk from pathogens.
- Pathogens may also migrate from the soil into the drains or underlying aquifer; quantifying these risks is also problematic.

Assessing the risk – Scottish Borders Case

- This zero risk approach was taken following a confirmed case of inhalation anthrax in the Scottish Borders.
  - The source of the anthrax had been traced to a drum made from an imported infected hide.
  - Some sites where this drum had been used were later found to be contaminated with anthrax spores.
  - Affected sites were decontaminated until no viable spores were detected.
  - This ensured there was no risk public health for these sites, albeit at a cost of £460k (£227k - decontamination contract).
- Estimates of the human LD50 for inhalation anthrax range from 4,100-10,000 spores, other studies have shown humans can be exposed to around 1,000 spores without contracting anthrax.
- Despite the growing evidence, there are still gaps in the dose response relationships between anthrax exposure and infection, especially for dermal infections.
- If this information is provided then a risk based approach may be possible.
- *But one cell is theoretically all that is required for infection.*

Pathogens and Legislation

- Planning (PPS 23: Planning and Pollution Control, England)
  - PPS23 describes the hazards posed by a contaminant to include biological (pathogens) and therefore sites at risk from pathogens proceeding through the planning system requires an investigation to consider the risks posed by pathogens during and after development.
- Environmental Liabilities Directive and Environmental Damage Regulations
  - The definition of environmental damage in respect of 'land damage' is "any land contamination that creates a significant risk of human health being adversely affected as a result of the direct or indirect introduction, in, on or under land, of substances, preparations, organisms or micro-organisms".
- The Control of Substances Hazardous to Health (2002) Regulations
  - COSHH requires that any risk associated with biological agents must be considered prior to worker activity that might place employees or the public at risk; this includes the investigation and remediation of potentially contaminated land.
- Pathogens included in EU/UK waste legislation, Hazard H9 - “Infectious”
- Pathogens can be dealt with through Statutory Nuisance legislation.

Pathogens and Legislation

- *Public Health (Control of Disease) Act 1984*, (substantially amended by the *Health and Social Care Act 2008) and various Health Protection Regulations 2010,* including the *Health Protection (Part 2A Orders) Regulations 2010*:
  - Local authorities and JP to take action to protect public health from a risk of significant harm from infection or contamination. Registered medical practitioners and laboratories, to notify a specific list of notifiable infectious diseases and ***causative agents*** and also other infections or ***contamination***, such as with chemicals or radiation, that may pose a significant risk to public health.
- Specified Animal Pathogens Order 2008 (SAPO), A person must immediately notify a veterinary inspector if:
  - has possession of any thing in respect of which they have reasonable grounds for suspecting that an animal pathogen specified in Part 1 of Schedule 1 (e.g. *B.anthracis*) is present and does not have a licence in respect of that pathogen.
- Notifiable diseases in animals must be reported to the Animal Health and Veterinary Laboratories Agency.
- Notifiable diseases in humans must be reported to the local Consultant in Communicable Disease Control and under RIDDOR.
- Pathogen specific legislation, e.g. The Anthrax Order 1991

Part 2A and Pathogens

- Pathogens are not included or excluded from the definition of a “substance”.
- A substance is defined in section 78A(9) of Part 2A of the Environmental Protection Act 1990 as: “any natural or artificial substance, whether in solid or liquid form or in the form of a gas or vapour”.
- Can a pathogen be classed as a ‘substance’ under Part 2A?
  - the definition of a substance is unspecific and unclear; and
  - the definition of a substance in Part 2A has not been looked at in case law.
- The position of the Environment Agency was that microorganisms are not mentioned in the definition of a “substance” in Part 2A, whereas in other legislation they are.
- They believe that their omission from Part 2A was intended and that pathogens should not be considered a “substance” under Part 2A, and therefore should fall outside the remit of Part 2A.
- **However** – the decision lies with the local authority, only they are able to determine a site to be contaminated land based on the presence of pathogens under Part 2A!

Analysis of Pathogens

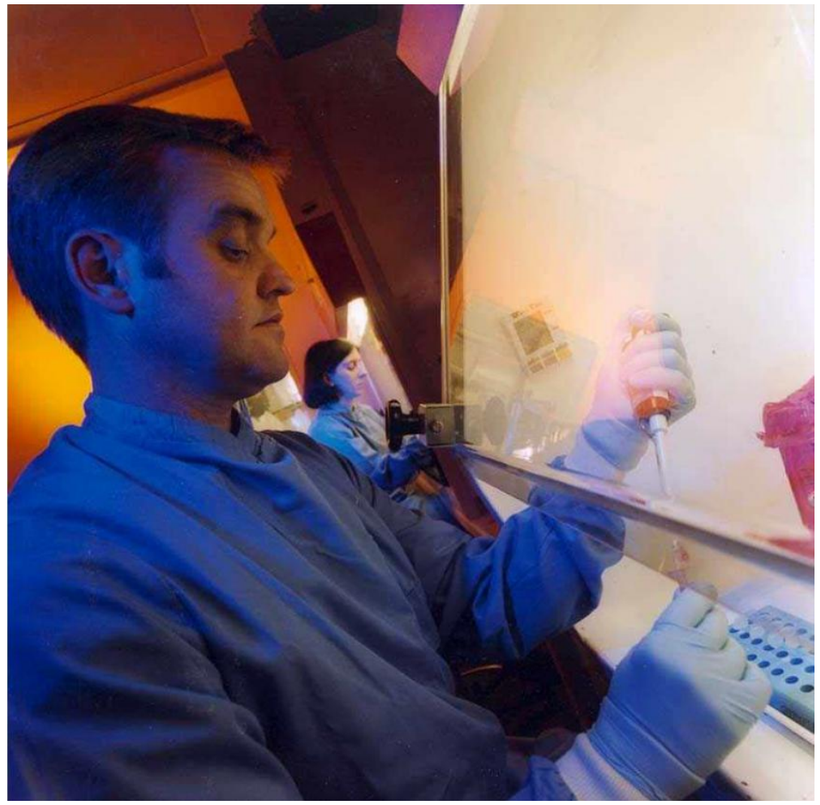
- Tests for many pathogens have been developed for detection from human or animal bodily fluids; they are not optimised for detection from soils/water.
- Some tests used for detection in soil/water samples do not accurately quantify pathogen numbers (cells/spores/viruses).
- With the exception of *Legionella*, there are a limited number of laboratories that can test for pathogens from environmental samples.
- Seek advice from experienced microbiologists.
- Tests must be carried out in specialist microbiology facilities; *B. anthracis* requires Level 3 Containment.
- Analytical methods are based one or both of:
  - culturing, growing cells in broth or agar plates, or growing virus in tissue culture
  - molecular detection, analysis of RNA or DNA.

Analysis of Pathogens

- For the rapid selective isolation and detection of *Bacillus anthracis* in potentially contaminated materials (e.g. animal hair or soil) the HSL uses a combination of enrichment culture and molecular detection by polymerase chain reaction (PCR).
- Culture takes overnight and PCR, which tests for unique DNA sequences from the *B. anthracis* toxin genes, takes 4-6 hours.
- Similar approaches can be used for the detection of spore forming *Clostridium Sp.* and opportunistic pathogens such as *Pseudomonas Sp.* in soils, water and building material.
- *Legionella* testing in water is commonly undertaken by commercial environmental Labs; this is a culture based test.
- *Leptospira* can be analysed in water samples although it is a lengthy process (6 weeks) and not recommended for large surface water bodies. It is feasible to undertake PCR based tests. Testing in humans is done by the HPA in Hereford.
- The detection of Smallpox in humans could only be undertaken at a specialist facility such as (HPA Porton Down)

Factors to Consider for PCR Testing

• Molecular detection by PCR is rapid (hours), sensitive (our anthrax PCR detects down to less than 10 spores) and specific…..



BUT:

• Molecular tests can be affected by interferents such as humic acids and organic debris – important for environmental/soil samples to have a validated clean-up step.

• A positive result shows that DNA sequences are present, not necessarily live micro-organisms. Which is why we use culture as a back-up. However a rapid PCR positive result can be used as an alert for countermeasures or to focus further tests.

• The assay results are only as good as the sample taken.

Sampling Strategies

- Statistically based strategies:
- For example, Visual Sample Plan (VSP) – Pacific Northwest National Laboratory and US Dept of Energy http://vsp.pnnl.gov/ - a software tool for optimal sampling design and statistical analysis for environmental monitoring, characterisation and remediation, response to CBRN events, sampling of soils, buildings, groundwater, sediment, surface water, subsurface layers.
- Favored by Government Decontamination Service for sampling to support clean up.
- Targeted/intelligence led sampling:
- Be prepared to step outside the Plan-led sample collection – in the Scottish anthrax case the main focus of contamination was one floor mat. Use your eyes and imagination.
- Supplement statistical sample plan with site specific information.
- Details of past history and use of site. Talk to ex employees or residents.
- Previous location of buildings, activities, effluent drains

Bioaerosol Sampling

- Examples of fixed point and personal sampling methods for measuring bioaerosol emissions:
- Andersen impactors;
- Liquid impingers;

Bioaerosol Sampling

- Filtrations samplers (fixed point and personal):

Worker Protection

- Levels of live pathogens are likely to be low.
- General personal protection for outdoor work, including gloves, covering cuts and grazes and where required respiratory protection, likely to provide sufficient protection.
- During building remediation or demolition, asbestos protection also sufficient protection against pathogens (with safe disposal of contaminated PPE).
- This should be supplemented by a procedure for recording exposures, injuries and any subsequent ill-health.
- Suitable secure containers for storage of samples and transportation to analyst.
- Adequate information accompanying samples to ensure safe handling for analysts.

Future Considerations

- Continued emergence of non-fossil fuel energy technologies.
- Examples include mechanical & biological treatment (MBT), waste or biomass to energy, anaerobic digestion (AD).
- Potential for biological and chemical residues from the process contaminating surrounding soil, leachate run-off, bioaerosol emissions, also asphyxiant gases in confined spaces.
- Also subsequent spreading of wastes, such as AD waste, to land needs to be managed carefully.
- Scaled-down waste to energy projects (e.g., community heat and power) may be less well managed.

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Thanks for your Attention

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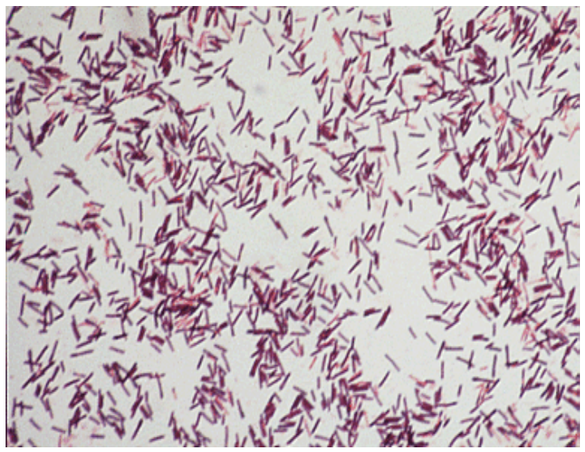

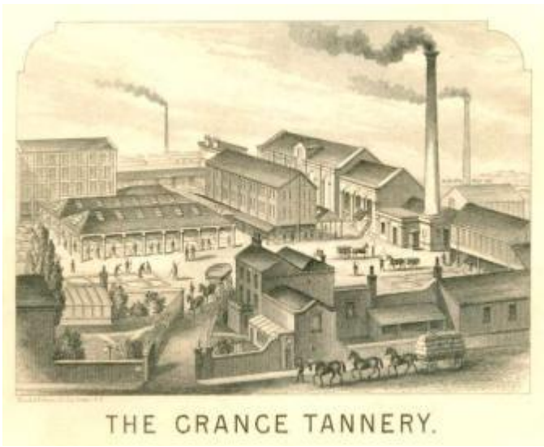

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