Durham University

Skeleton Science

Archaeology for the Older Generation

Above: crouched burial at the Anglo-Saxon Bowl Hole Cemetery at Bamburgh Castle, Northumberland

Front Page: residents and carers from The Millings visiting Binchester Roman Fort, County Durham

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Introduction

This booklet has been created by Dr. Kirsty McCarrison of Durham University's Culture Durham Learning Team and Professor Charlotte Roberts of Durham University's Department of Archaeology.

The booklet has been developed from a Teachers' Resource Booklet that accompanies our *Skeleton Science* travelling exhibition (http://skeletonscience.weebly.com). It is the outcome of a pilot study (April-June 2016) introducing archaeology to residents at The Millings Residential Care Home, Bedale, North Yorkshire (http://www.residential-homes.net/our-homes/the-millings), and has benefitted from discussions with The Millings residents and carers. The booklet introduces archaeology as a subject, and focuses particularly on using archaeological evidence to understand health and well-being.

The pilot study included short talks on what archaeology entails, how archaeological sites are discovered and excavated, and the different specialisms, including pottery, animal and plant remains, and human skeletons. Local sites of interest were included in discussions. The project explored with residents what questions archaeologists try to answer and how important it is to take a deep time perspective to understanding who we are today. The talks were accompanied by "hands on" sessions with objects (pottery and artefacts of other materials such as wood and metal), bones from a range of different species of animals, and replicas of human remains – all from archaeological sites. Durham University's Archaeological Services unit further provided pottery and animal bones from Binchester Roman Fort for residents to wash. We also visited Bedale Museum (http://bedalemuseum.org.uk/) and Swaledale Museum in Reeth, North Yorkshire (http://www.swaledalemuseum.org/) with some residents and carers for object handling sessions, and we went to see the Durham University excavations at Binchester Roman Fort in County Durham (https://www.dur.ac.uk/archaeology/research/projects/all/?mode=project&id=475).

We encourage others to use this resource within the wide range of "older generation" contexts, not only in the UK, but further afield in other countries. It is available as a downloadable resource from http://skeletonscience.weebly.com, and we welcome feeback on its use.

Professor Charlotte Roberts

Charlotte is a Professor of Archaeology in the Department of Archaeology, and a bioarchaeologist with a background in nursing (SRN), archaeology (BA), environmental archaeology (MA) and bioarchaeology (PhD). She is a Fellow of the British Academy (2014), and a member of the Paleopathology Association, American Association of Physical Anthropologists, and British Association of Biological Anthropology and Osteoarchaeology (BABAO) for which she is currently President. She does research on the history of disease and medicine, and especially infectious diseases such as tuberculosis, leprosy and syphilis. Throughout her academic career she has always engaged in public education through her research, including writing accessible books, public lectures, and featuring in TV and radio programmes; she particularly promotes public engagement throughout the life course, from "cradle to grave". For more information, see her webpage: www.durham.ac.uk/archaeology/staff/?id=163.

Dr Kirsty McCarrison

Kirsty is a Learning Officer at Durham University, working across Culture Durham including Palace Green Library Special Collections and Archive, the Oriental Museum, Botanic Gardens, Durham Castle, Museum of Archaeology and the World Heritage Site Visitor Centre. She completed her PhD in bioarchaeology in 2012 on the topic of prehistoric tuberculosis and continues to teach both children and adults about bioarchaeology at the Museum of Archaeology alongside a huge range of other subjects as part of the Learning Team's formal and informal learning programmes. She has previously served on the committees of both the Council for British Archaeology North and BABAO, in addition to a secondment to the North of England Civic Trust. She is now primarily responsible for learning and engagement projects across Culture Durham including events and activities to complement temporary exhibitions held at Palace Green Library.

What is Archaeology?

Archaeology is the study of the human past. It uses what has been left behind by our ancestors, be it artefacts (e.g. pottery, jewellery, weapons etc.), changes to the landscape (e.g. clearing trees from the land to farm crops and graze animals), or the actual physical remains of people who lived in the past and who were buried by their communities.

The part of archaeology most familiar to people is "excavation", where archaeologists dig areas of a site that have been found, record what is there, and usually remove finds from the ground for further study. The vast majority of archaeological work that now takes place is "rescue" archaeology. Legally, some level of archaeological investigation is required in advance of construction work on land designated for development (e.g. to build a new supermarket); this is to ensure that there is opportunity for any archaeological evidence to be recorded, and maybe removed entirely, before building work takes place. This archaeological work is constrained by the time and money available (usually limited), more so than "research archaeology", which can sometimes take place over months or even years.

Durham University Archaeological Services

One common question people have about archaeological excavations is 'how do you know where to dig?' It is actually possible to see some archaeological sites simply by looking! Sites such as prehistoric burial mounds and even remnants of castles etc. can still be seen because all, or part of them, are often preserved above ground level. Other methods of detection include:

Fieldwalking – walking across the landscape: this often occurs on recently ploughed fields where artefacts (e.g. pottery sherds) have been disturbed and are visible on the surface.

Aerial photography – photographs usually taken from small planes: these can highlight raised structures or identify cropmarks (shown by different levels of plant growth due to disturbed ground below the surface affecting moisture levels).

Satellite imagery – images taken from space; these help archaeologists to find previously unknown sites in often difficult to reach landscapes (like deserts).

Geographical survey – there are several different techniques which all involve using equipment to "see" below the ground, such as radar or electrical currents; the survey can show buried features. Usually this type of work only takes place to confirm ideas as to the location, size or shape of an archaeological site as it would be difficult and expensive to do this over huge areas of the landscape without having some idea of where to look.

Archival research – it is often useful to consult archives, such as old maps; these can hold very useful clues as to the location of ancient settlements and other structures.

What is Archaeology? (Continued)

Every archaeologist is very aware that excavating an archaeological site is a destructive process which means that every single detail of the process is recorded because it can never be repeated. It can therefore be a very slow and painstaking job; finding “treasure” is a most unusual occurrence!

However, if you like getting your hands dirty , archaeology is a very rewarding process; knowing you are the first person in tens, hundreds or even thousands of years to hold a particular artefact is both thrilling and humbling.

Excavation in Northumberland

Guide to archaeological periods:

Neolithic	c.4500BC - c.2500BC
Bronze Age	c.2500BC - c.800BC
Iron Age	c.800BC - AD43
Roman Britain	AD43 - AD410
Early Medieval Period	AD410 - c.AD1050
Late Medieval Period	c.AD1050 - c.AD1550
Post Medieval Period	c.AD1550 - c.AD1850

Archaeological Specialisms

Archaeologists come from many different backgrounds and do lots of different jobs. What they all have in common, however, is a passion for learning about the human past from what is left behind. Archaeologists who excavate sites are called "field archaeologists" but some may specialise in other archaeological skills. Below are listed a selection of these specialisms:

Academic archaeologist (usually works in a University): they will usually have a PhD (higher level research degree) on a particular archaeological topic. They do research, teach students, sometimes direct research excavations, and tell the public about their work (e.g. talks).

Durham University academic with students

Animal bone expert: also known as a zooarchaeologist (can also be considered under the more general term osteoarchaeologist – bone specialist). Will analyse animal bones in order to provide more information on things such as what species people exploited (e.g. cows, sheep, pigs), where and when animals were domesticated, their health, facts about human/animal relationships, and what this tells us about diet and farming practices.

Archaeological illustrator: prepares technical drawings of finds and site plans for eventual publication; some may also be asked to create reconstruction images of archaeological sites.

Archaeological surveyor: plans and records earthworks (e.g. banks and ditches surrounding a settlement), buildings, and excavated sites.

Conservator: ensures that artefacts, and even materials used for buildings, such as wood, are preserved for the future using the appropriate techniques and chemicals.

Conservation work

Curator: usually based in a museum or dedicated storage facility for archaeological finds; they organise long term storage and after-care of objects. Specialist curators in museums will often be responsible for deciding what archaeological finds go on display and for providing information for exhibitions.

Archaeology gallery at Palace Green Library, Durham University

Archaeological Specialisms (Continued)

Public educator: Presents the evidence excavated from archaeological sites, alongside relevant historical knowledge, to the public through events and activities. Can work for archaeological units, county councils, museums or universities and are subsumed under various job titles (e.g. Community and Events Officer or Learning Officer).

Fun in the Museum of Archaeology, Durham University

Environmental archaeologist: scientifically studies the relationship of past humans to their environment. This often includes the study of biological remains such as seeds and pollen which can help reconstruct past diets.

Finds specialist: identifies, analyses and interprets archaeological artefacts, including estimating their date. These artefacts can be very wide ranging and include things such as pottery, glass objects, things made of wood and leather, jewellery and weapons. Every type of artefact can help build a more coherent picture of what life was like in the past, including what jobs people did.

Archaeological find: flint (front and back view)

Students working in the Fenwick Human Osteology Laboratory at Durham University

Human bone expert: also known by other names such as bioarchaeologist (see next page). Sometimes excavates and always analyses and interprets human remains found on archaeological sites. Human remains can, amongst other information, help build up a clearer picture of people's lives, including health and well-being, and their burial practices. They also can provide key facts such as people's age at death, how many men, women or children were buried, and their stature (height).

Landscape archaeologist: searches for traces of ancient sites often over large areas, and studies the ways people in the past constructed, used, changed, or adapted the landscape. Aerial photography is often very useful in addition to archival material such as old maps, parish records, census documents, and artworks.

Underwater archaeologist: discovers, records and excavates archaeological sites buried beneath rivers, lakes and the oceans.

The following section will look more closely at the work of a 'bioarchaeologist' which is, in itself, hugely varied.

What is Bioarchaeology?

Durham University Archaeological Services recording burials onsite

In Britain, this term generally applies to those who study biological remains, including plants, animals and humans, from archaeological sites. In this booklet it is used to refer specifically to the study of human remains (as in other countries, such as the USA). The name indicates that bioarchaeology takes a multidisciplinary approach; this means that the information recorded from human remains (biological) is interpreted using other archaeological information, such as what their houses were like or what food they ate, and how that affected their lives. Other terms may be used, including "human bone specialist", "osteoarchaeologist" (one who studies human/animal remains in archaeology), "osteologist" (a general bone specialist) and "palaeopathologist" (one who specifically studies disease in human remains). There is much confusion of names even within the archaeological community!

Bioarchaeologists can learn huge amounts from studying human remains as they give us a unique opportunity to come face to face with history, to learn about when, why and how past societies were created, and how they developed. The following pages focus primarily on what information can be recorded by studying *skeletal* remains, but additional information relating to other types of analyses (tests) that can be applied to human remains like Egyptian mummies (which often have preserved bones *and* soft tissue) can be found within this booklet; some techniques can be useful whatever kind of human remains are being studied.

Over the past few decades, the study of human remains has become much more complex and much more scientific; we can find out much more about our ancestors than we could 20 years ago. As with other scientific research, we ask specific questions about the past, and propose theories. For example: did people become less healthy when they started to farm crops and animals for food? The purpose of the research is therefore very clear – it is a quest for answers that are reached by recording information from the skeleton. Bioarchaeologists tend to ask questions based on particular themes of interest, for example: migration patterns, the effects of conflict on people, the origin and evolution of specific diseases, and the impact of occupation, diet, climate and social status on health.

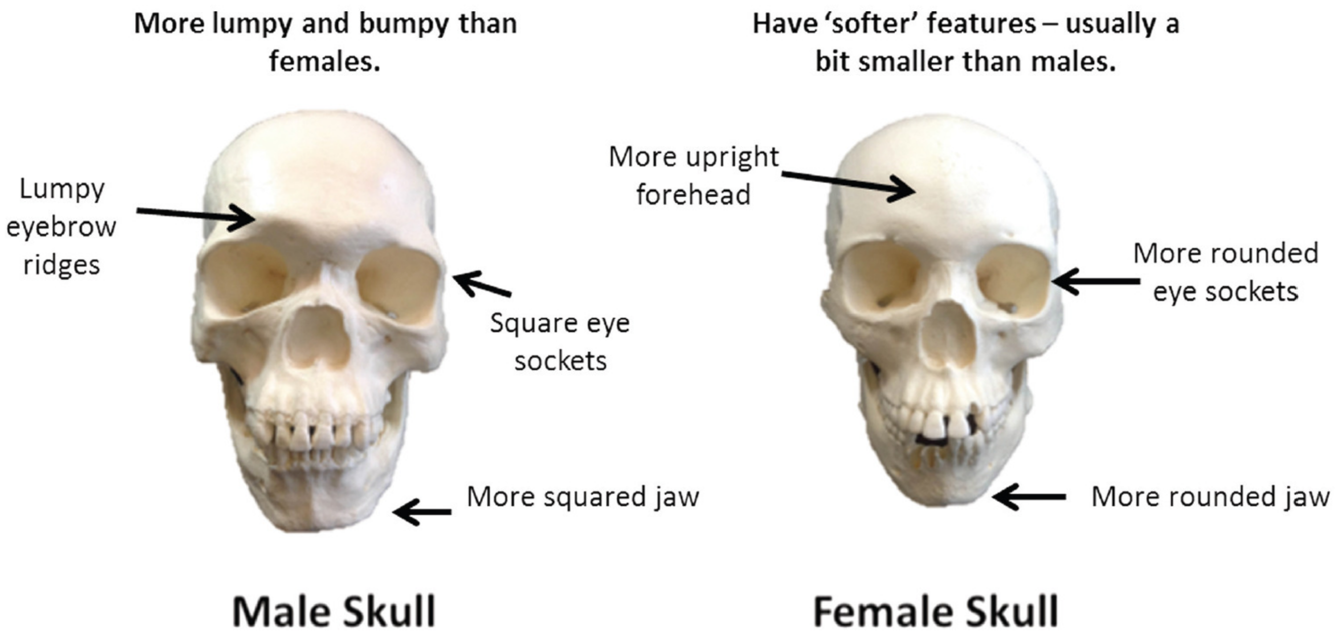
As always, while research may answer those questions, supporting or contradicting assumptions, it also tends to produce new questions, which then leads to new projects that drive bioarchaeological research forward.

In the following pages we will look first at the basic data we would collect from a skeleton including age at death, biological sex, injury and disease; most of this work can be done macroscopically (just by careful visual examination). We will then look at some of the additional scientific techniques that can be applied to skeletons in order to learn more about diet, health, relationships between individuals, and even whether people had to contend with parasites in the past.

Male or Female?

As children grow up and start to go through puberty, there are some things that we can see happening; a boy's voice might start to get deeper or a girl might start wearing a bra as her body develops. There are also lots of things happening inside our bodies that we don't necessarily see and that most people don't know about. For example, the shape of your bones start to change as you get older so men and women's bones are a slightly different shape; before puberty, children's skeletons look the same whether they are a boy or a girl.

This is great for bioarchaeologists, who only see the skeleton of a person, because they can usually work out if the person was a man or a woman just by looking at the skull and the pelvis. Every individual is different though so it doesn't work all the time and sometimes it's very difficult, especially if the skeleton is not well preserved.



Different angles - the 'sub-pubic' angle is one example below. See how the female's is wider?

How Old?

As children grow, their bones develop too. Most people know that the average adult skeleton has about 206 bones but a child's skeleton has over 300.

Some of our bones fuse (join) together as we get older to make bigger, stronger bones. Different bones in the body fuse at different ages which means that a bioarchaeologist can work out, quite accurately, how old a person was if they were a child or young adult (20-30 years) when they died.

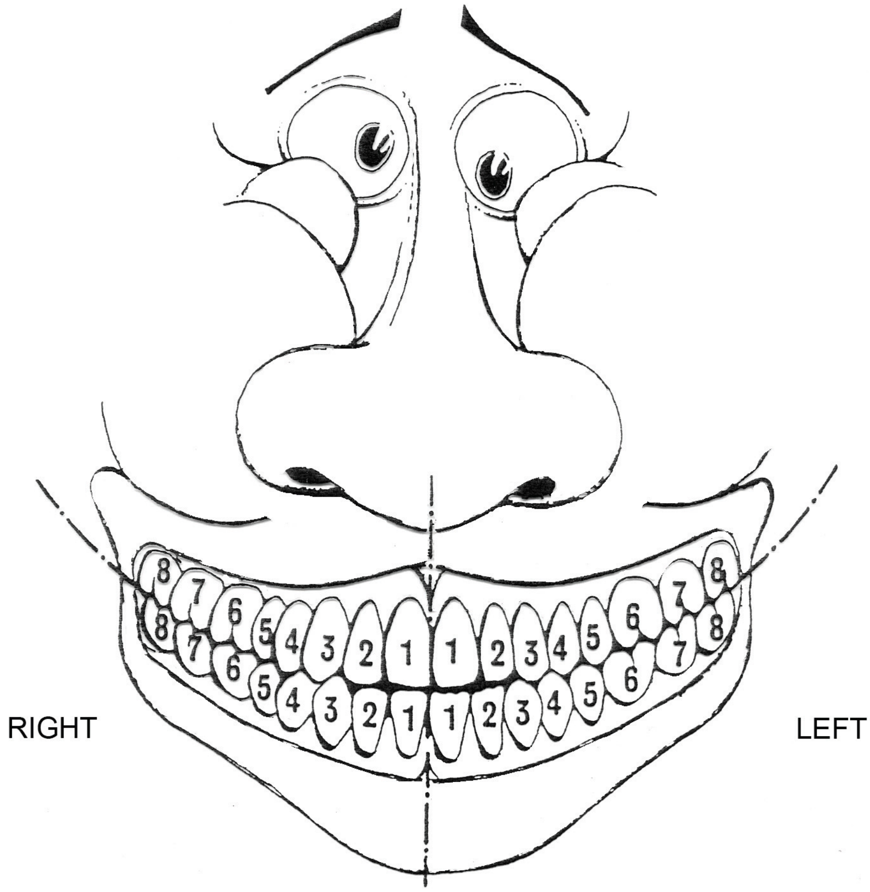
Once an adult is fully developed it becomes much harder to work out the age just from the skeleton as you have to start looking at the wear and tear on the body, for example, considering how much joints or teeth have worn down.

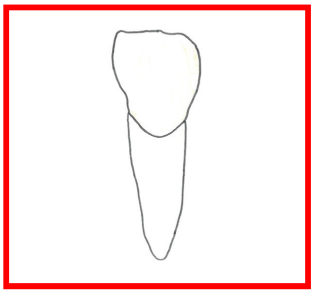
The femur (thigh bone) at different stages of development

Teeth

Teeth are a fantastic source of information for bioarchaeologists, not just to help work out age at death, but also to show dental disease which is discussed in more detail on page 13.

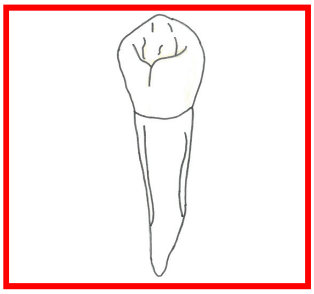
A normal adult mouth contains 32 teeth; 16 in the top and 16 in the bottom jaw. The different types of teeth look different from one another because they are designed to do different jobs.





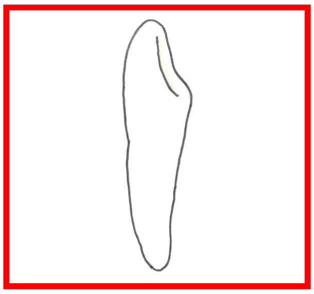
Incisors

There are 8 of these at the very front of the mouth. They are very sharp and designed to cut food whilst pushing it into the mouth.



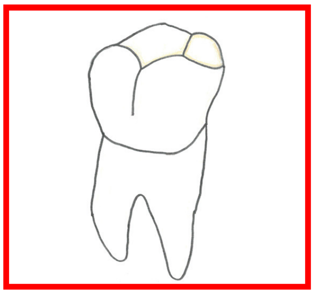
Premolars

These are the teeth between the canines and molars and are meant for crushing food; there are 8 of them.



Canines

There are 4 of these that sit just next to the incisors. They are built for grasping at and tearing food.



Molars

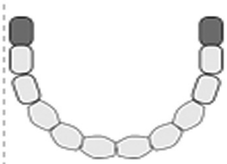
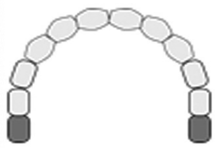
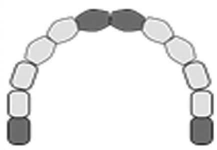
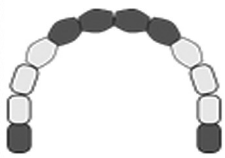
Eight flat teeth at the back of the mouth which are bigger and flatter than all the other teeth because they are designed to chew and grind food into smaller pieces.

Wisdom teeth (third molars)

These teeth erupt at around age 18, but are sometimes taken out because they can push other teeth out of the way. This is because over time, through the process of evolution, people jaws have become smaller meaning there's not as much room for our teeth as there used to be. This is why lots of people have braces now, because teeth are often fighting for a place in our mouth and can become crowded and consequently crooked! There is one in each corner of the mouth although sometimes they never come through at all because there's no room.

Dental Development

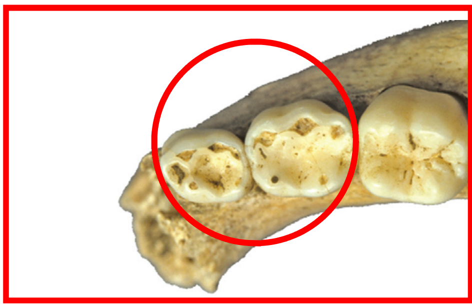
Baby teeth begin to develop before we are born but usually erupt through the gums between the ages of 6 and 12 months. Most children have 20 milk or deciduous teeth and these are fully developed by about the age of three years; they start to fall out from around five years old. Because the teeth of populations around the world can develop at slightly different rates, understanding the rate of dental development in a particular population allows bioarchaeologists to better estimate the age of an individual. It is much more difficult to estimate the age of an individual with such accuracy once they are an adult and all of their teeth have erupted. Bioarchaeologists have used dental wear to estimate age in adult skeletons but this is very specific to particular populations and communities as the rate of dental wear is heavily influenced by the type of diet a person has; those with very coarse diets will show greater signs of wear at an earlier age than those with 'softer' diets. Other, additional methods of ageing are used wherever possible.

	How Many Teeth?			
Age	Adult	Baby	Upper	Lower
6 - 7 Years	4	20		
6 - 8 Years	8	16		
7 - 9 Years	12	12		
9 - 11 Years	16	8		
10 - 11Years	20	4		

Key: Adult Teeth Baby Teeth

When Teeth Go Bad

Dental diseases are very frequently seen in skeletons, and include caries ("rotten teeth"), abscesses (infection in the jaw), periodontal disease (loss of bone of the jaw leading to eventual loss of teeth), and calculus on teeth (originating in the soft substance called plaque that dentists instruct us to get rid of from our teeth by brushing); these all remain common today and provide us with an understanding of people's diet and whether they attended to their oral hygiene.

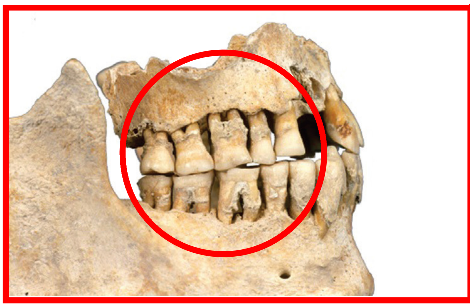


Tooth Wear

This is where the enamel on the surface of the tooth gradually wears away. The amount of tooth wear increases with age and is worse if you have a very gritty diet like the ancient Egyptians did. Today the foods we eat are much softer and therefore our teeth do not wear down like they did in the past.

Abscess

An infection in the tooth caused by bad bacteria; it is often very painful. Dentists today can treat abscesses by draining the pus and with antibiotics but in the past people would have suffered.



Plaque and calculus

Calculus starts as plaque, and is a result of a build-up of bacteria. The bacteria particularly like foods that contain sugars (milk, soft drinks, cakes and sweets). Plaque is easily removed by brushing the teeth, but otherwise it gradually builds up and forms a hard layer (calculus) which cannot be brushed off. Plaque can cause red gums (gingivitis) if not removed from the teeth and this may lead to an inflamed jaw bone and eventual loss of teeth because the tooth roots are not as secure. Calculus is very common from all periods of time.

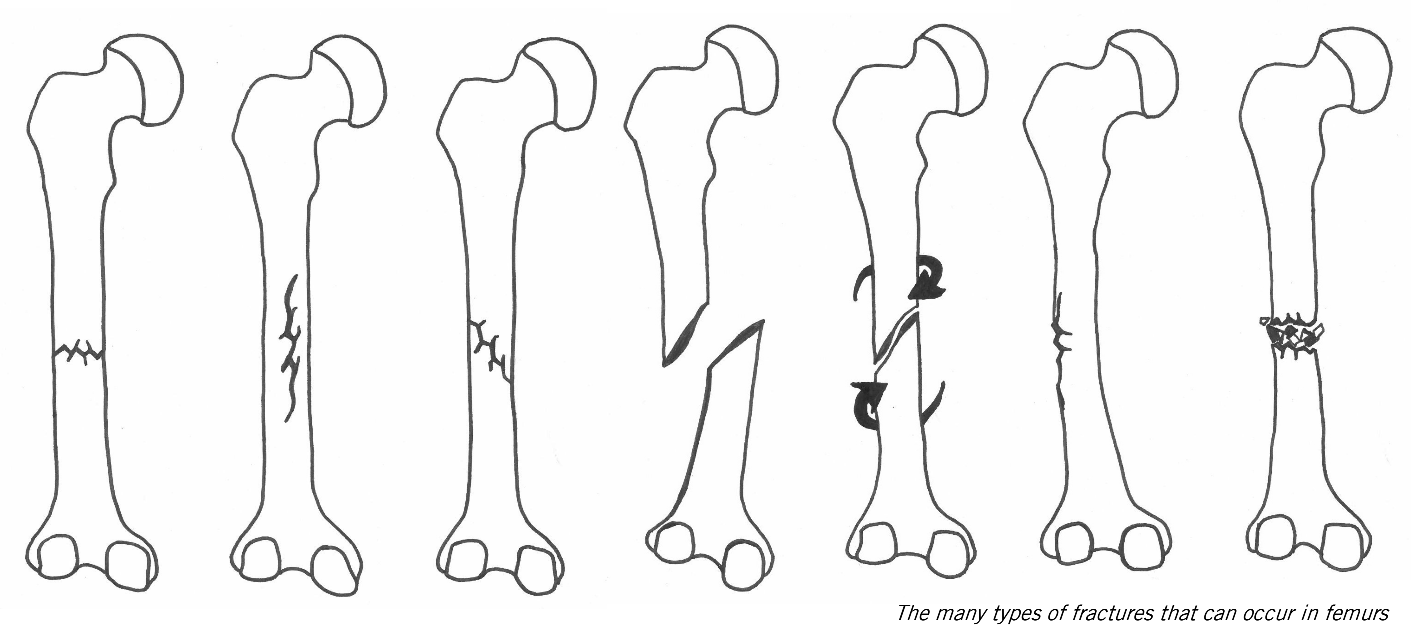
Caries

If plaque is not brushed away the bacteria react with the sugars and a cavity or tooth decay occurs. A hole forms in the tooth because of infection and if it's not treated straight away it can become very deep and very painful. This is the most common problem dentists see and it usually results in having a filling to stop the tooth getting any worse. Skeletons in the past show that caries was a problem for people when they started to eat more sugary foods. The Romans particularly ate figs, dates and honey that all contain lots of sugar.

Injury

Injuries, or 'trauma', are one of the most common abnormalities we see in skeletons. If a person who is injured survives a long time before death the injury will show evidence of healing, sometimes so well that it is difficult to identify the original injury. Trauma around the time of death (perimortem) may show some evidence of healing but this will not be complete, and damage to a bone sustained after death (postmortem) will show none.

Fractures: These are the most common bone injuries both today and in the past; healed and unhealed fractures can be identified in skeletons. Modern data collected on fracture types can be very helpful when thinking about the type of activity a person might have been doing when they sustained a particular fracture type. For example, we know certain types of fractures are consistent with falling in a particular way (on an outstretched hand, breaking the wrist: "Colles" fracture) or when trying to defend oneself when being attacked (breaking a forearm bone: "Parry" fracture).

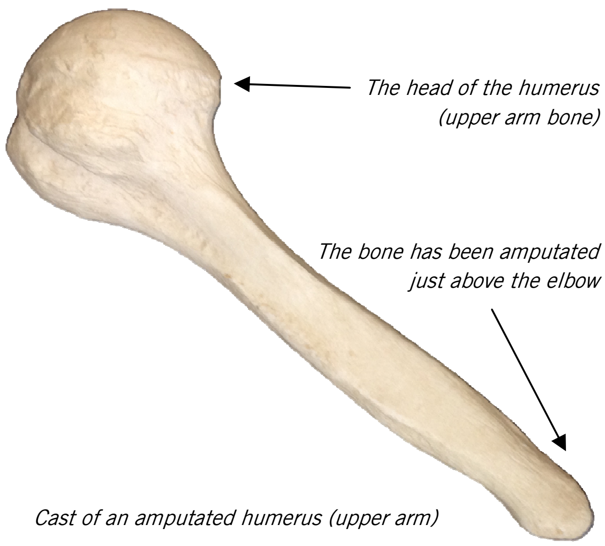


The many types of fractures that can occur in femurs

Projectile wounds: Gunshot wounds seen in bones of the skeleton tend to be recent in date because guns were a relatively late invention (14th century); however, injuries as a result of "projectiles" other than bullets, are found throughout prehistory (e.g. Neolithic arrowheads embedded in the spine).

Decapitation: Often identified by small cuts to the cervical (neck) vertebrae, and in some burials the skull is placed between the knees or by the feet.

Amputation: This was at times surgically performed on limbs because of severe injury or infection, or it happened accidentally (e.g. an industrial accident). Amputations in the past did sometimes heal well, but in many cases they did not and people probably died through shock and/or haemorrhage from the surgery, in addition to post operative infections.



Cast of an amputated humerus (upper arm)

Injury (Continued)

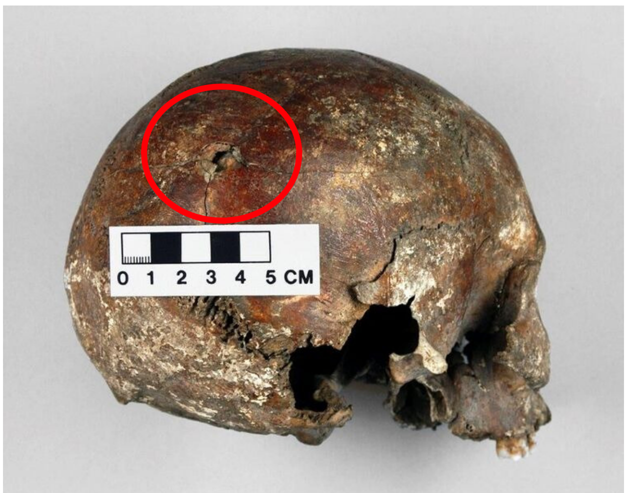
Dislocations: These describe bones of a joint that are out of normal alignment; they are common today (especially of the shoulder) but not seen much in the past. They are usually recognized by a bioarchaeologist when a dislocated bone has not returned to its original position, and an entirely new joint surface has formed to compensate.

A new joint due to dislocation of the humerus (upper arm bone) has formed on the scapula (shoulder)

Trepanation: This describes the surgical removal of part of the skull. Examples can be found from different cultures around the world and from prehistoric to 19th century archaeological sites. Reasons suggested range from treatment of head trauma to ritualistic purposes.

Cast of a trepanation from South America - formed by 'cutting'

Blunt force trauma: Often seen on the skull as a result of being hit with a blunt object like a club or a hammer (but people can also accidentally fall and hurt their head). Here a depression of the bone may be seen with radiating fracture lines.



Blunt force trauma on a skull. Roman or Civil War period, NE England

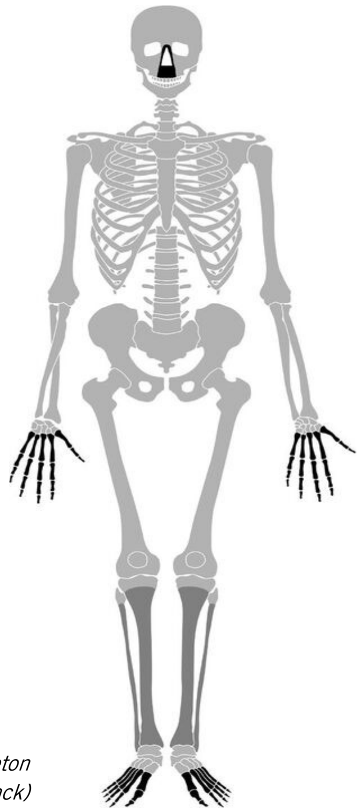
Sharp force trauma: Caused by some form of sharp blade (e.g. a sword); one side of the cut is usually clean and straight, and the other rough where a flake of bone fractures and often detaches due to the force of the blow.

Sharp force trauma on an Iron Age/Early Roman skull from Herefordshire/Worcestershire, England

Disease

Evidence of disease (palaeopathology) seen in human remains allows us to explore their origin, evolution and history. Everybody is ill at some point in his or her lives today, and we can be sure that they were in the past; illness of course affects the very function of societies. Studying past illness is important because it give doctors a deeper time perspective on health, thus helping us to understand why we contract diseases today, and perhaps helping us plan for a future of good health.

The primary source of evidence for disease in the past is the trace left in human remains. However, studying disease is not an easy task, but we have, as a base, a vast amount of literature about how diseases in living people affect the bones and teeth. By comparing what we see in human remains with what is known in medicine, we can begin to piece together the disease experiences of our ancestors. We can also use information from research in medical anthropology – the study of health often in people in developing countries who live "traditionally"; they are the closest comparison for the past because our ancestors probably lived in very similar ways. Studies in evolutionary medicine (understanding of health today from an "evolutionary" perspective) also provide us with information that is directly relevant to palaeopathology; this is because we study human remains that can be up to thousands of years old.



Right - areas of the skeleton affected by leprosy (in black)

Below - evidence of bone destruction seen on the skull

Disease can lead to bone formation, destruction or both (and destruction of the teeth and jaws). Observing and recording the distribution of lesions (areas of damage) caused by disease in the bones and teeth in a skeleton helps with diagnosis. However, it is important to remember that many diseases do not affect the skeleton (e.g. malaria and plague only affect the soft tissues), or only in a few per cent of untreated people (e.g. 3-5% of people with tuberculosis) and therefore it is not possible to detect those soft tissue diseases when analysing skeletons, unless DNA analysis is used. Often too we see no disease evidence in skeletons, which might mean a person died before bone damage could develop.

We use several methods for analysis: visual, histology (using a microscope to help see microscopic signs), imaging (radiography using x-rays), and biomolecular (such as DNA analysis). Particular diseases might damage the bones or teeth in specific ways such as "Pott's" disease of the spine in tuberculosis (p17), but often changes are non-specific (such as bone formation on ribs; any number of lung diseases that cause this inflammation), meaning they could have been caused by a number of different diseases .

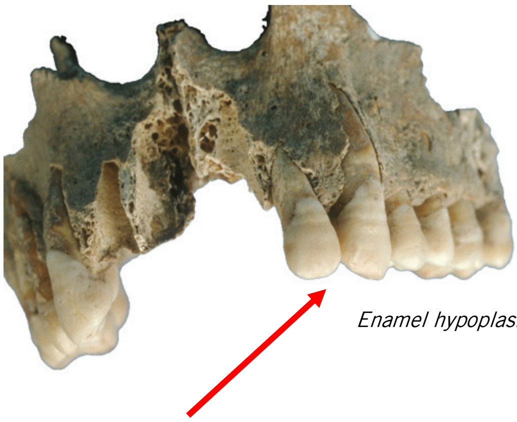
There are some key categories of disease that are fairly regularly identified in human remains; the following page shows some brief overviews of each of these (for dental disease see page 13).

Disease (Continued)

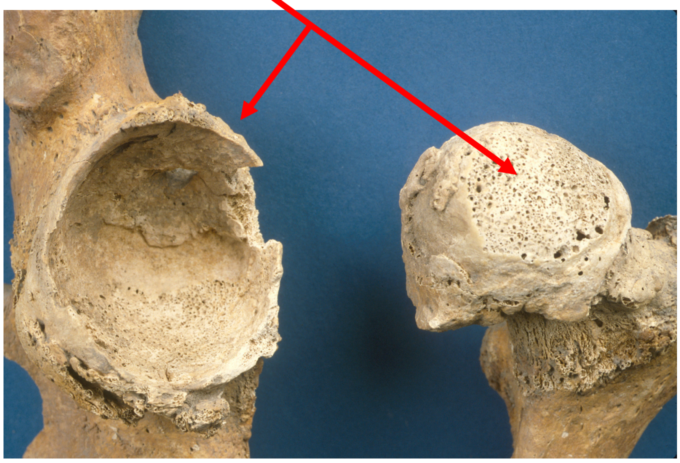
Infectious disease: Evidence of infection can range from very slight extra bone formation on the surface of a bone to severe destructive lesions or extensive bone formation. Some of the most obvious changes are as a result of bacterial infections such as tuberculosis, syphilis and leprosy. Some of these infections are still around today (especially TB), even in Britain where there is very good health care. Note on the right the 'hunchback' spine due to destruction of vertebrae.

"Potts Spine" – a classic sign of TB

Joint disease: Joint disease such as osteoarthritis, a common condition today, is caused by the wearing away of cartilage in the space between particular types of joints (synovial: e.g. knee and hip) which then leads to bone rubbing against bone. The body both *makes* bone to strengthen the joint, and *destroys* bone (see holes on the femur head and pelvis 'cup'). This is seen very frequently in archaeological skeletons, is associated with increasing age, and may be linked to particular occupations, such as mining.



Enamel hypoplasia



Osteoarthritis in a hip joint

Metabolic disease: These conditions are often the result of dietary deficiencies and affect people in the growing period when they are young. While both Harris lines (thin, horizontal, white lines representing a dense layer of bone that can sometimes be seen on radiographs of leg and arm bones) and defects on the teeth (enamel hypoplasia; ridges of dense enamel) represent recovery from episodes of malnutrition or illness in childhood, vitamin C deficiency can cause scurvy, while vitamin D deficiency is known to cause rickets, a disease making a worrying comeback in the 21st century. Osteoporosis results in a reduction in bone density and mass that can often be seen on radiographs and is also one of the most common metabolic disorders amongst the elderly.

Other, less common diseases include those affecting the endocrine glands, some of which can result in people being very tall (gigantism), or very short (dwarfism), and neoplastic disease (benign or malignant tumours); the latter is increasingly common today compared to the past, but is also a very ancient disease. We can also find out about heart disease from fatty plaques preserved in blood vessels of mummies, and sometimes affected arteries may be found with skeletons.

Continue reading for a more in-depth look at some diseases seen in history, a number of which still survive today.

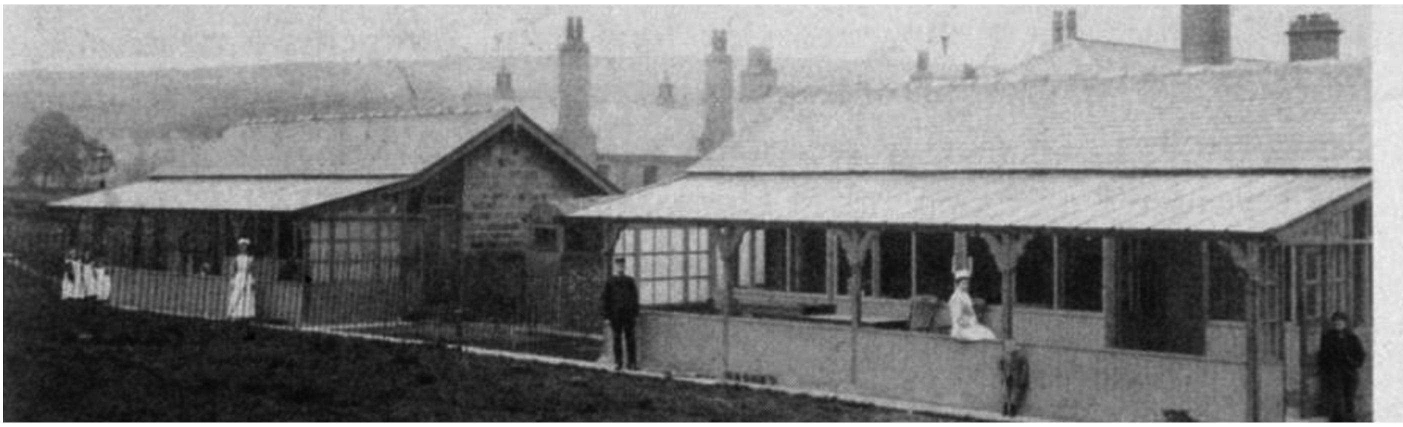
Disease Profile: Tuberculosis

Tuberculosis (TB) is an infectious disease caused by a bacterium. It was thought that TB had been "conquered" back in the 1980s with better living conditions and diets, TB testing of cattle and pasteurization of milk, and available vaccinations and antibiotics, but it "re-emerged" from the 1990s onwards, (World Health Organization "Global Emergency", 1991). TB is found everywhere in the world today, even in towns and cities in the UK. In 2014 1.5 million people died of TB and 9.6 million people fell ill with the infection, but deaths from TB have declined over the last 25 years by nearly 50%. However, while streptomycin was the first effective antibiotic cure (1943), TB started to become resistant to it, and others, and now four antibiotics are used. The multi-drug approach to curing TB can be highly effective, but multi-drug resistant TB is now being seen too.

Sneezing sends out millions of droplets, a common method of TB transmission

Many older people remember TB, and may have had relatives and friends who had the infection. The legacy of sanatoriums bears witness to how common it was in the recent past. Today, governments around the world today are very aware of the problem of TB, and much work is being put into developing more effective treatments, reducing poverty and improving health education. Ending the TB epidemic by 2030 is an aim of the newly adopted United Nations Sustainable Development Goals (2015).

Sanatorium in Yorkshire



Two species of the bacteria, *Mycobacterium tuberculosis* (*M.tb*) and *Mycobacterium bovis* (*M.bovis*) are the main ones affecting humans. People inhale the former into the lungs and ingest the latter into the digestive tract (infected meat and milk from animals). TB affects the body in many ways. Depending on whether the TB affects the lungs or gut, people become weak, lose their appetites and weight, are pale, have difficulty in breathing, cough up blood and have chest pain, diarrhea and abdominal pain, experience night sweats and have a high temperature. There are many risk factors for contracting TB, including poverty, a poor diet, stress, living in crowded conditions, smoking, vitamin D deficiency, contact with infected animals through work, migration to new places, and having the viral infection HIV.

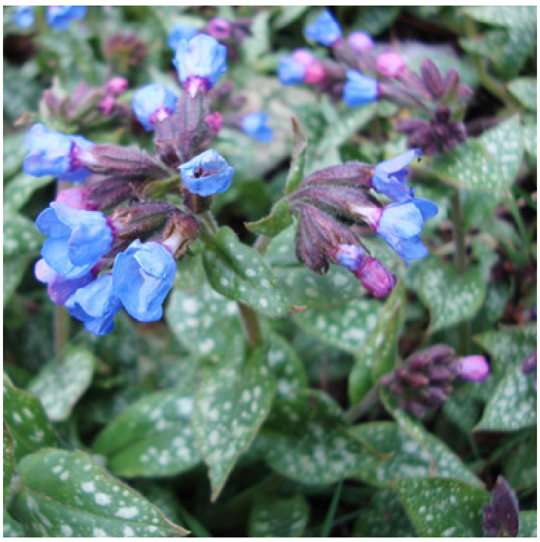
TB has had a several thousand-year history in the archaeological record, but it is likely that it originated in Africa and spread as people migrated. It is possible to detect TB in archaeological skeletons and preserved bodies like Egyptian mummies. People in the past did not have the treatments we have today, so when bacteria entered the lungs or the gut, they were able to spread to other parts of the body through the bloodstream and lymphatic system. In the skeleton the bacteria likes to deposit themselves in the vertebrae that make up the spine. There, they destroy the bone and eventually the spine collapses in the region affected (see image on page 17). This is how TB is diagnosed in skeletons.

Disease Profile: Tuberculosis (Continued)

It is possible to also diagnose TB by finding and analysing DNA of the bacteria, which can be preserved in skeletons and mummies. In this way, not only can a diagnosis of TB be made, but the actual species of TB (*M. tb* or *M. bovis*) can be identified, along with different strains that appear to be related to different locations in the world, and even within countries. This type of work can tell us much more about how TB was being spread around the world in the past. It is also relevant to understanding the impact of rapid and frequent travel on TB transmission amongst people today. In recent work different strains of TB at one Roman site in England have been found, and in Peru the TB strain that affects seals and sea lions has been found in 1000 year old human skeletons.

Lesions on ribs (lighter areas), related to a lung problem, possibly TB

The earliest evidence of TB is in skeletons excavated from cemeteries in Germany, dating back at least c7000 years. Evidence from skeletons and mummies with TB from the Americas suggest a much more recent date (the oldest from Chile, about 1300 years old). Some old documents also record that TB affected people, for example in a Chinese text that is nearly 5000 years old. The frequency of TB increased with the Neolithic revolution when people started to farm crops and domesticate animals that can contract TB, such as cattle. They also lived in permanent houses and in more crowded conditions (page 34). When people started to live in towns and cities in Europe, especially from the 12th century AD onwards, TB increased in frequency until the early to mid 20th century when living conditions got better and antibiotics were developed for treatment. Prior to antibiotics people had been treated with herbal remedies, such as lungwort in the medieval period (*Pulmonaria*), and in the 1500s to 1700s AD in England and France people with TB were touched on the head by the king or queen and given a gold piece. This was meant to cure them of their TB.



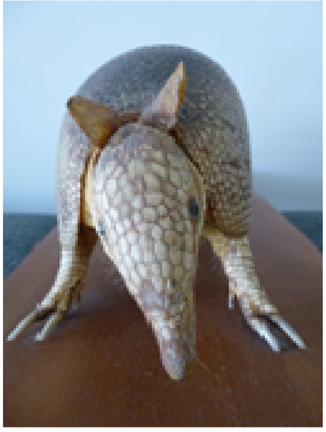
Pulmonaria (Lungwort)

The bacterium that causes TB was first identified in 1882 by Robert Koch, a German doctor and scientist. As he presented his discovery of *Mycobacterium tuberculosis*, at what is now considered to be one of the most important lectures in medical history, he said that "*If the importance of a disease for mankind is measured by the number of fatalities it causes, then tuberculosis must be considered much more important than those most feared infectious diseases, plague, cholera and the like*".

He brought with him tissue dissections from guinea pigs infected with TB from the lungs of infected apes, from human brains and lungs infected with blood-borne TB, from TB masses found in human lungs and in the infected abdominal cavities of cattle. The key finding was that the cultures of bacteria taken from the artificially infected guinea pigs were exactly the same, no matter from where the bacterium originally sourced.

It is reported that no applause was heard that evening – the audience was stunned into silence by the giant leap forward just taken in medicine and bacteriology. Shortly afterwards, as news of the discovery spread, Robert Koch became known as "The Father of Bacteriology" and was eventually presented with the Nobel Prize in Physiology or Medicine in 1905 "for his investigations and discoveries in relation to tuberculosis."

Disease Profile: Leprosy



Nine banded armadillo

Leprosy is an infection caused by bacteria: either *Mycobacterium leprae* or *Mycobacterium lepromatosis*. The nine-banded armadillo is the only other animal, apart from humans, that can harbor the bacterium. Armadillos are found in America today, especially in the southern states such as Louisiana and Florida. People contract leprosy from inhaling the bacteria from others (droplet infection); armadillos can also be a source of infection (people keep them as pets and hunt and eat them). There are about 250,000 new diagnoses of leprosy in the world today, mainly in Brazil, India and Indonesia, but people in many other countries are affected. Although it is curable with antibiotics (provided free of charge), many still do not get treatment for various reasons, and permanent damage to the skin, nerves, limbs and eyes may occur.

Skull showing leprosy from Medieval Denmark

Below: foot showing leprosy from a person buried in Medieval Denmark compared to the upper normal foot

With leprosy, skin lesions develop, and the bacteria enter the respiratory tract and spread around the body, including into the nerves. People eventually lose their sense of touch, and control over their fingers and toes. They may develop ulcers on their hands and feet because they cannot feel damage to them (e.g. walking over rough ground). The hand and foot bones can then be affected, leading to possible disability. The nose also collapses because the facial bones of the skull are affected, and the front teeth may drop out. Unfortunately, people with leprosy are often subject to stigma because many do not understand the infection and how it affects people, which can lead to those with the disease being isolated from their communities.

Leprosy has been with us since at least 2000BC. Most evidence from archaeological skeletons comes from Europe, and there is virtually no evidence in the Americas. It was most common in the Medieval period (12th-16th centuries AD) and there is a lot of evidence in Britain, Denmark and Germany. Leprosy hospitals were opened for people, but most skeletons with leprosy have actually been found in cemeteries not associated with leprosy hospitals; this suggests that people were more accepted in communities than has been previously thought. It started its decline in the 14th century and by the 19th century it had all but died out. This was probably because tuberculosis increased (urban living) and people became more susceptible to TB and less to leprosy (cross immunity). The many myths associated with this disease are gradually being dispelled, for example, leprosy (now more commonly referred to as Hansen's Disease), is *not* described in the Bible!

Disease Profile: Plague

Londoners fleeing to the country to avoid the plague, 1630

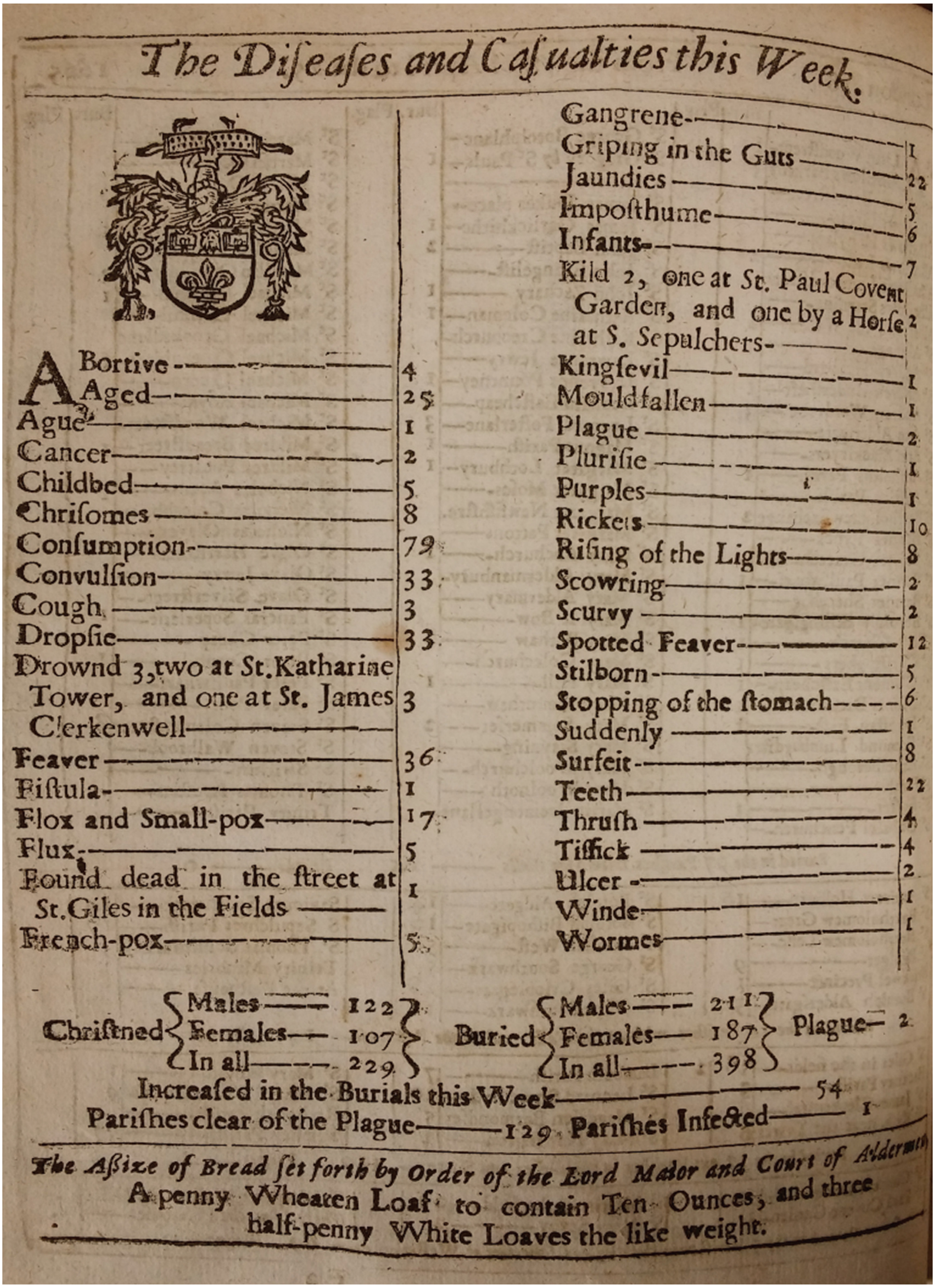
Plague is an infectious disease caused by the *Yersinia pestis* bacteria that has been responsible for the deaths of many millions of people across the world. The most famous outbreaks of the plague in England are referred to as The Black Death (1348-50 AD) and The Great Plague of London (1665–66 AD), the last extensive recurrence of the disease in this country. Plague still affects people in some parts of the world, especially in tropical countries. The infection is spread from infected rats to humans by fleas that carry the bacteria; they then bite humans. There are three main types of plague: bubonic (affecting the lymphatic system), septicaemic (affecting the blood stream), and pneumonic (affecting the lungs). Plague can spread and kill quickly. During The Black Death approximately 1.5 million people died out of an estimated population of 4 million in England; in total, it is thought that 30-60% of the entire population of Europe died. During The Great Plague of London approximately 15% of London's population died from pneumonic plague (spread amongst humans via the air).

Group of plague artefacts including a plague bell (left)

For many years it has been believed that The Black Death was primarily caused by bubonic plague. Bubonic plague is well known because of the way in which it is thought to have been introduced by rats from Asia. Recent research has suggested that the speed at which plague spread during The Black Death could not purely have been the result of flea bites but, rather, must have been airborne and spread from person to person (pneumonic), but there is no conclusive answer to this question just yet and research is ongoing. Plague does not affect the skeleton, but researchers have been able to extract the DNA of this bacterium from the bones and teeth of archaeological skeletons. Recent research found that when compared to the DNA of bacteria causing modern plague, the DNA "codes" were an almost perfect match. This means that the plague which caused The Black Death was no more virulent than that which we still see in the world today. Despite being able to now treat plague with antibiotics, it has not yet been eradicated.

Bioarchaeologists approach their work in a multidisciplinary way, bringing together information from many different sources. Primary source material from archives can be extremely useful for understanding the scale, nature or spread of disease outbreaks in history (although must be read with a critical eye!). The *Bills of Mortality* (starting in the late c16th) recorded the deaths, and causes of death, each week in the city of London. Two extracts are shown on the following pages, one from early 1665 and one from later that year. Issued weekly, the bills chart the rise and fall of plague during the year.

Bills of Mortality (Plague)



The Diſeaſes and Caſualties this Week.

Abortive	4
Aged	25
Ague	1
Cancer	2
Childbed	5
Chriſomes	8
Conſumption	79
Convulſion	33
Cough	3
Dropſie	33
Drownd 3, two at St. Katharine Tower, and one at St. James Clerkenwell	3
Feaver	36
Fiſtula	1
Flox and Small-pox	17
Flux	5
Found dead in the ſtreet at St. Giles in the Fields	1
French-pox	5
Gangrene	1
Griping in the Guts	22
Jaundies	5
Impoſthume	6
Infants	7
Kild 2, one at St. Paul Covent Garden, and one by a Horſe at S. Sepulchers	2
Kingſevil	1
Mouldfallen	1
Plague	2
Pluriſie	1
Purples	1
Rickets	10
Riſing of the Lights	8
Scowring	2
Scurvy	2
Spotted Feaver	12
Stilborn	5
Stopping of the ſtomach	6
Suddenly	1
Surfeit	8
Teeth	22
Thruſh	4
Tiſſick	4
Ulcer	2
Winde	1
Wormes	1

Chriſtned: Males 122, Females 107, In all 229

Buried: Males 211, Females 187, In all 398 — Plague 2

Increaſed in the Burials this Week 54

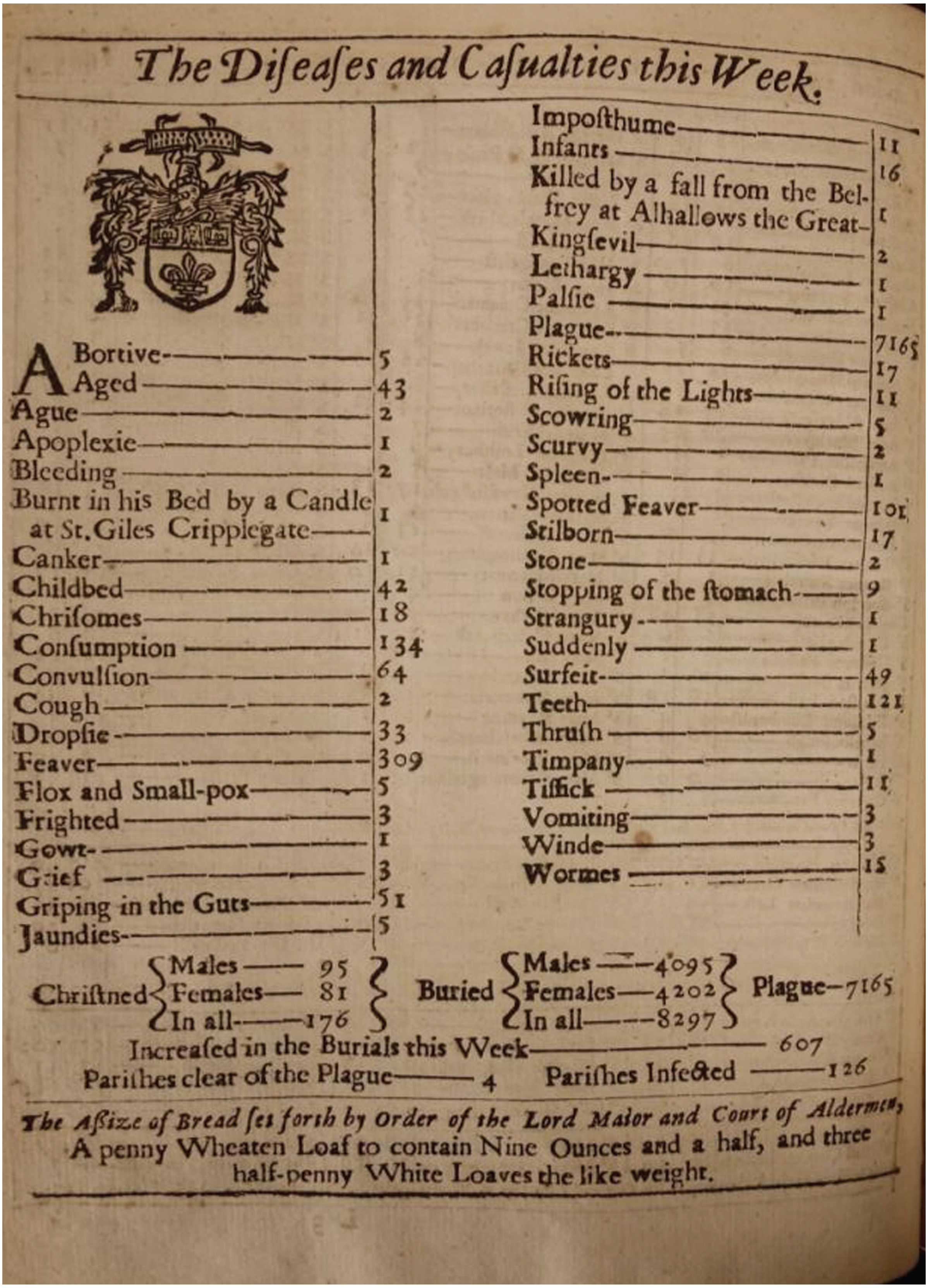
Pariſhes clear of the Plague 129. Pariſhes Infected 1

The Aſſize of Bread ſet forth by Order of the Lord Maior and Court of Aldermen.

A penny Wheaten Loaf to contain Ten Ounces, and three half-penny White Loaves the like weight.

25th April – 2nd May 1665: compare the number of deaths seen in this period with the next page

Bills of Mortality (Plague)



The Diſeaſes and Caſualties this Week.

Abortive	5
Aged	43
Ague	2
Apoplexie	1
Bleeding	2
Burnt in his Bed by a Candle at St. Giles Cripplegate	1
Canker	1
Childbed	42
Chriſomes	18
Conſumption	134
Convulſion	64
Cough	2
Dropſie	33
Feaver	309
Flox and Small-pox	5
Frighted	3
Gowt	1
Grief	3
Griping in the Guts	51
Jaundies	5
Impoſthume	11
Infants	16
Killed by a fall from the Belfrey at Alhallows the Great	1
Kingſevil	2
Lethargy	1
Palſie	1
Plague	7165
Rickets	17
Riſing of the Lights	11
Scowring	5
Scurvy	2
Spleen	1
Spotted Feaver	101
Stilborn	17
Stone	2
Stopping of the ſtomach	9
Strangury	1
Suddenly	1
Surfeit	49
Teeth	121
Thruſh	5
Timpany	1
Tiſſick	11
Vomiting	3
Winde	3
Wormes	15

Chriſtned: Males 95, Females 81, In all 176
Buried: Males 4095, Females 4202, In all 8297
Plague 7165

Increaſed in the Burials this Week 607
Pariſhes clear of the Plague 4 Pariſhes Infected 126

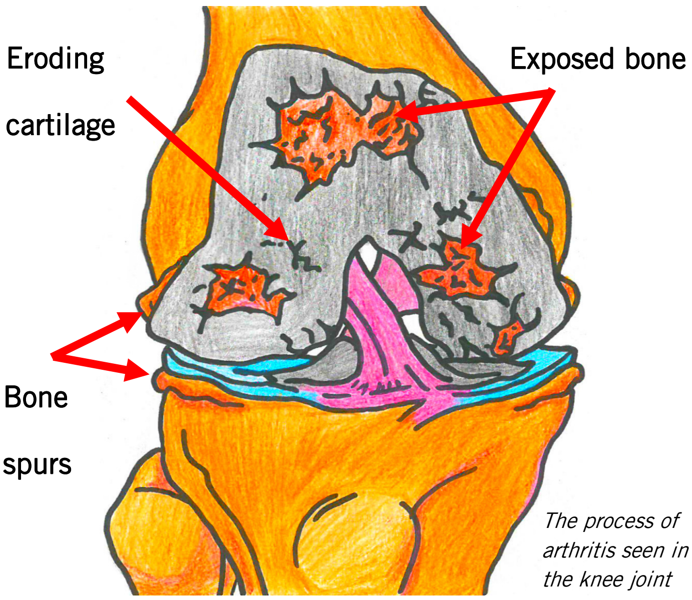
The Aſſize of Bread ſet forth by Order of the Lord Maior and Court of Aldermen, A penny Wheaten Loaf to contain Nine Ounces and a half, and three half-penny White Loaves the like weight.

19th – 26th September 1665: overall, the number of deaths documented this week far exceed those seen earlier in the year

Disease Profile: Arthritis

Arthritis is a disease of joints and is very common in the UK, affecting about 10 million people today, but joint problems in humans go back three million years ago. Osteoarthritis (OA) and rheumatoid arthritis (RA) are the most common types, but other joint diseases include gout and psoriatic arthritis.

OA usually affects people over 40 years of age, and women more than men; it might also happen after an injury to a bone which has healed badly. The synovial joints are affected, and mostly those in the spine, hands, knees and hips. The knees and hips take a lot of the bodyweight and so being overweight can lead to damage of those joints. We were also never meant to walk on two legs! This led to back problems, including osteoarthritis. OA can run in families (inherited) and specific occupations can cause wear and tear. The cartilage covering the joints wears away and the underlying bones rub against each other. There is inflammation and swelling, it can be painful and there may be loss of normal function of the joints. Anti-inflammatory drugs and even joint replacements are possible treatments. Osteoarthritis was common throughout history and was frequent when people were hunter-gatherers (page 33), compared to when they started to farm the land and keep animals (less physical activity - but hunter-gatherers lived longer and OA is associated with increasing age). Unfortunately, our ancestors could not have joint replacements like we can today (the first ones were done in the 19th century), but they might have had herbal remedies to treat joint pain.



The process of arthritis seen in the knee joint

Bones of the spine (neck vertebrae) showing enlarged joints with holes on them as a result of osteoarthritis

Rheumatoid arthritis is a chronic inflammatory joint problem that affects the small synovial joints of the hands and feet, and also the shoulders, elbows, wrists, knees, and ankles. It affects about 700,000 people in the UK today; they are mostly women and the most common age for it to start is between 30 and 50 years. The joints and associated soft tissues become inflamed, and the bones can get damaged. In this disease the body's immune system attacks and destroys healthy body tissue by mistake.

The cause of autoimmune disorders is unknown, but bacteria, viruses or drugs may trigger changes that confuse the immune system. This may happen more often in people who have genes that make them more prone to autoimmune disorders. It can also run in families, and 70% of people with it have the rheumatoid factor in their blood. It causes pain, swelling, stiffness and deformities in the joints. It cannot be cured but anti-inflammatory drugs and joint replacements can be done.

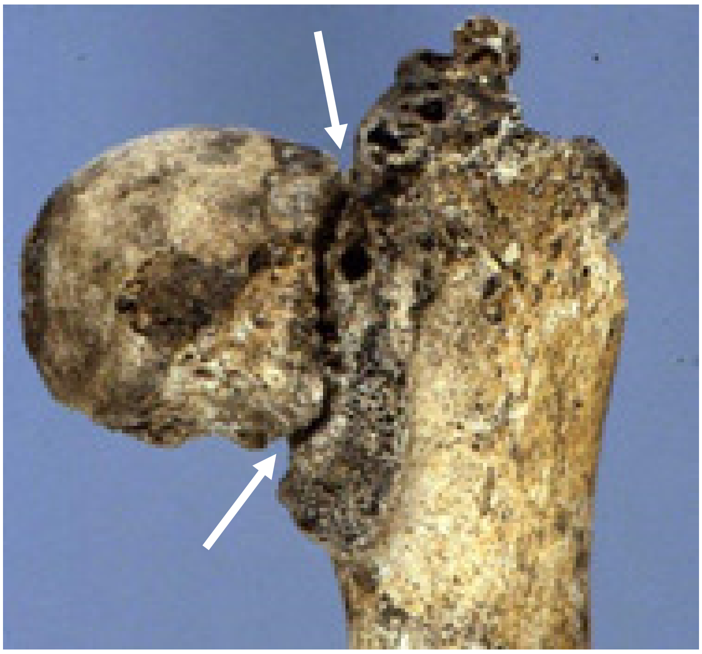
RA seems to be a modern disease and was not described well until 1800; the earliest evidence in archaeological skeletons in England is the 15th century.

Without bones and joints, our bodies could not be supported or move but it is inevitable that our joints wear out eventually. Unlike our ancestors though, we have much better treatments to combat the effects of joint disease.

Disease Profile: Osteoporosis

Osteoporosis refers to significant bone loss with associated fragile bones, which can lead to fracture. Normally bone formation and bone destruction in the body is balanced, which maintains bone health, but in osteoporosis there is more bone lost than formed. It is associated with increasing age today and is seen more in women than men, especially after the menopause when the hormone oestrogen decreases (necessary for bone strength). A genetic predisposition to osteoporosis needs also to be considered because genes can affect bone metabolism. Osteoporosis affects over three million people in the UK and half a million people are treated with osteoporosis related fractures every year.

Keeping physically active and eating a well balanced diet with calcium and vitamin D are preventive measures (as is drinking in moderation and not smoking), but hormone replacement therapy is used to supplement the oestrogen decline in some women. Osteoporosis is usually diagnosed in people today when they break a bone, and this is usually of the wrist, hip, or spine. However, osteoporosis can affect most of the skeleton, one part (e.g. paralysis following a 'stroke'), or be very localised and related to infection and tumours. It can also occur with other conditions (e.g. rheumatoid arthritis) and can be related to health problems that have led to limb disuse (e.g. poliomyelitis).

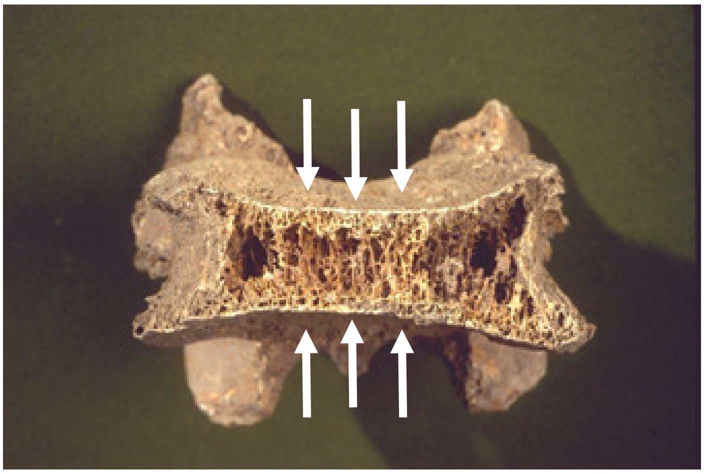


Above - Late Medieval femur from a person buried at Whithorn, Scotland broken at its neck because of osteoporosis (hip fracture); it did not heal

Osteoporosis has been diagnosed in skeletons from archaeological sites through evidence of fractures, observing thinning of the bones in radiographs, and measuring bone mineral density. For example, skeletons from the North Yorkshire Medieval site of Wharram Percy revealed significant bone loss in the women when compared to a modern group of people. This was surprising considering the likely more active lifestyle of the Medieval women. This was also found in a study of a 18th/19th century London population (Christchurch, Spitalfields). Osteoporosis has also been noted in skeletons from the Negev Desert, Israel (6th century AD), prehistoric, Viking-Age and medieval populations in Norway, and chimpanzees from Africa, showing how widespread its effects were.

Below left – forearm bone (radius) from a woman from Berinsfield, Oxfordshire, has a healed Colles fracture (fall on an outstretched hand) – it has the typical "dinner fork" deformity

Below: - Roman vertebra that has been "crunched" because it is weak from osteoporosis; it has lost a lot of its height; lots of vertebrae affected like this in a person's spine would cause a deformity ("dowager's hump")

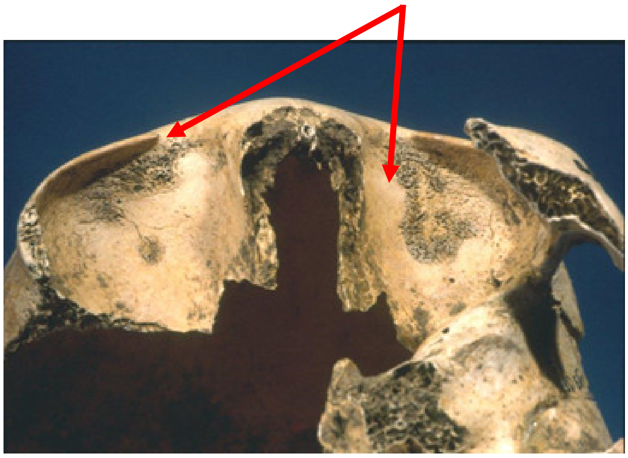


Disease Profile: Scurvy and Rickets

Diets deficient in some nutrients can cause specific diseases, one being scurvy or vitamin C deficiency. It is necessary to make protein, which is found in many body tissues, including bones, skin and blood vessels. This vitamin is found in fresh fruit (e.g. lemons, oranges, strawberries) and uncooked vegetables (e.g. cabbage, sprouts and sweet potatoes) and cannot be made in the body, unlike other vitamins (like vitamin D). It is also needed to absorb iron. Today it is seen in older people who are not eating a healthy diet and people who are poor; unfortunately it is on the rise in England. Tiredness, pain in the legs and joints, spots on the skin, swollen and bleeding gums, easily bruised skin, and shortness of breath are signs and symptoms. It has been described in the past, for example, people who went on long sea voyages without ready access to vitamin C containing foods were susceptible; James Lind, the English physician, wrote about his experimental work with treating sailors with scurvy in 1753. Skeletons in many areas of the world have also been diagnosed with scurvy damage, due to bleeding from fragile blood vessels resulting in bone formation on areas of the skull and leg bones.

Like scurvy, vitamin D deficiency is also making a comeback in many western countries, including the UK (rickets in children and osteomalacia in adults). Oily fish is a source of vitamin D but it is also made in the skin due to the action of sunlight; D is necessary for absorption of calcium and phosphorus in order to form strong bones. Exposing the skin to the sun is therefore necessary for D formation, but not too much that skin cancer is a risk. Children in particular today are developing rickets because they are staying indoors more and using computers, and perhaps excessive protective sun cream is being applied to their skins by worried parents. People with darker skins are also susceptible. Because arm and leg bones are weak, they bend when the child starts to crawl and walk, and may fracture. Osteomalacia also causes soft bones and if this affects the pelvic bones, it can be a problem for women who want to have children.

Rickets has also been found in skeletons in the past and it was described by Roman writers back in the 2nd century AD. It became a problem in Medieval Europe as people started to live in polluted towns and cities because people were working long hours indoors, and the polluted air prevented UV rays getting to people's skins. Called the English Disease in the 17th century, it was particularly a problem in the 18th-19th century Industrial Revolution where scientific advances and technological innovations led to growth in agricultural and industrial production, economic expansion, and changes in living conditions. However, high status people have been diagnosed with rickets in Renaissance Italy, as well as in the English post-Medieval poor, and also in Medieval rural communities.

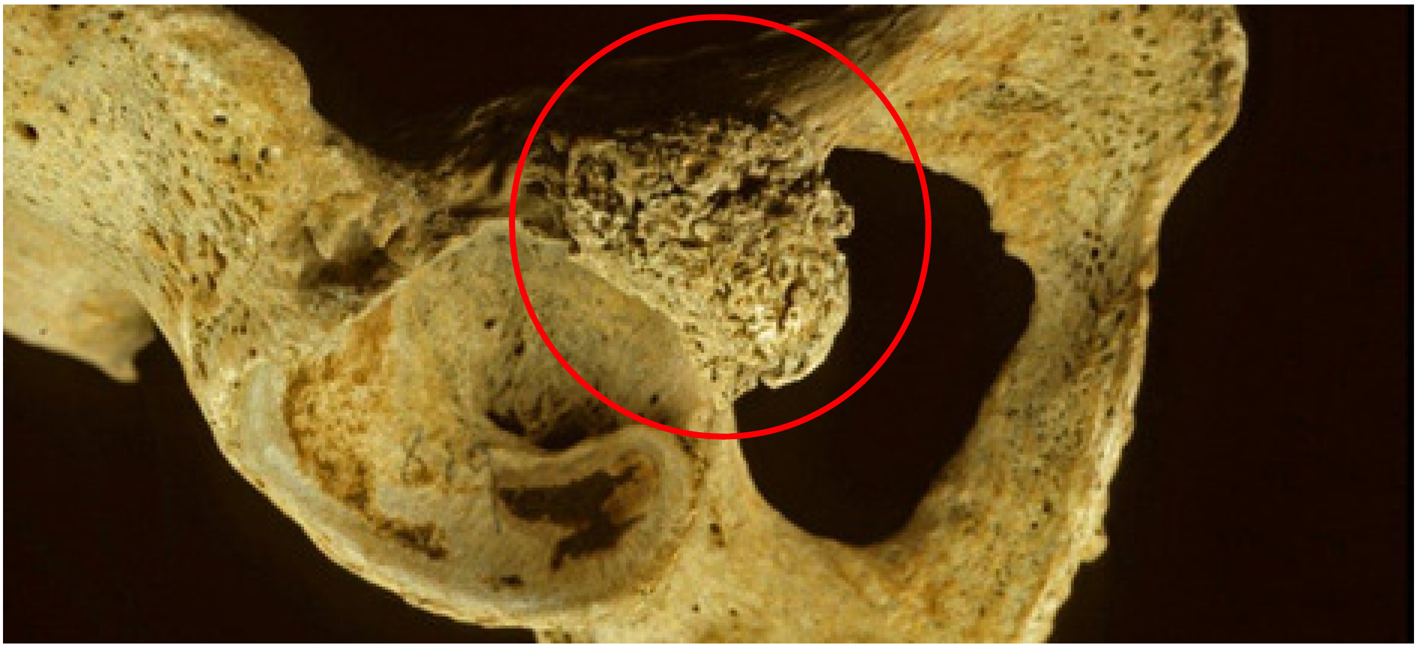


Top - the skull of this Iron Age person has bone formation as a result of scurvy (between late 800BC to 100 AD)

Below left - these lower leg bones (tibia and fibula) are bent because of rickets – from a child from Medieval north-east England

Below right - the model of a child shows bent limbs as a result of rickets

Disease Profile: Cancer



Above - pelvis with a tumour that is not cancerous

Cancer (malignant tumour/neoplasm) occurs when cells in a specific part of the body grow and reproduce uncontrollably. The cells can destroy surrounding healthy tissue, including organs of the body. Cancer can start in one part of the body and spread to another (metastasis). There are also benign cancers that do not kill. Today there are many types of cancer, with breast, bowel, prostate and lung cancers being the most common. 8.2 million people die of cancer each year, and in the next 20 years there is predicted to be a 70% increase. Chemotherapy, radiotherapy, and surgery are used as treatments, therapies whose effectiveness have improved markedly over the decades. There are many lifestyle risk factors, for example smoking, drinking alcohol, obesity and bad diets, physical inactivity, infections, environmental pollution, radiation and occupational hazards.

Different cancers affect different groups of people, for example the young and the old, and men and women. Cancer is believed to be a recent disease, but it has been detected in the more distant past, for example in the skeleton of a 1200BC man from Amara West in ancient Nubia, thus showing that carcinogens (things that lead to cancer) were around long before the 20th and 21st centuries. However, it is likely that because society was not as complex as it is today, risk factors such as air pollution, working in certain occupations, such as metalworking, and specific dietary factors probably played their part in the occurrence of cancer. There is evidence for cancer in skeletons from many countries of the world and ranging in date, but much is found in people who lived in towns and cities where carcinogens were perhaps more common. However, our ancestors were not as fortunate as us in having treatments for this devastating disease.

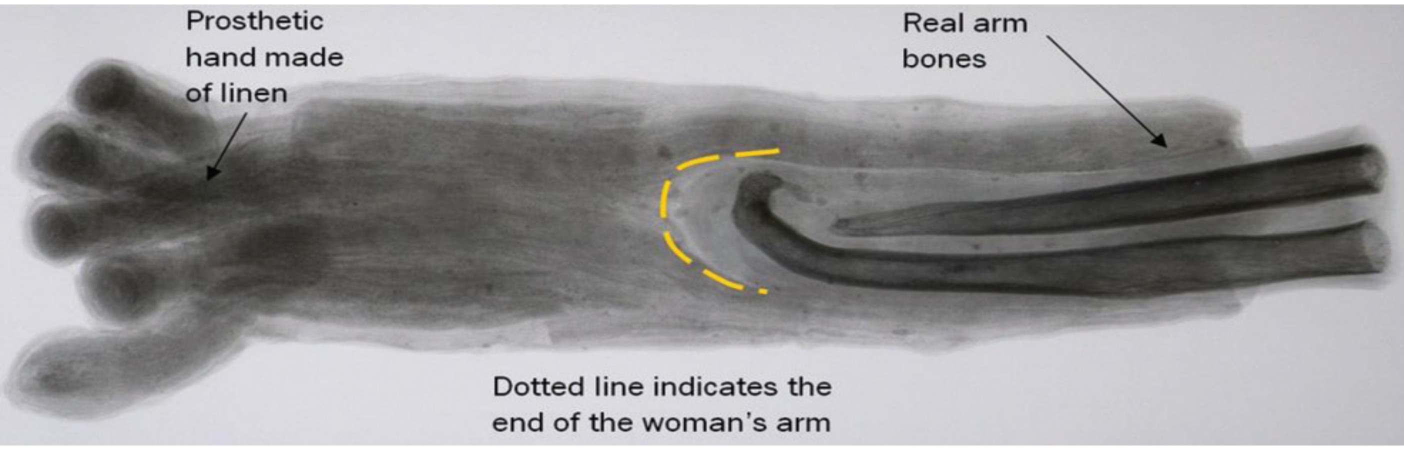
Having explored different types of disease and the history of some specific examples, we will now look at the various methods and tools available to bioarchaeologists engaged in identifying and researching them in human skeletons.

Rib of a 1200 BC man with cancer; the holes seen on the bone, and even more on the radiograph are as a result of cancer. More bones were affected

Looking Deeper

The ability to use sophisticated techniques to see inside things that the naked eye cannot - without causing irreparable damage - is a major advantage for archaeologists, and particularly bioarchaeologists. Many portable "imaging" machines have developed in recent years, and therefore can be taken to excavations, to museums, or used in university laboratories.

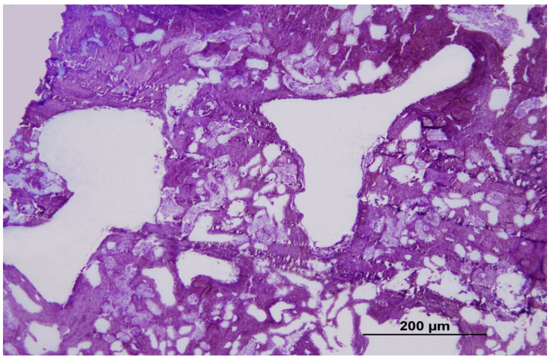
Radiography: The most common imaging technique used on archaeological human remains is plain film radiography (the same type of X-ray technique usually used in hospitals for broken bones). A 2D life size image of a bone (or joint) is produced which can be used to identify and interpret a number of things, including post-mortem changes that are not due to injury or disease and also affects features related to age at death, trauma and disease. Microradiography can also be used to see the internal structure of bones and teeth at a microscopic level.



Radiograph of the Mummy's arm and artificial hand attachment at the Oriental Museum, Durham

CT (computed tomography) scanning: A CT scanner records images of the body in very thin slices, which can then be used to recreate 3D images of the whole body. MicroCT, much like microradiography, can also be used to see normal and abnormal changes to bone. CT scanning can help bioarchaeologists understand the details of injuries and disease or even the impact of activity on bones and joints.

Palaeohistology: This is the study of the microscopic structure of tissues in the body and has been used to successfully identify diseases in archaeological skeletons such as rickets, scurvy, osteoporosis and tumours, all of which change the microstructure of the bone.



Histological View of Paget's Disease.

Other ways of seeing inside bone range from assessing biomolecular (e.g. DNA) preservation to understanding diet through analysis of plaque (calculus) and microscopic indications of wear on the surface of tooth enamel through the effect of diets eaten. The most common methods are TLM (transmitted light microscopy) which looks at thin slices of bone/tooth through a 'light' microscope, and SEM (scanning electron light microscopy) which provides a 3D picture. SEM can also be used to identify vitamin D deficiency and osteoporosis, and the characteristics of a specific weapon used to inflict damage to a bone; in this case modern experimental cut marks on bone can be compared to archaeological ones.

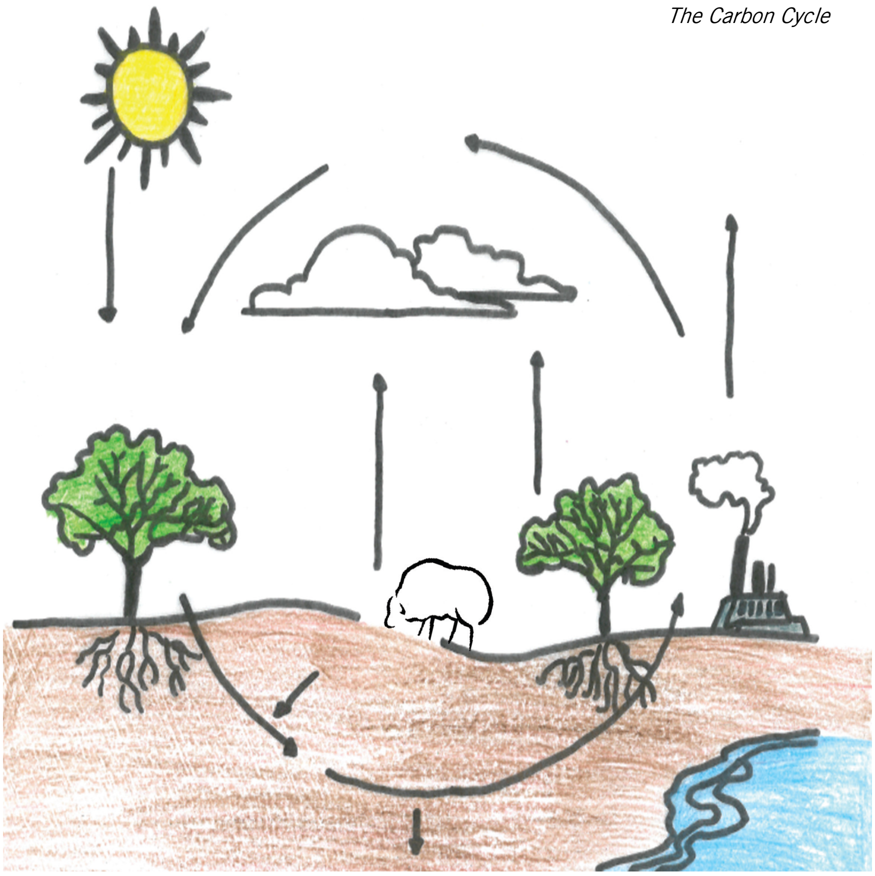
Evidence relating to disease and injury is really useful but it is also important to be able to date skeletons and mummies. This helps us further understand type and frequency of disease and injury seen in particular time periods.

Dating Human Remains

Archaeologists are usually able to work out roughly when a person died based on stratigraphy, the layer in the ground in which they are found. If a person has any grave goods included or there are associated finds nearby, this allows the archaeologists to narrow down the time of death to a particular period or perhaps even specific part of that period; coins are one of the most useful pieces of evidence for this but things such as the predominant material with which the finds have been made (e.g. stone, metal) and design of artefacts etc. all help. Sometimes archaeologists need a more precise date; being able to date a skeleton means that we can better understand the historical context in which a person lived, worked and died. In these cases they can turn to the process of radiocarbon dating. To understand how this works, first it is necessary to understand "the carbon cycle".

Carbon is an element which is present in all living organisms and is essential for life on Earth. Most chemicals that make up living tissue contain **carbon** and when these organisms **die**, the carbon is **recycled**. The model that describes the processes involved is called the **carbon cycle.** Carbon enters the atmosphere as **carbon dioxide** from respiration and combustion. Carbon dioxide is absorbed by producers to make **carbohydrates** in photosynthesis. Animals feed on the plant passing the carbon compounds along the food chain. Most of the carbon they consume is exhaled as **carbon dioxide**, formed during respiration. The animals and plants eventually **die**. The dead organisms are eaten by **decomposers** and the carbon in their bodies is returned to the atmosphere as carbon dioxide. In some conditions decomposition is **blocked** (for example in peat bogs). The plant and animal material may then be available as **fossil fuel** in the future for combustion.

The Carbon Cycle



Radiocarbon dating (sometimes called carbon dating) is the most common and most well-known dating technique used by archaeologists. Radiocarbon dating is based on the decay of carbon, specifically the isotope carbon-14 or ${}_{14}C$ (for more information on 'isotopes' see page 32). The ratio of ${}_{14}C$ to 'normal' carbon (${}_{12}C$) in the air and in all living things and at any given time stays pretty much the same. Once a living organism dies, the ${}_{14}C$ decays but is not replaced, whilst the level of ${}_{12}C$ in that organism remains constant. We know that the half-life of carbon-14 is around 5,700 years, which means 5,700 years after an organism has died, there will be half as much carbon-14 present as at the time of death. Comparing the ratio of ${}_{14}C$ to ${}_{12}C$ in an archaeological skeleton therefore means we can estimate an approximate time of death, sometimes to within a few decades.

The next method of analysis for human remains that we will explore is one that is being increasingly used (particularly to diagnose disease): ancient DNA analysis.

Ancient DNA (aDNA)

DNA (deoxyribonucleic acid) is something everybody has heard of; it is the set of genetic instructions that control the development and functioning of all living things. The work of Francis Crick and James D Watson in 1953 (also see Maurice Wilkins and Rosalind Franklin) in unlocking the human genetic code was one of the most important scientific breakthroughs of the 20th century. DNA is specific to a person and is therefore used in modern forensic investigations to prove (or disprove) a person's involvement with a crime, but also to identify bodies. It can also be used to show whether a body is male or female, or even to identify a person's lineage (ancestry). Many people do not, however, realise that under the right conditions DNA can survive for thousands of years and can be just as helpful for answering archaeological questions; we call this long surviving DNA, ancient DNA or aDNA.

aDNA can be extracted and analysed from the bones, teeth and preserved soft tissues to learn more about the following:

- Whether a person is male or female. This is particularly important if skeletons are not adults, or if they are poorly preserved.
- Family links between skeletons.
- Migration of people from one place where they were born, to another, where they died and were buried.
- The presence of disease.

Inside an ancient DNA clean laboratory

Any surviving aDNA is released from a small piece of archaeological bone or tooth by a series of chemical and physical reactions. A method called PCR (polymerase chain reaction) is used to amplify – make millions of copies of – the DNA fragments which can then be 'read' and compared to known DNA sequences (codes). Most aDNA work has so far concentrated on exploring infectious diseases, and so it is the aDNA of the actual pathogen (bacteria, virus or parasite) which is sought rather than human aDNA (which tells us about family relationships, for example). So far, attempts have been made to study a number of diseases in this way, including malaria and plague, that we cannot 'see' in the bones, and some infections that do affect the bones including leprosy (a disease much more common in the past than now) and tuberculosis (common today and in the past).

The majority of successful work has been on tuberculosis aDNA which may survive better than DNA of other infections over time because of its structure. This type of analysis can, in some circumstances, even identify the particular strain of an infectious disease that affected a person. This might then also tell us about whether the person moved around a region, country, or even across the world, taking their TB strain with them and infecting others. There are problems associated with aDNA work, including poor survival of the aDNA and contamination of bone and tooth samples with modern DNA from both the burial environment (where the person was buried) and from living people handling the bones or teeth (the latter is a major problem for modern DNA analysis too). However, newer methods of analysis are attempting to overcome these problems, and appear to be doing so quite successfully. All aDNA work takes place in strictly controlled laboratory conditions, making bioarchaeologists look more like characters from television crime dramas than typical archaeologists!

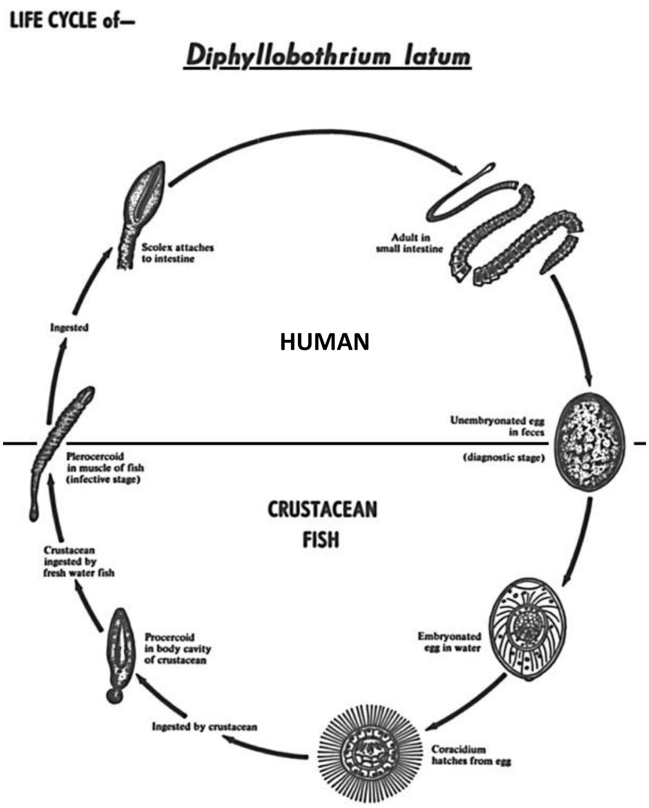
Palaeoparasitology

As previously mentioned, ancient DNA can also be used to identify and study ancient parasites, one of the organisms that can cause infections in humans and animals today. In the past people were clearly affected by parasite infection and detecting them is one way of definitely proving a parasite's existence. Parasites are organisms that spend all or part of their lifecycle living in or on another living organism; there are endoparasites, which cause infection inside the body, and ectoparasites, which cause infection superficially within the skin (ticks, fleas, lice and mites). Parasite infection affects health and well-being today, and because parasites consume nutrients from the diet that should be reserved for the human host, they are closely linked to overall immune system strength.

These diseases often affect communities in the tropics and subtropics, but parasitic infections also affect people in developed countries. There are three kinds of parasites that cause this type of infection in humans: helminths, ectoparasites, and protozoa (e.g. giardiasis: an infection of the digestive system, malaria: bite of mosquitoes, and leishmaniasis: bite of sandflies). Helminths include hookworms, whipworms, roundworms, thorny headed worms and flatworms; these can be contracted from the soil in areas with inadequate sanitation (penetration of the skin) or by ingesting eggs or larvae in contaminated food. Of all parasitic diseases, malaria causes the most deaths globally. Malaria kills many people each year, most of them young children in sub-Saharan Africa. In 2015 an estimated 214 million cases of malaria occurred worldwide and 438,000 people died.

People in the past clearly endured parasitic infection and all three types of parasites have been identified. Parasite eggs of some of the intestinal parasites can survive well at archaeological sites in a variety of places, (grave soils, cess pits, toilets and sewer systems, ancient faeces, and intestinal contents of preserved bodies). Parasites not only provide direct evidence for specific infections, they further indicate contamination of water and food, poor hygiene, lifestyle, and past human migrations (because parasites travel with humans, e.g. fleas, mosquitoes etc.). Although this method of analysis for detecting disease in the past is in its infancy in palaeopathology, some examples of parasite infection that have been identified include:

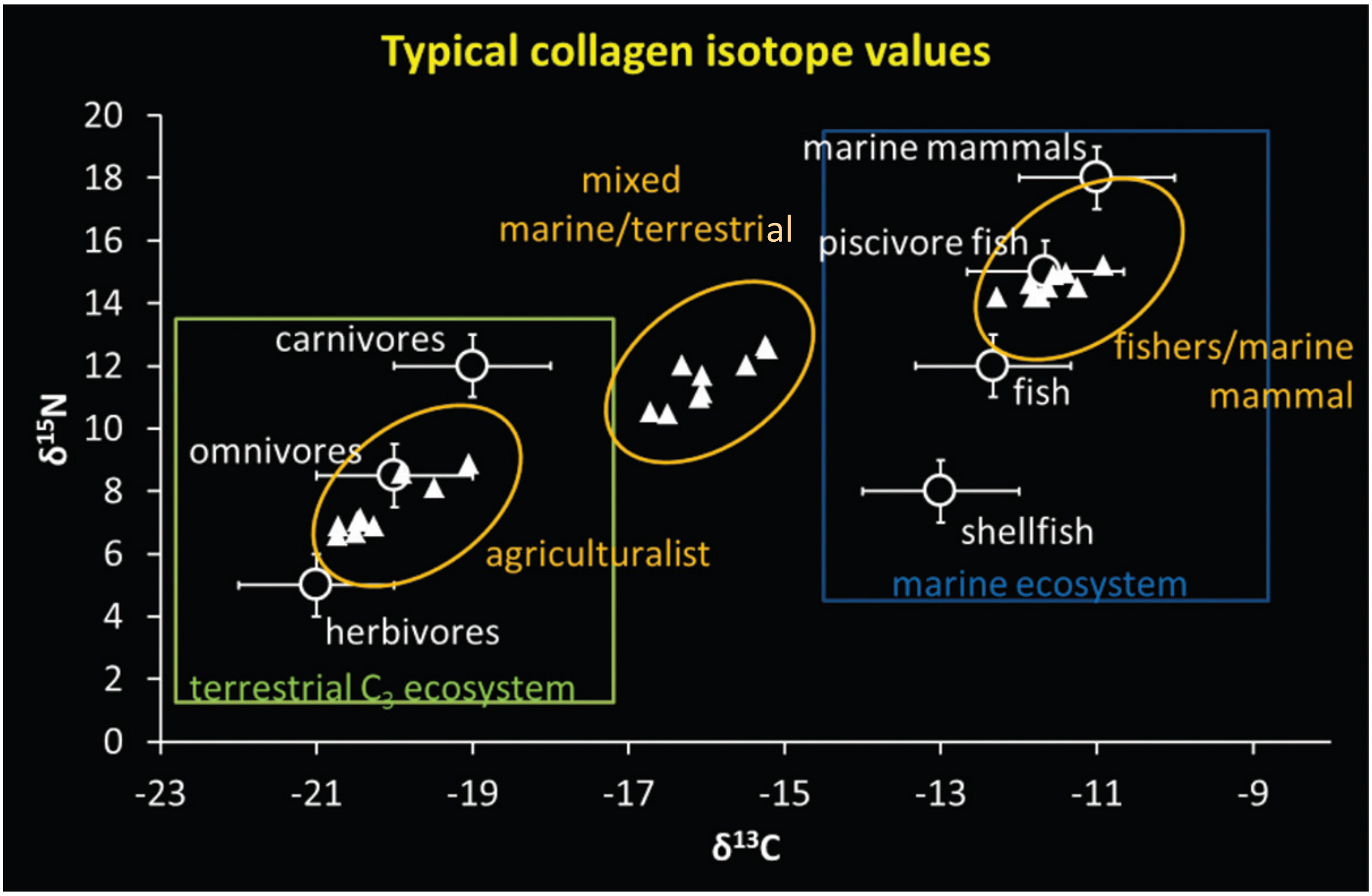
- **Schistosomiasis** (or bilharzia) in Northern Syria, 6500–6000 BP (found in tropical and subtropical freshwater today)
- **Hydatid disease** (*Echinococcosis*) in Medieval Iceland and Neolithic Siberia – contracted via faeces of dogs
- **The fish tapeworm** (*Diphyllobothrium latumin*) 14th century AD Latvia – eating raw or undercooked contaminated freshwater fish
- **The malaria (*Plasmodium*) parasite** in Renaissance Italy
- **Lice** in AD 79 (Roman) Herculaneum, Italy (on a hair associated with a preserved hair pin of a woman) and at Nahal Herman Cave, Judean Desert (Israel) (6900-6300 BC)



As discussed, some parasites get into our bodies through eating food; the next page in this booklet will demonstrate how bioarchaeologists work out what people ate by analysing their skeletons.

Reconstructing Ancient Diet

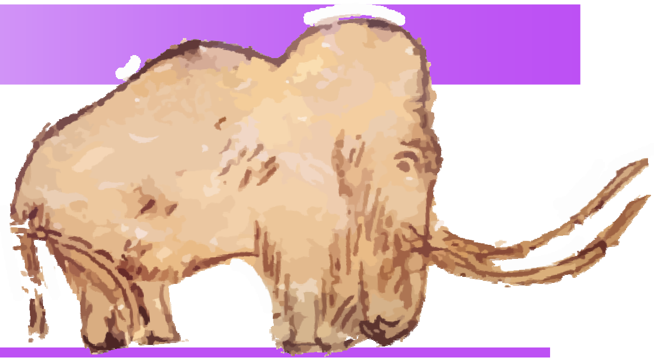
Analysing the diet of skeletons allows archaeologists to see more than just what was on the menu! Diet can reveal huge amounts about the economy of a given population, the resources they had access to, their knowledge of farming practices, the nutritional value of their diet and the impact this may have had on health, it might even shed light on social status, i.e. whether the rich and poor had different diets. Imagine out of a large group of skeletons analysed, that men and women had markedly different diets, that adults and children did or even that a whole population based by the sea had no evidence of fish in their diet (as is the case in some Neolithic studies). These findings lead to archaeologists asking more questions, seeking more answers as to how a particular population lived their lives and then perhaps how other populations from the same period may show similarities or differences. Combined with other types of analysis, such as looking for evidence of disease on the bones archaeologists can start to build a more comprehensive picture of past lives over the different periods of history.



To analyse ancient diet from skeletons, bioarchaeologists use "isotopes".

Isotopes (previously mentioned on page 29) are variants of a specific chemical element, like carbon. All isotopes of a particular element have the same number of protons but each has a different number of neutrons resulting in carbon-12 ($_{12}C$), carbon-13 ($_{13}C$) and so on. Carbon and nitrogen isotopes found in the collagen of bones mainly enter the body from protein in the diet. The ratio of $_{13}C$ to $_{12}C$ can be measured to show the source of food being eaten, with marine foods (e.g. fish) having a higher ratio than land-based (terrestrial) foods (e.g. beef from cattle). The ratio of nitrogen isotopes, $_{15}N$ to $_{14}N$, can also be measured, with values being lower for plant foods (e.g. barley) than meat and milk, and marine foods being higher still. Measurements can therefore demonstrate whether or not a population was reliant mainly on food from animals eating off the land, or the sea. **You really are, in effect, what you eat!**

Hunter-Gatherers



Everybody that lived before the development of farming in Britain would have been a ‘hunter-gatherer’ meaning they lived in a society where most or all food came from wild plants and animals; there is some evidence for cereal grain. Some of the information on the next two pages comes from isotope tests on skeletons as described under ‘reconstructing ancient diet’, other knowledge is gained from archaeological finds such as animal bones.

When did they live?	Mainly before 4500BC but the transition to farming was gradual.
Where did they live?	Because they were very mobile (“on the go”) they lived in places, such as caves; they moved and set up “camp” depending on the seasons of the year and the movement of animals.
What kind of settlement did they live in?	Small family groups living in temporary shelters or caves. Low numbers of people.
What kind of house did they live in?	Temporary shelters which would be built and then abandoned, or caves. Caves in particular may have been reused in following years.
What types of artefacts do we find with these societies?	Stone tools (e.g. flint arrows and axes), antler mattocks, beads, and decorated objects like pebbles.
Where did they get their food?	By hunting wild animals and gathering wild plants, nuts and fruits.
What kind of food and drink did they have?	Fresh wild meat that was not very fatty, fish and shellfish, and nuts, berries and plants as they become available during the year; water from rivers or other natural places like springs.
Why did they eat in this way?	Tradition. This was the way people had always obtained their food – by understanding the land, the seasons, and wild animals and plants. Some people live this way today but they are finding it difficult.
What factors affected the availability of their food?	The seasons, climate, and weather patterns. The movement of animals. Ability to catch animals and collect plant foods. Natural disasters.
What was their health like?	Generally quite good because they were mobile, fit and were not subject to the same build-up of ‘residential’ waste and subsequent health risks seen by later ‘settled’ groups. They ate a variety of nutritious food and were not reliant on their own production of this food, only their skills as hunters and gatherers. Although at risk of serious injury and some disease from the animals they hunted, they did not live in close quarters with them like farmers. Because population numbers were low, infectious diseases were also less than seen in later periods.

The First Farmers

Farming (cultivating land to grow food and/or raises animals), came to Britain over 6000 years ago and with it came huge changes to economy, lifestyle and health. There is great debate over the speed at which farming replaced the traditional hunter-gatherer lifestyle but there is likely to have been overlap between the two systems before people became reliant on farming. Farming could support and encourage greater numbers of people and was more reliable in a changing climate where animals and plant resources were becoming scarcer, but with reliance came great risks.

When did they live?	After 4500BC.
Where did they live?	In small permanent settlements because they had to be constantly present to ensure crops and animals were looked after.
What kind of settlement did they live in?	Larger communities made up of lots of families. They cleared large areas of land for planting crops and keeping animals, and used wood for building.
What kind of house did they live in?	Solid, permanent structures with thatched roofs and a central hearth, and sometimes their animals lived in the same houses.
What types of artefacts do we find with these societies?	Stone and flint tools, quernstones, pottery, bone and antler pins, beads, statuettes.
Where did they get their food?	By growing crops such as wheat, barley and oats, and raising domesticated animals such as sheep, cattle, goats and pigs. They may also have gathered some wild plants and fruits and hunted wild animals. Their food also needed more preparing (e.g. making wheat into flour for making bread).
What kind of food and drink did they have?	Wheat, barley, oats, fresh meat, dairy foods, cultivated fruit and vegetables, water from rivers or other natural places, beer, some wild nuts, plants and berries.
Why did they eat in this way?	The idea developed all over the world. It was a way of controlling food production, meaning that lots more food could be produced and more people could be supported.
What factors affected the availability of their food?	The seasons, climate, and weather patterns. Availability of people to work the land and farm animals and crops. Spread of disease: human (affects availability and ability to work) and animal (kills animals but animals also spread disease to humans). Pests on crops. Soil and water quality. Natural Disasters.
What was their health like?	Studies of skeletons from archaeological sites overwhelmingly show that people's health deteriorated when they became farmers (but not always!). This is because living in permanent settlements attracted refuse and vermin, water became contaminated, there were poor hygiene and sanitation levels, and a decline in the reliability of harvests (failures) and the variety of foodstuffs: more infections, dental (e.g. bad teeth) and dietary deficiency diseases like scurvy (vitamin C deficiency), enamel defects ("stress"), their jaws and teeth got smaller and animal diseases such as tuberculosis and respiratory problems increased.

Industrialization

Industrialization was a period of time when people's lives were transformed in many parts of the world. This occurred between the mid-18th and mid-19th centuries, and Britain was the first place to be industrialized. Although, in Britain, people did not really start to live in towns and cities until the late Medieval period (12th-16th centuries AD), when the Romans came to England during the 1st century AD they were establishing quite large towns, for example in Colchester (Essex), Gloucester (Gloucestershire) and York (Yorkshire).

Lower jaw of a 12-14 year old person with "Phossy jaw" who lived in North Shields, Tyne and Wear in the 18th/19th centuries (area of new bone formation circled). Associated with exposure to phosphorus which was a hazard of the match making industry

In the early medieval period following the end of the Roman period a rural existence was the predominant way of life. In the Industrial period there was intensified farming, coal became the predominant fuel and steam replaced water to create power for the many industries that functioned. There was great exploitation of natural resources, including coal and lead. Large factories developed to replace what had been relatively small-scale production. This went alongside massive migration from rural areas to urban situations where people could get work, just like we see today (people head increasingly to London and the South East). There was also a large increase in the population, which consequently impacted on the quality of life and health of those people in towns and cities. Production of goods to sell meant that trade networks grew, including overseas, and the mechanisms to transport products developed, such as the canal systems and railways in Britain.

While industrialization undoubtedly transformed Britain, it came with heavy costs to the health and well-being of the people who lived at that time. Poor living and working conditions challenged health, along with the impacts of trade and contact with many more people with diseases from other parts of the country and the world. People experienced dietary deficiencies from an unbalanced diet, but also excesses such as sugar, gut problems (water pollution), infectious diseases such as tuberculosis and syphilis (close contact due to population density and promiscuous activity respectively!), rickets (working in dark factories for long hours and air pollution preventing sunlight reaching the skin to make vitamin D), occupationally related trauma and joint disease to bones, respiratory health problems due to pollution in the air and in the workplace, and cancers as a result of occupational exposure to carcinogens. Skeletons tell that story well; cemeteries associated with this period in Britain have revealed that all these health problems and more existed in these populations.

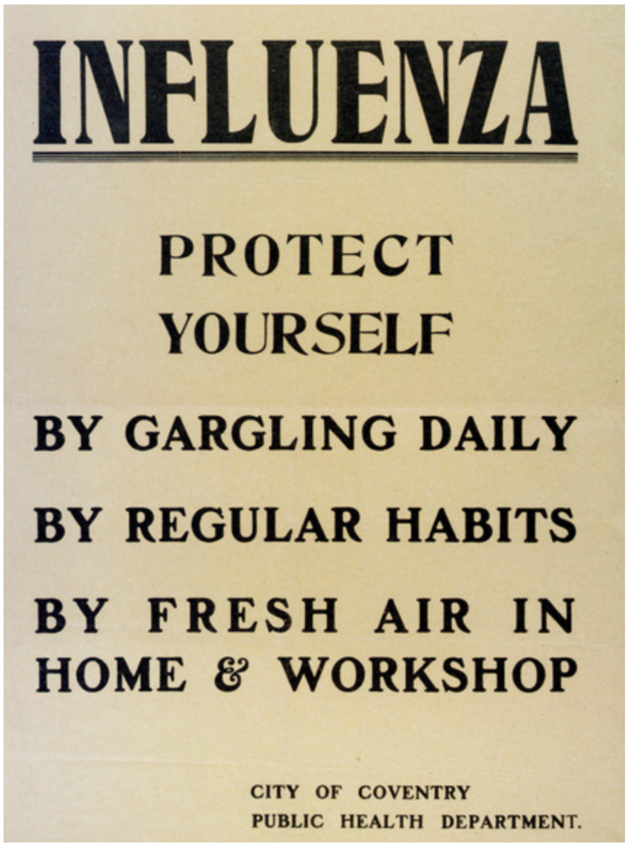
The next page will explore whether our health is any better today.

Health Today

Global health today is dominated by those health problems that relate to inequalities in people's lives. The gap between the rich and the poor is widening, not narrowing, and this puts a strain on the efforts of health services to keep people healthy; people who are poor tend to have more health problems. Even in one country, relative health may be experienced differently across regions, for example in the UK where there is a north-south divide, people in more northern regions, in general, tend to have poorer health. However, over the last 200 years, some populations have experienced a decline in infectious diseases due to vaccinations and antibiotic treatment, and an improvement in living conditions, but there has been a rise in degenerative diseases such as dementia, heart problems, cancers, and people experiencing many conditions at the same time; this is because people are living much longer and therefore have more time to develop multiple complaints. However, archaeological skeletons show us that some of these diseases have been around many hundreds of years as we have already seen. Nevertheless during the 20th century public health reforms improved people's living conditions, health and safety at work have reduced industrial accidents, and there has been a reduction in smoking. However, this has not been a global phenomenon because of health inequalities.

Top right - calcified femoral artery likely due to heart disease from a woman buried at the cemetery of Amara West

In the UK today, a new born baby boy could expect to live 79.1 years and a girl to 82.8, on average. However, the most common age at death for men is 86 and for women 89. Life expectancy at birth in the UK has increased since the early 1980s by 13.5 weeks per year on average for men, and 9.8 weeks per year on average for women. Contrast this with sub-Saharan Africa where there is a life expectancy at birth of 46 years for men. A boy born in 2012 in a high-income country could expect to live on average to the age of around 76 compared to a boy born in a low-income country at 60. For girls, the difference is even wider: 82 versus 63 years. This shows that people experience very real differences in health and well being around the world.



1910s UK City of Coventry Public Health Department Poster

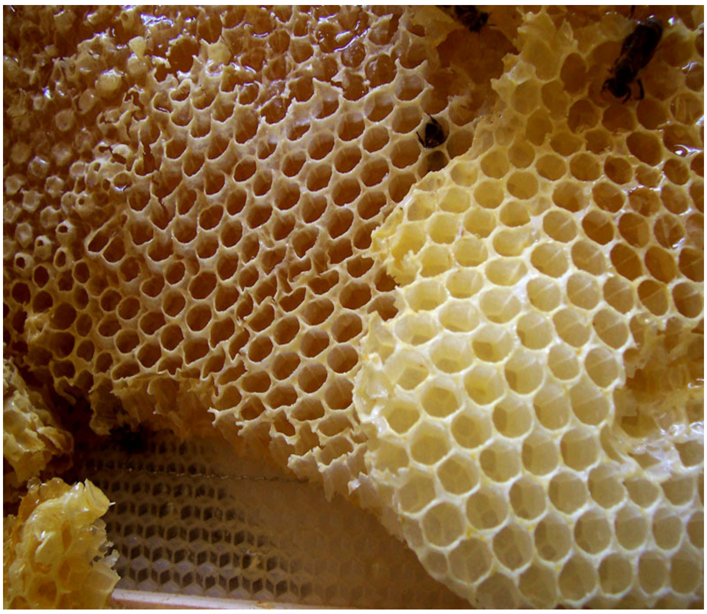
We are now in the throes of a third 'epidemiological transition', with familiar infections rising again (like TB), antibiotic resistance, and new diseases appearing. Globally, the top three causes of years of life lost due to premature death are coronary heart disease, lower respiratory infections (such as pneumonia) and 'stroke', followed by preterm birth complications, diarrhoeal diseases, HIV/AIDS, birth problems, road traffic injuries, chronic obstructive pulmonary disease, and malaria. However, in some countries infectious diseases remain big killers (e.g. Africa). The health of the world has come a long way since our ancestors' days but despite advances in medical and surgical care, we have a long way to go to achieve equalities in health.

History of Medicine

Much can be learnt about health and early treatment of disease and injury through a combination of archaeological discoveries, historical documents and artwork. Early medical or healing interventions may, however, appear "primitive" in comparison to modern medicine, as no doubt our "modern medicine" will be seen in the future. People's ideas about what causes disease affects choice of treatment, and this has varied through time and in different parts of the world.

There is very little direct evidence in human remains for treatment, although sites of Medieval hospitals and their cemeteries have been excavated in Europe. There is however, significant evidence that throughout time people have been acutely aware of their natural surroundings and able to identify plants and animal by-products that have healing properties, as we see in traditionally living people today in developing countries such as Africa and India.

For example honey, known to have antiseptic properties, was used as an ointment by Ancient Egyptians and is also recorded as being present in 30% of prescriptions on an ancient Sumerian tablet (1900 to 1250 BC). Beeswax has even been identified as a filling in a man's canine tooth from 6500 years ago which, if applied before his death, would be one of the oldest examples of dentistry in Europe.



Honeycomb

The scabious plant was also used to treat the skin lesions of leprosy in the European medieval period, perhaps reflecting confusion with other skin diseases such as scabies. Furthermore, there is evidence of drilling of teeth in Denmark (1800 BC), treatment of fractures (Egypt, 5000BC), the use of copper plates for infections in Medieval Belgium, England and Sweden (copper claimed to be a new way of treating infections today), the treatment of a syphilitic skin lesion on the arm of a 16th century Italian mummy with a bandage incorporating sulphur and ivy leaves, and finally an artificial big toe (950-710 BC) and artificial foot (6th century AD) being applied to people who had had amputations, for example in ancient Egypt and Austria, respectively.

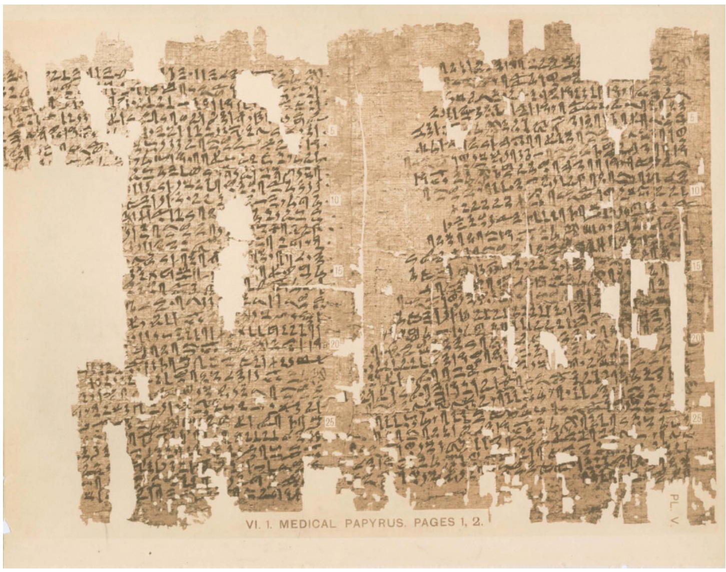
The history of medicine is complex with traditions reaching back to Babylon (now in modern day Iraq), Ancient China, Egypt and India, but it is perhaps Greek medicine that most readily comes to mind, perhaps due to the 'Hippocratic Oath' still taken by doctors today.

Hippocrates

History of Medicine (Continued)

A number of medical texts from ancient times survive, although often in a fragmentary state; the oldest is Egyptian and known as the Kahun Gynaecological Papyrus (c.1825 BC); it has 34 sections, each dealing with a particular female gynaecological problem, including its diagnosis and treatment. Medical knowledge and understanding of human anatomy has been challenged, changed and refined over thousands of years, with improvements seen during the Renaissance period, thanks in part, to human dissections and the resulting anatomical drawings provided by the doctor, anatomist and illustrator, Vesalius, and artists including Michelangelo and Leonardo Da Vinci. Knowing the anatomy of the human body is obviously a pre-requisite to developing effective diagnosis and treatments for disease and injury both today and in the past (see following pages).

To the bioarchaeologist, the most immediate physical evidence of ancient or historic medical intervention is the presence of unusual findings such as trepanation, assisted healing through bone setting, or some cases, Egyptian mummies demonstrating the use of artificial limbs to replace ones lost through accidents or surgery. However, these are rare finds.



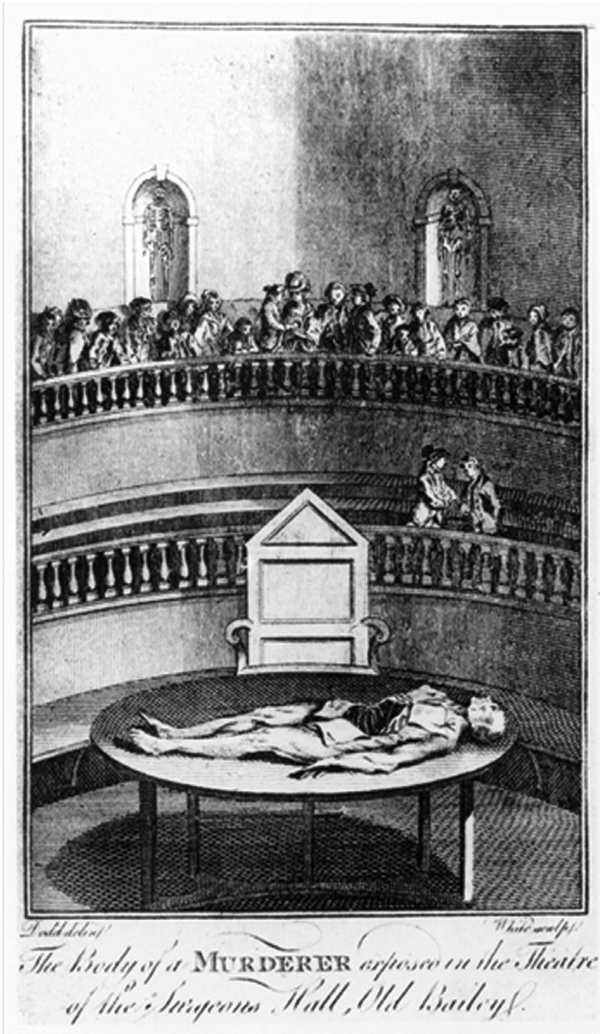
Papyrus Kahun VI. 1, pages 1 and 2; medical papyrus 12th Dynasty

Skeletons with evidence of trepanation - where a hole has been created in the skull to relieve pressure or pain after an injury, for migraine, epilepsy, or to “let the spirits out”- date back to prehistory and are found in numerous places around the world, such as South America, China and Europe. Examples of bone setting (reduction and splinting) have been confirmed by observing how fractures have healed in Britain from the Iron Age (800 BC - AD 43) and Roman (AD 43 – AD 410) periods onwards, although identification of surgical intervention can be challenging.

Example of a1200 year old trepanation by ‘scraping’, Bolivia

This area of research hugely benefits from a multi-disciplinary approach, and grounding the information within modern clinical data. The following pages detail some of the key moments and medical breakthroughs in history that have had (and in many cases continue to have) an impact upon people’s experience of disease and injury.

A Brief History of Anatomy



Dissection of a murderer – c18th AD

Human dissection was allowed in some places in ancient times because philosophers like Aristotle (4th century BC) said that a person's soul left the body after death. However, it was not permitted for religious reasons in many parts of the Roman Empire.

This ban on dissection meant that anatomists such as Galen (a Greek doctor, surgeon and philosopher of the 2nd-3rd century AD Roman Empire) had to use animals such as apes, pigs and dogs instead. This inevitably led to some mistakes. While the basic bones are the same/similar, there are obvious differences between humans and other animals. However, Galen did treat injured Roman gladiators so gained some knowledge of human anatomy from studying them whilst treating their wounds. His work was so important that it became the basis of all doctors' training for 400 years.

The fall of the Roman Empire in the 4th century AD saw a rise in the belief of superstition and magic, and much of the knowledge of the ancient Greeks and Romans was lost. The knowledge that did survive was thanks to its translation and use in the Islamic world.

The Christian Church started to become important in Europe from the 11th century AD, and although it favoured belief in supernatural causes for disease (i.e. a punishment sent by God) it did also accept the work of Hippocrates (5th century BC Greek doctor) and Galen. There was also a widespread belief in astronomy and astrology and these were used in the practice of medicine.

As medicine started to become more professional from the end of the 11th century AD, medical schools started to be established, and by the 14th century AD Departments of medicine had been set up at some universities across Europe.

Some European countries began legalising the dissection of executed criminals for educational purposes (and no doubt as an additional deterrent for would be criminals!) in the late 13th and early 14th centuries, with the first known public dissection taking place in approx. 1315 AD. The Murder Act of 1752 in England gave permission for this same fate for executed murderers, although human dissection had remained entirely prohibited in England until the 16th century and, even then, only a very few groups of doctors were permitted to carry out dissections. With access to a total of 10 cadavers each year between both the Royal College of Physicians and the Company of Barber-Surgeons in the mid-18th century, it was no wonder that body-snatching (dug up from cemeteries) became a frequent, though obviously illegal, trade. This situation ultimately led to the Anatomy Act in 1832 which allowed a much greater legal supply of cadavers for educational dissection. Today medical students dissect human bodies that have been donated before death by their owners. This is very important to enable future doctors to be able to understand their patients' illnesses better and to treat them effectively.

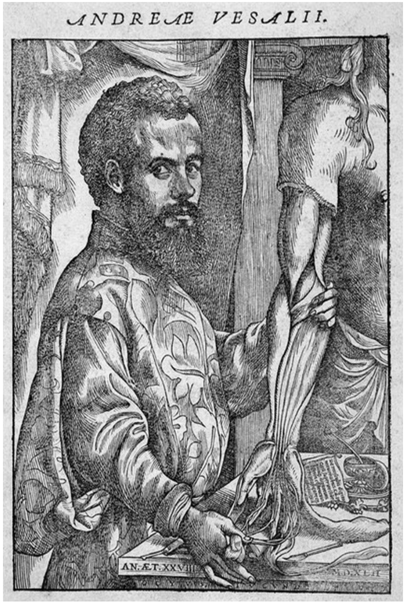
A Brief History of Anatomy (Continued)

"Anatomists retard the inexperienced student if they do not first explain the bones..."

Vesalius' book *De humani corporis fabrica* is one of the landmarks of Renaissance Science. It placed the study of anatomy on a firm foundation of observation.

Vesalius was born in Belgium and studied at the Universities of Leuven and Paris before moving to Padua where he was offered the Chair (Professorship) of Surgery and Anatomy, which he accepted. Vesalius broke with tradition in many ways, predominantly by doing the dissections himself rather than using assistants. He dissected the bodies of humans (normally criminals) rather than animals and, having viewed the anatomy of the bodies for himself, he criticised the findings of Galen.

Although remarkable in itself, Vesalius' work did not necessarily revolutionise the study of medicine although such detailed anatomical drawings had never been produced before. Pointing out the inaccuracies of Galen had been met with derision from the Church and many doctors refused to accept his work. Vesalius also did not offer any theories on diseases or cures but his work did allow others to make progress.



Portrait of Vesalius

The Frontispiece of *De humani corporis fabrica*

1. It has been argued that the image is a subtle criticism of Galen, whereas others have suggested that Vesalius would have been respectful of earlier teaching and not intended it as such.
2. At the top of the image is Vesalius' family crest with the image of 3 weasels.
3. The naked man looking toward the dissection from the left of the image demonstrates lifelike musculature, perhaps making reference to surface anatomy. This figure contrasts directly with the female form being dissected on the table.
4. The presence of the monkey and dog refer to the importance of these animal species in dissection. Depending on how you view the image as a whole, these may refer to Galen's use of them in his understanding of anatomy.
5. The barber-surgeons would previously have done the actual dissection but they have now been relegated to sharpening Vesalius' tools.
6. The figure being dissected is that of a woman. It has been suggested that this is the body of a woman who was scared of being hanged and, as such, declared herself pregnant. After examinations from midwives she was found to be lying and was thus sentenced to death and subsequent dissection. Other interpretations are that a female figure (the vast majority of bodies dissected/depicted are male) is a novelty.
7. The skeleton in the centre of the image demonstrates the importance of osteology (the study of bones) in the study of anatomy. It is perhaps slightly larger than life to emphasise this point.
8. There are two figures amongst the crowd holding books. One is reading the book rather than watching the dissection, and the other holds a closed book and points towards the dissection. It could be argued that the former is engaged in the reading of earlier anatomy texts, such as Galen, and is unwilling to accept Vesalius' teaching, and the latter has closed the book on the old teaching and is learning from the new.
9. This picture is the first known illustration of an anatomical theatre – the background may have been copied from a woodcut of a normal theatre.
10. Vesalius himself is pictured in the centre of the image. The way he is stood and positioned here is very similar to that in his portrait.


ANDREAE VESALII
BRVXELLENSIS, SCHOLAE
medicorum Patauinæ professoris, de
Humani corporis fabrica
Libri septem.
CVM CAESAREAE
Maiest. Galliarum Regis, ac Senatus Veneti gratia & priuilegio, ut in diplomatis eorundem continetur.
1.
2.
9.
3.
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10.
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4.

B A S I L E AE·

Dealing with the Plague

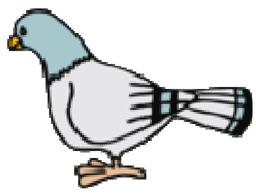
Less than one hundred years after the death of Vesalius, England was to suffer the Great Plague of London (1665-66 AD). Plague had never truly disappeared in Europe since the Black Death in the 14th century (see pages 21-23) but this new outbreak gave rise to a series of public health measures and suggested 'cures'. Due to its devastating impact on populations, historic plague outbreaks leave us with a significant quantity of documentary evidence which give us a unique insight into people's understanding of the disease at particular times in history. Below are some of the public health measures employed in the 17th century, in response to the Great Plague, some of which would certainly have helped to contain the disease but others are likely to have had little effect other than making people smell a little better:

17th century petition to God asking to end the plague

- Specific plague doctors, apothecaries and surgeons were assigned to the city
- Neither 'men nor goods' were to be allowed to come from any infected places without a certificate of health
- Cats, dogs and tame pigeons were to be destroyed or 'kept sparingly'
- People were discouraged to flee to the countryside unless to an uninhabited house
- Bodies were to be buried at night with all relevant authorities informed
- No clothing or 'householdstuff' was to be removed or sold from an infected house
- Bonfires were to be lit in the street to clean the air
- Perfumes or pomanders were to be used

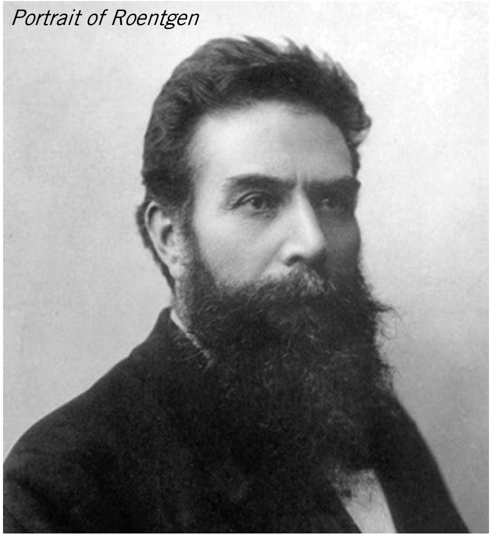
'Cures' for the Black Death in the 14th century had included strapping live chickens around the sores caused by the plague or drinking potions with ground horn from mythical unicorns. Some suggested cures for the Great Plague were perhaps a little more manageable, if not very effective:

- Fig cordial
- Blood letting
- Inducing vomiting
- A poultice made of elderflowers, rocket seed, oil of lilies and pigeon dung



The next page is a leap ahead to the 19th century, to the discovery of a technique useful to both doctor and bioarchaeologist!

Discovery of X-Rays



Portrait of Roentgen

In 1895, an amazing leap forward was taken for medicine; the discovery of the X-ray. With this discovery, medical professionals could look inside a human body without the need for surgery – bones were visible through a photographic image.

The person to discover this revolutionary technique was a Professor of Physics in Bavaria called Wilhelm Roentgen. He discovered the potential of electromagnetic radiation to create X-rays which in turn can create radiographs (what most people inaccurately refer to as ‘x-rays’).

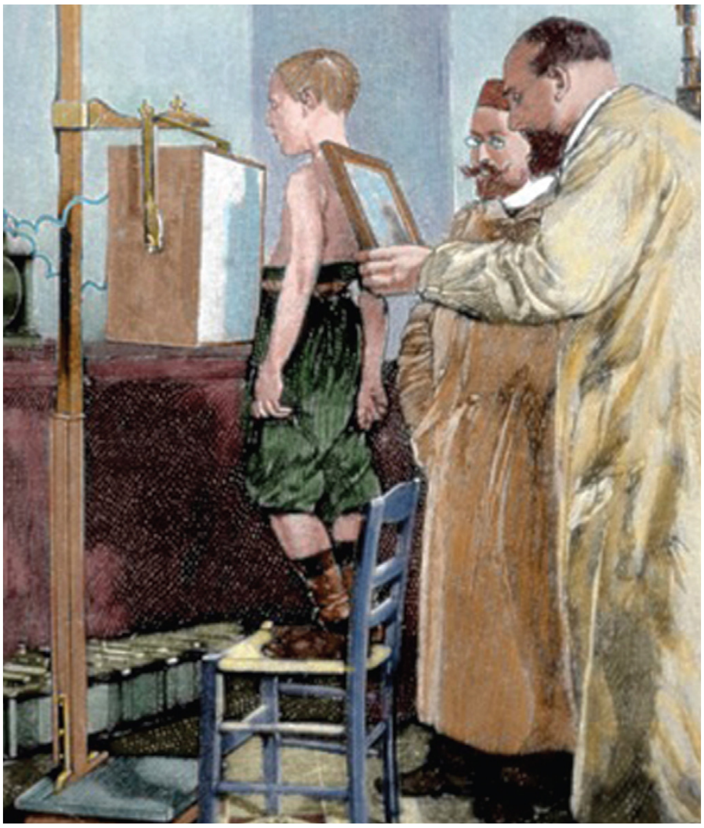
Roentgen realised that a number of objects could be penetrated by electrical rays. By using a photographic plate, Roentgen was able to capture an image of his own hand where there was a clear contrast between the opaque (“white”) bones and translucent (“black/grey”) flesh.

By the following year Glasgow Royal Infirmary had established an X-ray department where some incredible radiographs were produced, including that of a kidney stone and one showing a penny in the throat of a child. Additionally, in 1896, Dr Hall-Edwards discovered a needle embedded in a woman's hand, making him one of the first people to make a diagnosis on the basis of a radiograph.

Following Roentgen's discovery, radiographs were used to help treat soldiers fighting in the Boer War, and then the First World War, by locating bone fractures and embedded bullets. More recently, a rather more unique use of x-rays has been to radiograph Egyptian mummies and archaeological skeletons (see page 28). Using X-rays for this purpose means that huge amounts of information can be extracted without needing to unwrap and dissect a mummy, which is highly destructive and unethical (CT scanning is also now used to achieve high resolution “sliced” images).

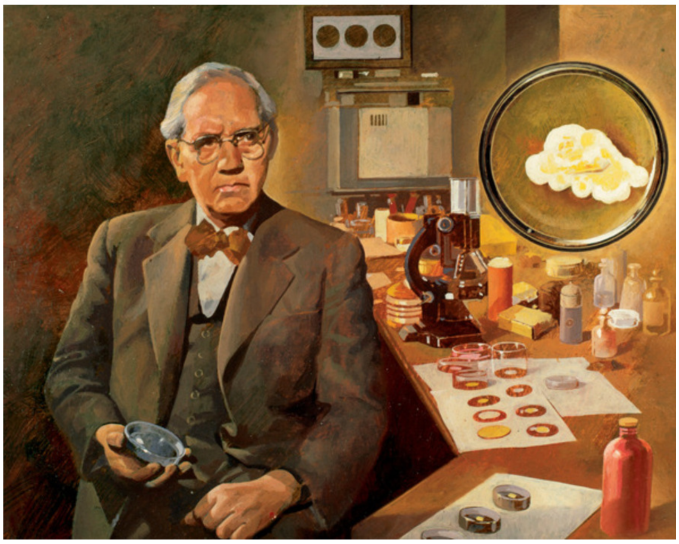
Hand of Anna Bertha Ludwig (Roentgen’s wife)

Once it was recognised that frequent exposure to X-rays was harmful, safety measures were introduced, meaning that now patients and doctors are protected through the process. Another positive outcome of this technology was recognised by the early 1900s when the destructive qualities of x-rays were shown to be very powerful in fighting cancers and skin diseases.



Roentgen examining a child with an x-ray device

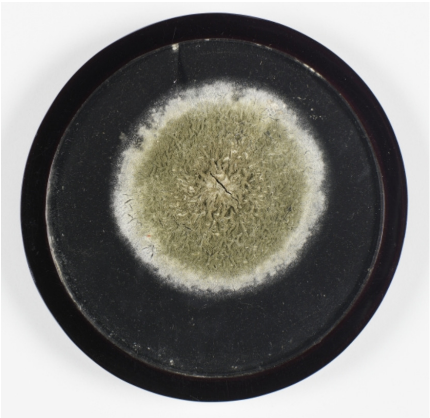
Antibiotics



Portrait of Alexander Fleming

Infectious diseases can be caused by bacteria, viruses, parasites, and fungi. Infections caused by bacteria include diseases like tuberculosis, leprosy, and syphilis. The first antibiotic (penicillin) was discovered in 1928 by the Scotsman Alexander Fleming, a medical doctor (1881-1955). He had found in his laboratory that a mould had grown on a dish in which there were Staphylococcus bacteria. Around it, bacteria were absent or dead, and he showed that the "mould juice" was effective against bacterial strains including many that affect humans. He received the Nobel Prize for this work in 1945. Antibiotics were developed in the 1940s and 1950s to treat bacterial infections, and this has reduced illness and death from these diseases; these work best if the antibiotic is specifically known to attack a certain bacteria. Usually a "broad spectrum" antibiotic is given that covers a range of bacteria that could have caused an infection. However, if tests then identify a specific bacteria that is not covered in the broad spectrum drug, a more appropriate antibiotic is used.

Prior to the mid-20th century there was a high number of deaths from infections, including over the long period of the history of human evolution. For example in 17th century London, 20% of all deaths were from tuberculosis. Although we are fortunate to have antibiotics, overuse and misuse over the decades since they were introduced as a treatment has led to resistance of bacteria to them. That is why it is very important to take the whole course of an antibiotic, instead of stopping taking it when you feel better. In some cases people with infections may be resistant to several antibiotics and increasingly, multiple antibiotics are used in combination to treat infections in case one of them does not work. Bacteria are very clever organisms; they can adapt to where they live, and change their composition so that antibiotics cannot kill them. As new infections appear (e.g. Lyme disease) and old ones re-emerge (e.g. tuberculosis and methicillin-resistant *Staphylococcus aureus* - MRSA), we need to make new antibiotics to be able to combat infections that are currently resistant to the antibiotics we have.



Analysis of the genetic structure of specific bacteria (genome analysis) is very common now in medicine and the information can be used to explore the origin and evolution of bacteria, and antibiotic resistance. Genome analysis is also being carried out on small samples of bones and teeth from archaeological skeletons to look at the strains of bacteria that were around in the past. If we know what strains are with us today and their locations in the world, it is possible then to compare what we see in the past. For example, in one study in England, different tuberculosis strains were found in people buried in 19th century sites, and at one Roman site there were two people with tuberculosis who had different strains.

Penicillin mould, presented to the Student Representative Council by Sir Alexander Fleming when elected Rector, 1952

Vaccination

One of the most transformative measures for health in the world has been the development of vaccinations to prevent infectious diseases. Two to three million deaths in the world each year are avoided because of vaccination. Vaccination (or immunization) consists of the administration of a vaccine containing antigens specific to an infection, an antigen being a foreign substance that causes the body's immune system to produce antibodies against it. Antibodies identify and help remove foreign antigens or targets such as viruses and bacteria. Every different antibody recognizes a specific foreign antigen. Vaccinations stimulate an individual's immune system to develop immunity/resistance to a pathogen that causes a disease, as in the diphtheria, tetanus and whooping cough vaccinations given to children.

Vaccination has a long history. In the 5th century BC, the Greek historian Thucydides had described his observations that people who survived smallpox did not become re-infected with it. However, although there is evidence in China back to 1000 AD for smallpox vaccination by exposing healthy people to scabs caused by the disease (putting the scab tissue under the skin or placing powdered scabs up the nose), the most famous historical description is that of Edward Jenner in 1796; he used cowpox material to create immunity in humans. A rabies vaccine followed (Louis Pasteur, 1885) with vaccines for diphtheria, typhoid, tetanus, anthrax, cholera, plague, and tuberculosis developed in the first half of the 20th century. The mid 20th century was very active for vaccine research and development, and now some vaccine research is focusing on not just infections, but non-infectious diseases. In 1955 the polio vaccine was introduced in Britain (nearly eliminated in the world now) and smallpox was officially eradicated in 1980. By 2008 a vaccination for cervical cancer became available in the UK, by 2013 the National Health Service was vaccinating against rotavirus, shingles and child influenza, and in 2015 for meningitis B.

Although vaccination has prevented infections and reduced deaths, it is not without controversy that goes back to the late 19th century when people simply did not believe it worked. However, vaccines are very safe, and most vaccine reactions are usually minor and temporary, such as a sore arm or mild fever. Serious health events are extremely rare. People are far more likely to be seriously injured by a vaccine-preventable disease than by a vaccine. The benefits of vaccination greatly outweigh the risk, and many more injuries and deaths would occur without vaccines. Clearly, new vaccines continue to be developed, and vaccination remains a key weapon in the armoury of preventing infectious diseases, but public health programmes are also incredibly important to prevent people being exposed to risk factors for individual infectious diseases.

Members of the French vaccination committee against Tapp, a health officer resisting the new discovery, c19th

Changing Burial Customs

Although we have a huge arsenal of medical treatments at out disposal, eventually, we all face the same natural fate of death, hopefully after a long and fulfilling life. The way in which people bury their dead is diverse, depending on their religion, their customs and traditions and the place and time in which they live. How the living regard their dead ancestors is also reflected in ritual traditions (e.g. Day of the Dead in Mexico and other parts of the world). Some funerals are very celebratory events with parties that can last for weeks whereas others are very solemn and quiet. A traditional Christian funeral in the UK has not changed much since the Victorian period. Funeral processions are easy to spot; guests will mainly wear black out of respect for the dead person, a hearse will transport the coffin to the church or crematorium, and flowers and wreaths adorn the coffin. Following a service to celebrate the life of the person, the body is either buried in a cemetery or cremated and their ashes scattered somewhere. Although this might be what we see as traditionally 'British', funeral customs have been changing in this country and elsewhere for thousands of years; people have been buried or cremated, depending on the fashion of the time.

Typical image of offerings to the dead in Mexico during the November Dia de los Muertos (Day of the Dead) celebrations along with orange marigolds

Our ancestors' burial methods developed considerably over time including trends in cremation versus inhumation (burial of the body); at times there also appears to have been some recognition of the status of the deceased (e.g. grave goods, burial position in a cemetery). In Britain, during the Palaeolithic period (10,500-8,000BC) people were buried in caves, with Mesolithic people also placed in caves, but also in shell middens in Scotland. By the Neolithic period (4000-2500BC), individual or small group burial, or larger numbers in cairns (stone mounds) or in earth tombs with interior chambers of stone slabs, were the norm, and there were some cremation burials. The Bronze Age (2600-800 BC) saw round barrows (mounds) dominate the burial tradition with both inhumation and cremation practiced. This mixed practice is also represented in the Iron Age (late 800 BC to 100 AD), but burial in wet places (e.g. rivers), cist graves (stone, slab lined coffin-like boxes) and scattering of remains across areas were also practiced.

The Roman period (AD43-410 AD) reveals that large inhumation cemeteries, especially in towns, was the normal burial rite. However inhumation burial with the head to the west (reflecting adoption of Christianity) replaces cremation in the 2nd century AD until the end of the period. Grave goods with burials during all of these periods are seen.

Prehistoric burial mound, Scotland, 3000BC

Roman burial at Binchester , County Durham

Medieval crypt, Rothwell Parish Church

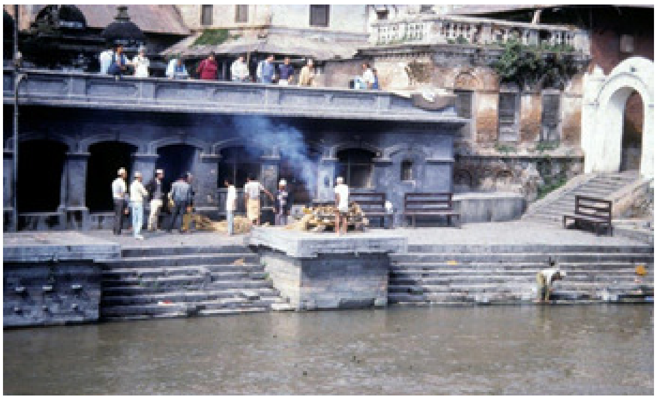
Changing Burial Customs (Continued)

In the Anglo-Saxon and early Medieval period (5^{th}-11^{th} century AD) non-Christian pagan cremation and inhumation burials are clear, continuing the tradition of containing grave goods, but by the early 7^{th} century inhumations with no grave goods appear, reflecting Christian tradition, and become the norm by the end of the period.

In this period in particular, people migrating to Britain have been found to integrate and use local customs, or at least be buried alongside local people so that there is no immediate visual evidence to suggest they were not locals. Isotope analysis can see where they came from. For example at Bamburgh Castle in the 7th-8th century AD, locals and others from elsewhere in Britain were buried alongside people who had come from places like Scandinavia.

The late Medieval period (12^{th}-16^{th} century AD) is characterized by Christian burial, sometimes in coffins or wrapped in a shroud, and special burial places are identified for battlefield and plague victims, along with hospital cemeteries. From the 16^{th} century, as in the previous period, large cemeteries of inhumations in the Christian tradition are apparent, often in coffins, along with burial in crypts.

Medieval skeleton in the remains of a coffin at the site of Hull Magistrates Court , Kingston-Upon-Hull, Humberside

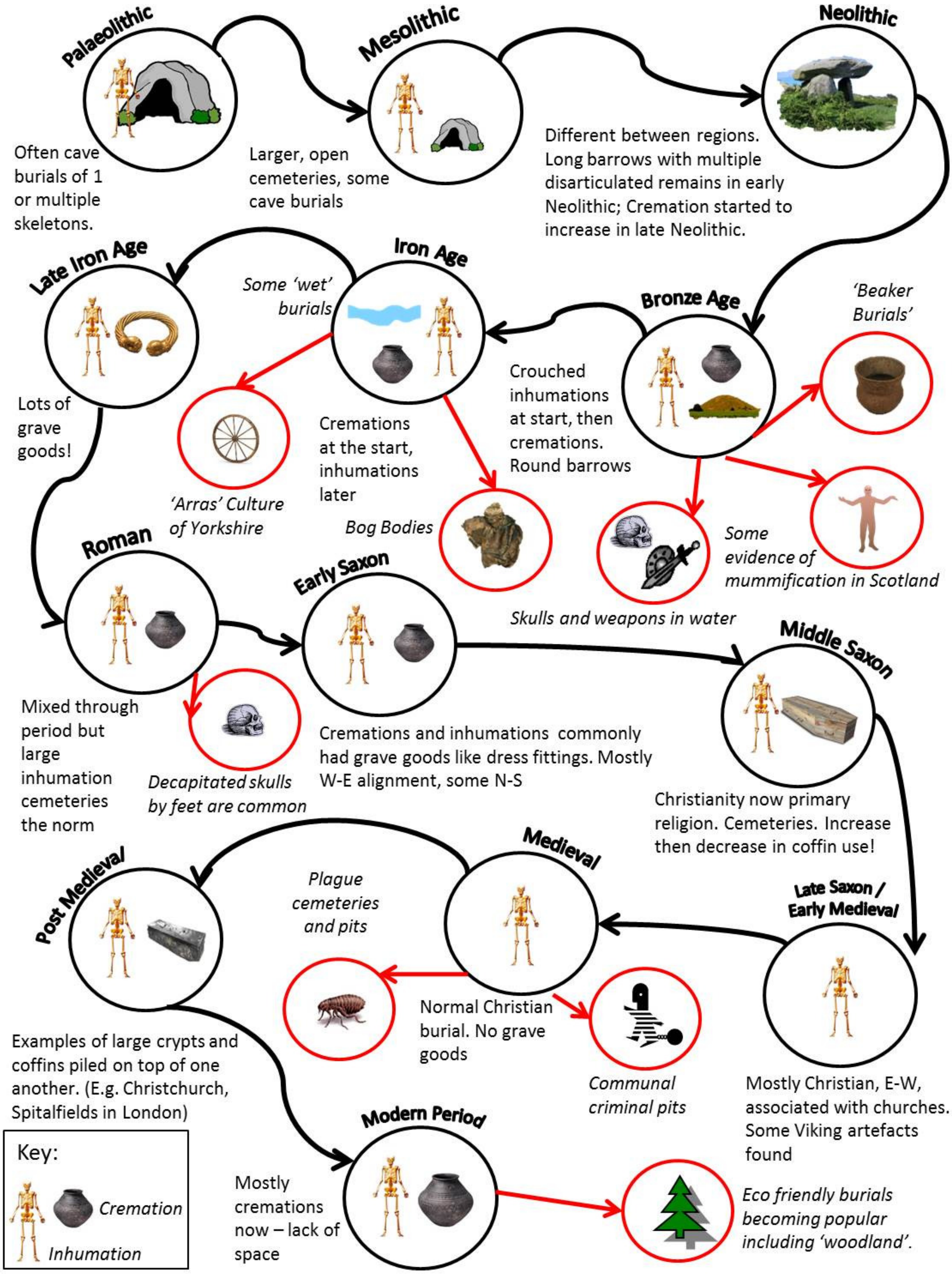


Modern outdoor cremation by the river in Kathmandu, Nepal

Aerial view of modern cemetery in Harrogate, North Yorkshire

The UK is now a very multicultural country and the variety of burial customs practiced is diverse, particularly amongst different religious groups. Even traditional 'British' burial customs are now changing as a more individual and personalized celebration of a person's life becomes the norm. Most people used to be buried in graveyards but due to a lack of space (there are so many people in the world!), about 75% of people are now cremated, which is also less expensive. There has also been a move towards 'green burials' where people are buried in the ground (often in coffins made of cardboard or willow), in dedicated woodland areas. This has gone alongside more funeral services being humanist in character, and not religious; this reflects the decline in religious affiliation in the UK.

Burial/Cremation Through Time



Activities

The following pages are filled with activities that you might enjoy having a go at! First you will find some templates to accompany the first two activities listed below. Some activities will put your mind to work, others your creativity! Feel free to photocopy and adapt any of the activities you wish and if you have a good idea for a new activity, please get in touch!

Activity 1

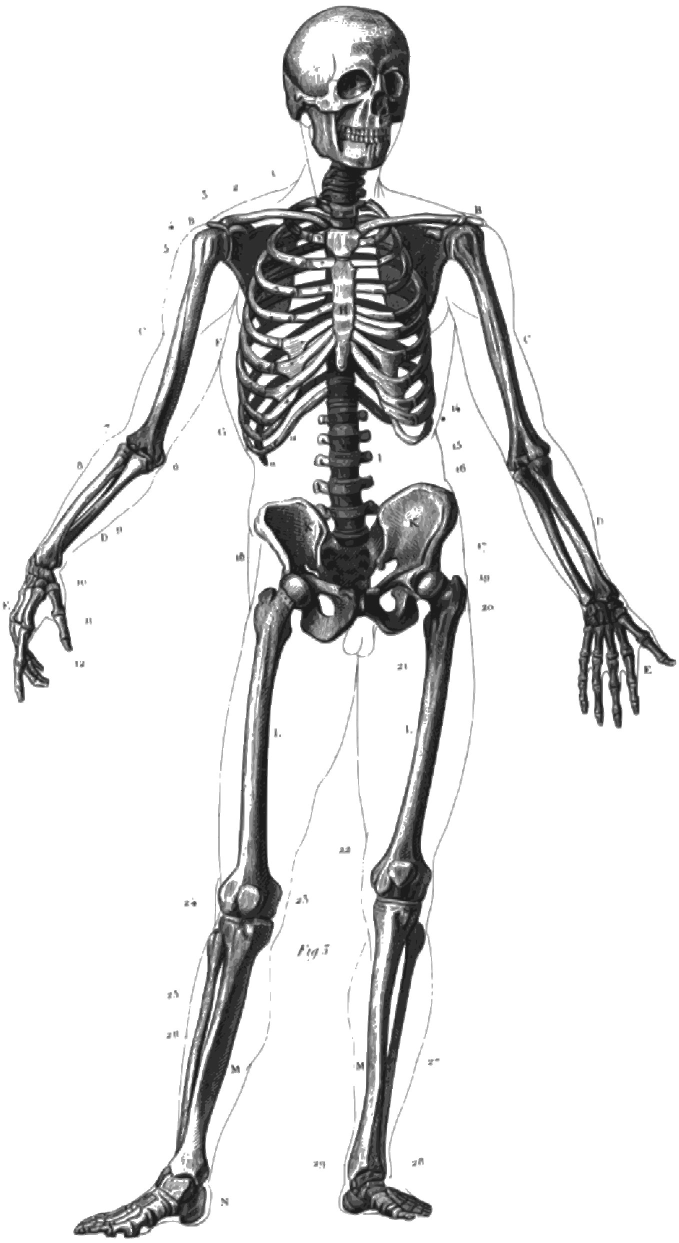
Dangling Skeleton (pages 50 and 51)

Materials:

Template (provided) / string / split pins / scissors / hole punch

Instructions:

You will need both pages. Cut out the template and articulate the bones, connecting with the split pins. This can then be hung up in a window or as part of a display.



Activity 2

Day of the Dead Mask (page 52)

Materials:

Template (provided) / card / coloured pens or pencils / scissors / hole-punch / lollipop stick

Instructions:

Research the Mexican Day of the Dead festival (begins 31st October). Colour in the mask as brightly as possible. Either hole-punch the mask at either side and attach string or attach a lollipop stick so that you can hold the mask in front of your face.

Activity 3

Skeleton Says

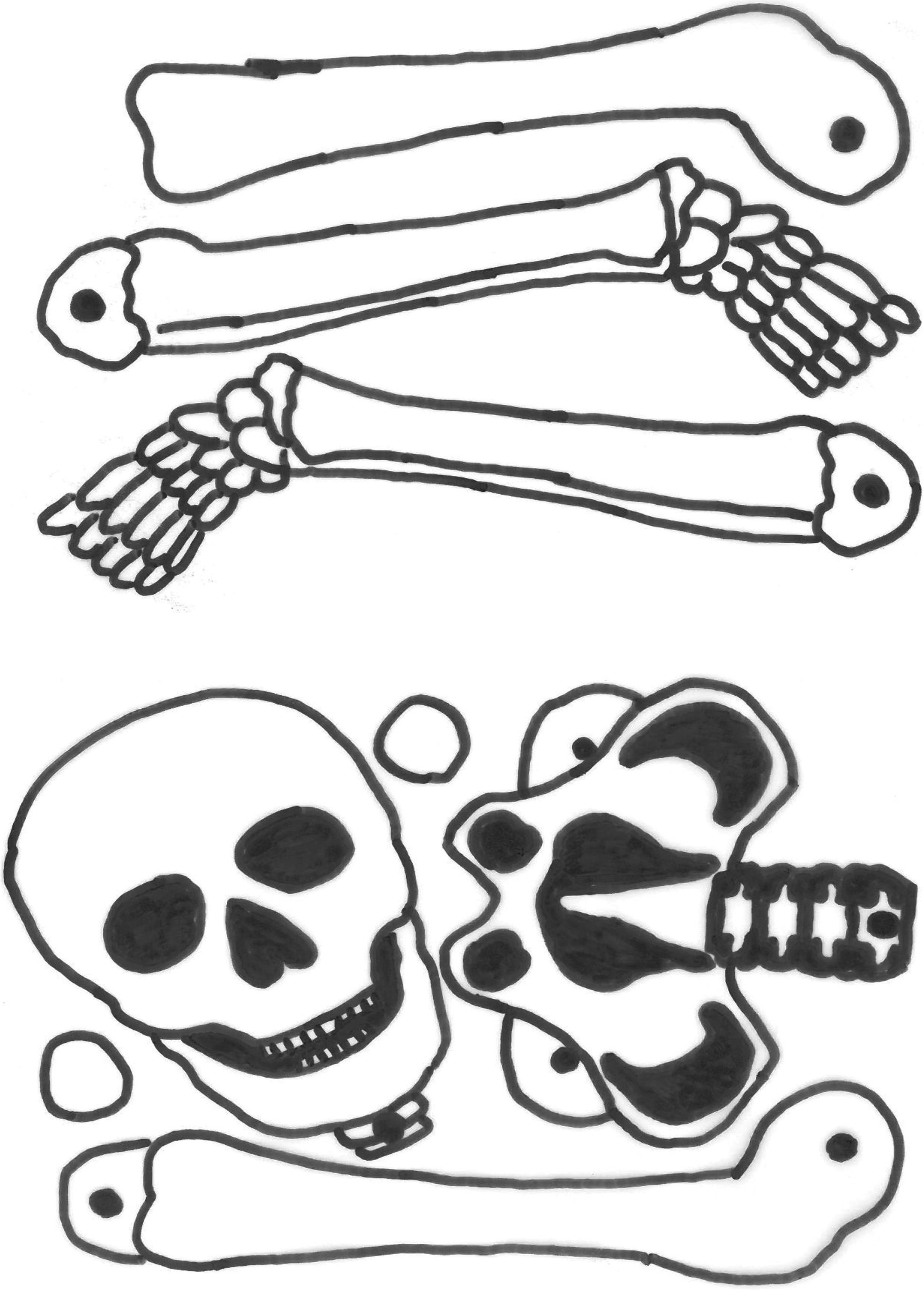
Materials:

None

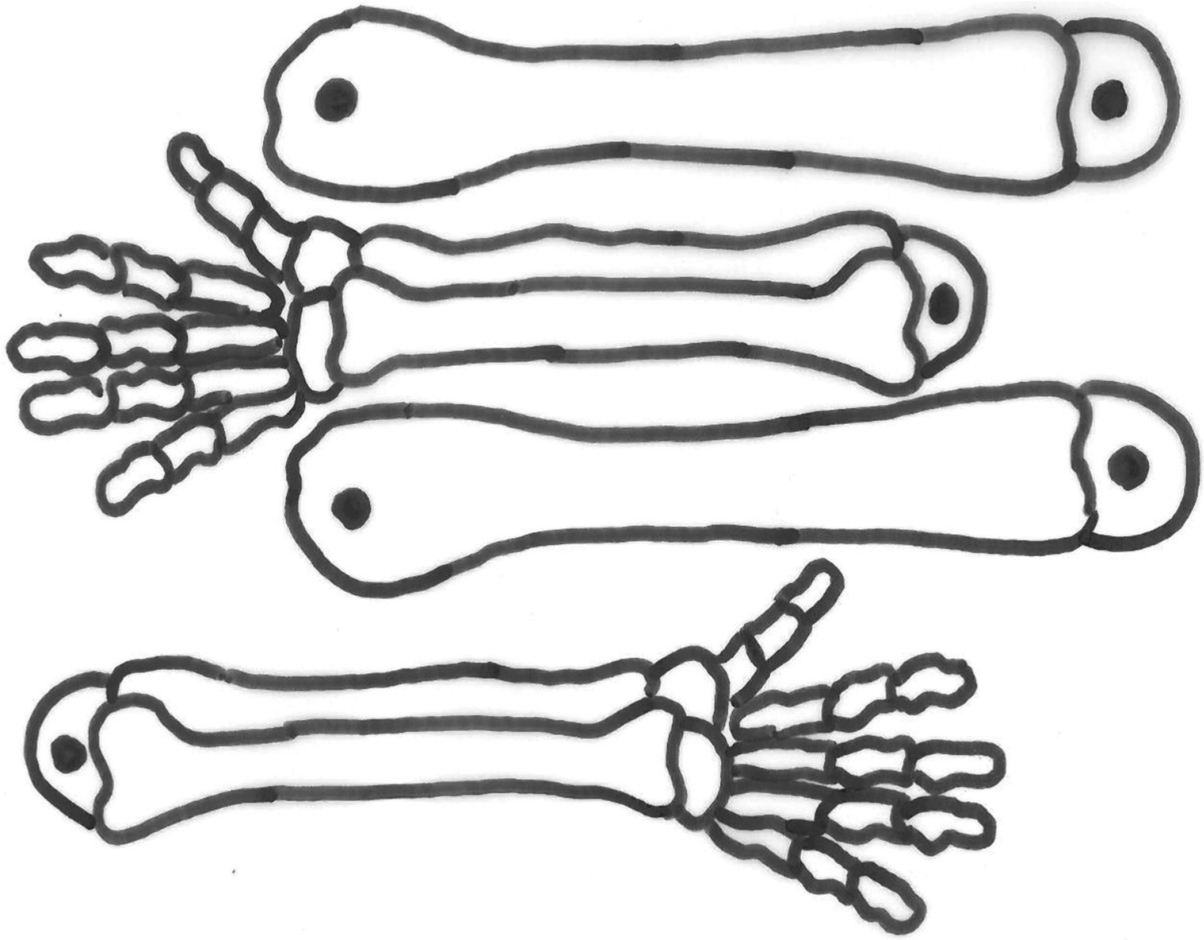
Instructions:

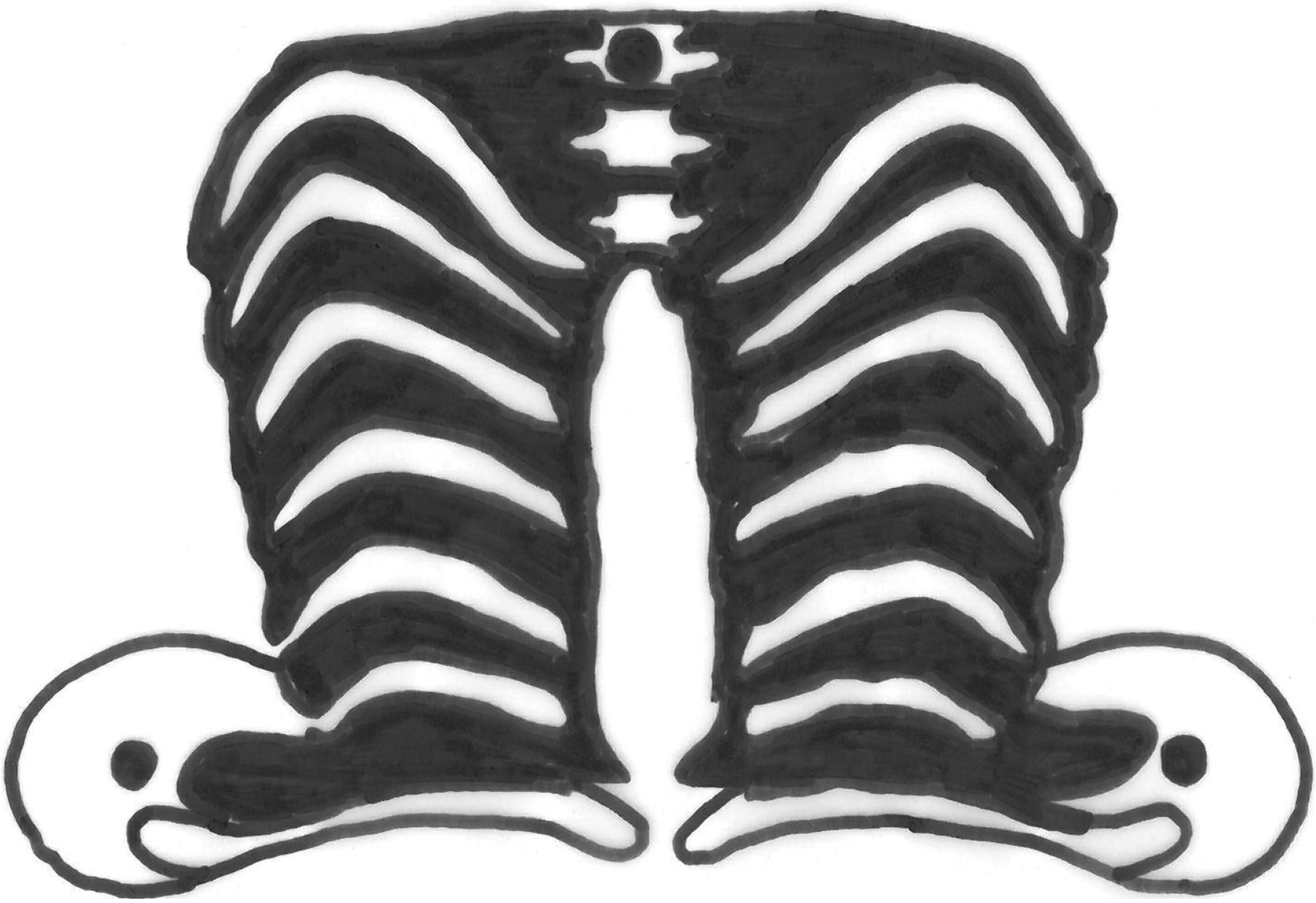
This is a group activity! It’s a quick game to test your memory of the parts of the skeleton. Adapt the game 'Simon Says' but using bone names, for example, "Skeleton says, touch your knees".

Dangling Skeleton (1 of 2)



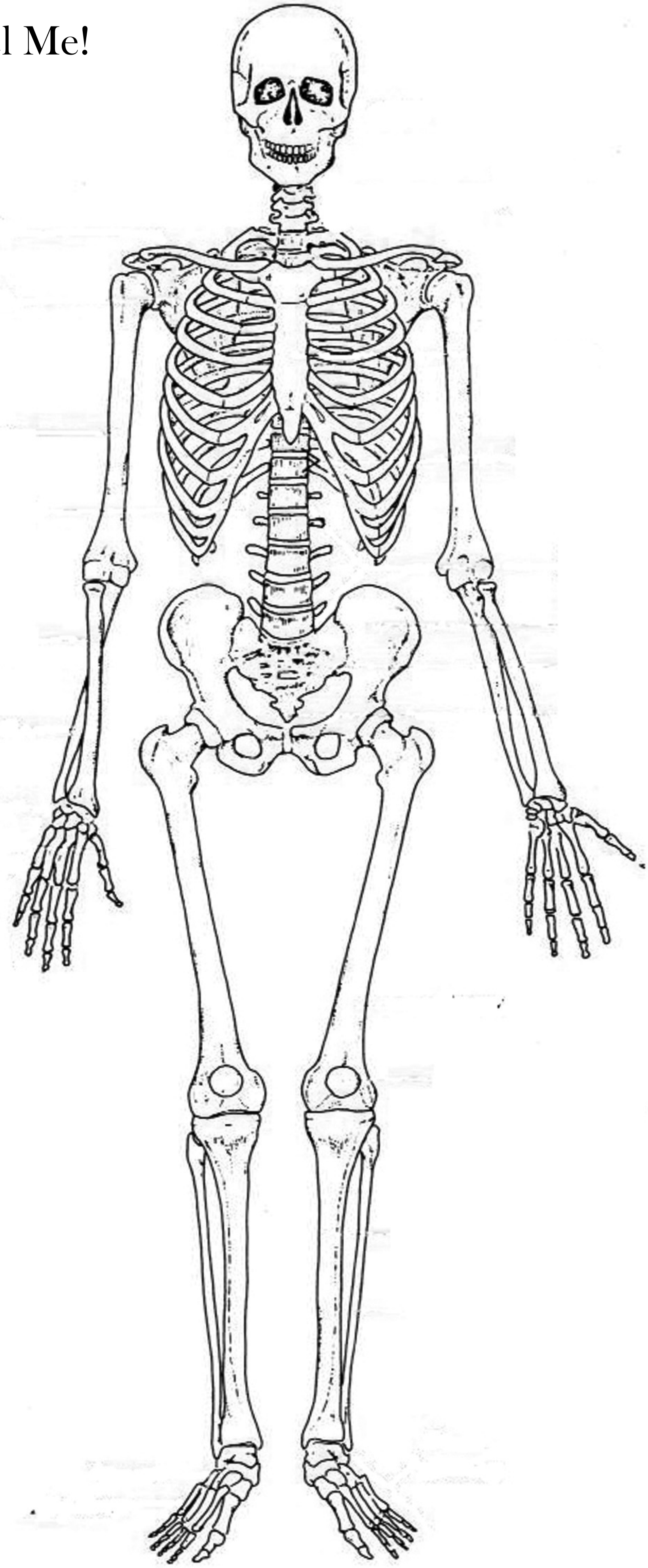
Dangling Skeleton (2 of 2)



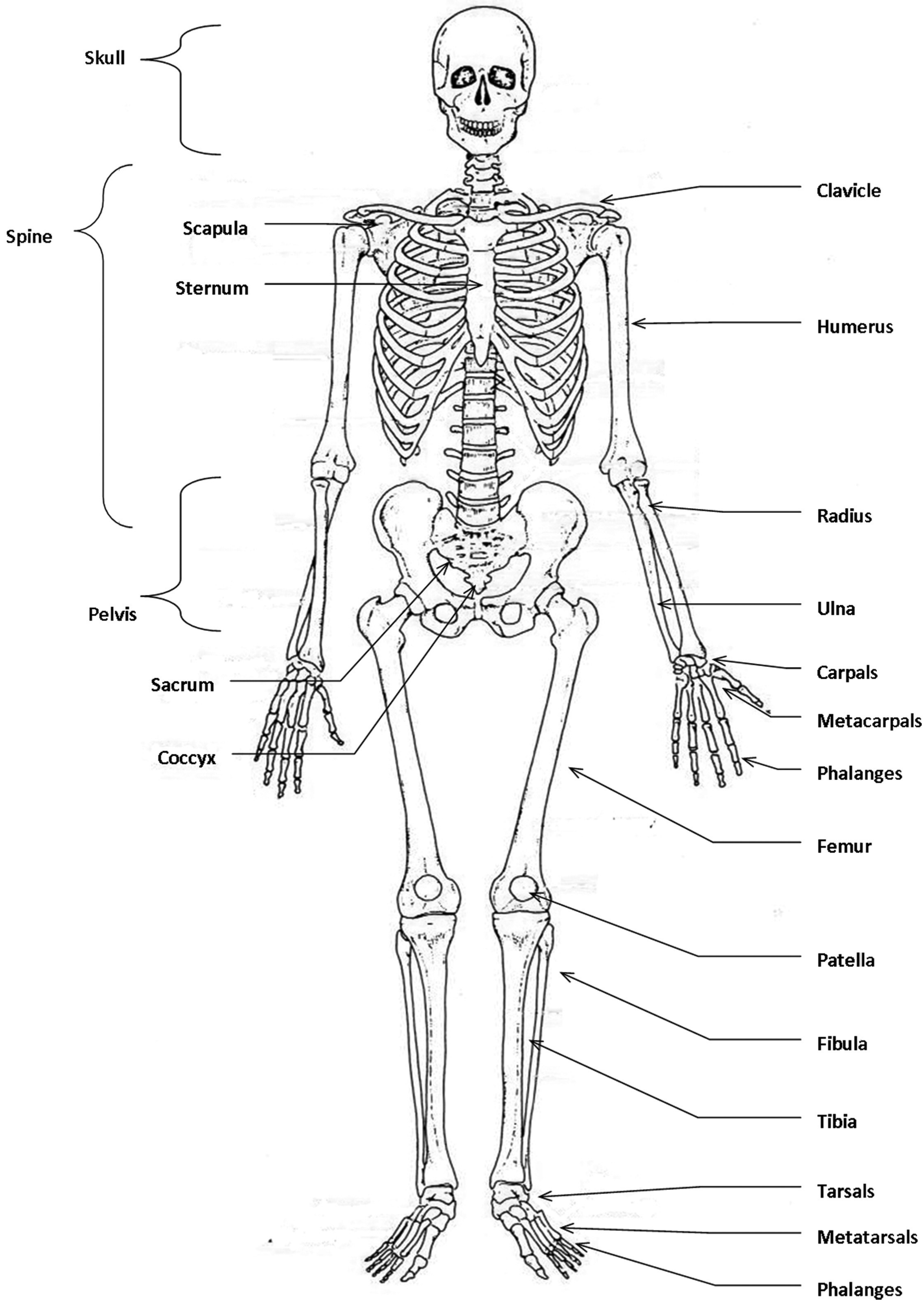


Day of the Dead Mask

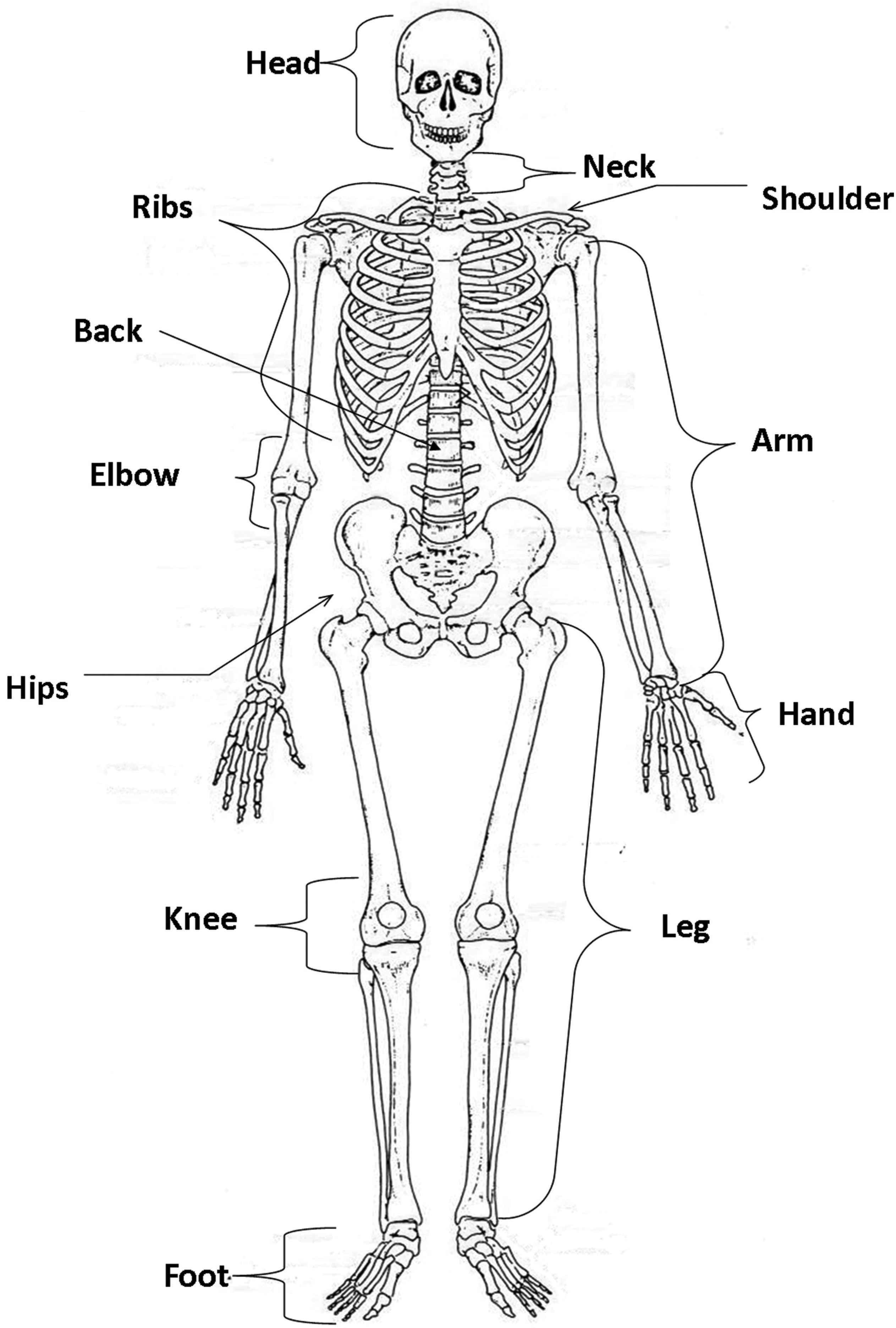
Activity 4: Label Me!



Labelled Skeleton - Anatomically Correct (for reference)



Labelled Skeleton - Simplified (for reference)



Egyptian Mummification

Read through this page to learn more about Ancient Egyptian mummification. The next page contains instructions as to how you can mummify a banana using a very similar process!

The Mummification Process

1. The body was washed in water from the Nile to clean it. The water was mixed with natron to make it salty, which would have helped to preserve the body and act as antiseptic to clean it.
2. The brain was removed through the nose!
3. A cut was made on the left side of the body, and the stomach and intestines removed. Next the lungs and liver were taken out and all the organs were dried and each put in special canopic jar (see image below).
4. The body was packed with stuffing and covered with natron for 40 days. The body would turn a darker colour and become lighter in weight as it dried out.
5. The stuffing was taken out, the body was rinsed, dried and then stuffed with linen. The slit was stitched up and the body 'anointed' with oils, spices, beeswax and other nice smelling things.
6. The body was bandaged up (this took 15 days) and magical spells were spoken over the body.
7. A mummy mask was fitted over the head and shoulders of the mummy.

Set of four canopic jars

The Science of Salt:

Natron is a salt (a natural mix of sodium carbonate and bicarbonate) that could be found as crystals along the edges of salt lakes in ancient Egypt.

Salt absorbs water, via osmosis. In mummification, it removes moisture from the body, causing the tissues (the skin, muscles etc.) of the body to dehydrate, but stay flexible. This means that the body will be preserved. If a body is not mummified then bacteria in and on the body will start to cause the body to decay. However, bacteria cannot live in very dry conditions.

Nowadays, we would use a freezer to preserve a body, as very cold temperatures also have the same effect.

Anubis was the Egyptian God of Mummification

How to Mummify a Banana

Activity 5:

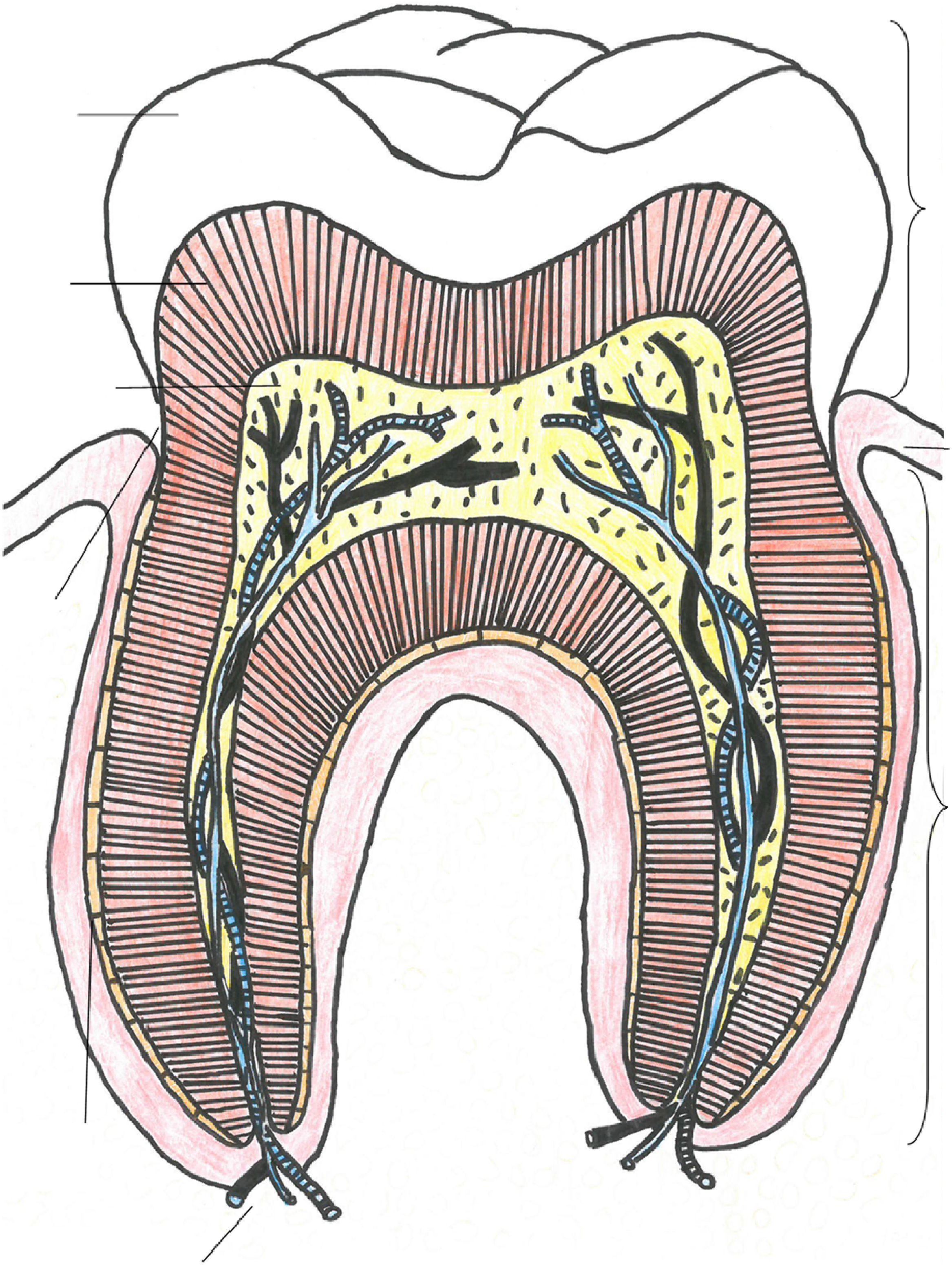
A slightly easier activity, that doesn't involve any sewing, is mummifying a tomato! Take out all the seeds, leaving just the skin. Cover in salt, (replace salt part way through if necessary) and wait until you have a leather-like, mummified tomato!

1. Find a banana.
2. Peel open the banana but keep hold of the skin.
3. Eat the banana! (Try our recipe for banana splits below!)
4. Put the open banana skin in table salt. Make sure all the skin is covered.
5. Leave the banana in the salt for about 2 weeks. Be patient! (You may need to replace the salt part way through).
6. When the banana is dry, try to brush off the salt.
7. Now you need to sew up the banana skin! Start from the bottom and leave a gap at the top.
8. Stuff the skin with sawdust and nice smelling herbs and spices.
9. Now finish sewing up the skin so that the filling doesn't fall out.
10. Wrap the stuffed banana skin in strips of cloth – maybe use an old t-shirt if you don't have any plain cloth – now it really looks like a mummy!
11. Wait a few weeks and you will have a dry, lovely smelling, mummified banana that won't go rotten! (Unless you get it wet!).

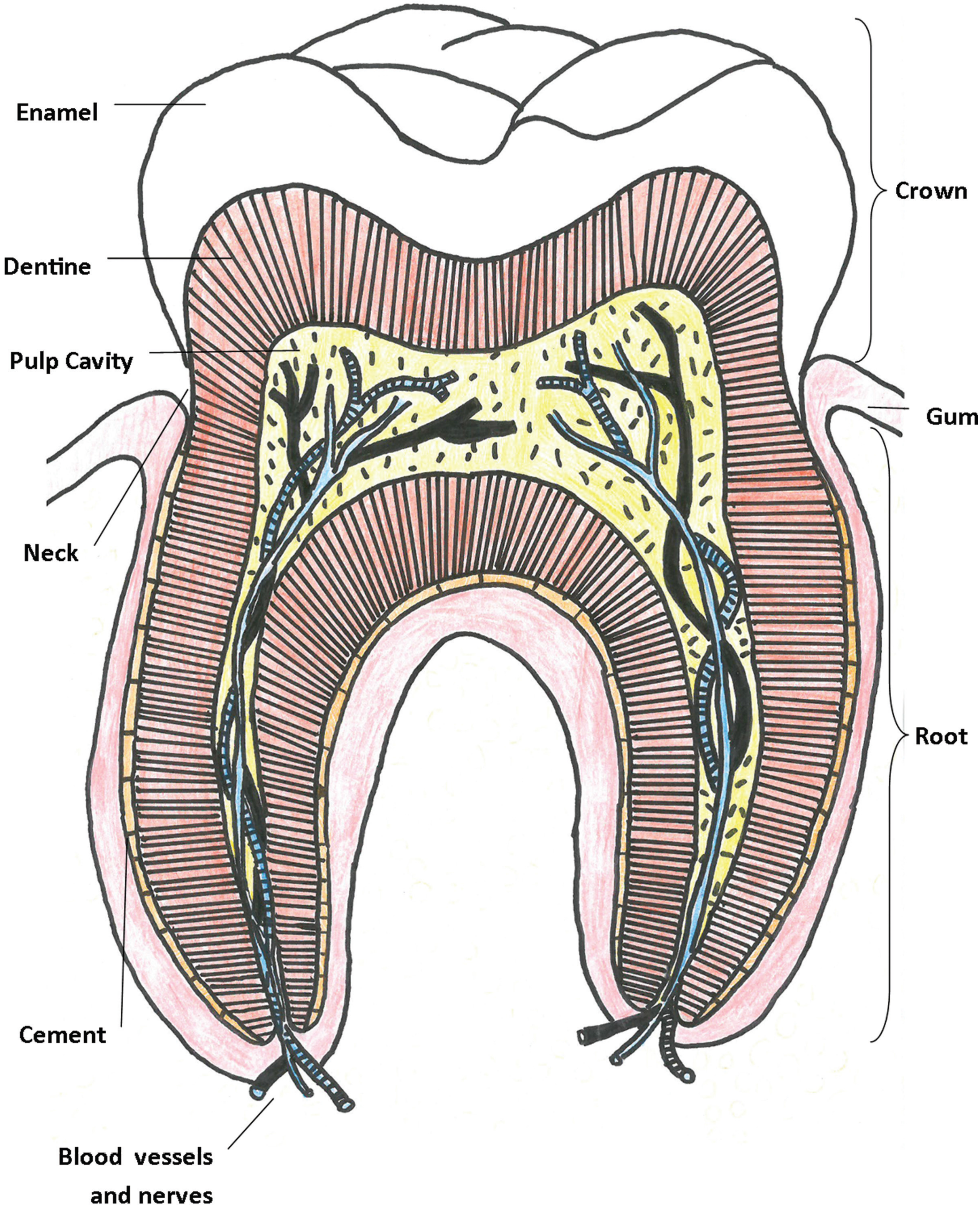
Banana Splits!

You should never waste a healthy banana (full of potassium!) so once you have peeled off the skin, place your banana in an oval dish and cut in half length ways. Add a couple of scoops of ice-cream (any flavour) and some extra fruit - strawberries and raspberries are delicious! Top with some melted chocolate or chocolate sauce and either chopped nuts or crunched up biscuits. Enjoy!

Activity 6: Label Me!



The Tooth (for reference)



Activity 7: Spot the Skeleton

Match the name of the animal to its skeleton.

Cow

Fish

Frog

Squirrel

Dolphin

Gorilla

Bat

Lion

Human

Lizard

Activity 8: Join the Jaws - Draw a line from the name of the animal to the matching jaw (note the scale showing the size of the jaws!).

WARTHOG PIG

RED DEER BADGER

PIRANHA CAT

RABBIT PIT PONY

a.

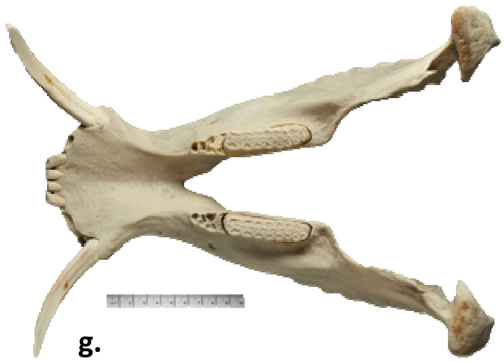
b.

c.

d.

e.

f.



g.

h.

Answers: a. Cat b. Pig c. Rabbit d. Badger e. Pit Pony f. Piranha g. Warthog h. Red deer

Activity 9: Skeleton Word Search

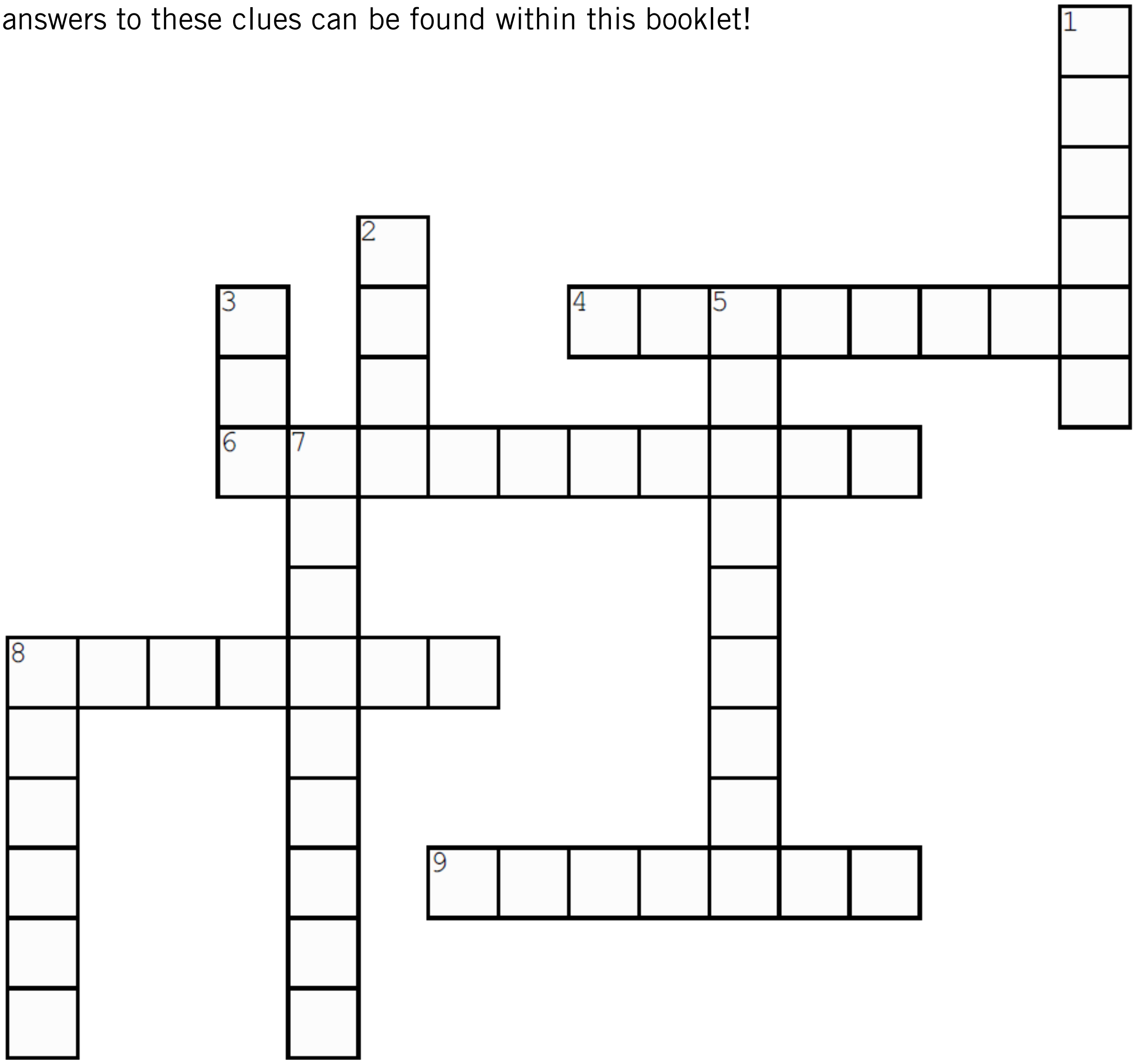
W	M	H	S	P	L	B	X
S	K	E	L	E	T	O	N
B	W	A	R	M	S	N	M
A	H	A	N	D	L	E	G
C	H	E	S	T	W	V	P
K	I	Z	P	S	P	O	Z
O	P	B	S	K	U	L	L
W	S	F	O	O	T	H	C

LEG SKULL HAND BACK SKELETON

ARMS CHEST FOOT HIPS BONE

Activity 10: Bioarchaeology Crossword

All the answers to these clues can be found within this booklet!



Across

4. Greenstick is a type of what? (8)

6. Type of medicine given to somebody with an infection (10)

8. Correct anatomical name for the kneecap (7)

9. Sharpest type of tooth (7)

Down

1. Hardest part of the tooth (6)

2. Metatarsals are found here (4)

3. Short name for *deoxyribonucleic acid* (3)

5. Degenerative disease that often causes pain in joints (9)

7. Period in which farming began (9)

8. What disease can be 'bubonic'? (6)

Further Reading

- **Council for British Archaeology**: http://new.archaeologyuk.org/
- **National Health Service Choices**: http://www.nhs.uk/pages/home.aspx
- **World Health Organization**: http://www.who.int/en/
- Brown and Brown 2011 **Biomolecular archaeology**. An introduction. Wiley-Blackwell.
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