A Brief Guide To Some Of The Science Behind Archaeology

Clare Museum
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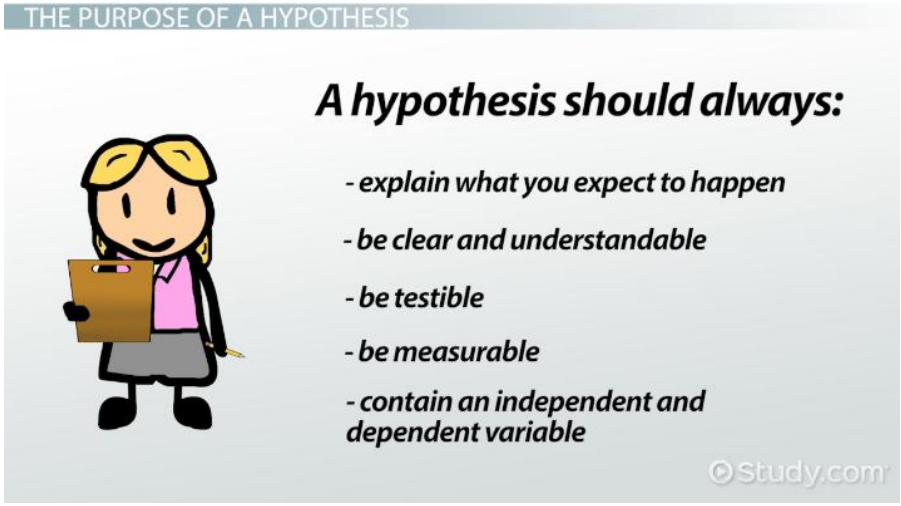
What is the Scientific Method? Scientists, including archaeologists, follow a logical process to acquire and interpret data — the Scientific Method. Scientists use hypotheses and theories to organize their data and explanations. Hypotheses are stated relationships between two or more variables in the empirical world that anticipate and explain the interaction between them. Scientists are required to be explicit about their assumptions when formulating a hypothesis. This allows other scientists to evaluate the foundations of the hypothesis and the validity of the test. A hypothesis is a specific and testable statement about something, generally tied to a broader theory about our understanding of the past. For scientists, a theory is a systematic explanation that can explain existing data and make predictions about what to expect from new data.



Types of Reasoning: Archaeologists use two different kinds of reasoning: inductive and deductive reasoning. With inductive reasoning, archaeologists move from the observation of a specific piece of data to develop a hypothesis about what that data might mean. With deductive reasoning, the archaeologist will start by suggesting a hypothesis, and then conduct research and search for data to either support or disprove the hypothesis.

For example, an archaeologist might have a theory that people in County Clare at 4,000BCE hunted and foraged for wild food from the local habitat to supplement what they could farm. They might hypothesize that the people ate salmon from the Shannon river. To test this, the archaeologists would conduct excavations in the area to look for the bones of the salmon in archaeological contexts indicating that the people had been fishing for them.

Theories that are supported by a lot of data, and not disproved by any data, are considered powerful explanations. However, future work may require that these theories be refined or modified to account for new data. The scientific method is a never-ending process of making and refining hypotheses, continually testing them with new data, and reformulating them when new data is available. For example, it was thought, for a long time, that people only arrived in Ireland about 8,000BCE, however, new evidence from the Alice and Gwendoline cave in County Clare, shows that people were active in the area at 10,500BCE.

Different Methods: Archaeological science can be divided into the following areas:

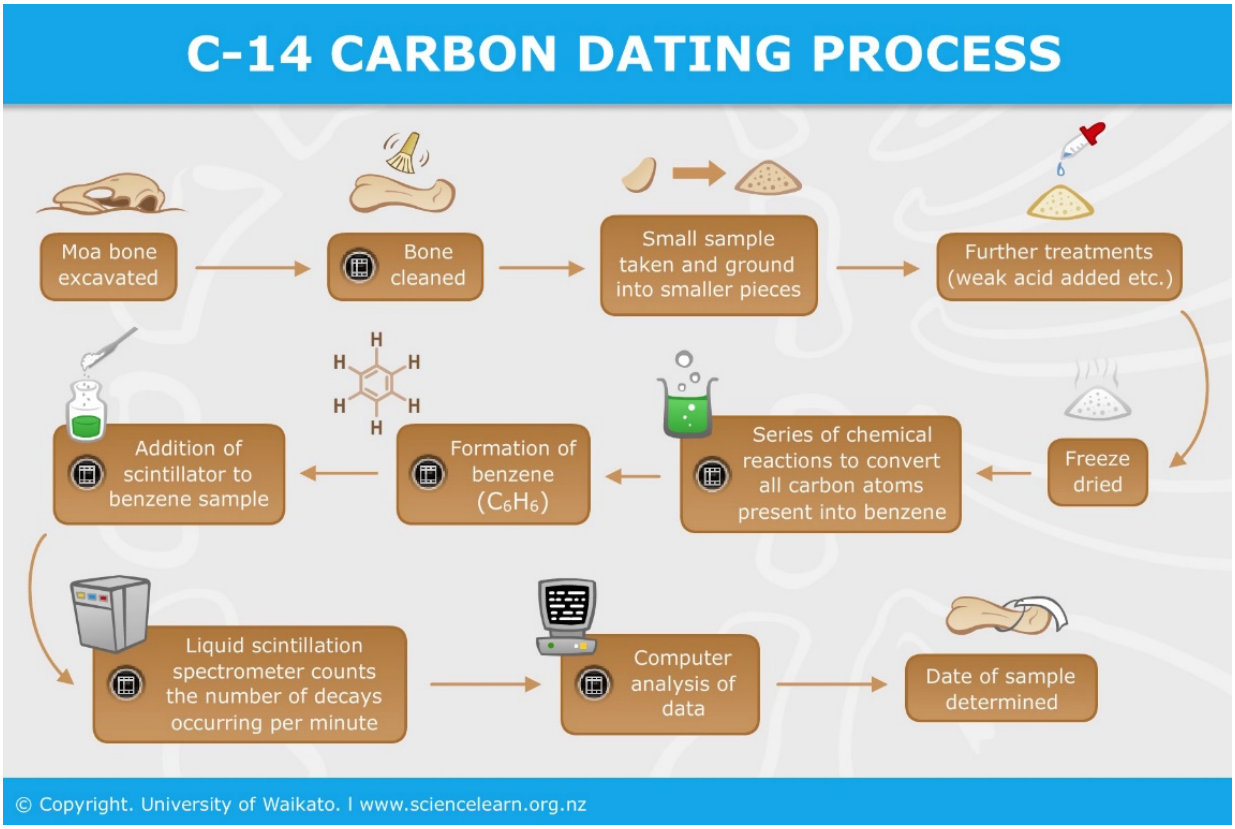
- Physical and chemical dating methods which provide archaeologists with absolute and relative chronologies (e.g. radiocarbon dating and dendrochronology).
- Artefact studies.
- Environmental approaches which provide information on past landscapes, climates, flora, and fauna; as well as the diet, nutrition, health, and pathology of people (e.g. isotopic analysis and pollen analysis).
- Mathematical methods for data treatment (including computer-based methods).
- Remote-sensing and geophysical-survey techniques for buried features.
- Conservation sciences, involving the study of decay processes (Taphonomy)and the development of new methods of conservation.

Some of the most important dating techniques include:

- Radiocarbon dating — especially for dating organic materials, e.g. bones.
- Dendrochronology — tree-ring dating; it is also very important for calibrating radiocarbon dates making them more accurate.
- Thermoluminescence dating — for dating inorganic material (including ceramics)
- Optically stimulated luminescence (OSL) — for absolutely dating and relatively profiling buried land-surfaces in vertical and horizontal stratigraphic sections, most often by measuring photons discharged from grains of quartz within sedimentary bodies.
- Electron spin resonance, as used in dating teeth
- Potassium-argon dating — for dating, for example, fossilized hominid remains by association with volcanic sediments (the fossils themselves are not directly dated)
- A variety of methods to analyse artefacts, either to determine more about their composition, or to determine their provenance. These techniques include:
    - X-ray fluorescence (XRF)
    - Inductively coupled plasma mass spectrometry (ICP-MS)
    - Neutron activation analysis (NAA)
    - Scanning electron microscopy (SEM)
    - Laser-induced breakdown spectroscopy (LIBS)

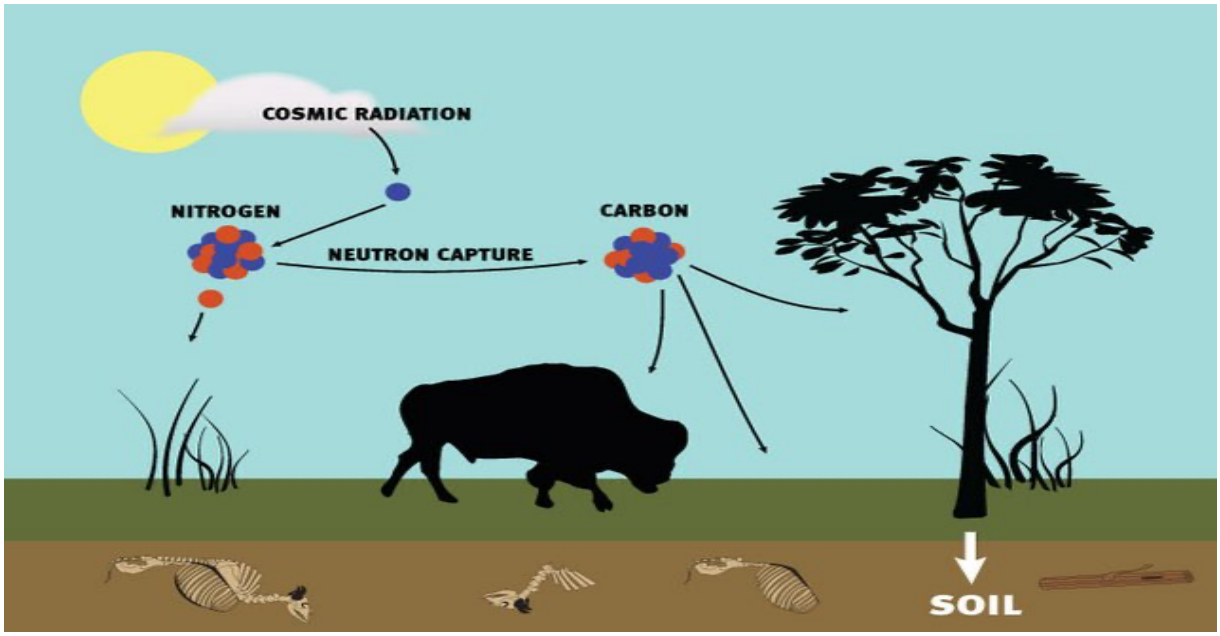
As radiocarbon dating (also known as carbon dating or carbon-14 dating) is the most well know of these dating techniques, let's take a closer look at it.

This dating method was developed in the late 1940s by Willard Libby, who received the Nobel Prize in Chemistry for his work in 1960. Its basis is that radiocarbon (^{14}C) is constantly being created in the atmosphere by the interaction of cosmic rays with atmospheric nitrogen. The resulting ^{14}C combines with atmospheric oxygen to form radioactive carbon dioxide, which is incorporated into plants by the process of photosynthesis; animals then acquire ^{14}C by eating the plants. When the animal or plant dies, it stops exchanging carbon with its environment, and from that point onwards the amount of ^{14}C it contains begins to decrease as the ^{14}C undergoes radioactive decay. Measuring the amount of ^{14}C in a sample from a dead plant or animal such as a piece of wood or a fragment of bone provides information that can be used to calculate when the animal or plant died. The older a sample is, the less ^{14}C there is to be detected, and because the half-life of ^{14}C (the period of time after which half of a given sample will have decayed) is about 5,730 years, the oldest dates that can be reliably measured by this process date to around 50,000 years ago.



Now let's look at some of the other analysis techniques available to help us to learn more about archaeological remains.

Stable Isotopic Analysis: Isotopes are present everywhere in the world in which we live and breathe but the ratios in which different isotopes of the same elements occur, varies between different substances (e.g. different types of food) and eco-systems (e.g. between land and sea or between different climate zones). As we grow and our body tissues continually renew themselves, the isotopes that are in the food we eat and the water we drink are being incorporated into all our body tissues, including our skeleton. By measuring the ratios of different isotopes in bones or teeth we can trace them back to their sources and find out many things about an individual, such as what their diet was like and the environment they grew up in.



Taphonomy includes the study of how a body decays. For instance, where was it placed after death, was it burned, was it moved at any time, did animals have access to it etc.

Taphonomy includes the study of how a body decays. There are five main stages of taphonomy: disarticulation, dispersal, accumulation, fossilization, and mechanical alteration.

1. Disarticulation: occurs as the body decays and the bones are no longer held together by the flesh and tendons.
2. Dispersal is the separation of pieces of a body caused by natural events (i.e. floods, scavengers etc.).
3. Accumulation: occurs when there is a build-up of organic and/or inorganic materials in one location (scavengers or human behaviour).
4. Fossilization: occurs when mineral rich groundwater permeates organic materials and fills the empty spaces.
5. Mechanical Alteration: this is processes that physically alter the remains (i.e. freeze-thaw, compaction, transport, burial).

Dental analysis focuses on the condition of the teeth and jaw bones. Dental palaeopathology is particularly important as it can provide direct evidence of the type of diet an individual consumed during life. An analysis of the angle of tooth wear evident on the crown of the tooth can help to distinguish between early hunter-gatherers and later agriculturists, whilst microwear features on the occlusal surface can help to discern subtle dietary shifts. Plant microfossils have been isolated from calculus (plaque) which can be identified using light microscopy. Teeth are particularly useful in ancient DNA studies due to the excellent preservation of biomaterials within the enamel shell of the tooth.

Bone pathology deals with the identification of bone diseases and diseases that can be identified via analysis of the remaining skeletal structure. For example, from studying the bones found at Poulnabrone we can determine that the people buried there suffered mainly upper body arthritis and degenerative joint disease. This suggests a life of hard manual labour especially carrying or pulling heavy objects using the upper body, neck and head. The lower limbs were relatively unaffected which implies that the people buried at Poulnabrone coped well with the uneven terrain of the Burren.

An odd note in relation to the location of arthritis in the hands, where it was most common, shows that degenerative changes in the hand were worse on the left side. This is surprising given that between 70-90% of people are right-handed.

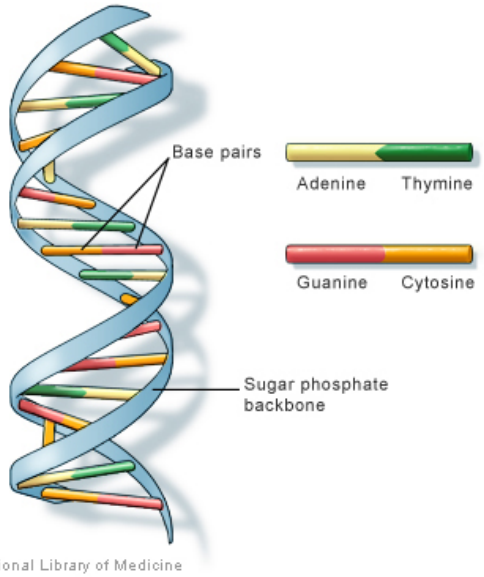
Five examples of bone trauma were identified amongst the remains:

1. A healed fracture on a second or third right rib bone
    a. Most likely caused by a blow to the chest.
2. A compression fracture on a left talus and calcaneus (ankle and heel bones)
    a. Arthritis set in as a result of this injury causing immobility of the left ankle and would have caused the person to walk with a limp and experience chronic pain.
3. A healed fracture of a proximal foot phalanx (toe bone)
    a. Most likely sustained from a weight dropping on the toe.

4. A depressed fracture of a left parietal (large skull bones to the left and right of the skull behind the frontal bone).
    a. There is no evidence of infection and the injury appears to have healed completely.
    b. The skull is that of an adult male.
    c. Most likely caused by a blow to the head from a small blunt object such as a stone.
5. Weapon wound on the hip bone
    a. Right hip bone of an adult, most likely male.
    b. Chert arrowhead point.
    c. Evidence suggesting the shaft of the arrow was broken off at some point.
    d. Arrowhead pierced the entire bone and must have been shot at force and from somewhere in the persons immediate vicinity.
    e. The arrowhead was fired from either behind this person or somewhere to their right.
    f. There is no evidence of infection or remodelling of the bone suggesting that the person died soon after the incident.

Pollen analysis is the study of fossil pollen and spores; and is one of the key methods for the reconstruction of past vegetation and environments. Microscopes are used to analyse the range of plant pollens present in archaeological layers: these can tell us what crops, vegetation or ground cover were likely to have been present when a layer was deposited. It is from pollen analysis, for example, that we can tell when the first people arrived in Ireland it was covered by a canopy of trees through-out. Willow was the first important producer of pollen along with juniper before these were quickly shaded out by the expansion of birch woods.

DNA Analysis or profiling (also known as DNA fingerprinting) is the process of establishing an individual's DNA characteristics, which are as unique as fingerprints. Archaeogenetics is the study of ancient DNA using various molecular genetic methods and DNA resources. This form of genetic analysis can be applied to human, animal, and plant specimens. Ancient DNA can be extracted from various fossilized specimens including bones, eggshells, and artificially preserved tissues in human and animal specimens. In plants, Ancient DNA can be extracted from seeds, tissue, and in some cases, faeces. Archaeogenetics provides us with genetic evidence of ancient population group migrations, domestication events, and plant and animal evolution.



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Seriation is a relative dating method. An example of a practical application of seriation, is the comparison of the known style of artefacts such as stone tools or pottery. When artefacts are found they are cleaned, catalogued and compared to published collections. This comparison process often involves classifying them “typologically” (according to their physical characteristics) and identifying other sites with similar artefact assemblages.

Stratigraphic relationships. The stratigraphy of an archaeological site can be used to date, or refine the date, of particular activities ("contexts") on that site. For example, if a context is sealed between two other contexts of known date, it can be inferred that the middle context must date to between those dates.

Microscopic use-wear analysis. Microscopic use-wear attempts to functionally analyse tools by observing utilised edges under magnification. It can be an effective and reliable means of determining tool function, particularly with regards to tool action and contact material (e.g., wood, leather, antler).

Provenance analysis has the potential to determine the original source of the materials used to make a particular artefact. This can show how far the artefact, or components of it, have travelled and can indicate the existence of systems of exchange.