• chronometry =
• relative v. absolute time
• relative dating
  – stratigraphy & law of superposition
  – cross-dating
• absolute dating
  – units & age range
  – accuracy, precision, resolution…
  – calendrics =
  – radiometric techniques
  – radioactivity & half life
  – radiocarbon ($^{14}$C)
• materials dated =
• atmospheric eq =
  – Potassium-Argon
• materials dated =
  – “dating gap”
  – Luminescence methods
  – Paleomagnetism
• direct v. indirect dates
• association
• practicalities
  – time & money

• Impossible to understand processes (causes and consequences) of change if we cannot control TIME
  – evolution & adaptation always a function of time

• chronometry = the measurement of time...

• relative time =
  – only able to say that something is older than or younger than (or the same age) as something else

• absolute time =
  – able to assign a unit of measurement to age of something
  – allows one to state how much older or younger something is compared with something else

• time & perspectives on adaptation...
  – relative = change has occurred & direction
  – absolute = & rate at which change occurred
  – radiocarbon ($^{14}$C)
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- Stratigraphy/Stratification = a sequence of stratigraphic layers whose order from bottom to top reflects the law of superposition
- stratum (pl. strata) = a layer of sediments (internally homogeneous) which may or may not contain archaeological materials

- Law of Superposition = the order of strata from bottom to top represents the temporal order of their deposition from oldest to youngest

  'Layer-cake' stratigraphy
  (reality is much more complex)

Complex Archaeological Stratigraphy (rule rather than exception)

- crossdating (aka sequence comparison)
- age assignment for an artifact, feature or site based on comparisons with a sequence of known relative or absolute age
- assumes that location being dated is related to the master sequence in some way (e.g., through trade or population movement)
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absolute (chronometric) dating

• Time is divided into arbitrary, but measurable units
  • BP = “before present” (by convention 1950)
  • BC = “before Christ”
  • BCE = “before the common era” (same as BC)
  • ka = (kilo annum) 1000 years
  • mya = millions of years ago

key concepts in absolute dating

• age range = the time range over which a particular dating technique works (e.g., \(^{14}\text{C}\) age range = ~50 ka to present)

• accuracy = is a measure of systematic error and refers to the “closeness” of a chronometric estimate to the true value

[Diagrams showing high, moderate, and low accuracy]
key concepts in absolute dating

- precision = is a measure of random error and refers to how often you arrive at the same answer for repeated dates

- Resolution = shortest unit interval of time by which two “things” can be distinguished

- My grandfather is an octogenarian and my grandmother is also an octogenarian. Who is older?
  – octogenarian = 80, 81 … 89 years old
  – decadal resolution...

key concepts in absolute dating

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 calendrics = relies dates inscribed on objects
  – e.g. Roman coins, Egyptian hieroglyphs, Mayan stelae, textual sources.
 only useful in literate times (last 5000 years), usually complex societies
 to be used successfully, one must…
  – understand the date, literally
  – understand what it dates. What is the literary context?
  – be able to translate it to a meaningful date referable to our time system.

radiometric techniques

  – based on systematic decay of unstable isotopes of common chemical elements into more stable isotopes
    – $^{14}$C, $^{40}$K, $^{235}$U, $^{238}$U
  – radioactive isotopes decay with a characteristic “half-life”
    – half-life = the amount of time it takes for ½ of the radioactive isotopes originally present to decay

Radioactive decay and half life

How does it work as a dating technique?

radiocarbon dating

  – $^{14}$C produced in upper atmosphere in bombardment of $^{14}$N with cosmic and solar radiation
    – $^{14}$N + n $\rightarrow$ $^{14}$C + $^1$H
  – radiocarbon oxidized to CO$_2$ and mixed quickly in atmosphere and oceans
  – all organic life builds $^{14}$C into makeup, ultimately via photosynthesis
• $^{14}$C half-life = 5730 years
  - $^{14}$C $\rightarrow$ $\beta + ^{14}$N
• all life in equilibrium with atmospheric $^{14}$C
  - all living organisms contain the same amount of $^{14}$C in them as the atmosphere
  - amount of $^{14}$C entering through photosynthesis or ingestion equals amount leaving the organism through decay
  - total amount does not change until…

• when organism dies it stops taking up $^{14}$C
• $^{14}$C present begins to decline through decay
• decay continues until no $^{14}$C remaining
• maximum age range of $^{14}$C dating determined by the minimum amount of radioactive isotope that can be measured
  – at approximately 9 half-lives (51,570 years) too little remains to be measured

• any organic material (and a few inorganic materials that incorporate organic carbon) can be dated using the radiocarbon method
  – wood, charcoal, bone, pollen, soils…
• critical assumption is that the amount of radiocarbon produced in the upper atmosphere has remained constant over time
  – It has not!!!
  – variability in solar radiation = variability in production rates

How is the $^{14}$C Clock Set?

Production

Living organism

Decay
40K-40Ar Dating

- only viable radiometric technique for dating very old archaeological materials
- based on the fact that the radioactive isotope 40K decays to the gas 40Ar
- comparing the proportion of 40Ar to 40K in a sample of volcanic rock, and knowing the decay rate of 40K, the date that the rock formed can be determined

K is one of the most abundant elements on Earth (2.4% by mass)
- one out of every 100 K atoms is radioactive 40K (19 protons and 21 neutrons)
- 40K half-life = 1.31 billion years
  - starting with 100 atoms of 40K...
  - only 11.2% of 40K atoms decay to 40Ar (89.8% to 40Ca)
    - starting with 0 atoms of 40Ar, you have 5.6 atoms after 1.31 billion years, 8.4 atoms after 2.62 billion years, 9.8 atoms after...

How is the 40K-40Ar Clock Set?

- When rocks are heated to melting point, any 40Ar is released into atmosphere
- When rock recrystallizes it becomes impermeable to gases again
  - 40Ar = 0 at t = 0
- As the 40K in the rock decays into 40Ar, the 40Ar gas is trapped in the rock

Limitations to K-Ar & the dating gap

- at 100 ka, only 0.0053% of the 40K in a rock would have decayed to 40Ar
  - dating range for K-Ar = >4.5 billion years to ~100 ka
- the dating gap
  - K-Ar and 14C do not work in the interval between ~100ka and 50ka
  - luminescence techniques partially fill this gap
Paleomagnetic stratigraphy
- Earth’s poles decompose and reemerge in opposite positions
  - Normal Polarity = like today
  - Reversed Polarity =
- happens every ~200ka
  - Brunhes/Matuyama Boundary 730 ka
- occurs rapidly; 1000 years (?)
- reversals distributed irregularly in time (cross dating)
- measure orientation of iron minerals in sediment samples
  - heated sediment or time to organize

Global paleomagnetic sequence is known
stratigraphic sequence of samples at a site may show the known unique pattern of reversals
samples compared with master sequence using what dating technique?

direct and indirect dating

- direct dating = determination of the age of a physical remain by direct analysis

- indirect dating = determination of the age of a physical remain using its association with objects or strata of known age

14C date on fossil?
K-Ar date on basalt stone tool?
association = occurrence of an object in archaeological context adjacent to another item in or on the same sedimentary matrix

2002 ???

does date on one reflect the true age of the other?