Tracing lost narratives:

unlocking secrets through isotope analysis of ashes

A human being

This metaphysical question of identity is one we've all asked ourselves at some point in our lives

Obviously, today we won't delve into the countless layers of responses that exist for this question.

Considering my slight bias, I will narrow down my focus to specific aspects.

Who are you

According to nutritionists

“You are what you eat”

Lindlahr, nutritionist, *The Bridgeport Telegraph*, 1923

As per nutritionists, there is a correlation between your nutrition and your state of health

According to biologists

“You are what you eat”

As per biologists, there is a correlation between the nutrients you ingest and your metabolism

Macronutrients VS **Micronutrients**

Macronutrients:

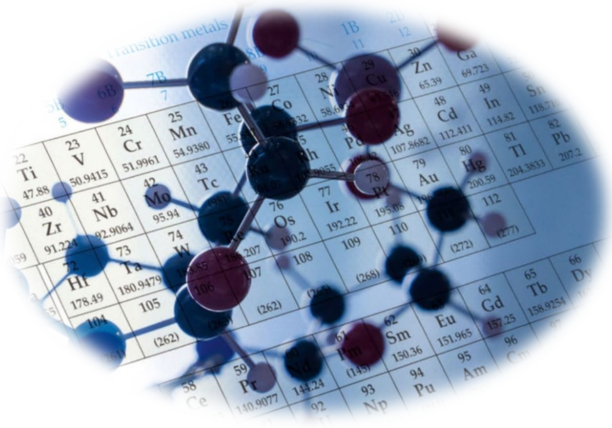
Energy {
- Carbohydrates
- Proteins
- Fats
- Alcohol
}
- Water
- Fiber

Micronutrients:

- Dietary minerals
- Vitamins

According to chemists

“You are what you eat (plus a few per ‰):
the carbon isotope cycle in food chains.”



DeNiro M.J. and Epstein S. (1976)
Geological Society of America Abstracts with Programs 8: 834-835.

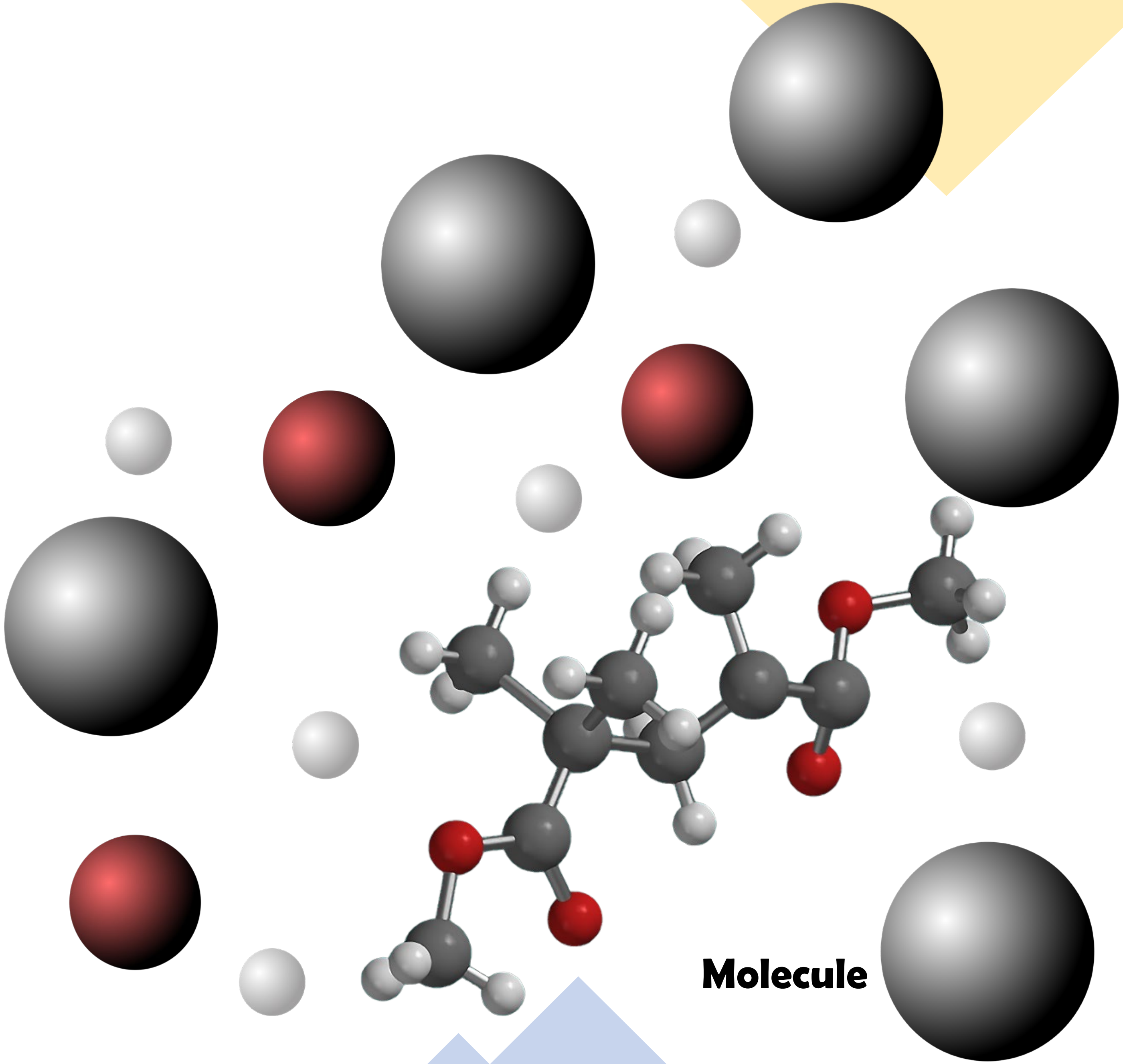
As per chemists, there is a correlation between your diet and the isotopic composition in your body → **But wait, what’s an isotope?**

Basics of chemistry:

a reminder

What's an atom?

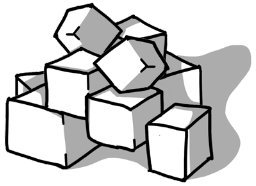
Atoms are the fundamental building blocks of chemistry



What's an atom?

Just like baked goods are made of a collection of different types of ingredients

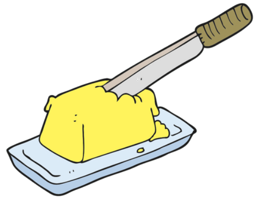
Flour



Sugar

Chocolate chips

Baking soda

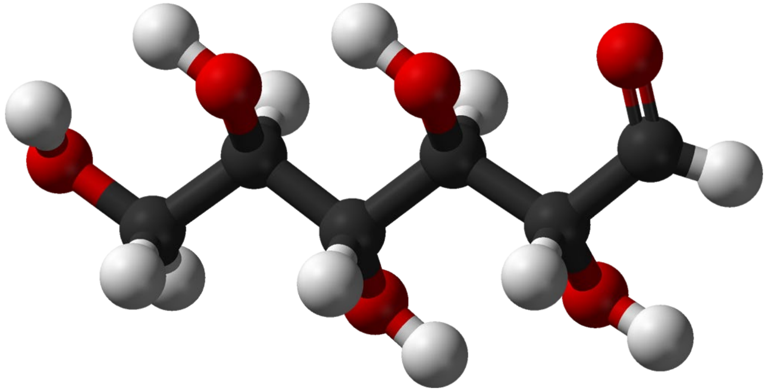


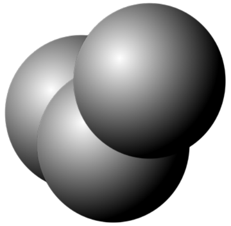
Butter

What's an atom?

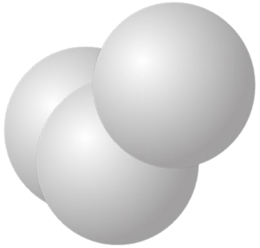
Matter itself is made of a collection of different types of atoms

Glucose molecule – $C_6H_{12}O_6$

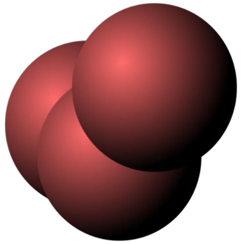




Carbon atoms



Hydrogen atoms

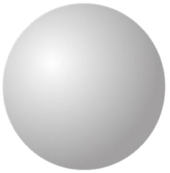


Oxygen atoms

What's an atom?

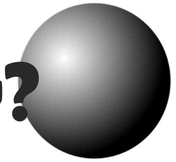
Fact: Only 94 occur naturally on Earth

Elements have very different properties. They don't look or act the same



Hydrogen atoms

Why?

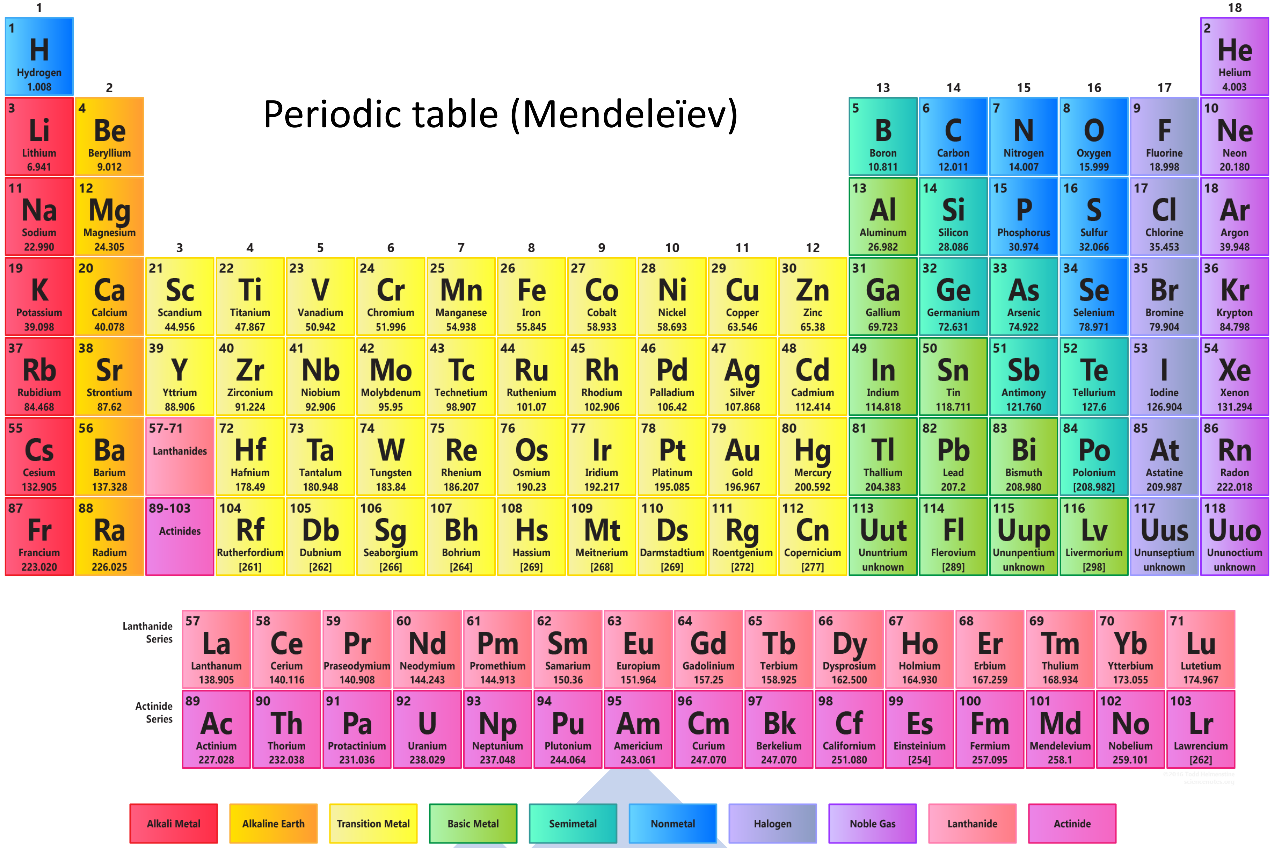


Carbon atoms

It comes down to what is inside their atoms

Oxygen atoms

118 kinds of atoms which we call elements



What's an atom?

$$^{A}_{Z}X$$

Mass number

- Symbol A
- Total number of nucleons in an atomic nucleus
- Protons + neutrons

Atomic number

- Symbol Z
- Charge number of an atomic nucleus
- Number of protons
- Define a chemical element

Number of neutrons

- Sometimes symbol N
- N = A – Z

Number of electrons

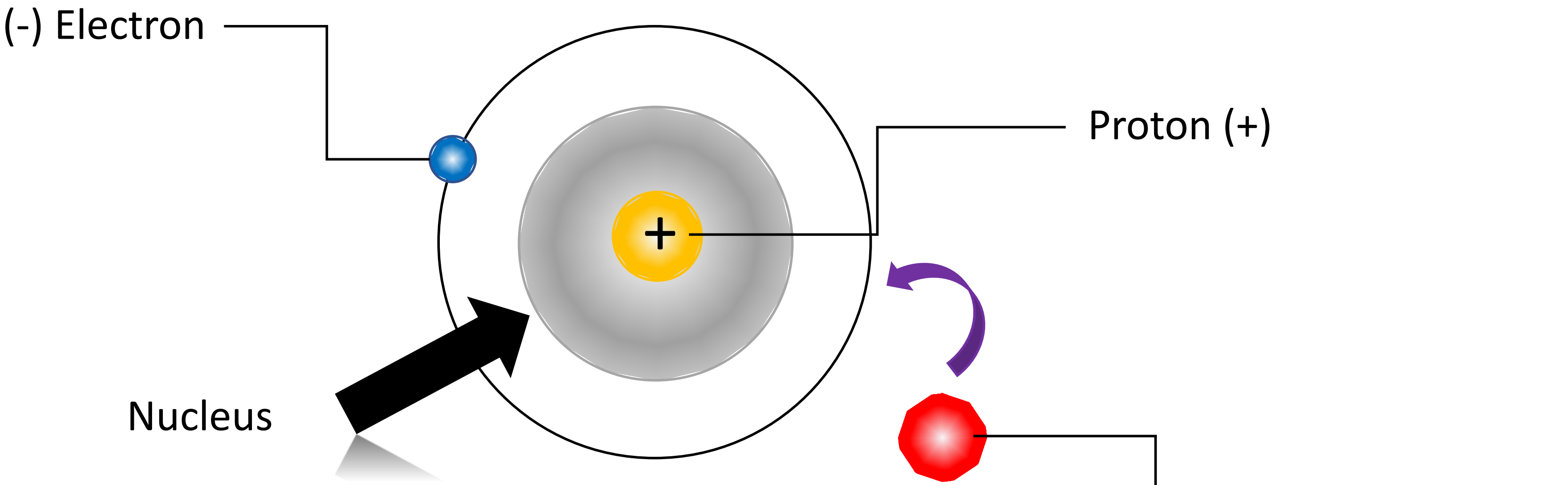
- Equal to the number of protons
- Determine the chemical properties of an element

N
Sr
H
O
C
S

What's inside an atom?

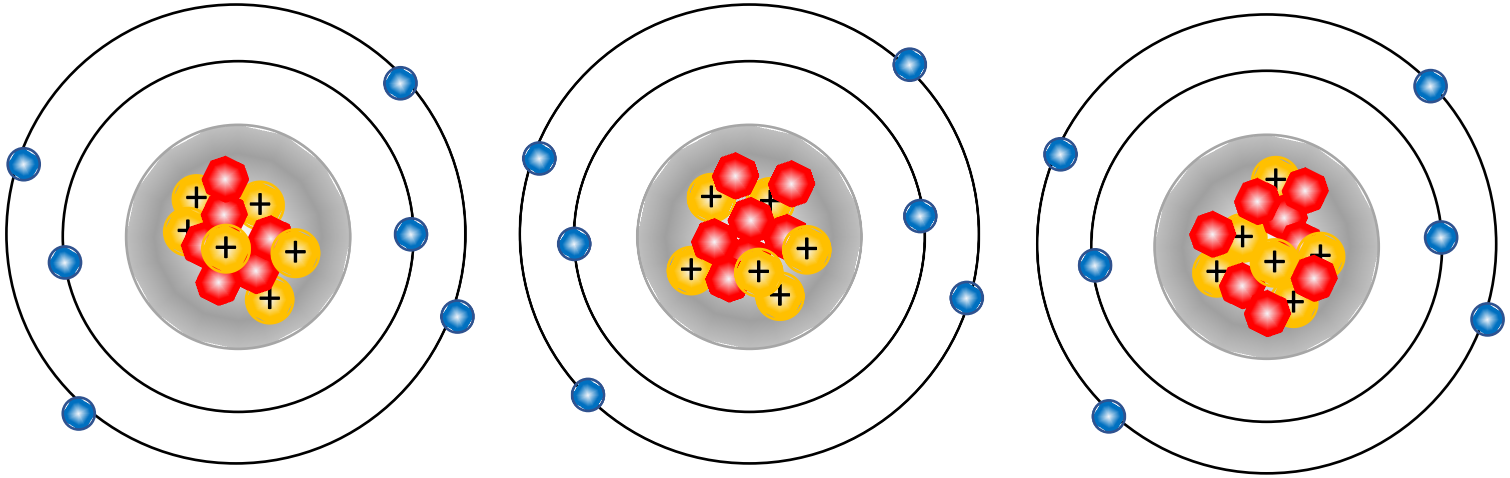
Particle	Symbol	Electric charge	Mass
Proton	p	$1,602*10^{-19}$	$1,6726*10^{-27}$
Neutron	n	0	$1,6749*10^{-27}$
Électron	e^-	$-1,602*10^{-19}$	$9,1094*10^{-31}$

Let's take the theoretical example



What's inside an atom?

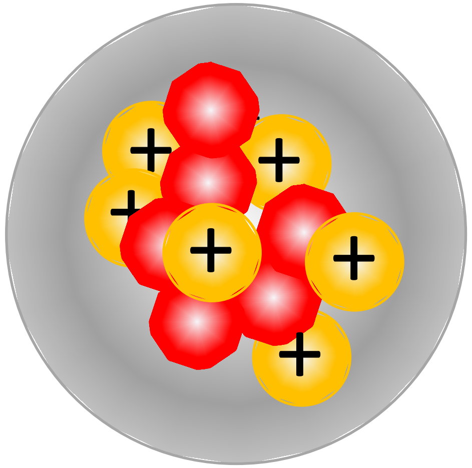
Take a look!



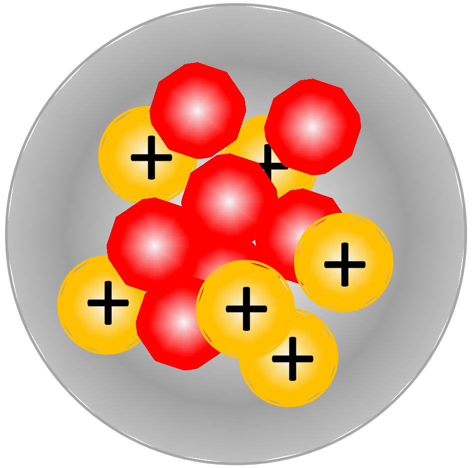
What is different?

What's inside an atom?

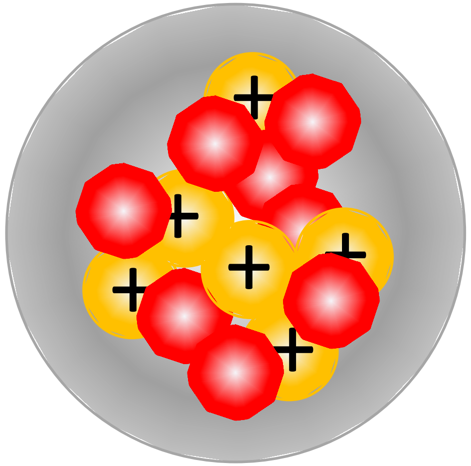
Number of neutrons in atoms of the same element can vary



Protons = 6
Neutrons = 6



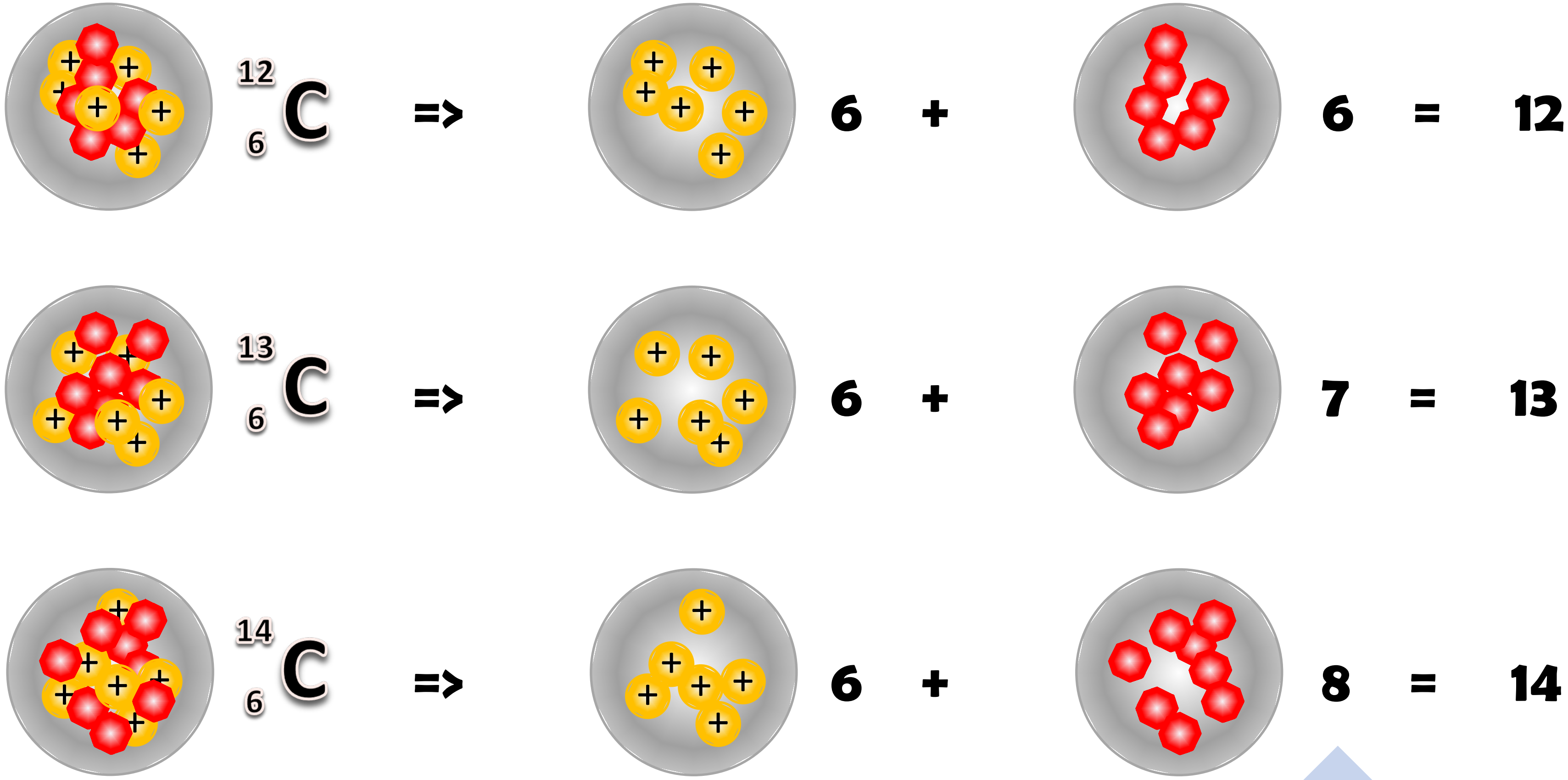
Protons = 6
Neutrons = 7



Protons = 6
Neutrons = 8

What’s inside an atom?

Mass number = Number of protons + Number of neutrons



What’s an isotope?

$${}^{12}_{6}C \qquad {}^{13}_{6}C \qquad {}^{14}_{6}C$$

Isotopes:

Atoms of the same elements with the same atomic numbers but different mass numbers

Same chemical properties (number of electrons) but different physical properties (number of neutrons; mass)

Here we are!

What's an isotope?

Isotopic ratio

- Notion δ
- Variation of a heavy isotope from a light isotope
- Expressed according to a standard
- There are some exception (e.g. Sr)

$$\delta^1X(‰) = \left\{\frac{{}^1X/{}^2X_{échantillon}}{{}^1X/{}^2X_{standard}} - 1\right\} \times 10^3$$

$^{87}Sr/^{86}Sr$

$\delta^{34}S$

$\delta^{15}N$

$\delta^{13}C$

$\delta^{18}O$

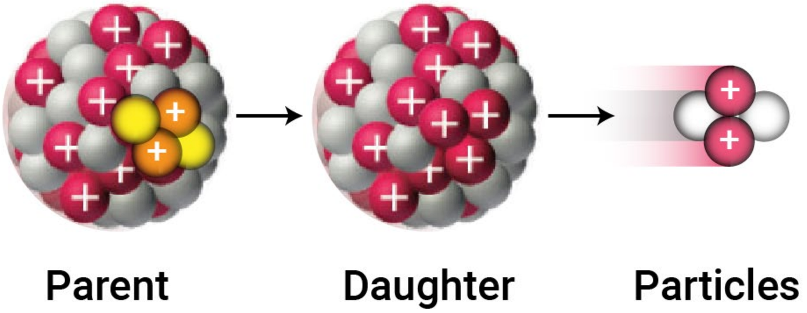
What's an isotope?

Fact: all the elements with an atomic number greater than 82 have only unstable isotopes.

If an isotope is **stable**, it will stay as it is.
There is no reason to change!

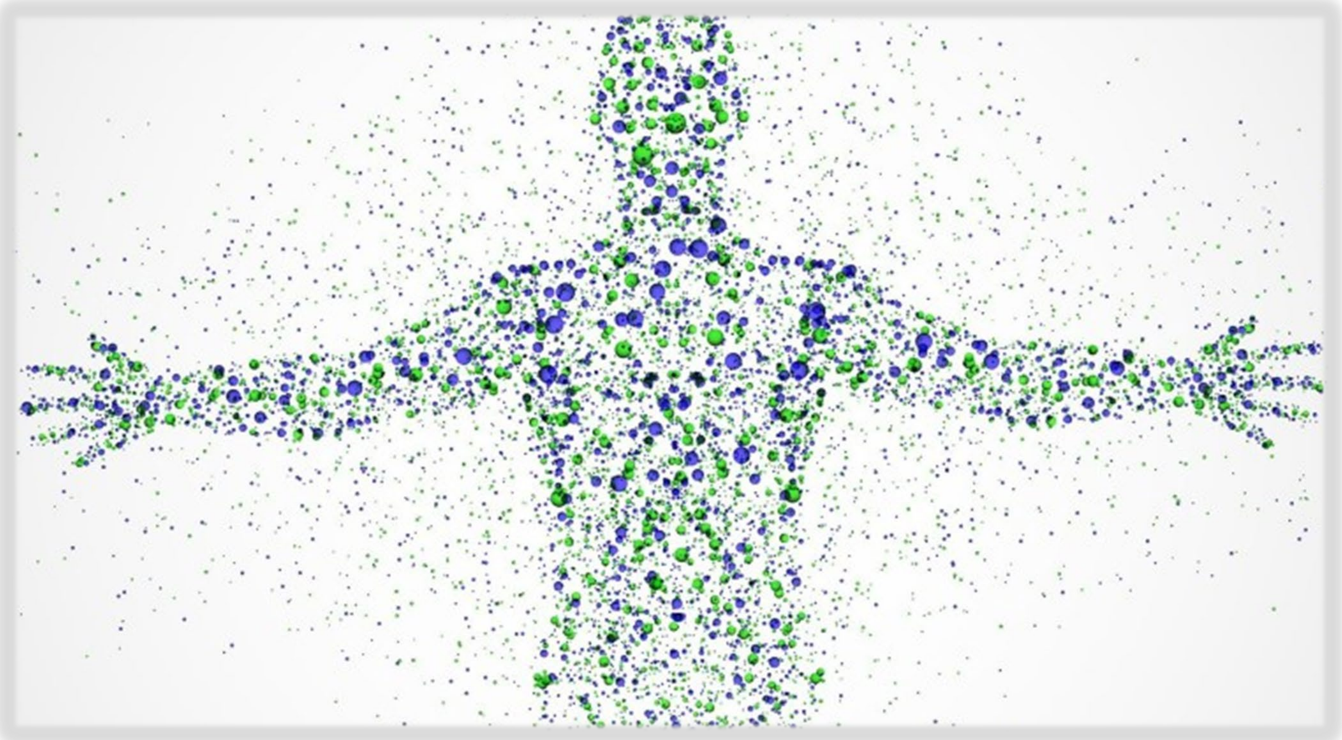
If an isotope is **unstable**, it will undergo a nuclear reaction in order to become stable.

Unstable isotopes **emit energy** in the form of a radiation when they break down (decay).



What's in your body?

Lots of atoms, in almost every possible form.



All deriving from your diet

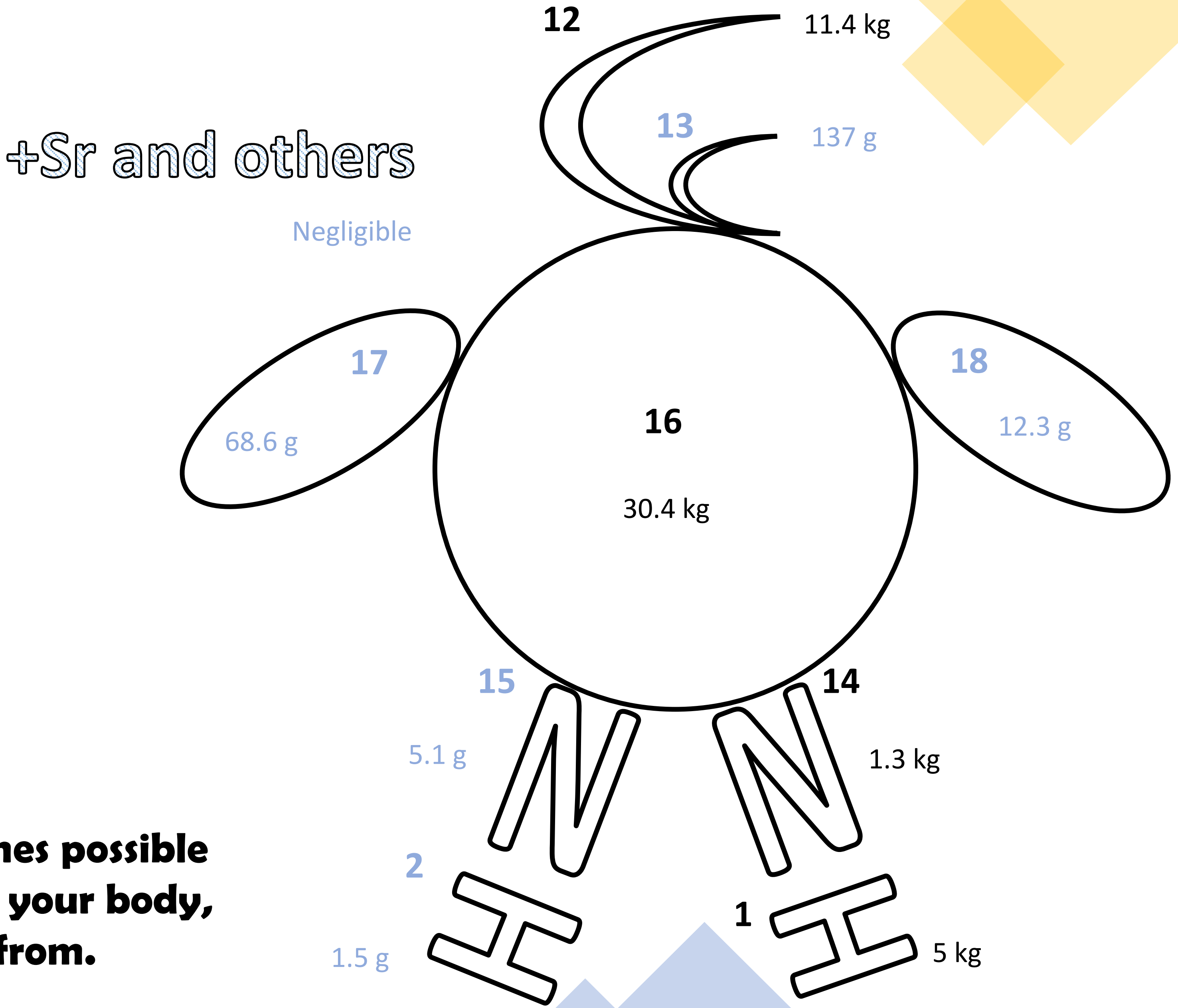
What's in your body?

Mister CHON :

Body mass: 50 kg

Heavy isotopes: 225 g

Simple, isn't it?



Through isotope analyses, it becomes possible to unveil the substances that enter your body, and where they are coming from.

What's in your body?

Social status
Dietary habits
Breastfeeding patterns

Cultural specificities
Regional diversity
Population particularities

DIET

Mortuary practices
Demography
Spatial organization

Migration
Population dynamics
Mobility

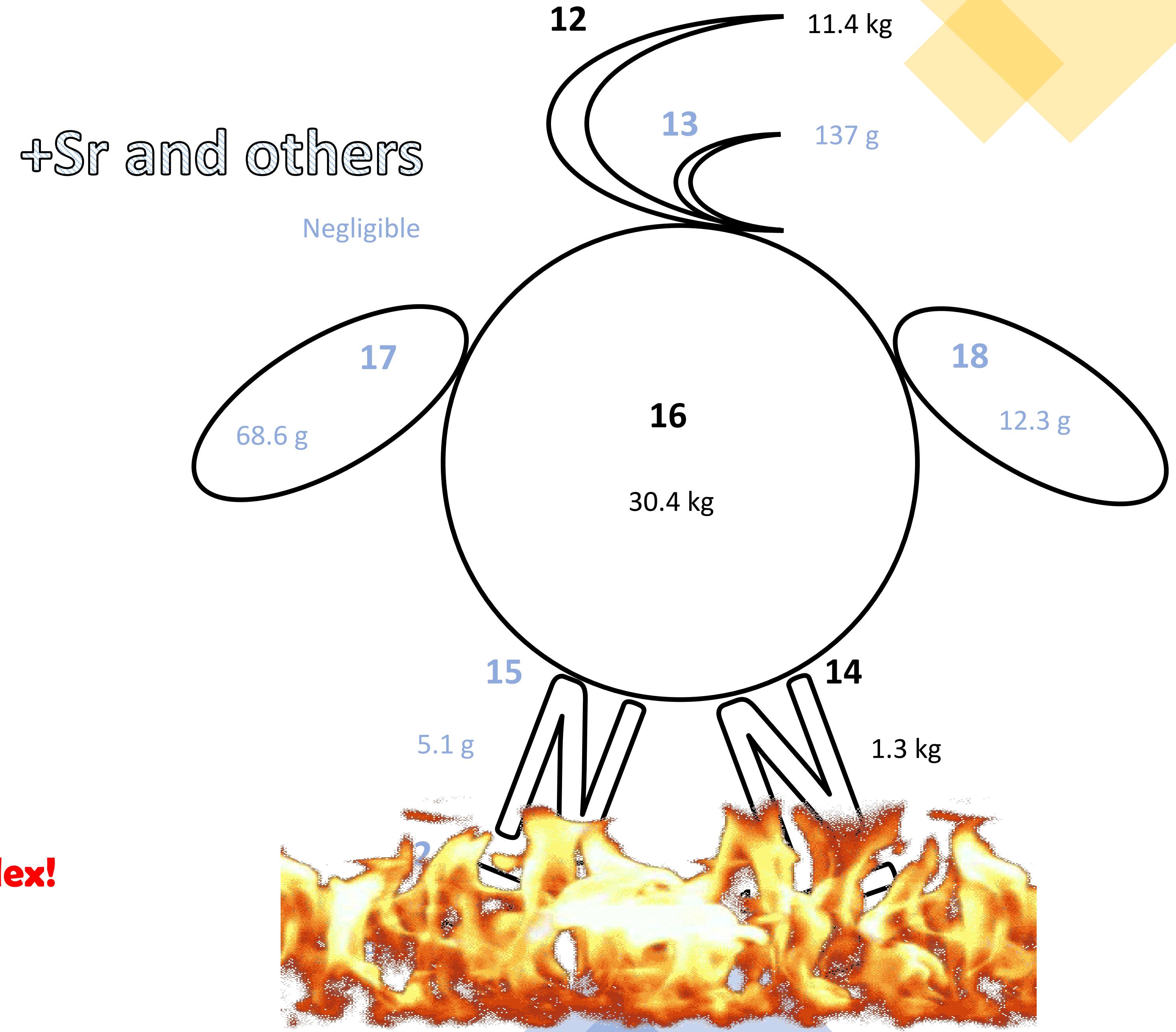
+Drinks

What's in your body?

Mister CHON :

Body mass: 50 kg

Heavy isotopes: 225 g



But what's happen when the body is set on fire?

Well, things begin to get complex!

Basics in bioanthropology:

Very basic!

The skeleton: An archive

Human remains

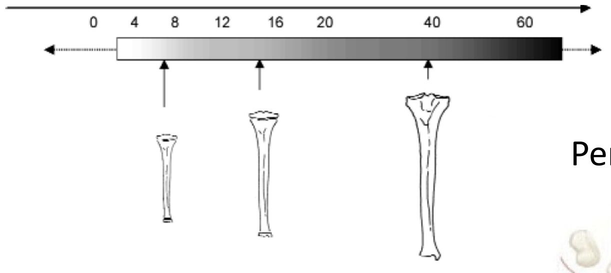
Time capsules

Diachronic investigation at the level of the individuals

Signal recording

Growth

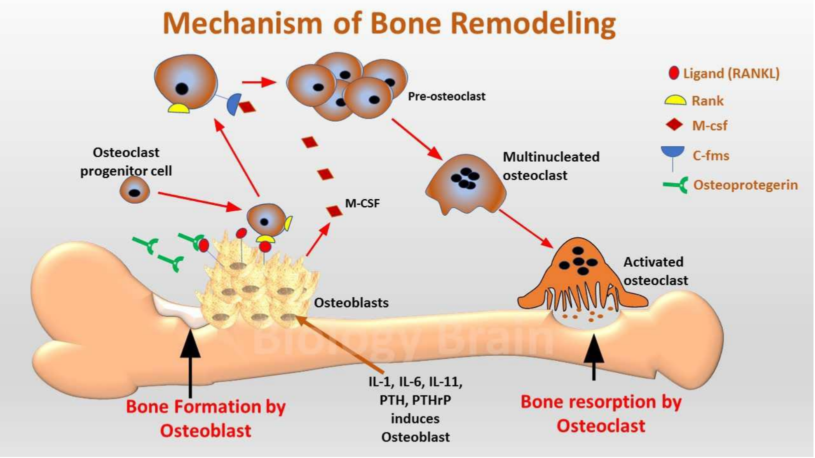
1st years of life



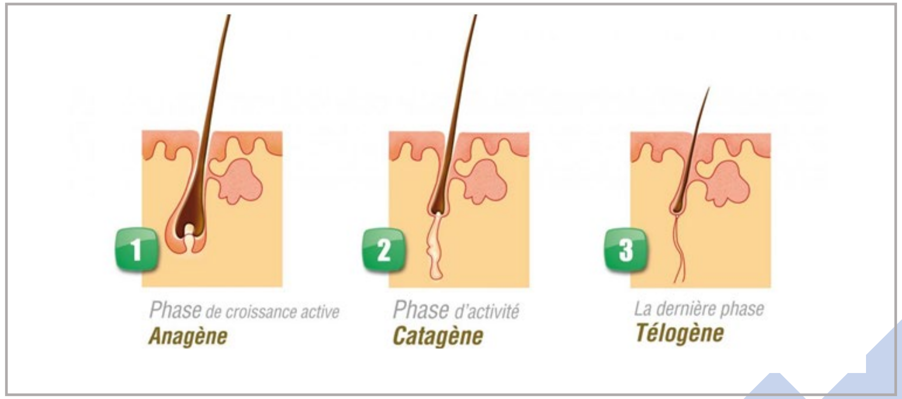
Permanent dentition

Mixed dentition

Turnover



Last years of life



Specific case: last months of life

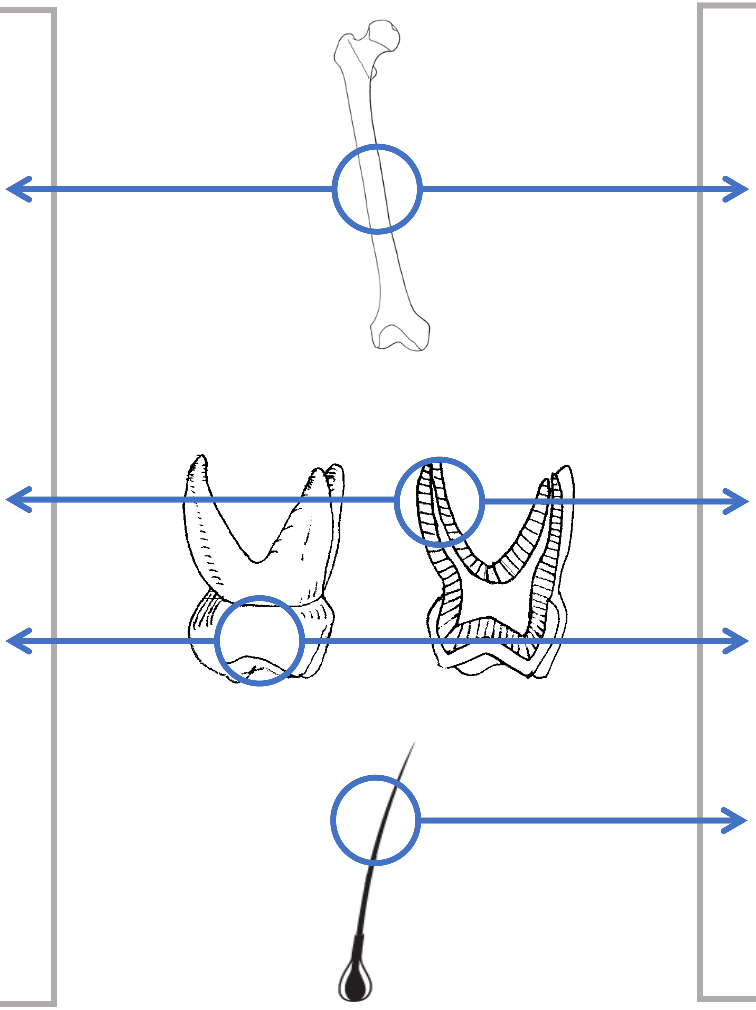
Tissue composition

Mineral fraction

Bone
70% carbonated
hydroxyapatite

Dentine
70 % carbonated
hydroxyapatite

Enamel
97% carbonated
hydroxyapatite



Organic fraction

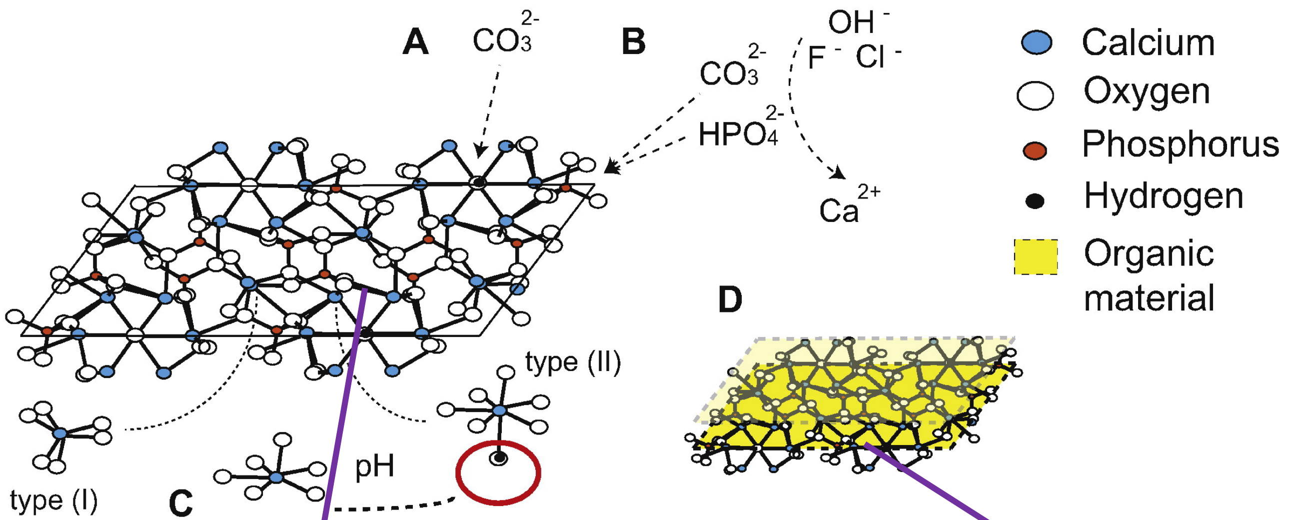
Bone
30% : collagen
& other proteins

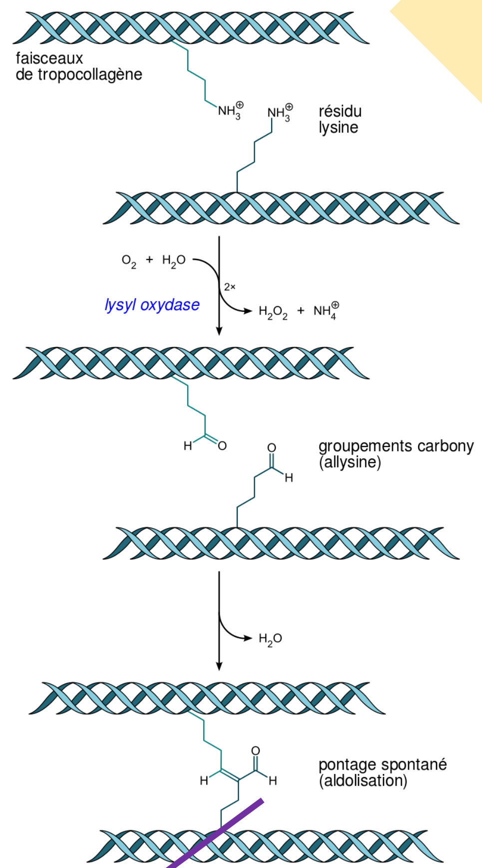
Dentine
30% : collagen
& other proteins

Enamel
3% :
Enamelin, amelogenin

Hair, nails
100% keratin

Structures



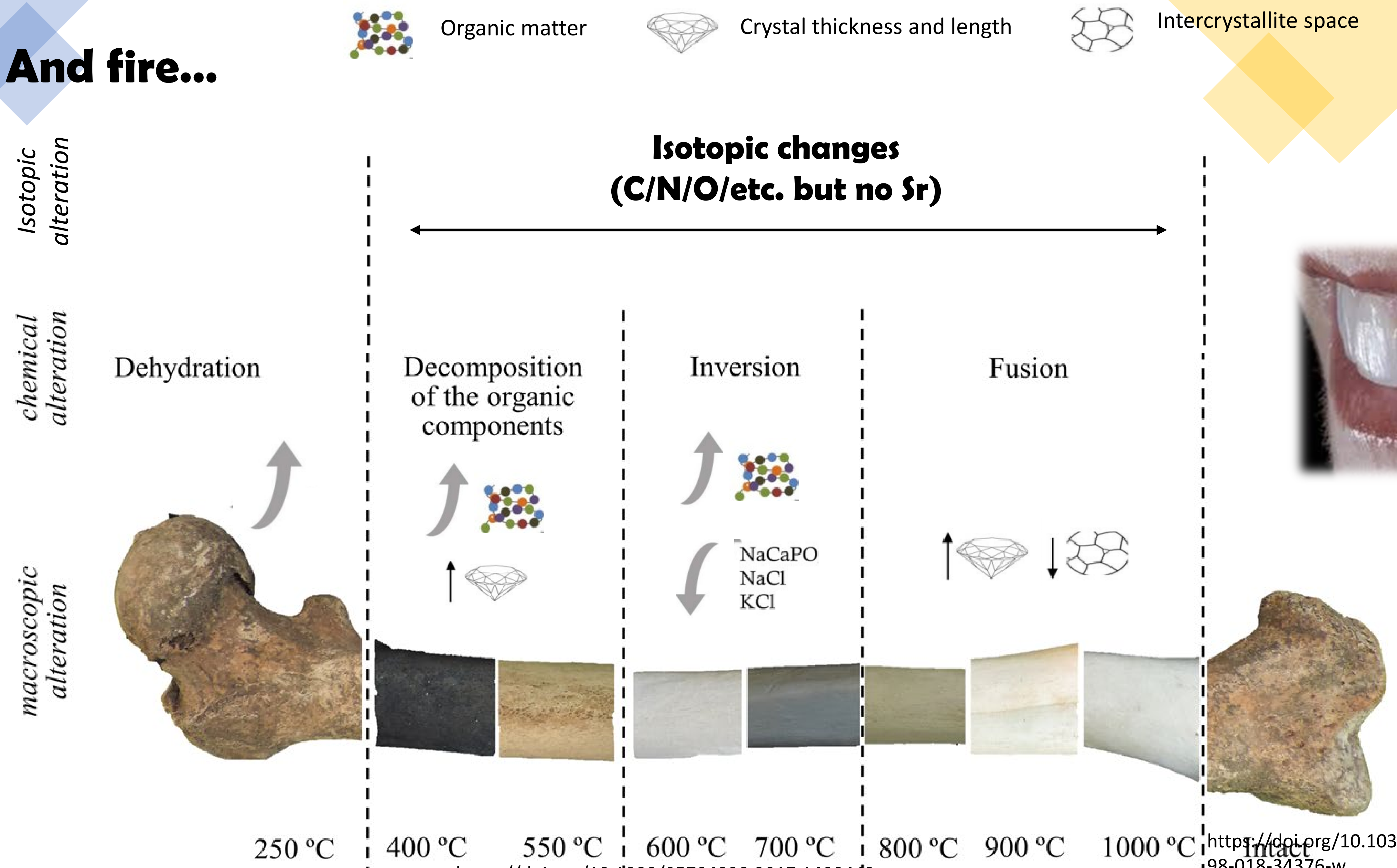


Bioapatite:

$$(Ca, Na, Mg, Ba, Sr, Zn, Pb, [\,])_{10}$$
$$(PO_4, HPO_4, CO_3, SO_4)_6$$
$$(OH, F, Cl, CO_3, O, H_2O, [\,])_2$$

Collagen:
Rich in C et N

And fire...

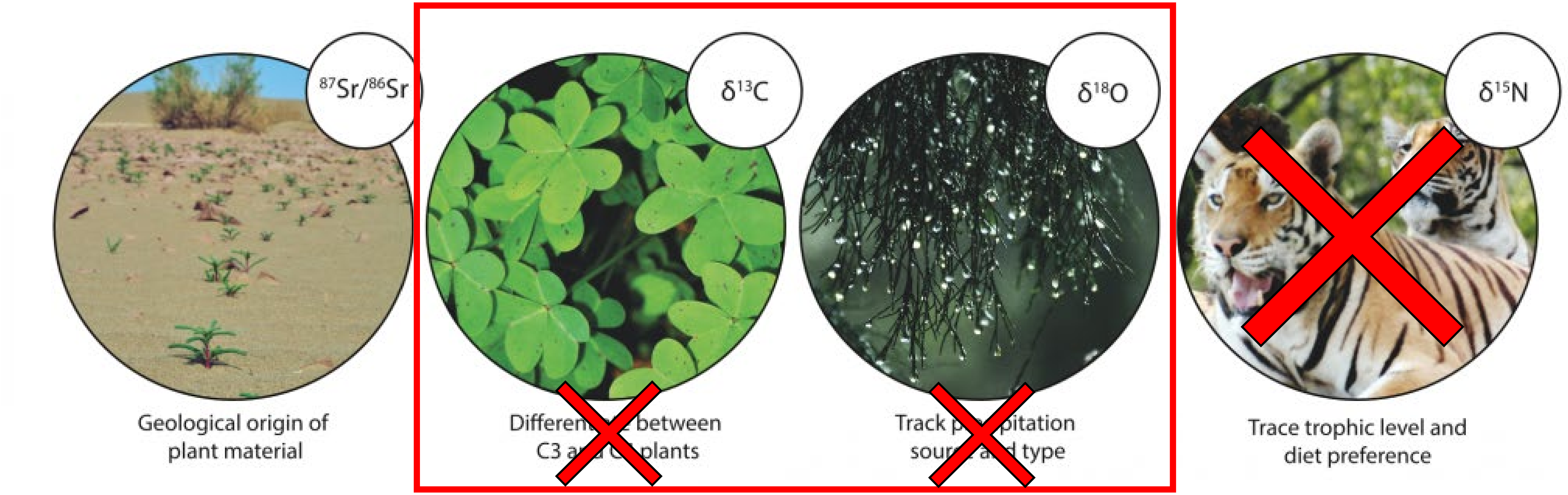


https://doi.org/10.1080/05704928.2017.1400442

https://doi.org/10.1038/s41598-018-34376-w

Why isotopes matter?

Convoluted but promising!



Awesome!

Forget about it!

Strontium:

the unaffected isotope

Not so strong-tium

Strontium (or Sr) has chemical similarity to calcium, which enables the replacement of calcium by strontium in biomineralization processes

About 99% of Sr in the human body is concentrated in the bones

Sr concentrations are relatively low in skeletal tissues (bone and tooth) and are expressed in ppm (parts per million).

Does supplemental strontium strengthen weak bone? The jury is in: and the answer is, it does not!

Strontium salts

What's strontium?

Sr is a soft silver-white yellowish metallic element that is highly chemically reactive.

Let's start with strontium (Sr)!

Natural stable strontium is not hazardous to health.

Because strontium has an electron configuration similar to that of calcium, it readily substitutes for calcium in minerals.

Sr are named after Strontian, a village in Scotland near which the mineral was discovered in 1790 by Adair Crawford and William Cruickshank.

What's strontium?

Sr has four stable, naturally occurring isotopes:

- ^{84}Sr = 0.56%
- ^{86}Sr = 9.87%
- ^{87}Sr = 7.04%
- ^{88}Sr = 82.53%

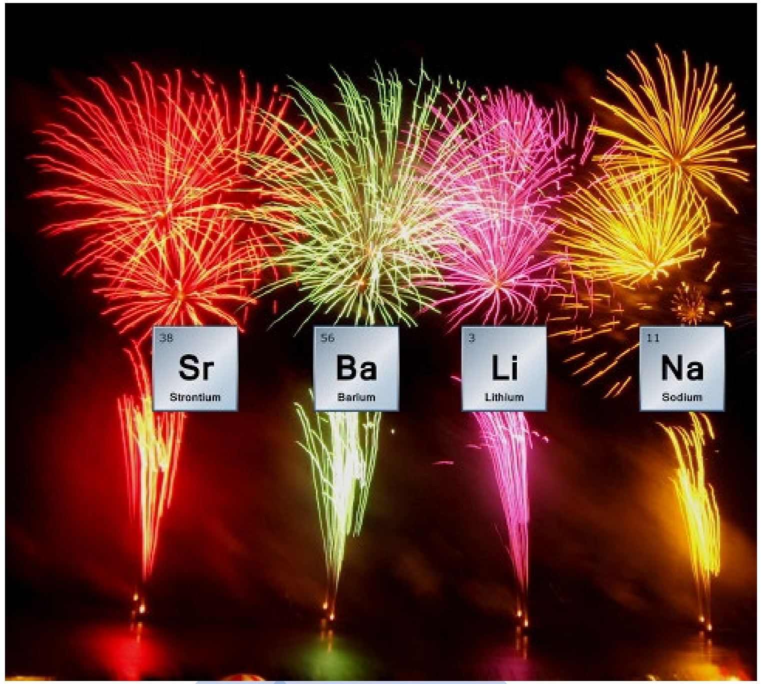
Only ^{87}Sr is radiogenic

A radiogenic nuclide is a nuclide that is produced by a process of radioactive decay. It may itself be radioactive or stable.

^{87}Sr derived from ^{87}Rb, which has a half-life of 4.88×10^{10} years (i.e. more than three times longer than the current age of the universe).

The ratio of ^{87}Sr to the other isotopes is therefore a function of the variable abundance of ^{87}Sr.

How colors in fireworks are produced. Purple = Mixture of Sr and Cu compounds. Red = Sr salts.



What's strontium?

32 unstable isotopes of strontium are known to exist, ranging from ^{73}Sr to ^{108}Sr.

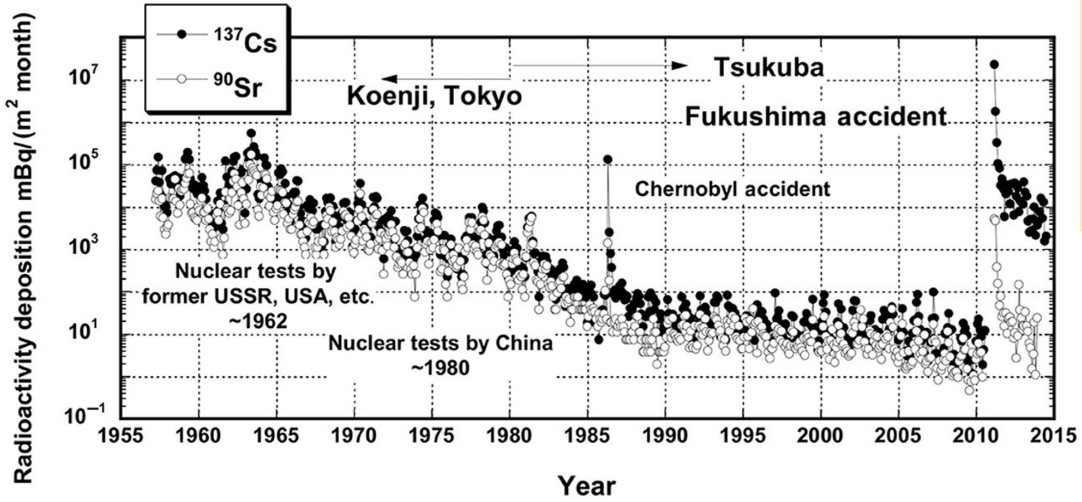
The longest-lived of these isotopes, and the most relevantly studied, are:

- ^{90}Sr with a half-life of 28.9 years,
- ^{85}Sr with a half-life of 64.853 days,
- ^{89}Sr with a half-life of 50.57 days.

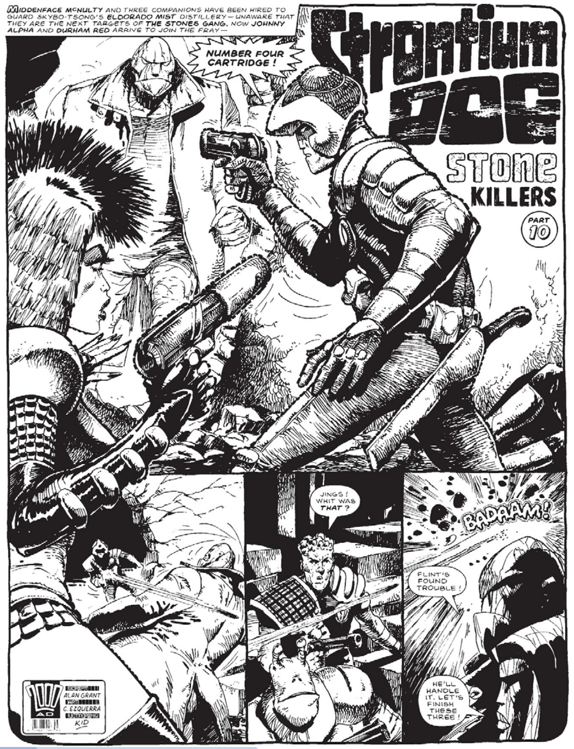
One neutron away:

- **^{89}Sr = used in treatment of bone cancer**
- **^{90}Sr = causes health problems (cancer of bone, marrow, nearby soft tissues and leukemia)**

^{90}Sr is present in dust from nuclear fission after detonation of nuclear weapons or a nuclear power plant accident.



Monthly deposition of ^{90}Sr and ^{137}Cs observed at the MRI, Japan since 1954.
Nakajima et al. 2019, https://doi.org/10.1017/9781108574273



Strontium Dog was a long-running British comics series. Due to nuclear fallout of ^{90}Sr, humanity has an increased number of mutant births, most of whom have physical abnormalities but some of whom possess superhuman abilities.

What's strontium?

Sr is a heavy element with a standard atomic mass of 87.62 u.

^{87}Sr has 49 neutrons.

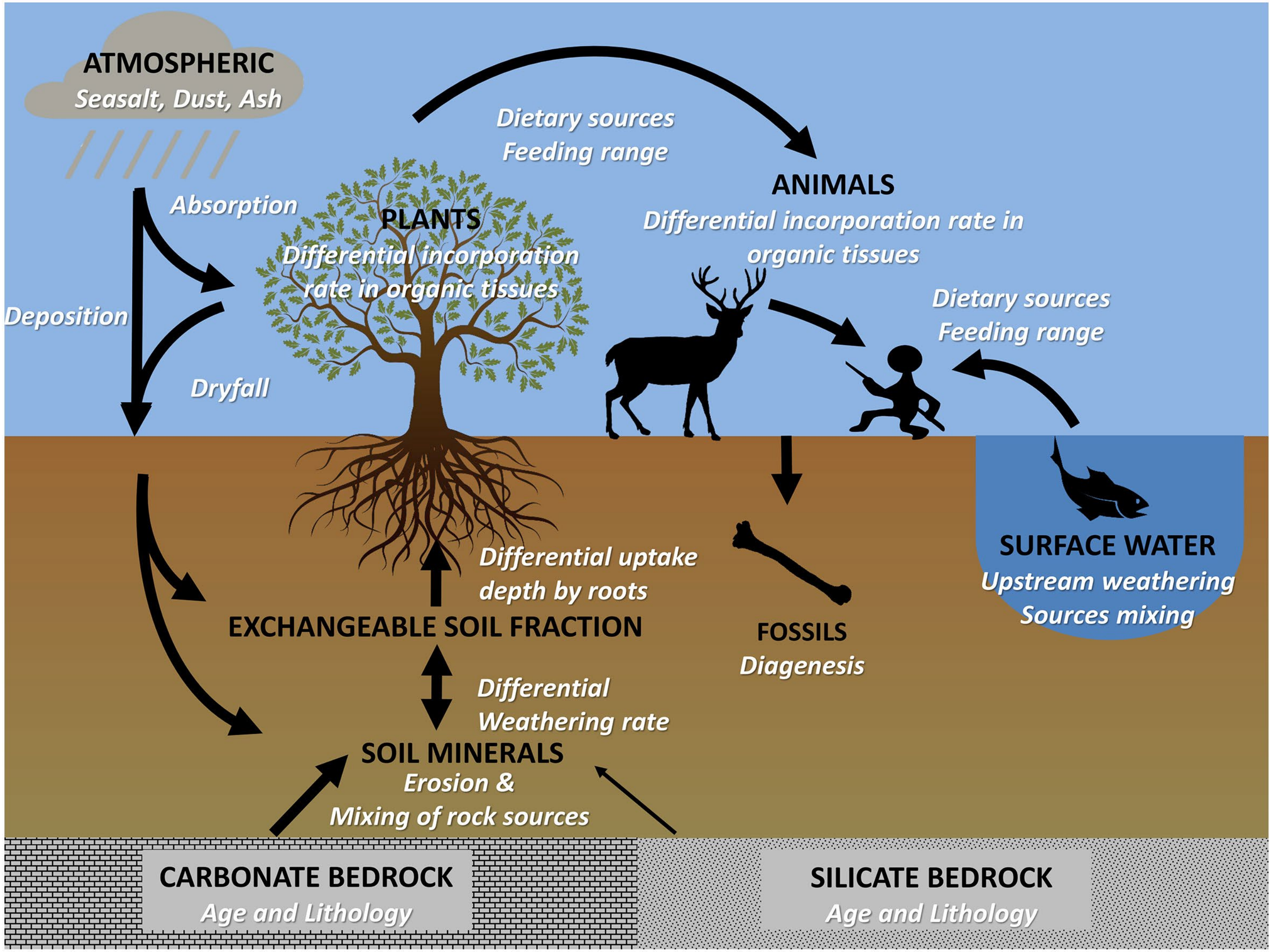
In provenance studies, Sr isotope variations are typically represented using the ratio of ^{87}Sr relative to ^{86}Sr ($^{87}Sr/^{86}Sr$).

Mass differences between Sr isotopes are very small and isotopic fractionations in biochemical reactions are undetected so far.

Strontium is inspiring…

Strontium cycle

Simplified sketch of strontium isotope cycling from rocks to ecosystems.



Capitalized black words correspond to Sr reservoirs and italicized white words correspond to process modifying 87Sr/86Sr. Bataille et al. 2020, https://doi.org/10.1016/j.palaeo.2020.109849.

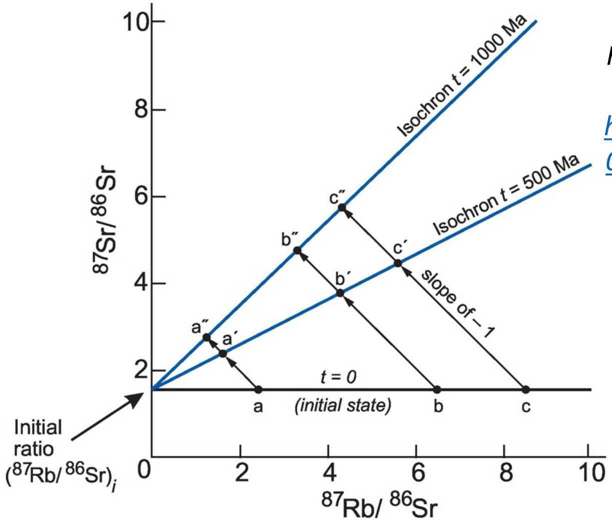
Sr in the geosphere

The $^{87}Sr/^{86}Sr$ in rocks and minerals is:
- mineral-dependent
(initial ^{87}Rb, ^{87}Sr, and ^{86}Sr abundances)
- time-dependent
(radioactive decay of ^{87}Rb to ^{87}Sr).

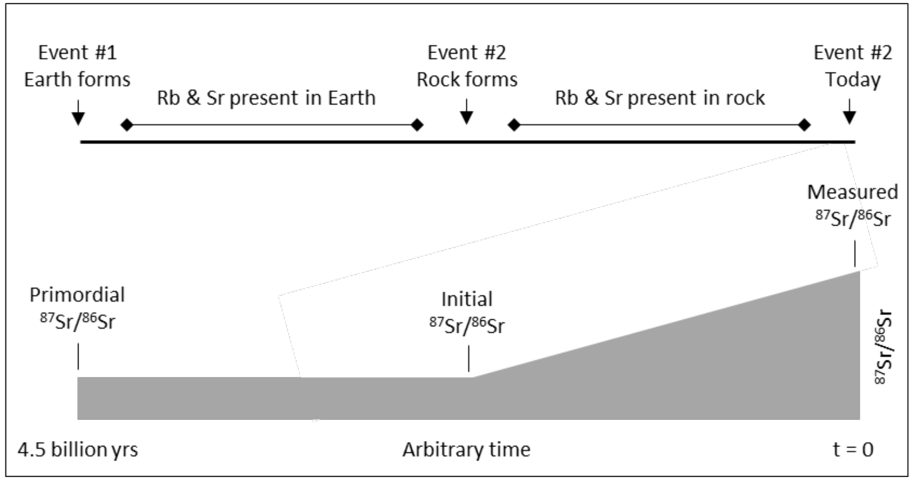
At the time of our planet's formation, the bulk Earth reservoir had a $^{87}Sr/^{86}Sr$ signature of 0.699.

As geochemical differentiation progressed, Sr and Rb concentrated in melts that preferentially contributed to the crusts.

This partitioning resulted in increased $^{87}Rb/^{86}Sr$ in the continental crust relative to the mantle, and over time, this led to differences in $^{87}Sr/^{86}Sr$ among geologic pools with the progressive decay of ^{87}Rb into ^{87}Sr.



Schematic isochron diagram used in Rb-Sr dating methods. Rollinson and Pease 2021, https://doi.org/10.1017/9781108777834.004.



Timeline of a simple event sequence from Earth's origin (event 1) until today (event 3). Event 2 created a new reservoir with higher Rb/Sr, causing $^{87}Sr/^{86}Sr$ to grow more rapidly thereafter until today.
After Long 1998, https://doi.org/10.1007/1-4020-4496-8_279.

Sr in the geosphere

The combined effects of geochemical partitioning of Rb and Sr and radioactive decay explain the large range of $^{87}Sr/^{86}Sr$ in igneous, sedimentary, and metamorphic rocks.

The Acasta Gneiss from Canada is considered as the oldest rock on Earth. It is composed of the Archaean igneous and gneissic cores of ancient mountain chains (4.031 ±0.003 Ga).

With equal initial $^{87}Rb/^{86}Sr$, older igneous rocks have higher $^{87}Sr/^{86}Sr$ than younger rocks because ^{87}Rb has had more time to decay in the older reservoir.

At equal age, more felsic rocks (with higher $^{87}Rb/^{86}Sr$) have higher $^{87}Sr/^{86}Sr$ than mafic rocks (with lower $^{87}Rb/^{86}Sr$) because more ^{87}Rb is available to decay into ^{87}Sr.

A cooled lava flow along the Kanaio coast in Hawaii dated from the 18 c. AD.

Old felsic igneous rock units (e.g., cratonic shields) have the highest measured $^{87}Sr/^{86}Sr$ (>0.720), while newly formed mafic igneous rock units (e.g., basalts, volcanic arcs) have the lowest $^{87}Sr/^{86}Sr$ (c. 0.703).

Sr in the geosphere

Siliciclastic sediments inherit $^{87}Sr/^{86}Sr$ from their parent rocks but are usually composed of a mixture of minerals with distinct parent rock, and thus different isotopic ratios.

Because local bedrock sources dominate the $^{87}Sr/^{86}Sr$, recently deposited siliciclastic sediments from young igneous rocks (e.g., volcanic arcs) tend to have lower $^{87}Sr/^{86}Sr$ than those forming in older felsic environments.

However, it becomes challenging to assess the original parent rock for older sediments due to tectonic and geomorphological evolution of the surface.

Rock formation El Silencio, Spain.

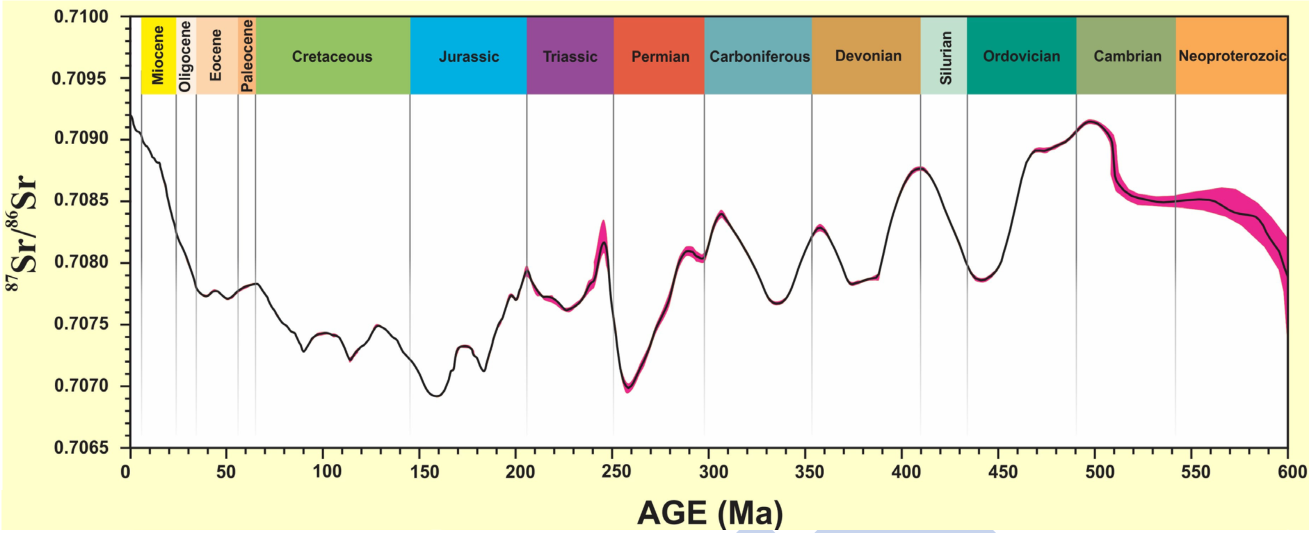
Siliciclastic rocks are clastic non-carbonate sedimentary rocks that are composed primarily of silicate minerals, such as quartz or clay minerals. They include mudrock, sandstone, and conglomerate.

Sr in the geosphere

They have a narrow range in $^{87}Sr/^{86}Sr$ because:

- Seawater $^{87}Sr/^{86}Sr$ has remained within a tight range throughout the Phanerozoic (0.707-0.709)
- Carbonates have small amounts of Rb but large amounts of Sr (Sr readily substitutes for calcium), which means their $^{87}Sr/^{86}Sr$ does not evolve significantly through time.

Carbonate rocks, on the other hand, primarily inherit their $^{87}Sr/^{86}Sr$ from seawater.



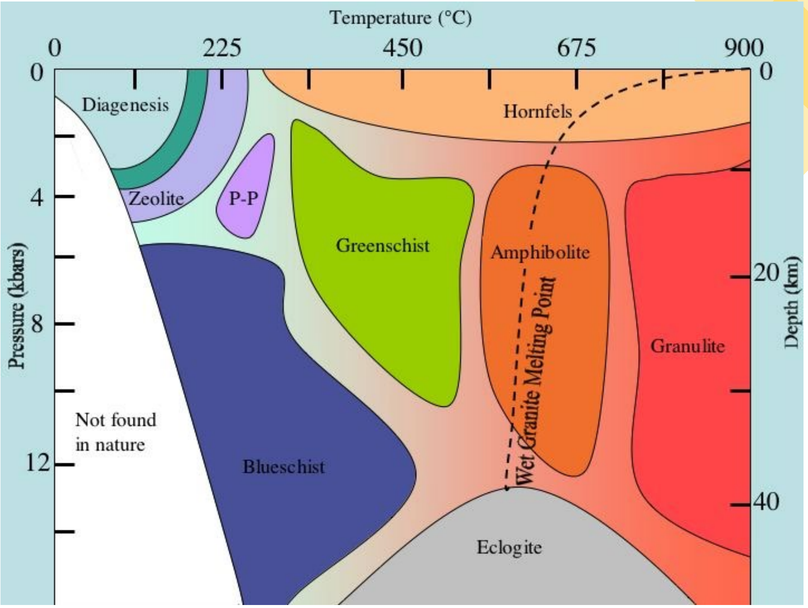
Strontium isotopic ratio of seawater during geological time based on analyses of bulk sediment, unaltered brachiopods, belemnites, conodonts and foraminifera samples from various locations around the world. Red area denotes the 95% confidence interval. Adapted from McArthur et al., 2001.

Sr in the geosphere

Metamorphism is the transformation of existing rock to rock with a different mineral composition or texture. Various forms of metamorphism exist.

Metamorphism can alter the $^{87}Sr/^{86}Sr$ of igneous and sedimentary rock units, which can lead to highly variable $^{87}Sr/^{86}Sr$ in metamorphic rocks.

Ultimately, the combination of igneous, sedimentary and metamorphic processes leads to considerable variability of $^{87}Sr/^{86}Sr$ in the geosphere.



Temperatures and pressures of metamorphic facies

Example of a metamorphic rock.

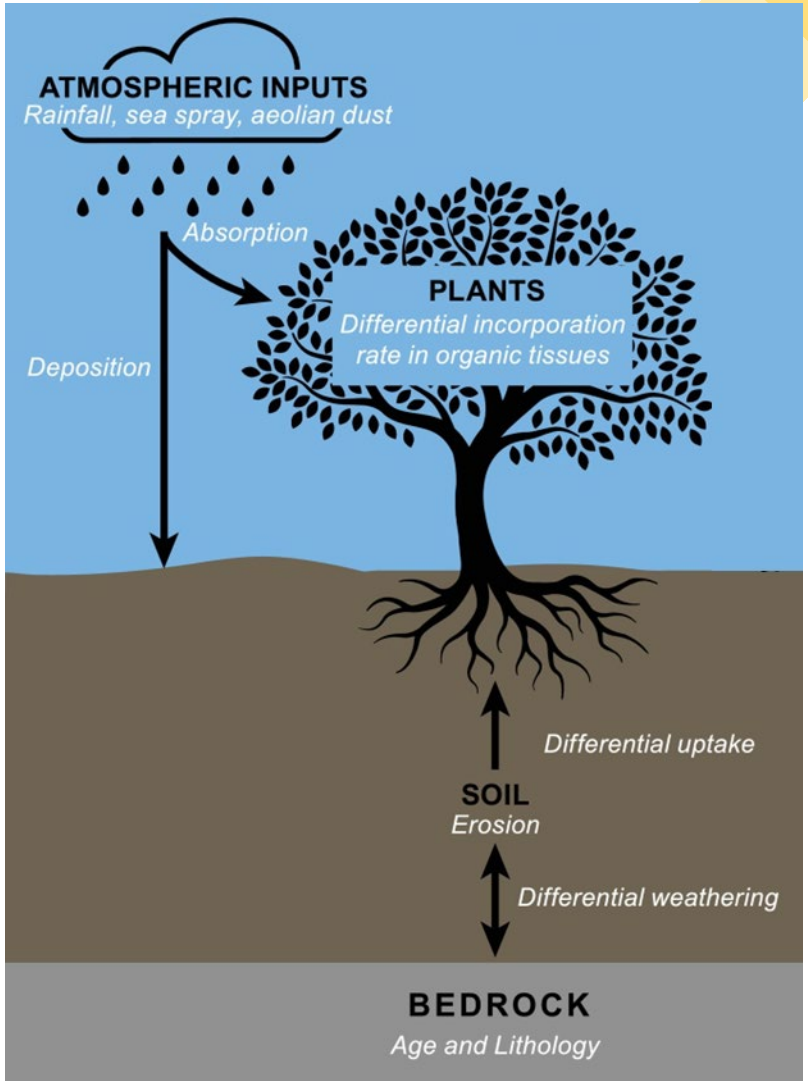
Sr in the geosphere

Soils primarily inherit their $^{87}Sr/^{86}Sr$ composition from parent rock, and consequently $^{87}Sr/^{86}Sr$ patterns in soils follow those of the underlying geology.

However, the observed relationship between soil and local bedrock $^{87}Sr/^{86}Sr$ is rarely 1:1.

Exogenous sources can drastically affect the $^{87}Sr/^{86}Sr$ of soil, such as:

- Unconsolidated sediments (e.g., loess)
- Aeolian dust from desert zones
- Volcanic tephra (e.g., ash)
- Sea salt aerosols (= seaspray)



Strontium pathways in soil. After Holt et al. 2021, https://doi.org/10.1016/j.earscirev.2021.103593.

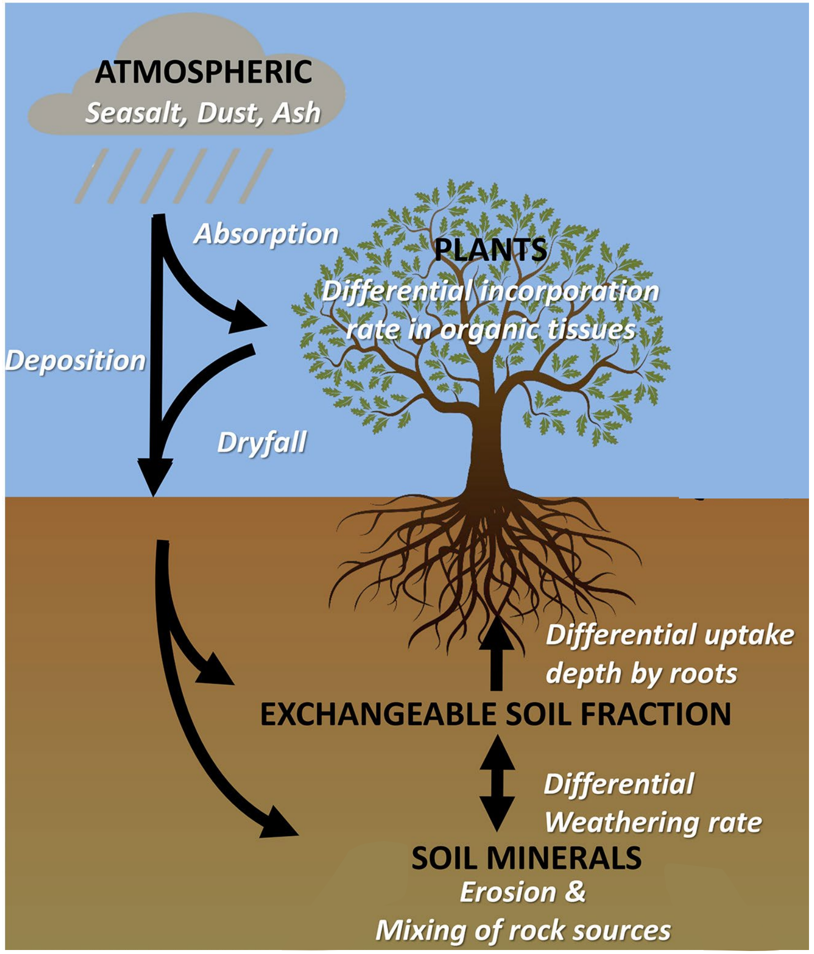
Sr in the geosphere

Different soil fractions can also have distinct $^{87}Sr/^{86}Sr$ compositions due to differential weathering and soil mixing processes.

The soil exchangeable Sr corresponds primarily to Sr dissolved in soil water and available to plants.

$^{87}Sr/^{86}Sr$ of this soil exchangeable Sr is strongly influenced by soil age.

As soils become more and more weathered, fewer primary minerals are available, and other sources increasingly contribute to the exchangeable Sr budget.



Strontium pathways in soil. After Bataille et al. 2020, https://doi.org/10.1016/j.palaeo.2020.109849.

Sr in plants

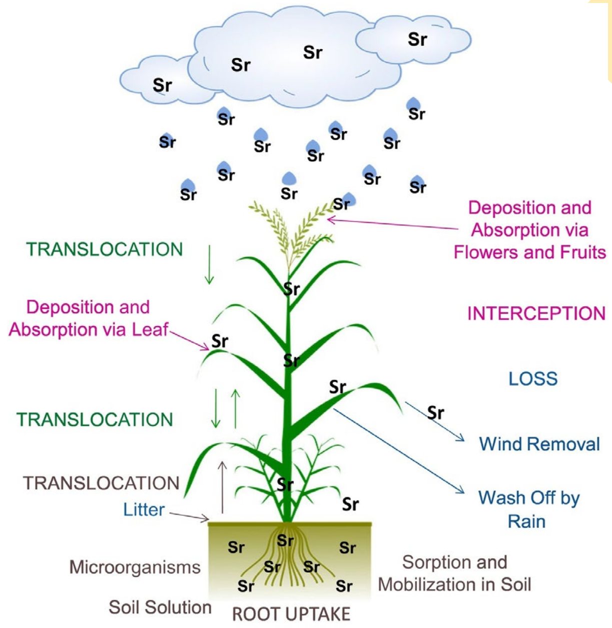
Plants take up Sr from the exchangeable soil fraction.

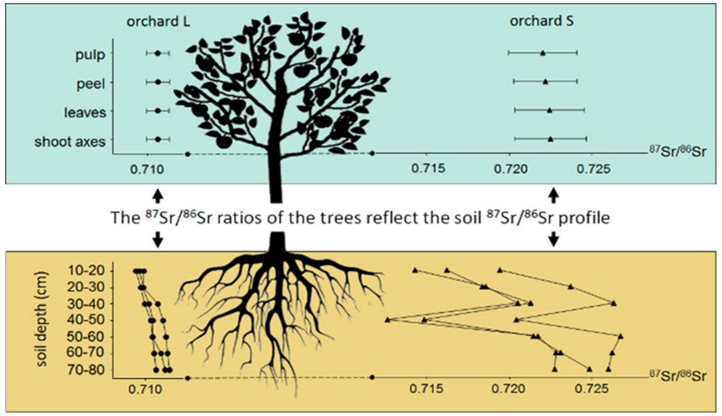
However, differences between $^{87}Sr/^{86}Sr$ in plants and the exchangeable Sr fraction can occur.

Differential weathering and soil mixing processes can lead to variable $^{87}Sr/^{86}Sr$ along the soil profile.

This variability is propagated among plants with different rooting depth.

Uptake of strontium by the plant. Burger & Lichtscheidl 2019, https://doi.org/10.1016/j.scitotenv.2018.10.312.





A moderate homogeneity of the $^{87}Sr/^{86}Sr$ was observed among subsamples of the same tree part. The variability of the $^{87}Sr/^{86}Sr$ of the apple trees is explained by the $^{87}Sr/^{86}Sr$ of the soil. Aguzzoni et al 2019, https://doi.org/10.1021/acs.jafc.9b01082.

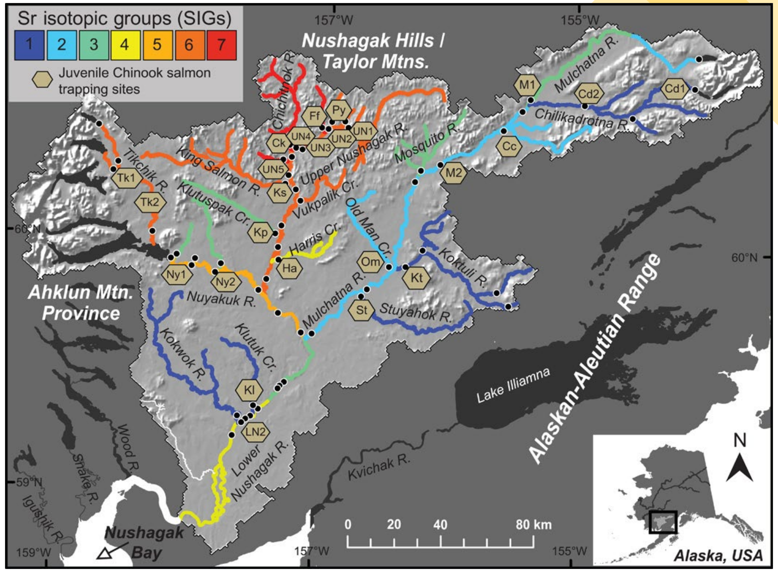
Sr in surface waters

Water inherits $^{87}Sr/^{86}Sr$ from rock weathering.

Consequently, spatial patterning of $^{87}Sr/^{86}Sr$ in the hydrosphere reflects that of rocks exposed on the surface and in aquifers.

However, the contributions of different minerals and rock units to the dissolved Sr pool vary broadly based on their weathering rate and Sr content, which in turn leads to distinct $^{87}Sr/^{86}Sr$ between the hydrosphere and geosphere.

Caution: Sr-rich and easily weatherable carbonates and evaporites contribute disproportionately to the dissolved Sr in the hydrosphere.



Mixed Stock Analysis model built using water data from throughout the Nushagak River (Alaska, USA), producing seven strontium isotopic groups. Brennan et al. 2015 https://www.science.org/doi/10.1126/sciadv.1400124.

At the scale of a catchment, the flux of Sr from isotopically distinct rock units is also modulated by geomorphological, climatic and environmental conditions.

Sr in animals & humans

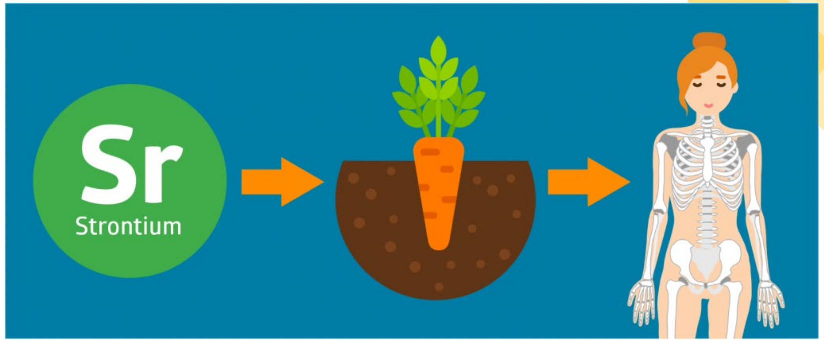
Primary terrestrial consumers obtain the majority of their Sr from diet.

As plants are at the base of many terrestrial food chains, $^{87}Sr/^{86}Sr$ for animals usually reflects that of local plants.

Reminder: no fractionation!

In some contexts, drinking water can contribute significantly to the Sr inputs when (1) water is Sr-rich (e.g., carbonate landscapes), or (2) animals drink frequently.

Different taxa sample Sr differently on the landscape depending on their feeding habits and feeding ranges (small rodents vs large herbivores).



Tooth preserve a snapshot of a specific period in the organism's life, while bone integrate Sr over longer time periods. They can therefore provide information about dietary signatures at different stages of an individual's life.

Humans can eat local terrestrial resources, hunt migratory mammals, harvest marine resources, inheriting a potentially very complex mixture of $^{87}Sr/^{86}Sr$ sources.

Humans can also obtain resources from distant localities via trade.

Sr in the skeleton

The application of strontium isotope analysis in archaeology arose from the realization that migrant individuals moving from one geological region to another could be identified by comparing the $^{87}Sr/^{86}Sr$ of different skeletal elements.

ELSEVIER

Journal of Human Evolution

Volume 14, Issue 5, July 1985, Pages 503-514

Strontium isotope characterization in the study of prehistoric human ecology

Jonathon E. Ericson

First publication in archaeology using $^{87}Sr/^{86}Sr$. Ericson 1985
https://doi.org/10.1016/S0047-2484(85)80029-4.

In theory, if the teeth and bones of a skeleton have different signatures, then the person spent his/her last years in a different geochemical province than during his/her youth.

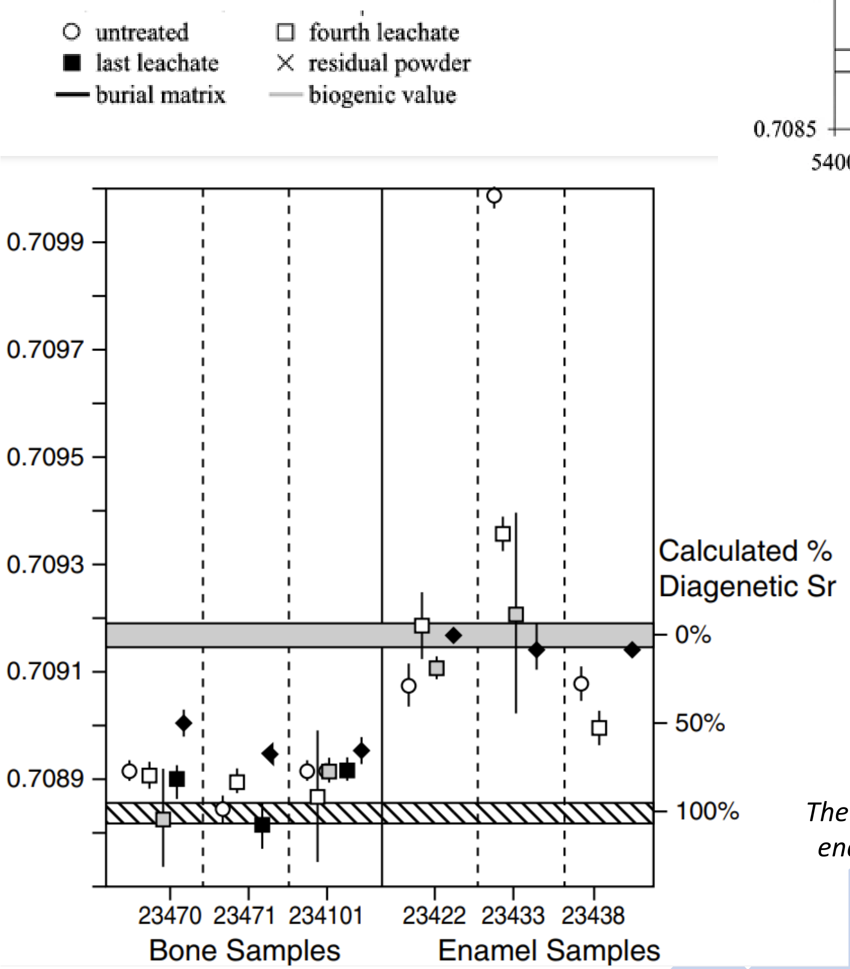
Sr in the skeleton

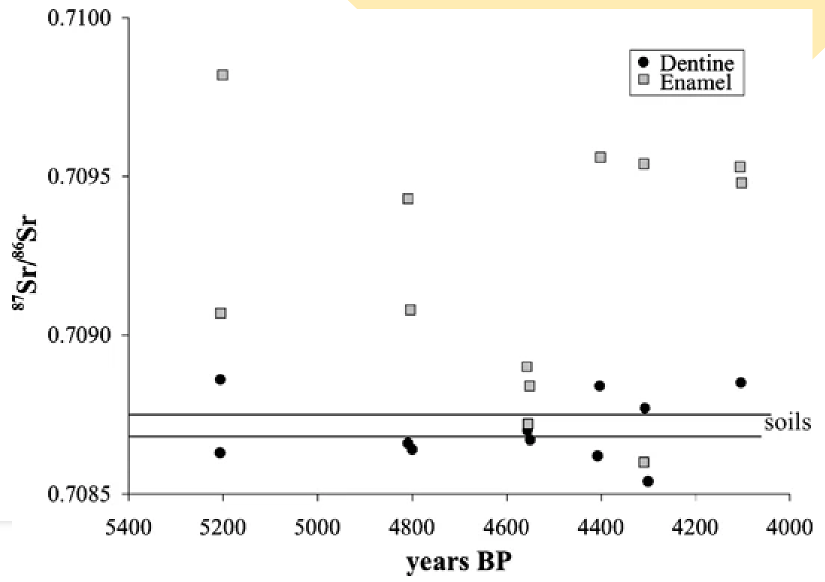
Unfortunately, archaeological bone is often contaminated during burial.

Soil water Sr can penetrate the bone after burial and overwhelm or even sometimes completely replace the biogenic Sr.

Post-burial contamination is the reason why it may not be reliable to define the local $^{87}Sr/^{86}Sr$ range based on the average $^{87}Sr/^{86}Sr$ of samples of human bones from the site.

Like bone, tooth dentine is also highly susceptible to contamination.





$^{87}Sr/^{86}Sr$ vs. age diagram of archaeological teeth from Switzerland, analyzed by Chiaradia et al. (2003). From Bentley 2006 https://doi.org/10.1007/s10816-006-9009-x.

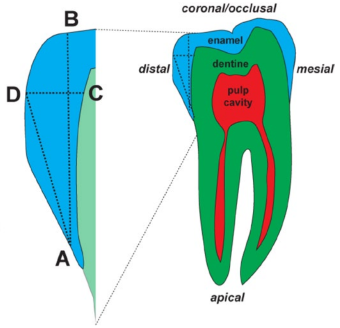
The $^{87}Sr/^{86}Sr$ ratios from sequential acid leaching of bone and enamel samples from a Holocene California fur seal. Hoppe et al. 2003, https://doi.org/10.1002/oa.663.

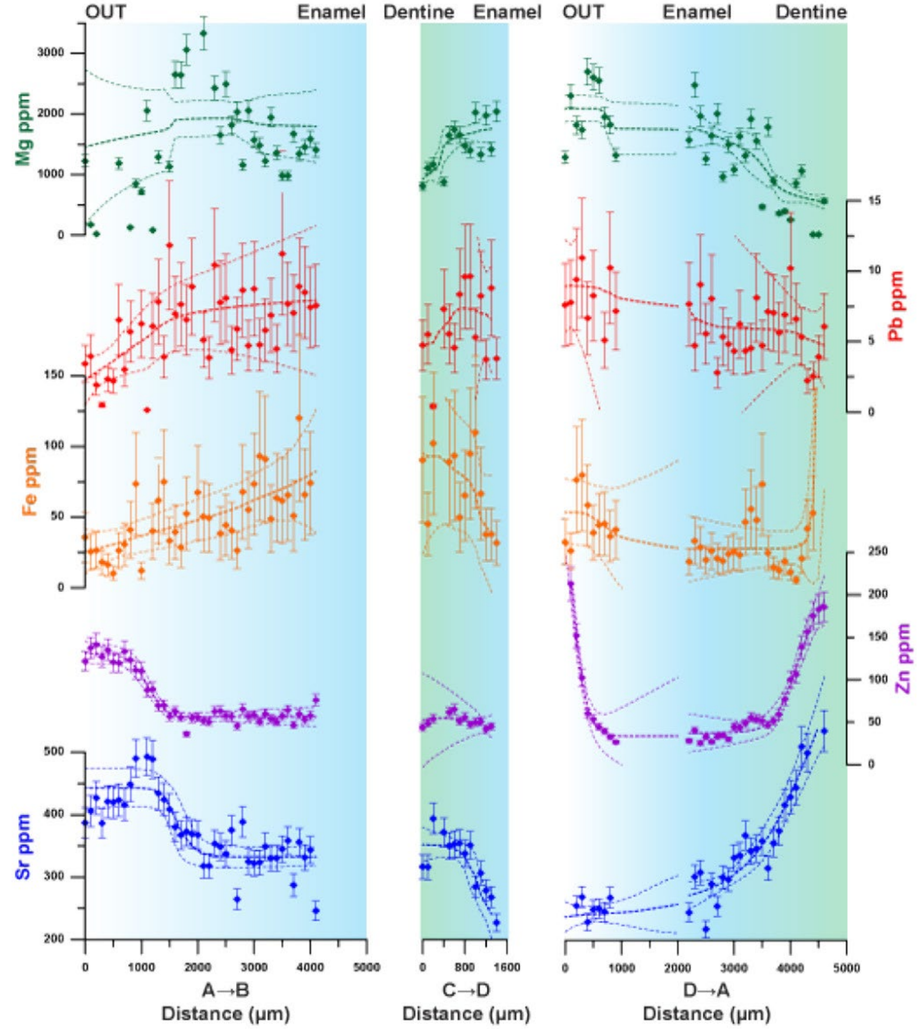
Sr in the skeleton

Micro X-Ray Fluorescence scanning reveals trace element variability in archaeological tooth enamel.
De Winter et al. 2017,
https://doi.org/10.1016/j.palaeo.2019.109260.

Repeated studies prove that tooth enamel is less sensible to diagenetic Sr than bone or dentine.

Outer enamel and enamel-dentine junction should be avoided or removed when sampling enamel for palaeo-reconstructions.

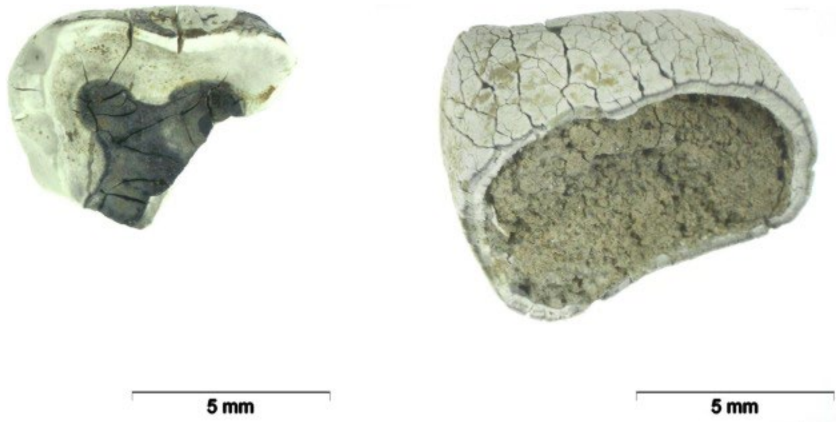




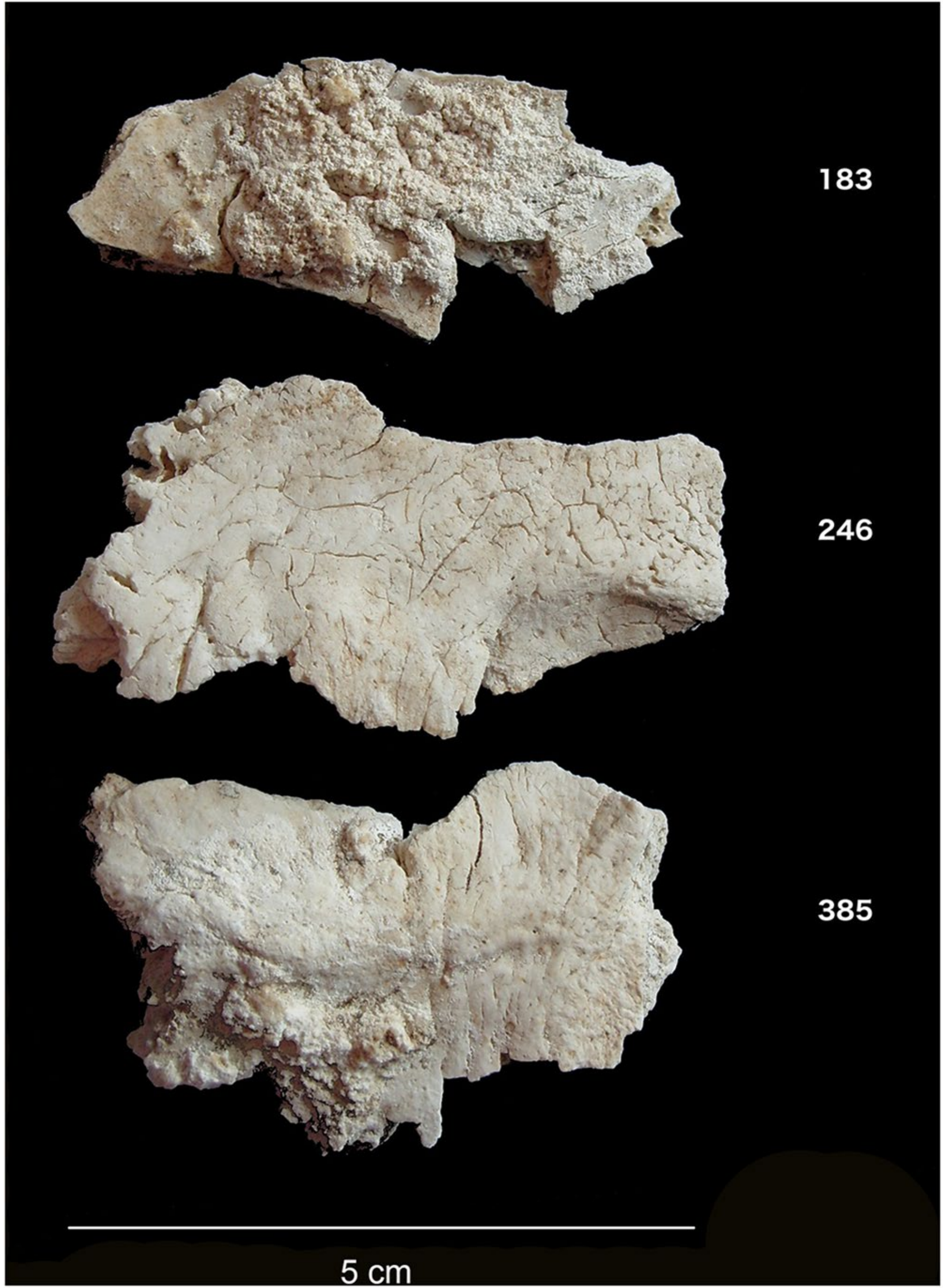
Teeth and cremation

Unfortunately, the recovery of burnt human teeth is relatively low.

They tend to become brittle and fracture either during the cremation process or upon excavation. Additionally, due to their small size, they are not always recovered after the cremation process.



Bone and cremation



Rapid Communications in Mass Spectrometry

Research Article

Calcined bone provides a reliable substrate for strontium isotope ratios as shown by an enrichment experiment

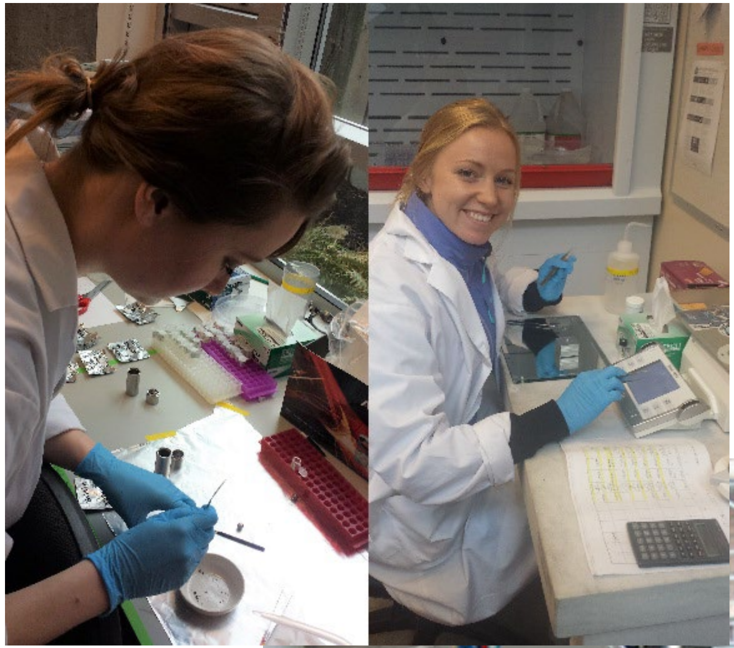
Christophe Snoeck, Julia Lee-Thorp, Rick Schulting, Jeroen de Jong, Wendy Debouge, Nadine Mattielli

First published: 02 December 2014 | https://doi.org/10.1002/rcm.7078 | Citations: 71

https://doi.org/10.1002/rcm.7078

Bones work!

Sr analysis



Where people come from?

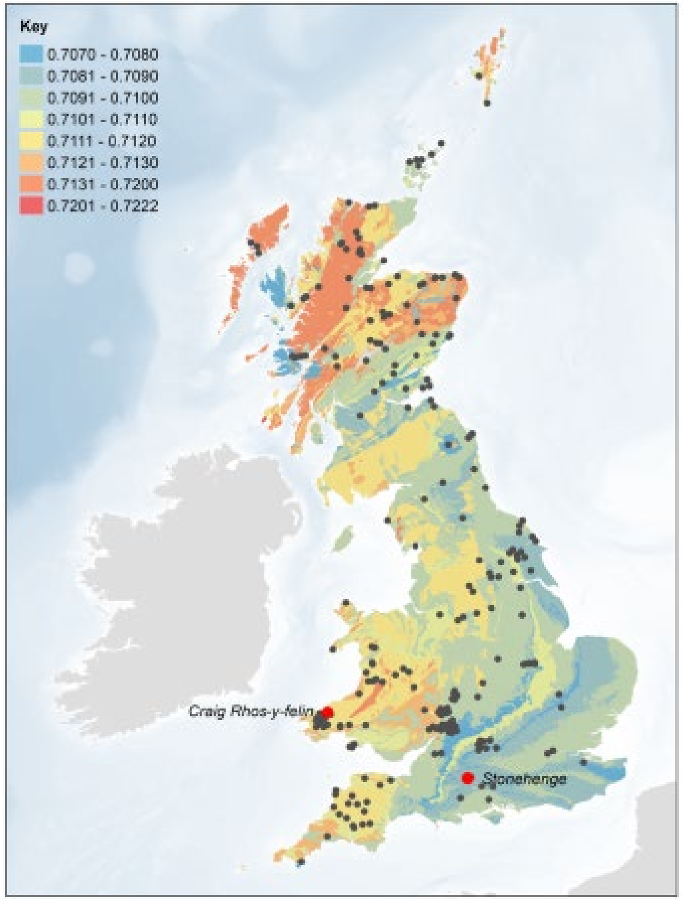
Article | Open Access | Published: 02 August 2018

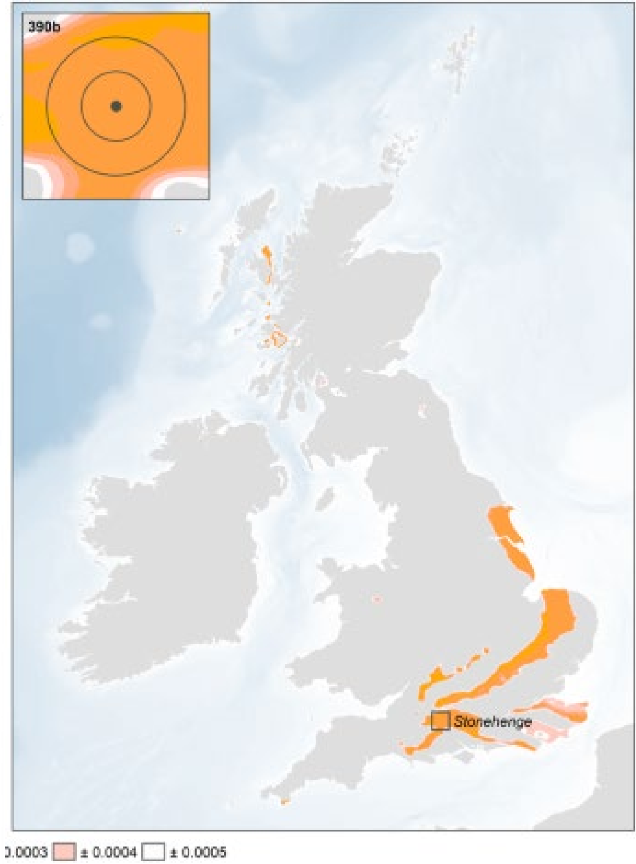
Strontium isotope analysis on cremated human remains from Stonehenge support links with west Wales

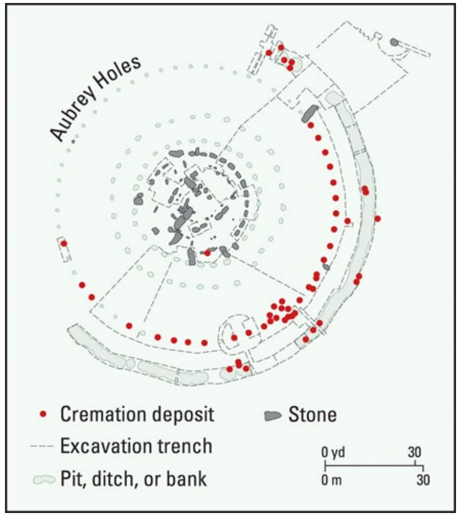
Christophe Snoeck, John Pouncett, Philippe Claeys, Steven Goderis, Nadine Mattielli, Mike Parker Pearson, Christie Willis, Antoine Zazzo, Julia A. Lee-Thorp & Rick J. Schulting

Scientific Reports **8**, Article number: 10790 (2018) | Cite this article

https://doi.org/10.1038/s41598-018-28969-8







What people ate?

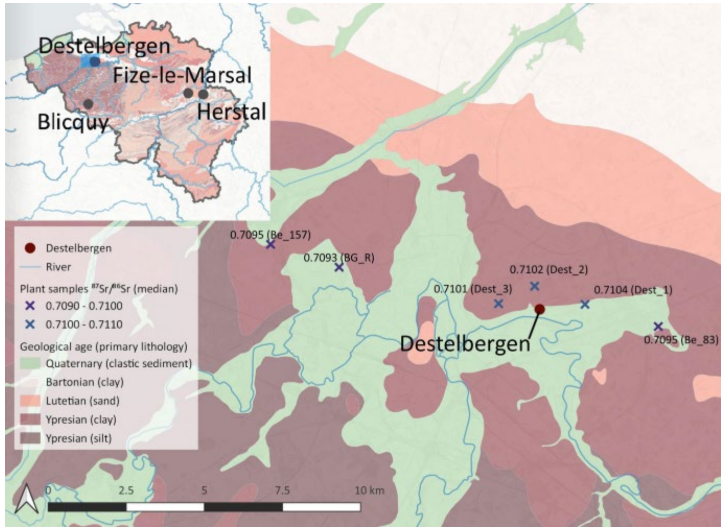
Article | Open Access | Published: 03 June 2022

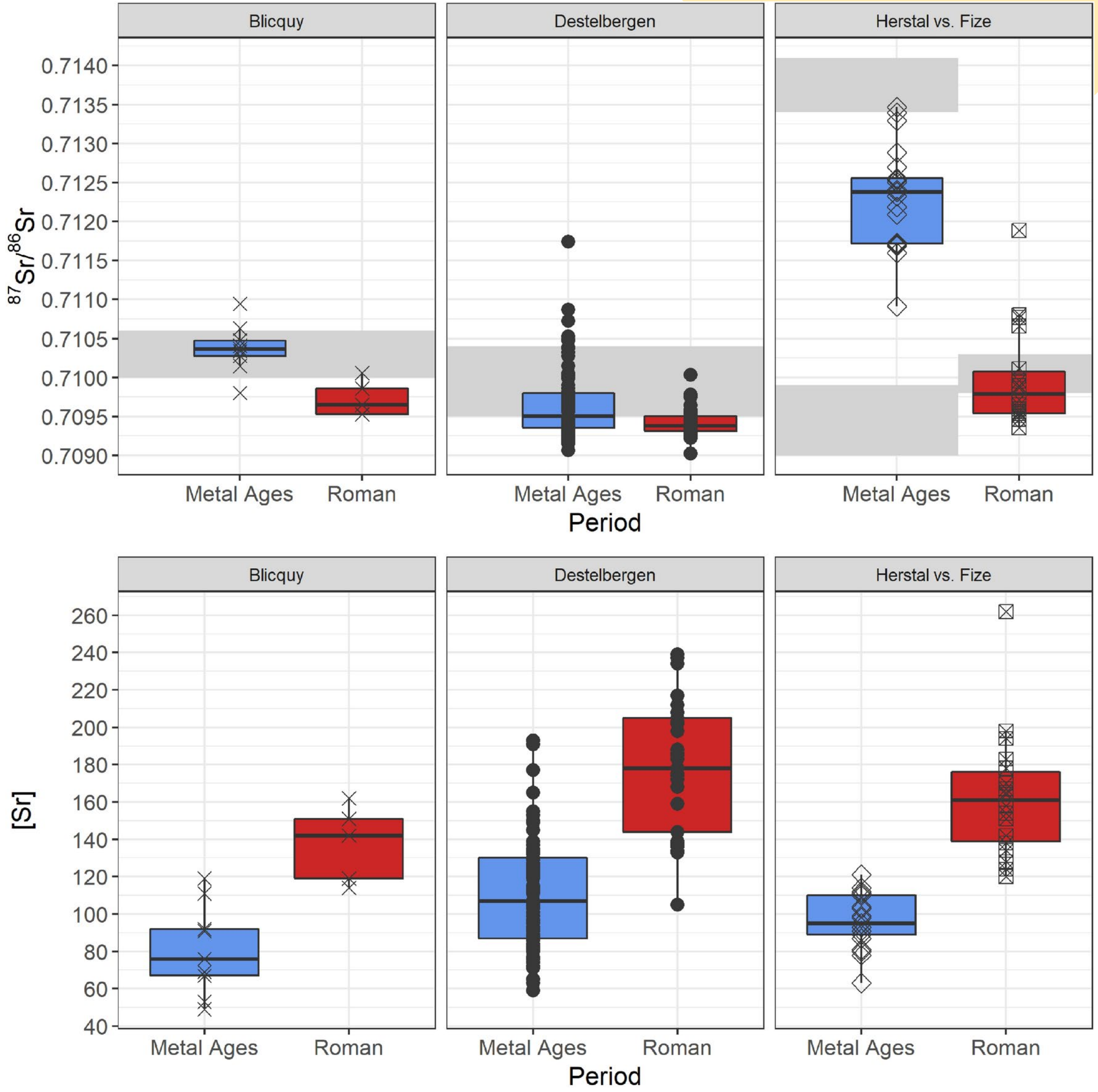
Strontium isotopes and concentrations in cremated bones suggest an increased salt consumption in Gallo-Roman diet

Sarah Dalle, Christophe Snoeck, Amanda Sengeløv, Kevin Salesse, Marta Hlad, Rica Annaert, Tom Boonants, Mathieu Boudin, Giacomo Capuzzo, Carina T. Gerritzen, Steven Goderis, Charlotte Sabaux, Elisavet Stamataki, Martine Vercauteren, Barbara Veselka, Eugène Warmenbol & Guy De Mulder

Scientific Reports **12**, Article number: 9280 (2022) | Cite this article

https://doi.org/10.1038/s41598-022-12880-4





Comparison of $^{87}Sr/^{86}Sr$ and [Sr] between the Metal Ages and Gallo-Roman buried individuals of Destelbergen, Blicquy, Herstal and Fize-le-Marsal. The available $^{87}Sr/^{86}Sr$ baselines are indicated in grey.

Carbon & Oxygen:

the underexplored isotopes

Background

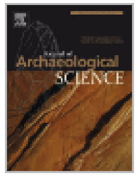
The current state of research shows that palaeodietary analyses in burnt bone are not possible

Isotope signatures of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{18}O$ preserve their original values only up to 200°C

Changes occurring above this threshold were identified experimentally, with varying degrees of influence on the final isotopic composition.

Background

Journal of Archaeological Science
Volume 65, January 2016, Pages 32-43



Impact of heating conditions on the carbon and oxygen isotope composition of calcined bone

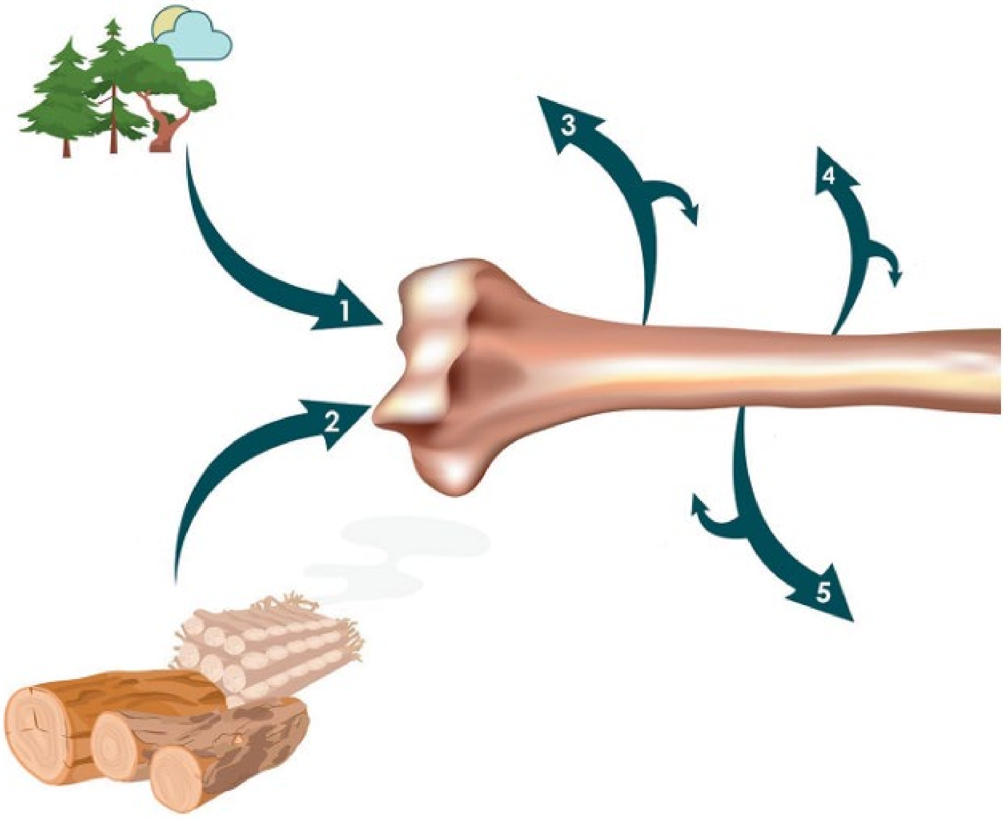
Christophe Snoeck [a], Rick J. Schulting [a], Julia A. Lee-Thorp [a], Matthieu Lebon [b], Antoine Zazzo [c]

https://doi.org/10.1016/j.jas.2015.10.013

A comparison of the results of $\delta^{13}C$ and $\delta^{18}O$ isotope analysis of remains from a single cemetery allows the pinpointing of those individuals who were cremated in different circumstances than others (i.e. their isotopic values do not correlate with the cemetery "baseline").

It has recently been pointed out that stable light isotopes may be used in studies oriented at reconstructing the cremation ritual, serving as proxies of the conditions in the funeral pyre during the burning of the deceased

Background



Sources of CO_2 that probably affect the isotopic composition of the carbonate fraction of bone apatite during heating/burning:

1) the atmosphere,
2) the burnt fuel,
3) the burnt organic matter, i.e. skin, muscle, fat, marrow
4) the burnt collagen,
5) the burnt carbonate fraction of bone apatite.

Wolska et al. 2020
10.15584/anarres.2020.15.1

A step forward

PLOS ONE

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

These boots are made for burnin': Inferring the position of the corpse and the presence of leather footwears during cremation through isotope ($\delta^{13}C$, $\delta^{18}O$) and infrared (FTIR) analyses of experimentally burnt skeletal remains

Kevin Salesse, Elisavet Stamataki, Ioannis Kontopoulos, Georges Verly, Rica Annaert, Mathieu Boudin, Giacomo Capuzzo, Philippe Claeys, Sarah Dalle, Marta Hlad, Guy de Mulder, Charlotte Sabaux, Amanda Sengeløv, [...], Christophe Snoeck

Reviewer #2 stated:

"I feel that the paper is certainly a **seminal work** on cremated remains."

Objective

This study aims at detecting the presence of garments worn by the deceased during cremations.

We are investigating whether the deceased worn shoes or not, as the latter is likely one of the most resistant clothing items to fire and might represent a proxy to discuss whether an individual was dressed with other clothing pieces or not.

Targeted anatomical section => Feet
Targeted clothing items => Shoes

It is not possible to answer such a question so far by classic archeological methods.

Research design

WORKING HYPOTHESIS:

Foot bones encased in unventilated shoes may experience heating conditions characteristic to confined-space cremation (low availability of oxygen, poorly ventilated, *etc.*).

Archaeological early modern footwear

Archaeological Roman boots

Research design

SCIENTIFIC APPROACHES:

Experimental archaeology &
cremations (outdoor & lab) in Belgium
During 2 sessions

SCIENTIFIC TOOL:

Stable isotope analysis ($\delta^{13}C$, $\delta^{18}O$) and other complementary approaches at AMGC lab in VUB (Brussels)

Experimentations

LEATHER SHOES:

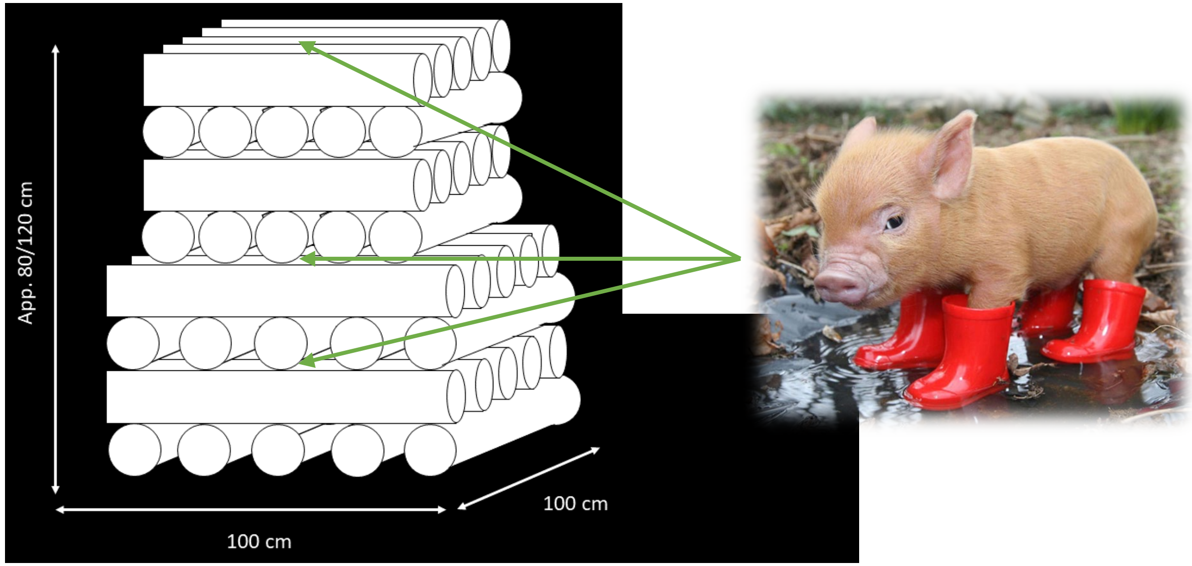
- ✓ Vegetable-tanned leather (Switzerland) to approximate leather used by past populations
- ✓ Already used in experimental archaeology to make Roman boots (Trans Alp Journey, Volken 2004)
- ✓ Cattle hides (3mm) & goat hide (1.5mm)
- ✓ Shoes laced with leather strips (same hides)
- ✓ 2 types of shoes: fully closed vs. one-side open

Handmade leather footwears

Experimentations

Pig Feet:

- ✓ 8 pigs from the same farm (Belgium)
- ✓ Per pig: 1 unburnt foot, 3 burnt feet (2 shoed & 1 unshoed)
- ✓ Per pyre: feet deposited at the same level
- ✓ Feet placed at the top, in the middle or at the bottom of the pyre



x 3

Experimentations

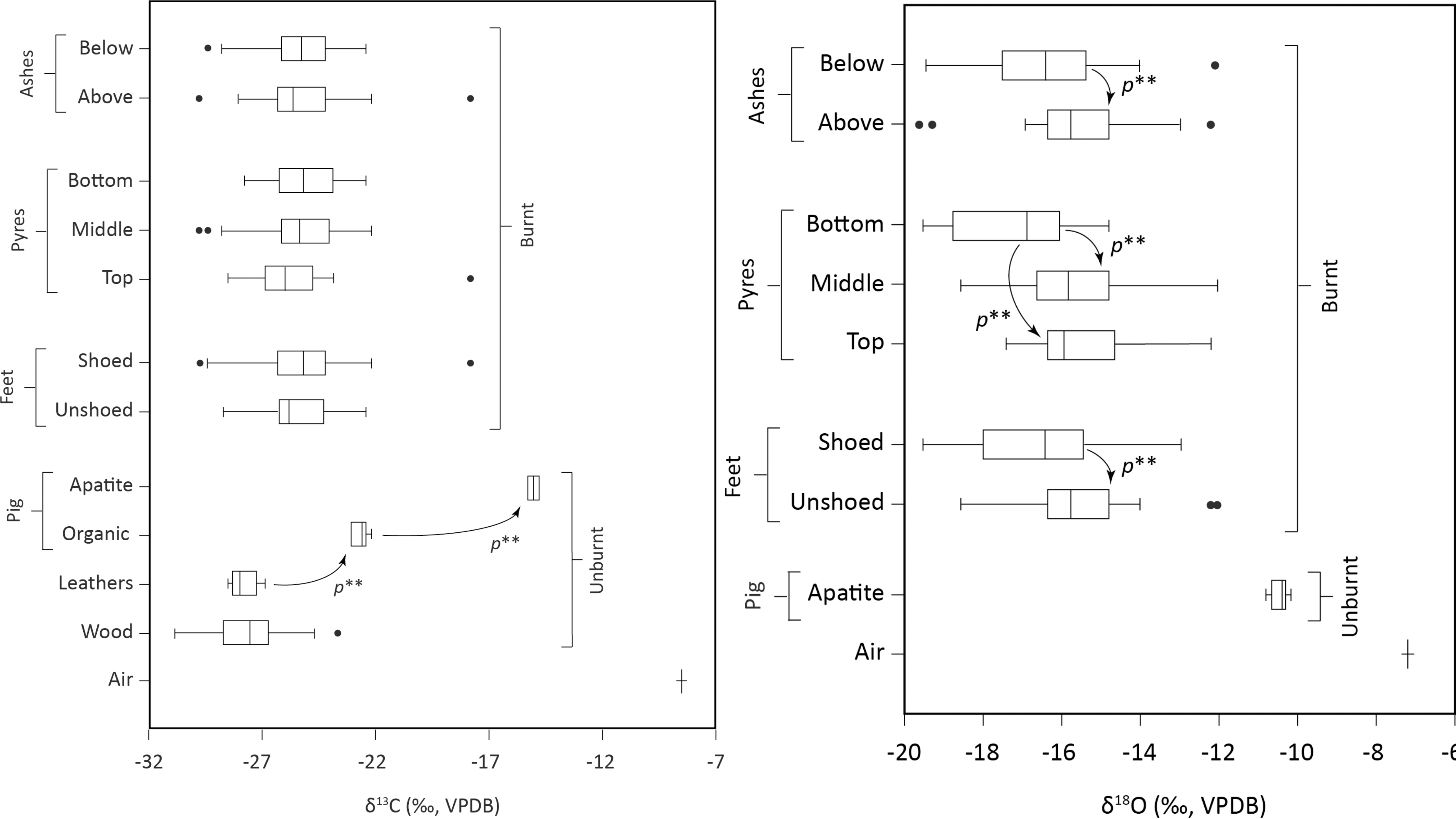
SAMPLING:

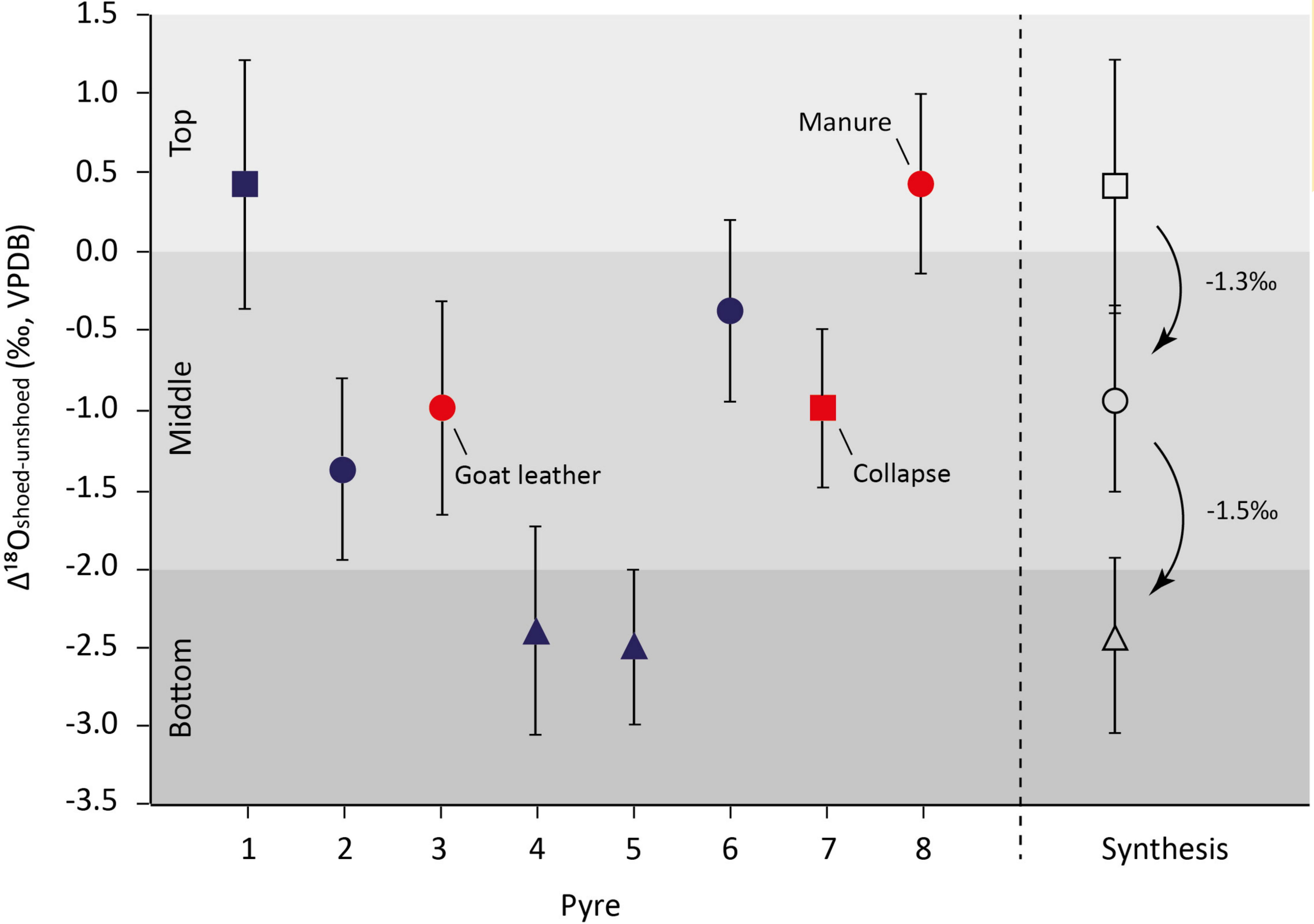
- ✓ Excavation of pyres
- ✓ Pig tissues (burnt & unburnt), leather pieces, and wood logs



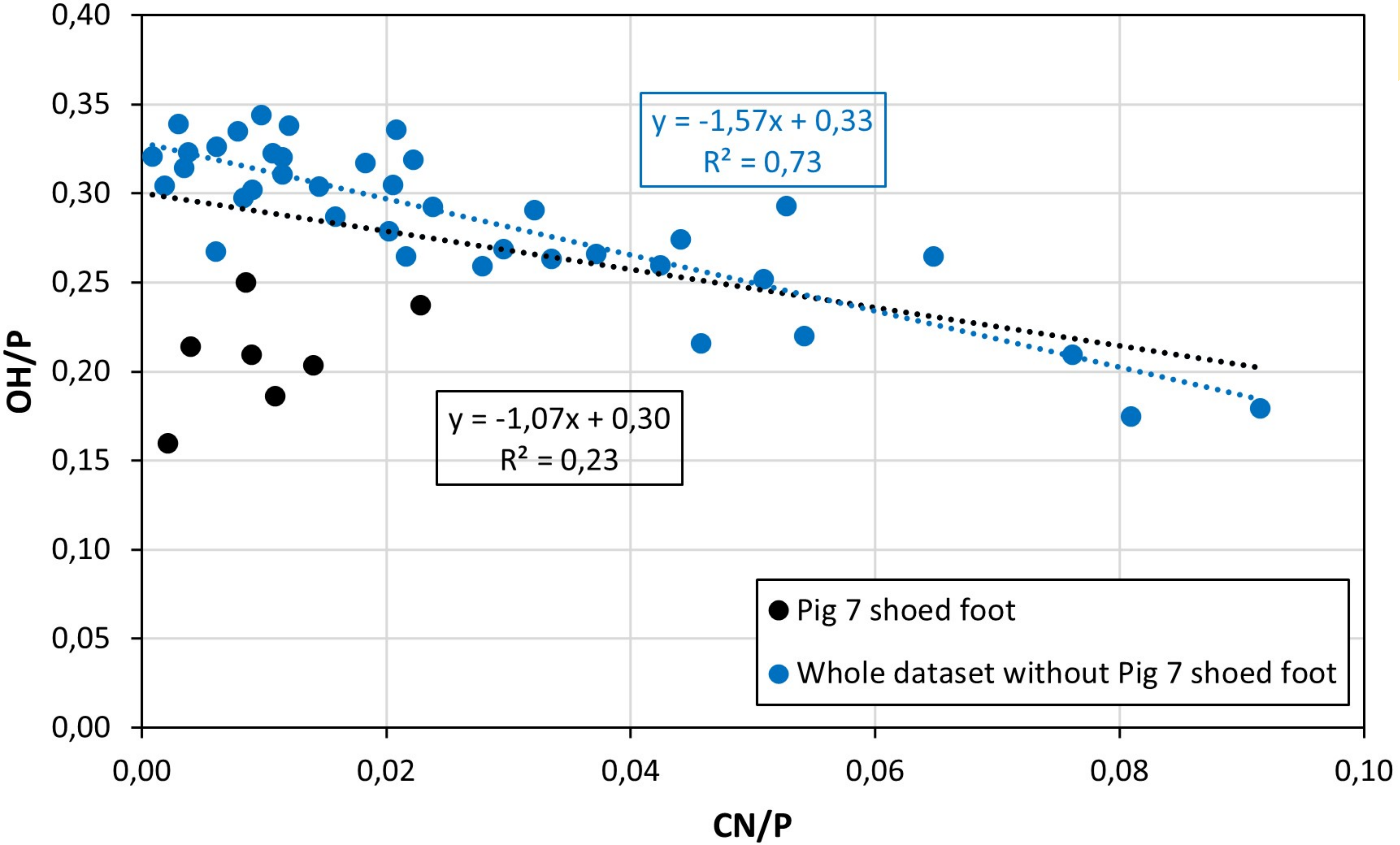


Overview of the different steps during our experimental cremations


Ashes
Below
Above
Pyres
Bottom
Middle
Top
Feet
Shoed
Unshoed
Pig
Apatite
Organic
Leathers
Wood
Air
Burnt
Unburnt
p**
-32
-27
-22
-17
-12
-7
δ13C (‰, VPDB)
-20
-18
-16
-14
-12
-10
-8
-6
δ18O (‰, VPDB)



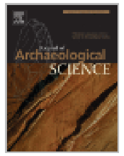
Δ18Oshoed-unshoed (‰, VPDB)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
Top
Middle
Bottom
Manure
Goat leather
Collapse
-1.3‰
-1.5‰
1
2
3
4
5
6
7
8
Synthesis
Pyre



0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
OH/P
0,00
0,02
0,04
0,06
0,08
0,10
CN/P
y = -1,57x + 0,33
R² = 0,73
y = -1,07x + 0,30
R² = 0,23
Pig 7 shoed foot
Whole dataset without Pig 7 shoed foot

Archaeological application

ELSEVIER

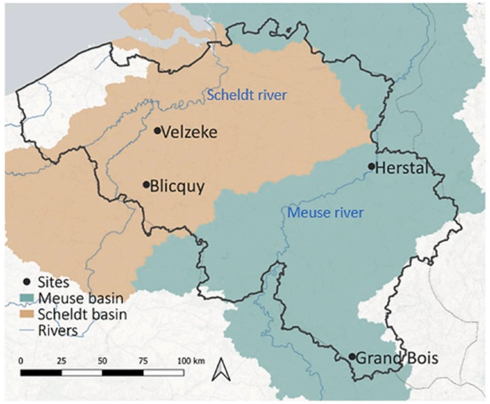


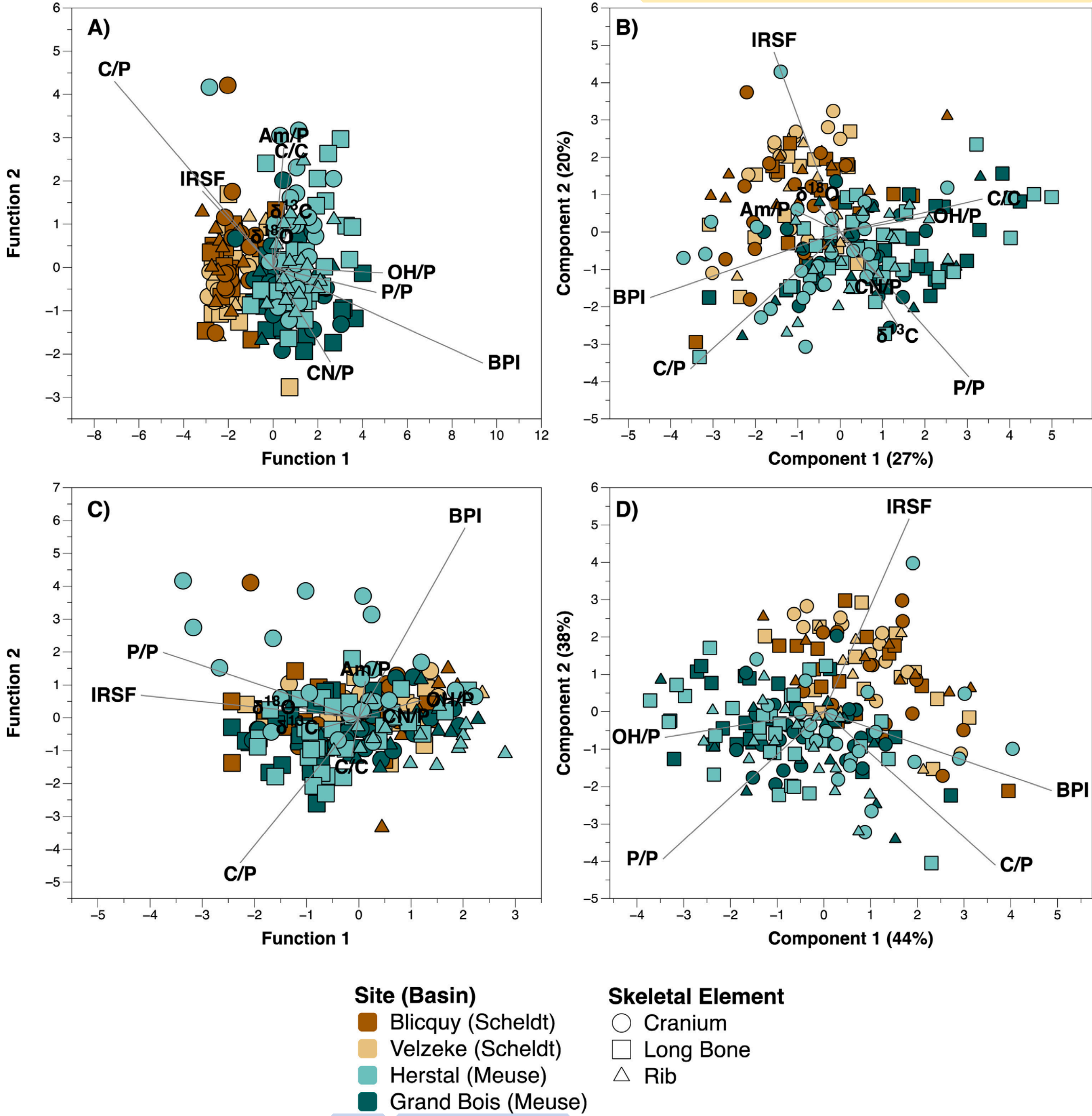
Journal of Archaeological Science
Volume 136, December 2021, 105509

Is it hot enough? A multi-proxy approach shows variations in cremation conditions during the Metal Ages in Belgium

Elisavet Stamataki [a b], Ioannis Kontopoulos [a h], Kevin Salesse [a b c], Rhy McMillan [c], Barbara Veselka [a c], Charlotte Sabaux [b e], Rica Annaert [a g], Mathieu Boudin [d], Giacomo Capuzzo [b], Philippe Claeys [c], Sarah Dalle [a e], Marta Hlad [a b], Amanda Sengeløv [b e], Martine Vercauteren [b], Eugène Warmenbol [f], Dries Tys [a], Guy De Mulder [e], Christophe Snoeck [a c]

https://doi.org/10.1016/j.jas.2021.105509





What next?

Using donated body for direct test

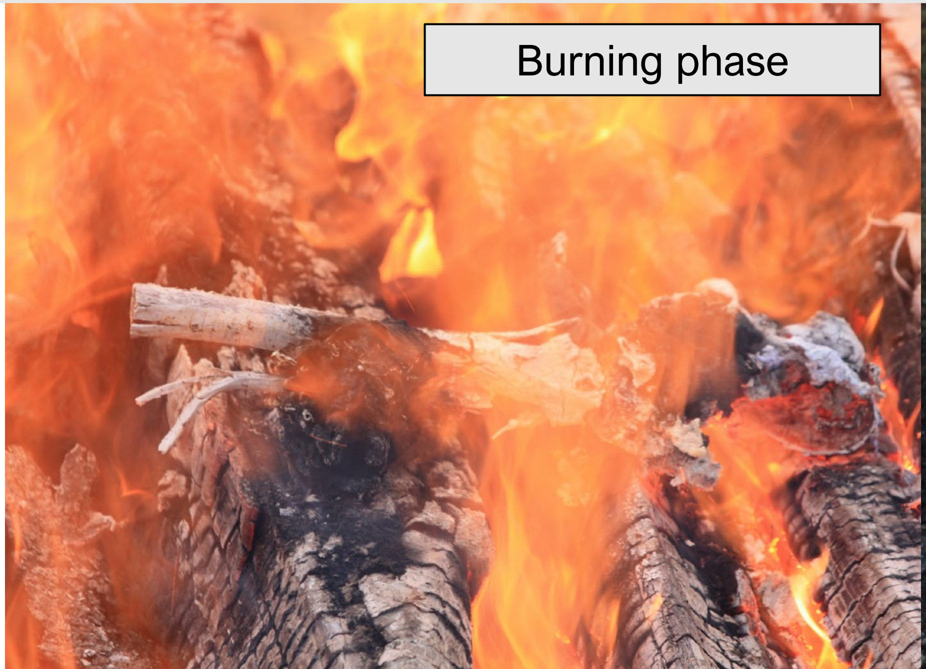
https://www.dailymail.co.uk/news/article-2512694/Stuntman-Joe-Toedtling-sets-human-torch-record-set-6-minutes.html

Setting up the experiments

Launching the experiments

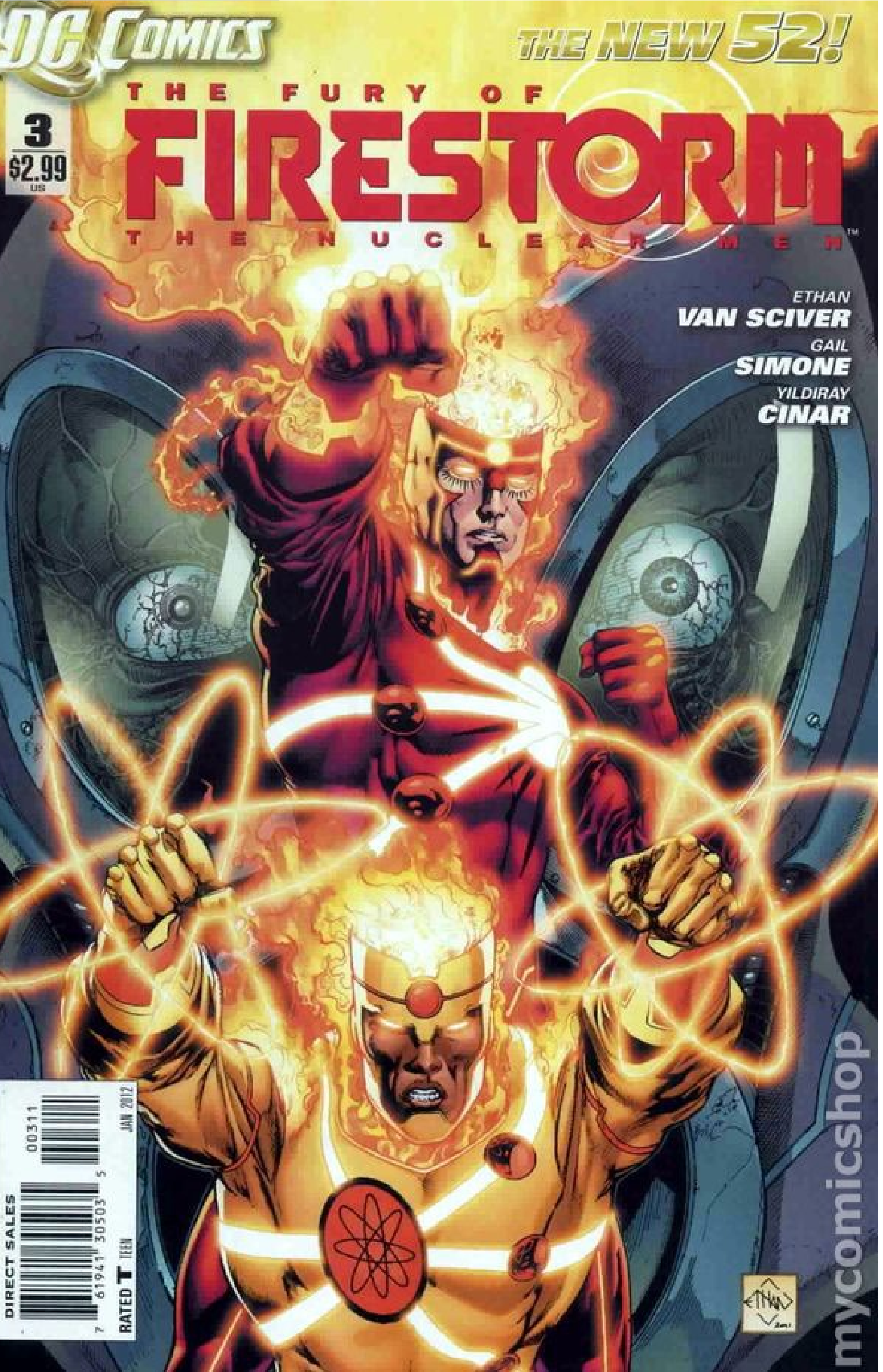

Burning phase

Burning phase



What next?

Stay tuned!


DC COMICS
THE NEW 52!
THE FURY OF
FIRESTORM
THE NUCLEAR MEN
3
$2.99
ETHAN
VAN SCIVER
GAIL
SIMONE
YILDIRAY
CINAR
mycomicshop

Thank you


FAIR ENOUGH.
FIRESTORM.
RAYMOND HAS IT IN HIS HEAD THAT BECAUSE I'VE READ A BOOK OR TWO, I'M AFRAID OF PHYSICAL CONFRONTATION.
SORRY TO LET YOU DOWN, RONNIE.
BUT WHILE BRUISERS LIKE YOU MIGHT WIN LITTLE BRAWLS NOW AND THEN--
SHOOT TO WOUND. SHOOT TO WOUND!
--IT'S THE GENERAL, THE EDUCATED MAN--
--WHO FIGHTS THE WARS THAT COUNT.
AND ONE OTHER THING MY DAD TAUGHT ME, WHILE I'M THINKING OF IT.