How physics can measure \textit{tempo} and \textit{mode} of human evolution

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Introduction

– Latest news on human evolution
– Nuclear clocks for the deep past
– Virtual paleoanthropology
– Expanding the brain and extending the mind
– Conclusion
physics and human evolution

X-rays, 1895
The Descent of Man, 1871
Radioactivity, 1898

W. Röntgen
1845-1923

C. Darwin
1809-1882

M. Curie
1867-1934
timeline of hominin evolution

Tuniz, Manzi, Caramelli, The science of human origins, 2014
body evolution

Million of years ago

Brain volume (cc)

H. neanderthalensis/sapiens
H. heidelbergensis
H. erectus
H. Ergaster
H. rudolfensis/habilis
A. afarensis/africanus
S. tchadensis

Million of years ago
Homo trajectories (evolution & migration)

OSL, 234U/230Th

40K-40Ar

10Be/26Al

Tuniz, Manzi, Caramelli, The science of human origins, 2014
A bit of physics: radioactive clocks

- radiocarbon
- uranium series
- potassium argon
- thermoluminescence
- stimulated luminescence
- electron spin resonance
- cosmogenic isotope dating
potassium-argon dating
the radioactive-decay law

Mass Spectrometry

Time Zero (lava solidification)
buried radioactivity

Zeroing event in the past

Laboratory analysis

Period of burial

Time zero

Time

Present day
Atmospheric production

$^{14}\text{C}$

5730 years

Surface production

$^{26}\text{Al}$

$^{10}\text{Be}$

0.7 Myr

1.5 Myr
radiocarbon dating

$^{14}\text{N}(n,p)^{14}\text{C}$

CO$_2$

Photosynthesis

Exchange

Food chain
$^{14}\text{C}$ radioactive decay

- Time Zero (death living organism)
- $^{14}\text{C}$ radioactive decay curve
- $^{14}\text{N}$ curve
- Accelerator Mass Spectrometry
ANSTO, Australia [1989 - ]
Rutgers University [1964 - 1989]
‘Peking man’/Homo erectus

Age of Zhoukoudian Homo erectus

$^{26}\text{Al}/^{10}\text{Be}$ burial dating

770,000 years

Shen et al. Nature 2009
new 3D microscopes

ELETTRA, Trieste

OPAL, Sydney

X-ray computed micro-tomography

Neutron computed micro-tomography
Inside the microscope

- x-ray, n detector
- x rays, n
- specimen
- rotation stage
- planar radiographs
- slice reconstruction

Tuniz, C. And Zanini, F. 2018, Microcomputerized Tomography (MicroCT) in Archaeology
x-ray ‘portable’ 3D microscope

x-ray your Neanderthal!

- skull, Po river, 100,000 yr?
- teeth, Southern Italy, 60,000 yr
- hyoid (FEA analysis), Israel, 60,000 yr
- knee-cup, Croazia, 70,000 yr
- flute ?, Slovenia, 60,000 yr

Neanderthal vs. H. sapiens
teeth: archive of life history

20 micron

5 micron

0.7 micron

age at death, stress, taxonomy, rate of development

Smith et al. (2015) PLOS ONE
unborn child from the Paleolithic

Pregnant mother

28,000 years cal BP

Virtual histology of child’s incisor
dentistry in the Neolithic

Beeswax
6645-6440 BP

Lonche jaw
6655-6400 BP

MicroCT analysis of the Neanderthal mandible from Archi, Southern Italy, F. Bernardini … Tuniz, C. Zanolli,
how to obtain virtual brains
brains from the Ice Age

Romito, Calabria, Italy
25,000 BP
it takes time to become a ‘real’ H. sapiens

Jebel Irhoud, 300,000 yr BP
Qafzeh, 95,000 yr BP

Scerri et al, Trends in Ecol and Evol 2018
our globular brains

Present day human

Neanderthal

Neubauer et al 2018
How to compare brain shape

Neandertals

H. erectus

H. sapiens

Present-day humans
expanding the brain

prefrontal cortex
orbital roof
eyeball
precuneus
extending the mind

brain

body

culture

Instruments

environment

Bruner & Iriki, 2015
self-domestication

Braincase shape and size

Browridge

Nasal bone projection

Tooth size

Jaw projection

prognathism
the first structured societies
Rituals to generate emotions

Hohle Fels venus

35,000-40,000 years BP (radiocarbon)

Hohle Fels flute

Conard, 2009
Hierarchical societies during the Ice Age

Hierarchical societies
Division of labor
Richness, inequality

Sungir Russia
35,000 years BP
More extensions of the mind

Brain

Culture

Environment

Body

Society

Instruments

Intelligent technologies
funding from Friuli Venezia-Giulia Region, (EXACT, Project)
Centro Fermi Rome (S.A.P.I.E.N.S. Project)
Croatia National Fundation

Multidisciplinary Laboratory, ICTP

F. Bernardini, G. Vinci, C. Zanolli, C.T.
Thanks for your attention!

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The BONE READERS
Atoms, genes and the politics of Australia’s deep past
CLAUDIO TUNIZ, RICHARD GILLESPIE & CHERYL JONES
2009

The Science of Human Origins
Claudio Tuniz, Giorgio Manzi, David Caramelli
2016

From Apes to Cyborgs
New Perspectives on Human Evolution
Claudio Tuniz & Patrizia Tiberi Vipraio
2020