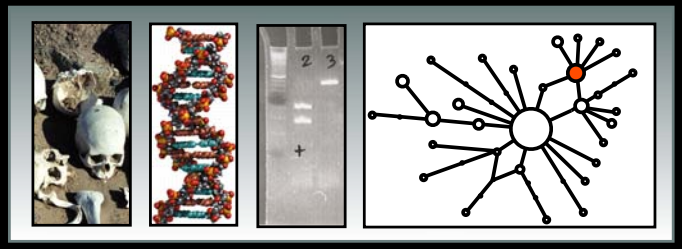
Anthropological Applications of Ancient DNA



Brian M. Kemp
Department of Anthropology
School of Biological Sciences

What I want you to get out of this lecture

1. What is ancient DNA? Importantly how is ancient DNA evidence of great value?
2. What are good sources of ancient DNA?
3. What are some applications of ancient DNA?

What is ancient DNA?

Ancient DNA research is "defined broadly as the retrieval of DNA sequences from museum specimens, archaeological finds, fossil remains, and other unusual sources of DNA…"

Pääbo et al (2004) *Ann. Rev. Genet.* 38:645-79

Ancient DNA: A unique approach to addressing prehistory

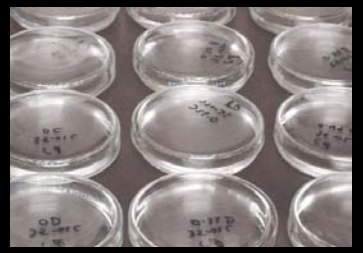
Analyzing ancient DNA allows one to directly test hypotheses that are based on theory from modern DNA studies through the ability to precisely date the age of remains that exhibit genetic types of interest.

Ancient DNA: very brief view of a rather short history

First extraction of ancient DNA---from the extinct Quagga (Higuchi et al. 1984)

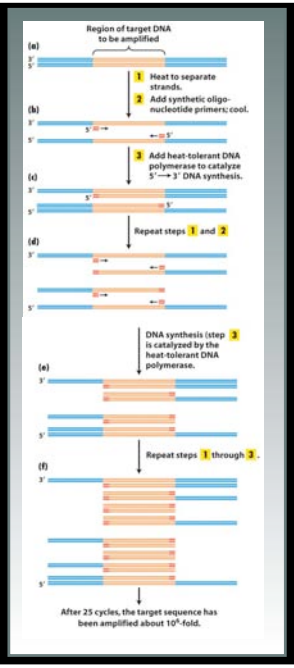
First extraction of ancient DNA from a human, an Egyptian mummy (Pääbo 1985)

Ancient DNA: Cloning



Ancient DNA: PCR

Thermus aquaticus yields *Taq* polymerase or *Taq*



Ancient DNA: post-PCR explosion of research!

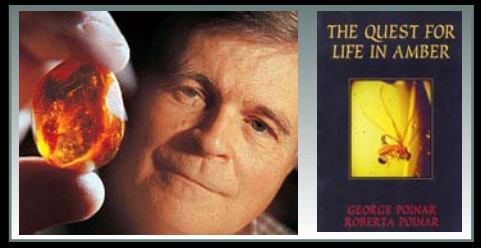
Extraction of ancient DNA from brain tissue, Little Salt Spring site (Pääbo 1988)

First extraction of ancient DNA from human bone (Hagelberg et al. 1989)

Photo from Pääbo (1993)
Scientific American

Ancient DNA: post-PCR explosion of research!

Dinosaurs, Miocene chloroplast DNA, and bacteria from the guts of amber encased insects…oh my.



Ancient DNA: >20 years of research

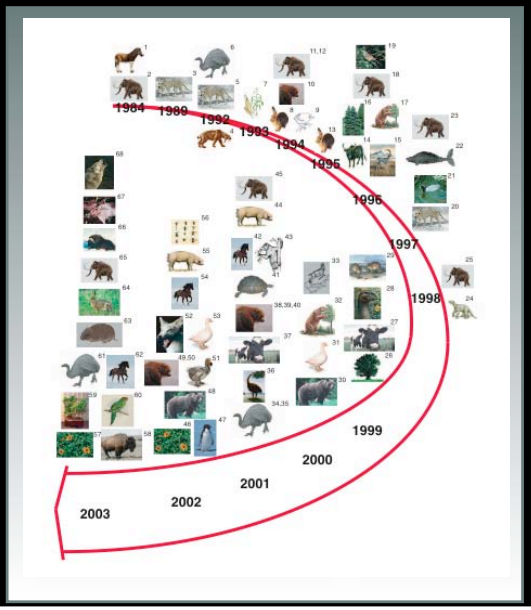
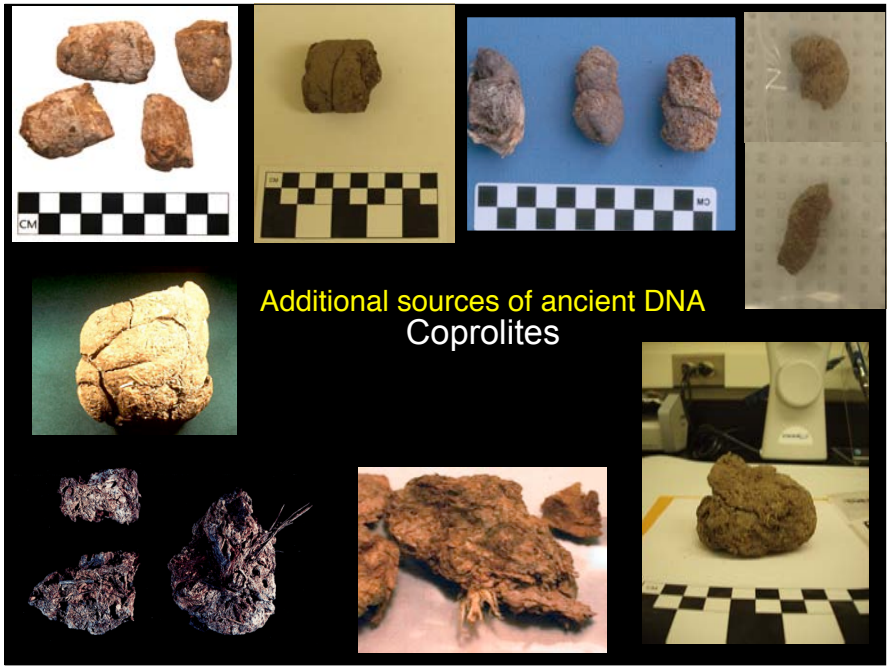


Image from
Gilbert (2003)

Sources of ancient DNA

Additional sources of ancient DNA



Coprolites

Additional sources of ancient DNA

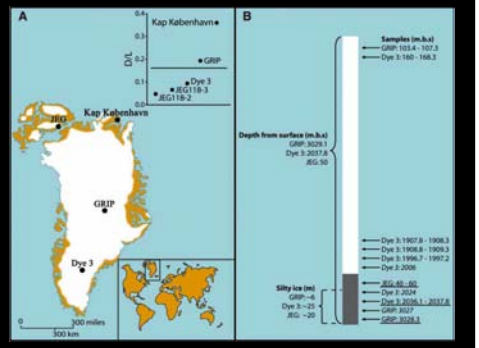
Quids

Additional sources of ancient DNA

Midden sample from Turkey Pen Ruins

Additional sources of ancient DNA

Permafrost and temperate sediments



Ice cores

WARNING!

Ancient DNA Research is Extremely Challenging and Requires a Great Attention to Details

Ancient DNA: Applications

Diet and environmental reconstruction

Study the genetics of extinct populations and/or species- determine evolutionary relationships

Study ancient diseases- e.g. the Black Plague

Test for population continuity vs. replacement

Molecular sex determination

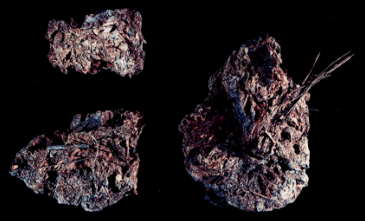
Domestication of plants and animals

Measure the rate of molecular evolution

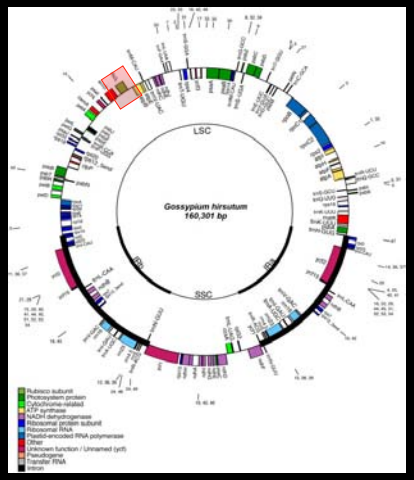
Ancient DNA: Human molecular coproscopy

Poinar et al. (2001) A molecular analysis of dietary diversity for three archaic Native Americans. *PNAS* 98: 4317-4322

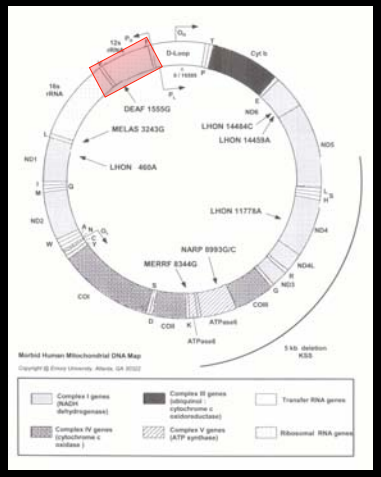
Extracted human mitochondrial DNA from three coprolites from Hinds Cave, Texas that date >2,000 years ago.



Ancient DNA: What the Humans Were Eating

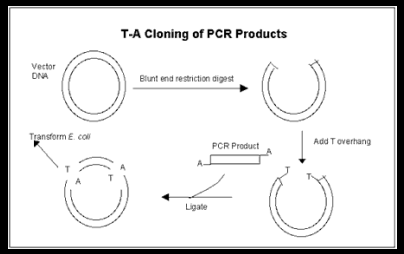


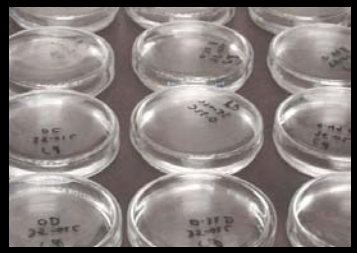
Chloroplast DNA



Mitochondrial DNA

Cloning PCR Product





AACCTATAAAGAACCTATAAAG
TTGGCTCTTTCTTGGCTCTTTC
AACCTTTAAAGTTGGCCCTTTC
AACCTATAAAGTTGGCTCTTTC
AACCTTTAAAGTTGGCCCTTTC
AACCTTTAAAGTTGGCCCTTTC
AACCTTTAAAGTTGGCCCTTTC

Ancient DNA: Ancient Human Diet Reconstruction

Sample I: pronghorn antelope, cottontail rabbit, packrat, squirrel, hackberry, sunflower family, yucca or agave, and cactus

Sample II: packrat, fish, hackberry, oak, sunflower family, yucca or agave, nightshade family, and legume family

Sample III: bighorn sheep, packrat, cotton rat, buckthorn family, hackberry, oak, sunflower family, yucca or agave, legume family, cactus, ocotillo

Ancient DNA: Ancient Human Diet Reconstruction

Indicates that these inhabitants of Hinds Cave had a diverse and well-balance diet.

Macroscopically three plants were confirmed, whereas six were not. Cactus was detectable only macroscopically.

Macroscopically no large mammals were detected, whereas small mammal bones and teeth were detected in the feces.

Ancient DNA: Applications

Diet and environmental reconstruction

Study the genetics of extinct populations and/or species- determine evolutionary relationships

Study ancient diseases- e.g. the Black Plague

Test for population continuity vs. replacement

Molecular sex determination

Domestication of plants and animals

Measure the rate of molecular evolution

The Neandertals

Type Specimen: Neandertal 1

Discovered in 1856, three years before the publication of "Origin of Species"

Neandertal Cranial Morphology

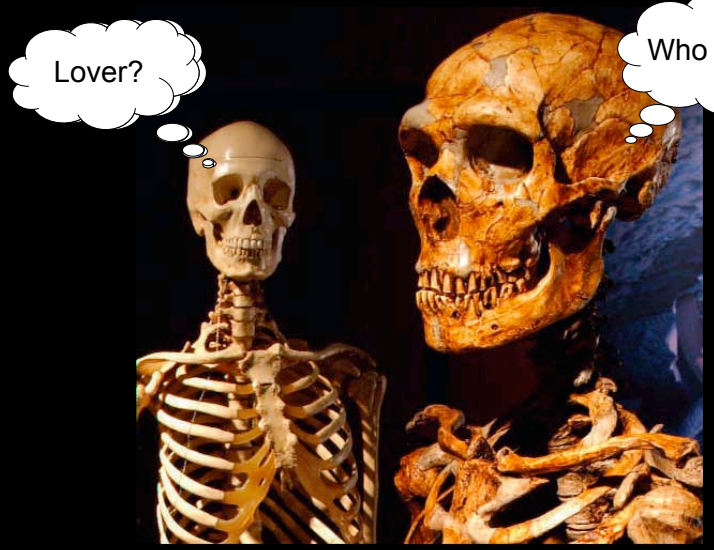
Neandertal

Homo sapiens

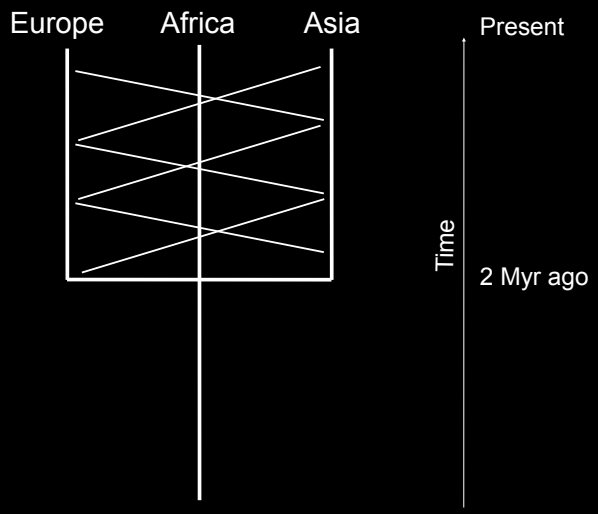
Neandertal Post-Cranial Morphology

Neandertal *Homo sapiens*

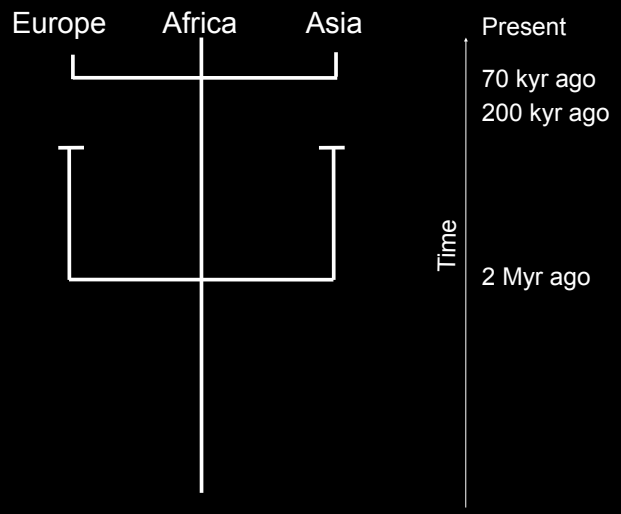
Neandertal *Homo sapiens*



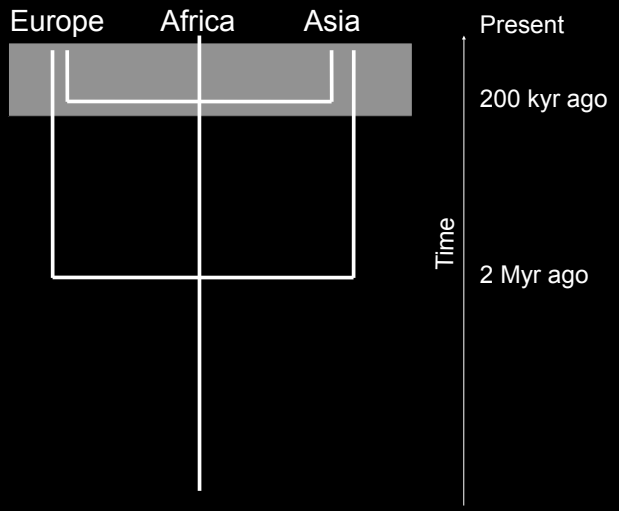
Multiregional Theory



Recent Out of Africa Theory



Weak Garden of Eden Theory

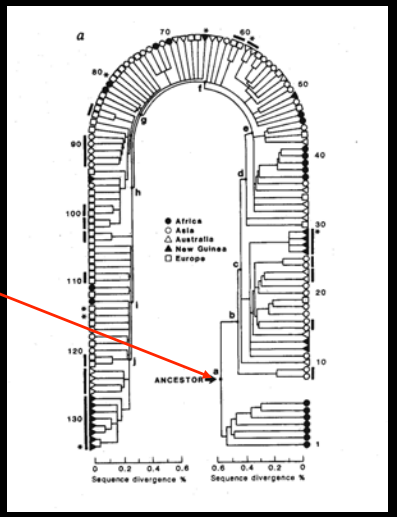


Mitochondrial Variation in Contemporary Humans

Cann et al. 1986

"Mitochondrial Eve"

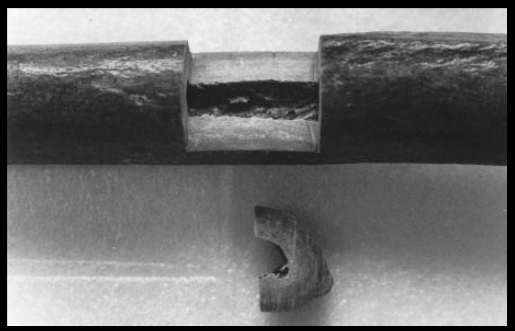
200,000 years ago

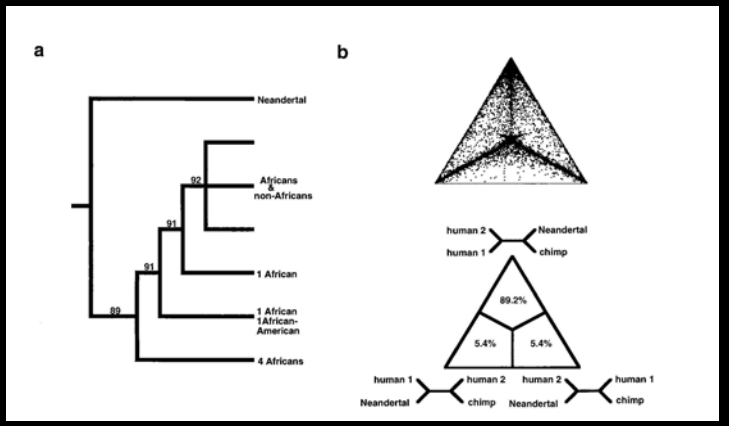


The First Genetic Look at A Neandertal

Krings et al. 1997 *Cell*

Extracted DNA from the Neandertal type specimen that was discovered in 1856





Human/Neandertal split: 550,000-690,00 years ago

I know what you are thinking…it's only one sample.

How can we say anything about Neandertal genetic variation?

Nearly a Decade of the Study of Neandertal Genetics

Krings et al., 1997: Feldhofer 1, Germany

Ovchinnikov et al., 2000: Mezmaiskaya, northern Caucasus, Russia

Krings et al., 2000: Vindija 75, Croatia

Schmitz et al., 2002: Feldhofer 2, Germany

Serre et al., 2004: Vindija 77 and Vindija 80, Croatia
Engis 2, Belgium
La-Chapelle-aux-Saints, France

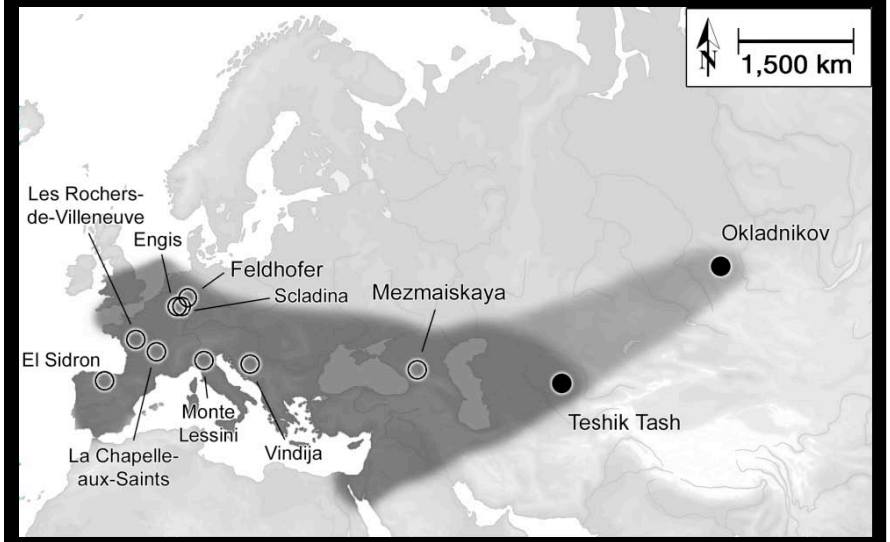
Lalueza-Fox et al., 2005: El Sidrón, northern Spain

Beauval et al., 2005: Rochers de Villenevue, France

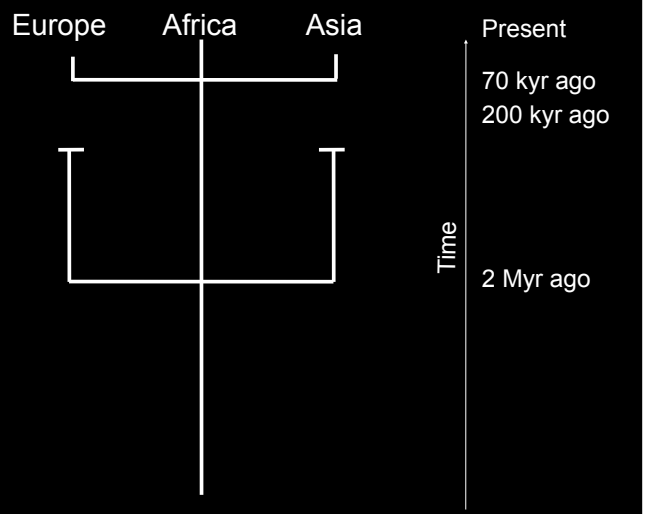
Carmelli et al. 2006: Monte Lessini, Italy

Orlando et al. 2006: Scandia Cave, Belgium

Two additional sample reported in 2007 by Krause et al.



Recent Out of Africa Theory

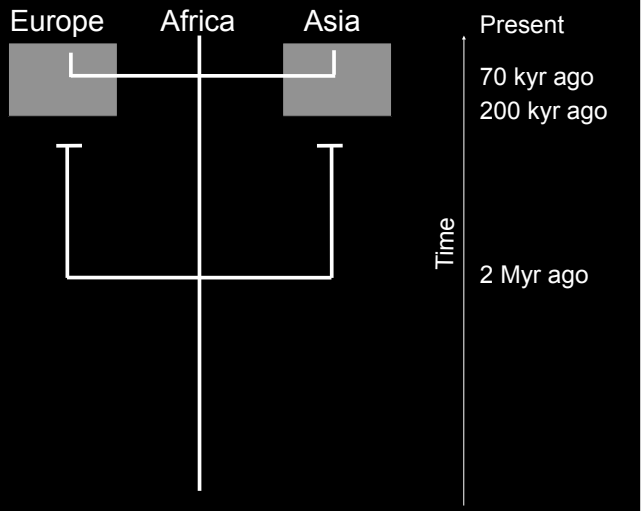


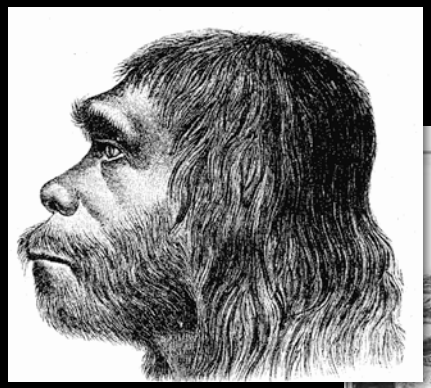
RESEARCH ARTICLE

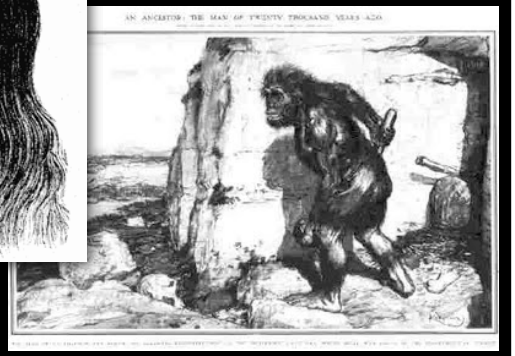
A Draft Sequence of the Neandertal Genome

Richard E. Green,[1]*†‡ Johannes Krause,[1]†§ Adrian W. Briggs,[1]†§ Tomislav Maricic,[1]†§ Udo Stenzel,[1]†§ Martin Kircher,[1]†§ Nick Patterson,[2]†§ Heng Li,[2]† Weiwei Zhai,[3]†‖ Markus Hsi-Yang Fritz,[4]† Nancy F. Hansen,[5]† Eric Y. Durand,[3]† Anna-Sapfo Malaspinas,[3]† Jeffrey D. Jensen,[6]† Tomas Marques-Bonet,[7,13]† Can Alkan,[7]† Kay Prüfer,[1]† Matthias Meyer,[1]† Hernán A. Burbano,[1]† Jeffrey M. Good,[1,8]† Rigo Schultz,[1] Ayinuer Aximu-Petri,[1] Anne Butthof,[1] Barbara Höber,[1] Barbara Höffner,[1] Madlen Siegemund,[1] Antje Weihmann,[1] Chad Nusbaum,[2] Eric S. Lander,[2] Carsten Russ,[2] Nathaniel Novod,[2] Jason Affourtit,[9] Michael Egholm,[9] Christine Verna,[21] Pavao Rudan,[10] Dejana Brajkovic,[11] Željko Kucan,[10] Ivan Gušic,[10] Vladimir B. Doronichev,[12] Liubov V. Golovanova,[12] Carles Lalueza-Fox,[13] Marco de la Rasilla,[14] Javier Fortea,[14]¶ Antonio Rosas,[15] Ralf W. Schmitz,[16,17] Philip L. F. Johnson,[18]† Evan E. Eichler,[7]† Daniel Falush,[19]† Ewan Birney,[4]† James C. Mullikin,[5]† Montgomery Slatkin,[3]† Rasmus Nielsen,[3]† Janet Kelso,[1]† Michael Lachmann,[1]† David Reich,[2,20]*† Svante Pääbo[1]*†

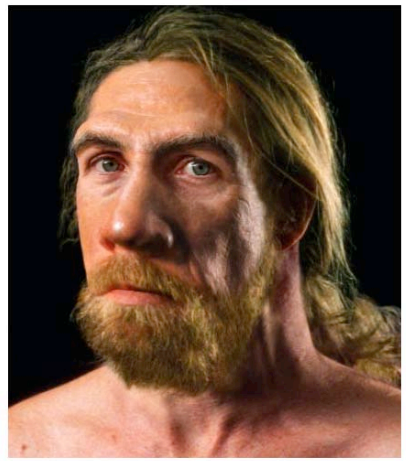
Recent Out of Africa Theory







Ancient DNA Reveals Neandertals With Red Hair, Fair Complexions



Ginger man. Some Neandertals had red hair and pale skin, as seen in this reconstruction of a French fossil.

Current Biology 17, 1908–1912, November 6, 2007 ©2007 Elsevier Ltd All rights reserved DOI 10.1016/j.cub.2007.10.008

Report

The Derived *FOXP2* Variant of Modern Humans Was Shared with Neandertals

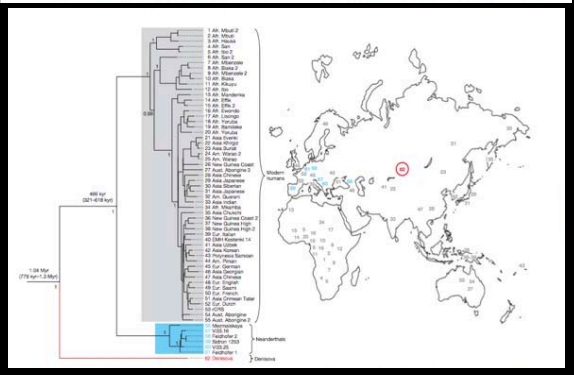
Johannes Krause,[1,*] Carles Lalueza-Fox,[2] Ludovic Orlando,[3,4] Wolfgang Enard,[1] Richard E. Green,[1] Hernán A. Burbano,[1] Jean-Jacques Hublin,[1] Catherine Hänni,[3,4] Javier Fortea,[5] Marco de la Rasilla,[5] Jaume Bertranpetit,[6] Antonio Rosas,[7] and Svante Pääbo[1]

doi:10.1038/nature08976 nature

LETTERS

The complete mitochondrial DNA genome of an unknown hominin from southern Siberia

Johannes Krause[1], Qiaomei Fu[1], Jeffrey M. Good[2], Bence Viola[1,3], Michael V. Shunkov[4], Anatoli P. Derevianko[4] & Svante Pääbo[1]



Ancient DNA: Applications

Diet and environmental reconstruction

Study the genetics of extinct populations and/or species- determine evolutionary relationships

Study ancient diseases- e.g. the Black Plague

Test for population continuity vs. replacement

Molecular sex determination

Domestication of plants and animals

Measure the rate of molecular evolution

Sex Identification of Children Sacrificed to the Ancient Aztec Rain Gods in Tlatelolco

Isabel De La Cruz, Angélica González-Oliver, Brian M. Kemp, Juan A. Román, David Glenn Smith, and Alfonso Torre-Blanco

Current Anthropology Volume 49, Number 3, June 2008

Temple R, Tlatelolco, Mexico

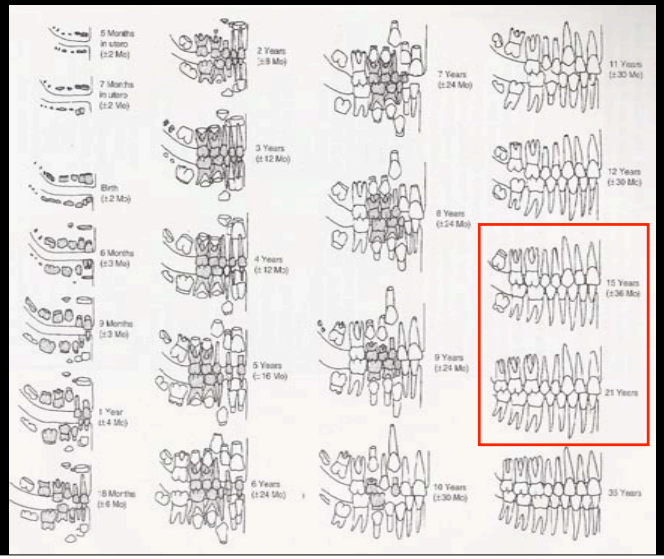
Ehecatl-Quetzalcoatl, from Codex Borgia

Sacrificial Victims

Six-year-old buried directly in ground.

Two-year-old buried in an olla.

How Old?
Dental Eruption



Research Question
Limited by Morphology Alone

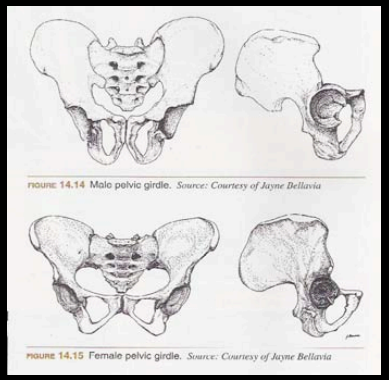


FIGURE 14.14 Male pelvic girdle. *Source: Courtesy of Jayne Bellavia*

FIGURE 14.15 Female pelvic girdle. *Source: Courtesy of Jayne Bellavia*

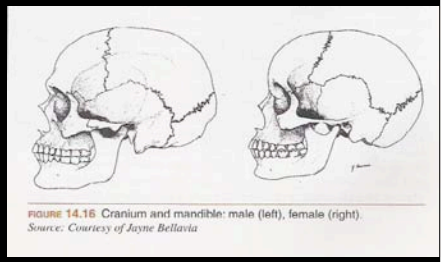
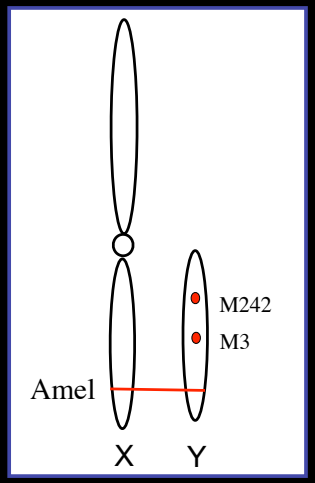
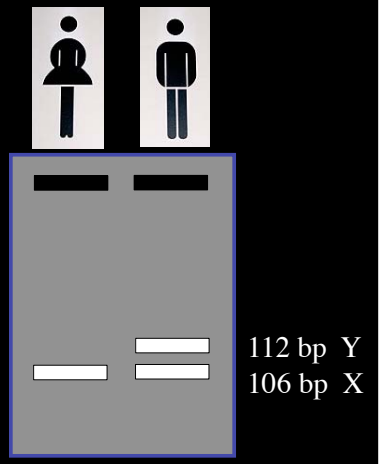


FIGURE 14.16 Cranium and mandible: male (left), female (right). *Source: Courtesy of Jayne Bellavia*

Research Plan
Get Right Down to the Point





Results

Mitochondrial DNA


Aztecs n=14

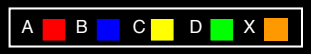
500 BP

De la Cruz et al. (2008)


Aztecs n=23

500 BP

Kemp et al. (2005)



Sex Determination

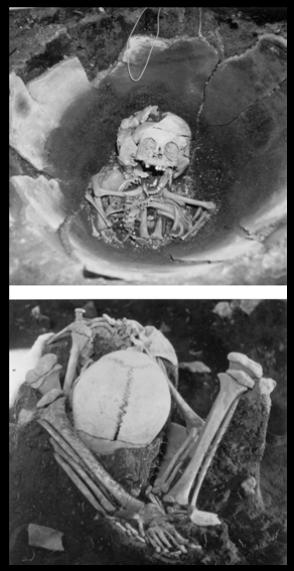
UNAM: 26/26=male

UC Davis: 9/10=male, 1/10=female

Implications


Tlaloc


Ehecatl-Quetzalcoatl



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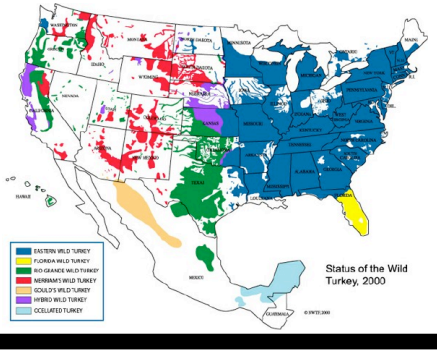
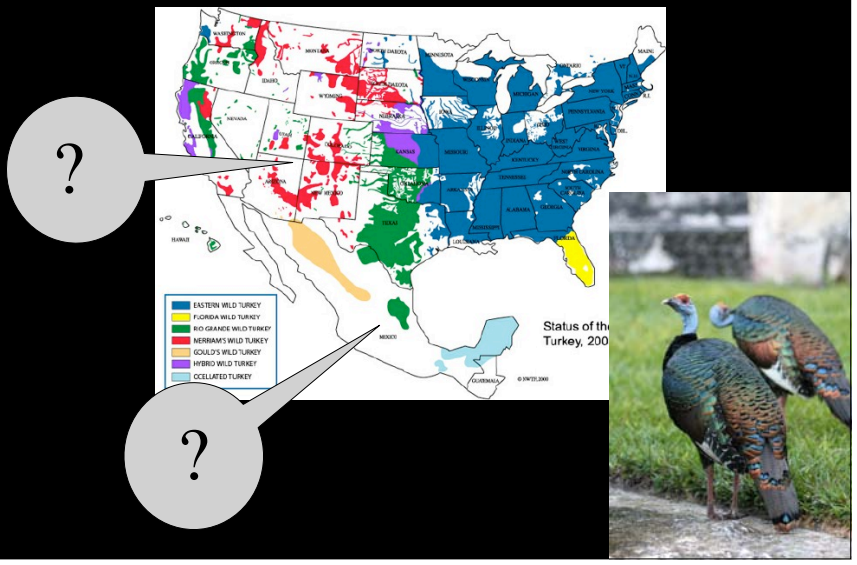
Turkey Domestication in the Southwest





PNAS

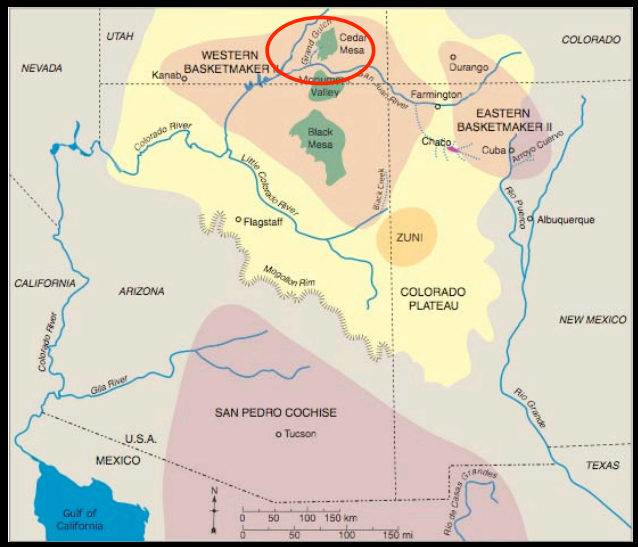
Ancient mitochondrial DNA analysis reveals complexity of indigenous North American turkey domestication

Camilla F. Speller[a], Brian M. Kemp[b,c,1], Scott D. Wyatt[b], Cara Monroe[c,d], William D. Lipe[b], Ursula M. Arndt[a], and Dongya Y. Yang[a,1]

[a]Ancient DNA Laboratory, Department of Archaeology, Simon Fraser University, Burnaby, BC V5A 1S6, Canada; [b]Department of Anthropology, Washington State University, Pullman, WA 99164; [c]School of Biological Sciences, Washington State University, Pullman, WA 99164; and [d]Department of Anthropology, University of California, Santa Barbara, CA 93106

Southwest Turkey Domestication: Hypothesis

Imported from Central Mexico



Turkey Pen Ruins

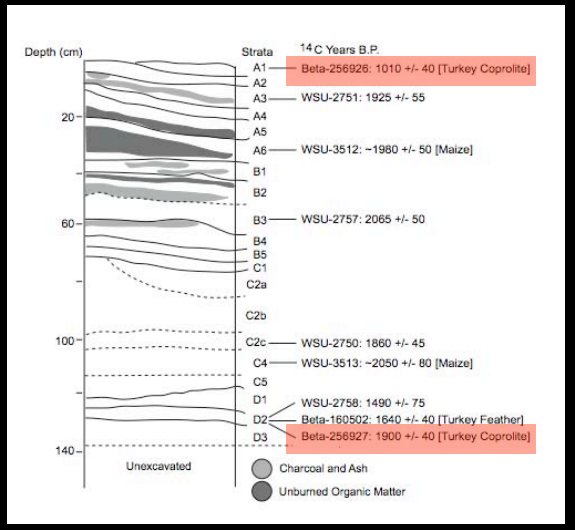
Turkey Pen Ruins

Bob Allen of the Green Expedition Excavating Turkey Pen Ruin, 1891

Image from Blackburn and Williamson (1997)

Members of the Green Expedition Excavating Turkey Pen Ruin, 1891

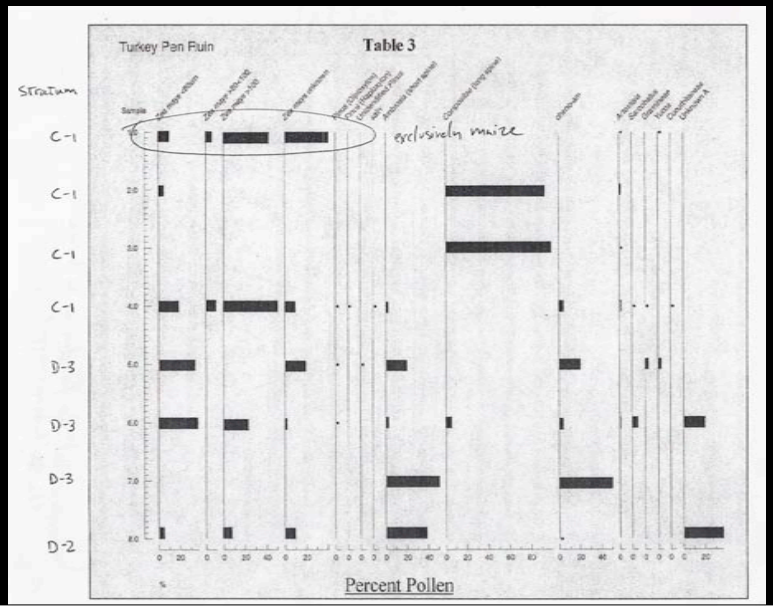
Image from Blackburn and Williamson (1997)

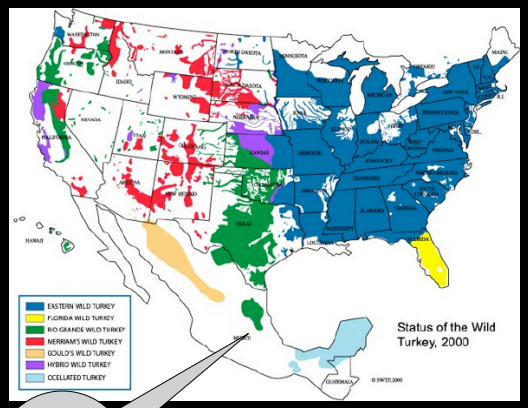


Modified from Matson 1991

How do we know they are coprolites from domestic turkeys?

How do we know they were “domestic” turkeys?



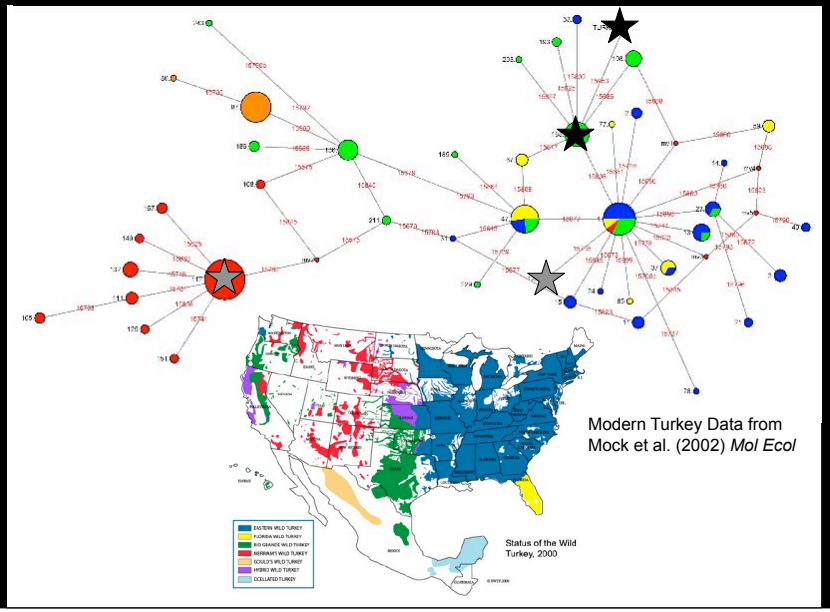


But, what about *M.g.gallopavo*?

Samples of the Extinct *Meleagris gallopavo gallopavo*
Courtesy of the Smithsonian

Catalog #	*Species:Subspeices*	County	State
185258	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185259	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185260	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185261	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185262	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185263	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185264	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
185265	*Meleagris gallopavo gallopavo*	Mexico	Michoacan De Ocampo
186838	*Meleagris gallopavo gallopavo*	Mexico	Veracruz-Llave
187318	*Meleagris gallopavo gallopavo*	Mexico	Veracruz-Llave

Results



Modern Turkey Data from Mock et al. (2002) *Mol Ecol*

PNAS

Ancient mitochondrial DNA analysis reveals complexity of indigenous North American turkey domestication

Camilla F. Speller[a], Brian M. Kemp[b,c,1], Scott D. Wyatt[b], Cara Monroe[c,d], William D. Lipe[b], Ursula M. Arndt[a], and Dongya Y. Yang[a,1]

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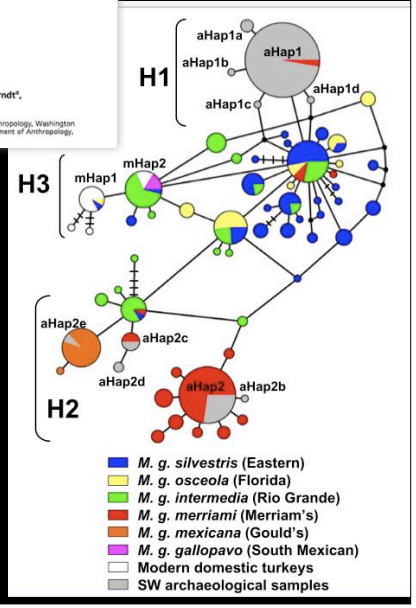

1 **Genetic and archaeological evidence for a former breeding population of Aleutian**
2 **cackling goose, *Branta hutchinsii leucopareia*, on Adak Island, central Aleutians,**
3 **Alaska**
4
5 B. J. Wilson, School of Biological Sciences, Washington State University, Pullman, WA
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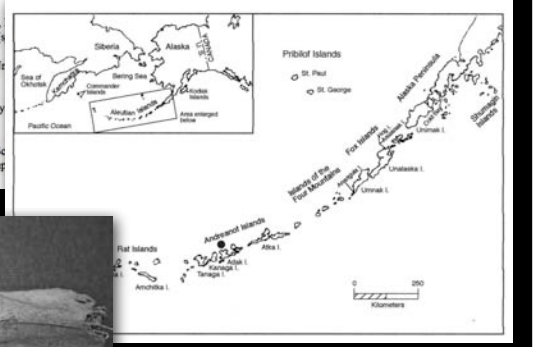

Ancient DNA: Applications

Diet and environmental reconstruction

Study the genetics of extinct populations and/or species- determine evolutionary relationships

Study ancient diseases- e.g. the Black Plague

Test for population continuity vs. replacement

Molecular sex determination

Domestication of plants and animals

Measure the rate of molecular evolution

Ancient DNA Studies

The future is now and it's great!

ARTICLES

Ancient human genome sequence of an extinct Palaeo-Eskimo

Morten Rasmussen[1,2]*, Yingrui Li[2,3]*, Stinus Lindgreen[1,4]*, Jakob Skou Pedersen[5], Anders Albrechtsen[4], Ida Moltke[4], Mait Metspalu[3], Ene Metspalu[3], Toomas Kivisild[3,6], Ramneek Gupta[7], Marcelo Bertalan[7], Kasper Nielsen[7], M. Thomas P. Gilbert[1,2], Yong Wang[8], Maanasa Raghavan[1,9], Paula F. Campos[1], Hanne Munkholm Kamp[1,4], Andrew S. Wilson[10], Andrew Gledhill[10], Silvana Tridico[11,12], Michael Bunce[12], Eline D. Lorenzen[1], Jonas Binladen[1], Xiaosen Guo[2,3], Jing Zhao[2,3], Xiuqing Zhang[2,3], Hao Zhang[2,3], Zhuo Li[2,3], Minfeng Chen[2,3], Ludovic Orlando[13], Karsten Kristiansen[2,3,4], Mads Bak[14], Niels Tommerup[14], Christian Bendixen[15], Tracey L. Pierre[16], Bjarne Grønnow[17], Morten Meldgaard[18], Claus Andreasen[19], Sardana A. Fedorova[9,20], Ludmila P. Osipova[21], Thomas F. G. Higham[9], Christopher Bronk Ramsey[10], Thomas v. O. Hansen[22], Finn C. Nielsen[22], Michael H. Crawford[23], Søren Brunak[7,24], Thomas Sicheritz-Pontén[7], Richard Villems[3], Rasmus Nielsen[4,8], Anders Krogh[2,4], Jun Wang[2,3,4] & Eske Willerslev[1,2]