DNA footprints of livestock domestication and evolutionary history

Paolo Ajmone Marsan
Istituto di Zootecnica
Università Cattolica del S. Cuore
Piacenza, Italy
paolo.ajmone@unicatt.it

Darwin Symposium, 60° EAAP meeting, Barcelona, August, 24, 2009

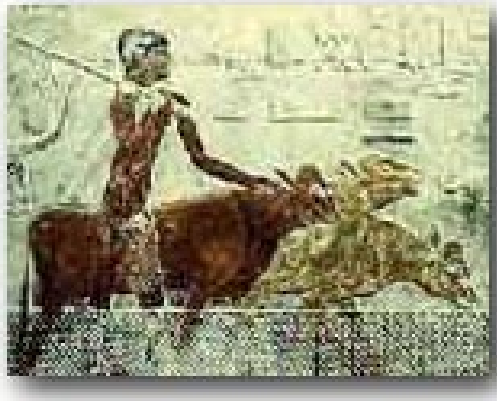
INDEX

- Domestication: a turning point
- Darwin and domestic animals
- A domestication experiment
- A few glances in the past
- What’s next?

Domestication: a turning point

Why investigating domestication and post-domestication history

To understand present biodiversity



MOLECULAR GENETICS

Models of genetic variability

Domestic animals molecular genetics

THE HUMAN PAST

Models of culture processes

Models of linguistic changes

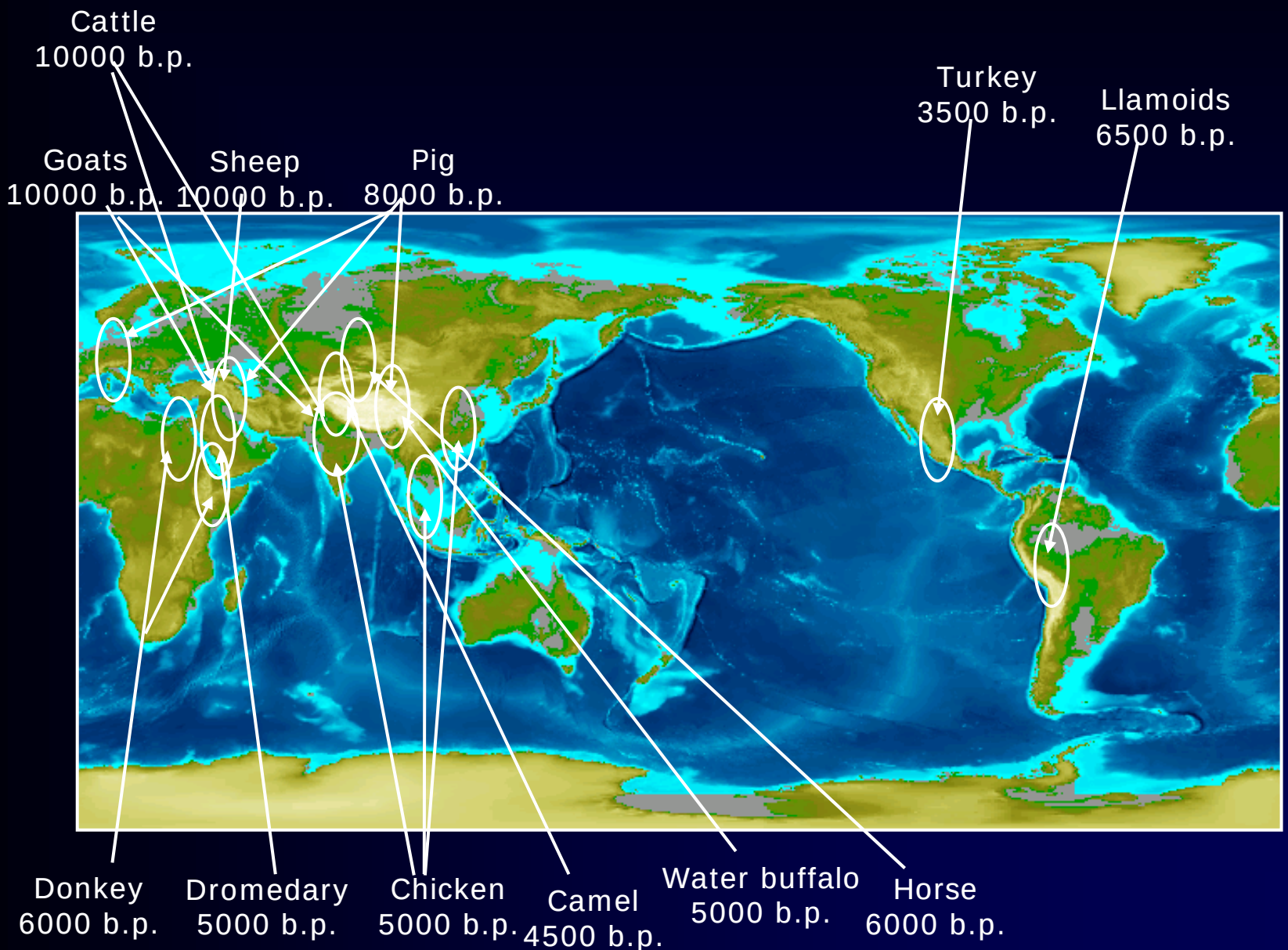
PREHISTORIC ARCHAEOLOGY

HISTORICAL LINGUISTICS

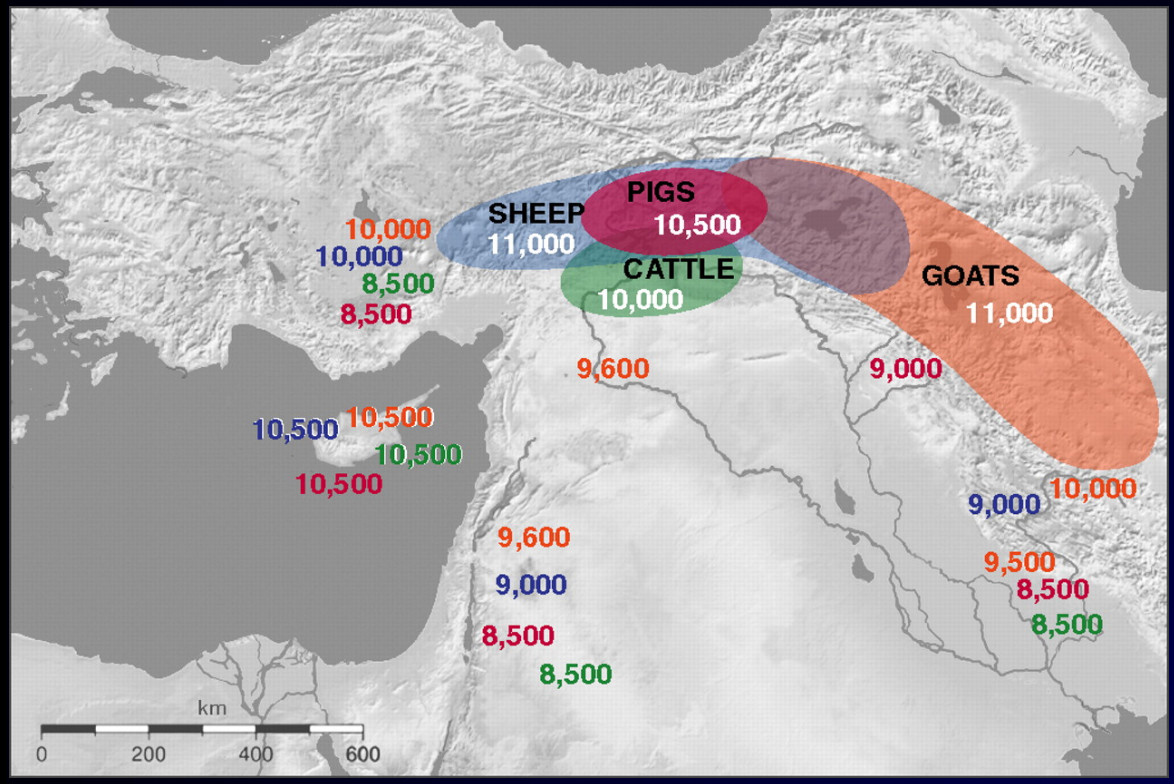
Rome

Barcelona

Multiple domestications



Archaeology and archaeozoology



Zeder M. A. PNAS 2008;105:11597-11604

Change in tools
Change in settlements
Artistic representations

Bone and horns morphology and size
Temporal shifts in faunal distribution
Sex ratio of remains

Radiocarbon dating

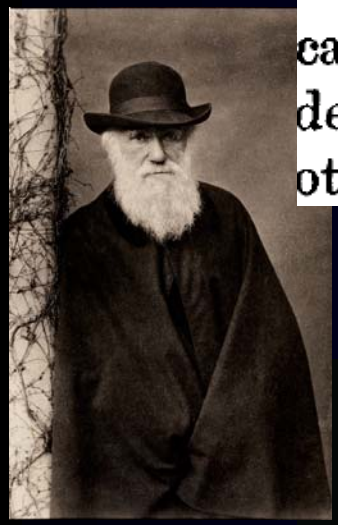
Cattle ancient remains

8500 BC in the Fertile Crescent
7000 BC in the Indus valley
6500 BC in Africa
4000 BC in North East Asia

(Meadow, 1993; Helmer et al., 2005; Payne & Hodges 1997)

Darwin and Domestic Animals

Darwin and domestic animals



I HAVE been led to study domestic pigeons with particular care, because the evidence that all the domestic races are descended from one known source is far clearer than with any other anciently domesticated animal. Secondly, because many

Darwin and domestic animals

No doubt man selects their varying individuals, sows their seeds, and again selects their varying offspring...

Man therefore may be said to have been trying an experiment on a gigantic scale; and it is an experiment wich nature during the long lapse of time has incessantly tried

C. Darwin The variation of animals and plants under domestication London: J. Murray 1868

Darwin's observation on domestic animals

Morphological or physiological changes	Species
appearance of dwarf and giant varieties	all
piebald coat color	all
wavy or curly hair	sheep, dogs, donkeys, horses, pigs, goats, mice, guinea pigs
rolled tails	dogs, pigs
shortened tails, fewer vertebrae	dogs, cats, sheep
floppy ears	dogs, cats, pigs, horses, sheep, goats, cattle
changes in reproductive cycle	all except sheep

Trut 1999, American Scientist

Trut 2009, BioEssays

Same genetic process during the domestication of different species?

A domestication experiment

Belyaev hypothesis

- Behavior is regulated by a fine balance between neurotransmitters and hormones
- Genes that control that balance occupy a high level in the hierarchical system of the genome.
- Slight alterations in those regulatory genes produce a network of changes.

The farmed fox Belyaev experiment

Results

- Change in morphological traits (ears, tail, spotting, skeletal)

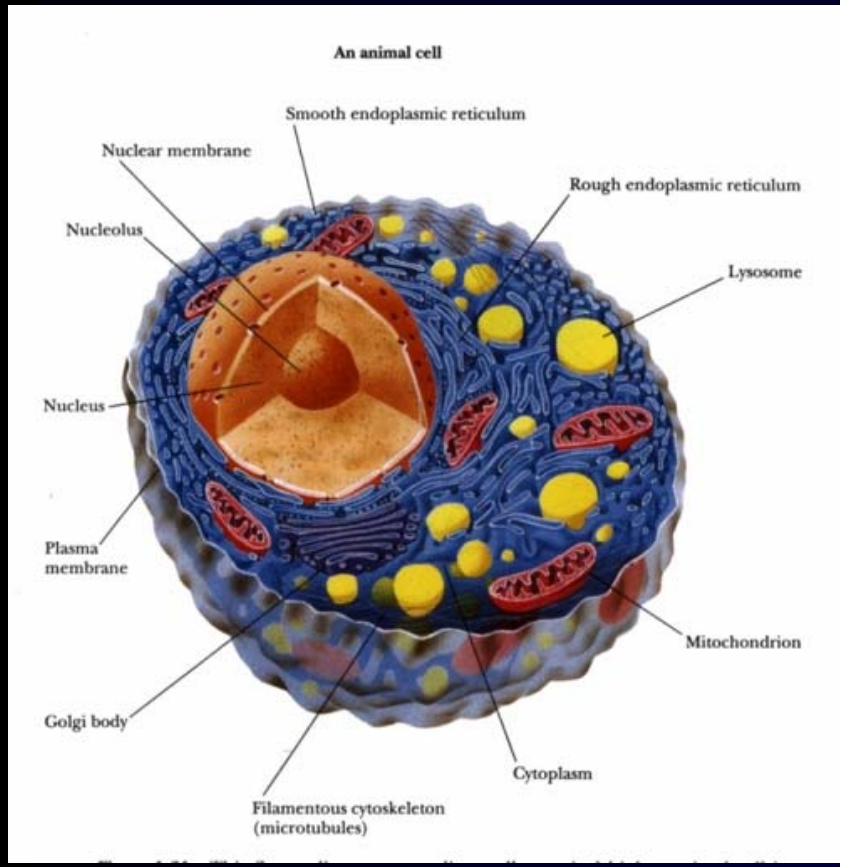


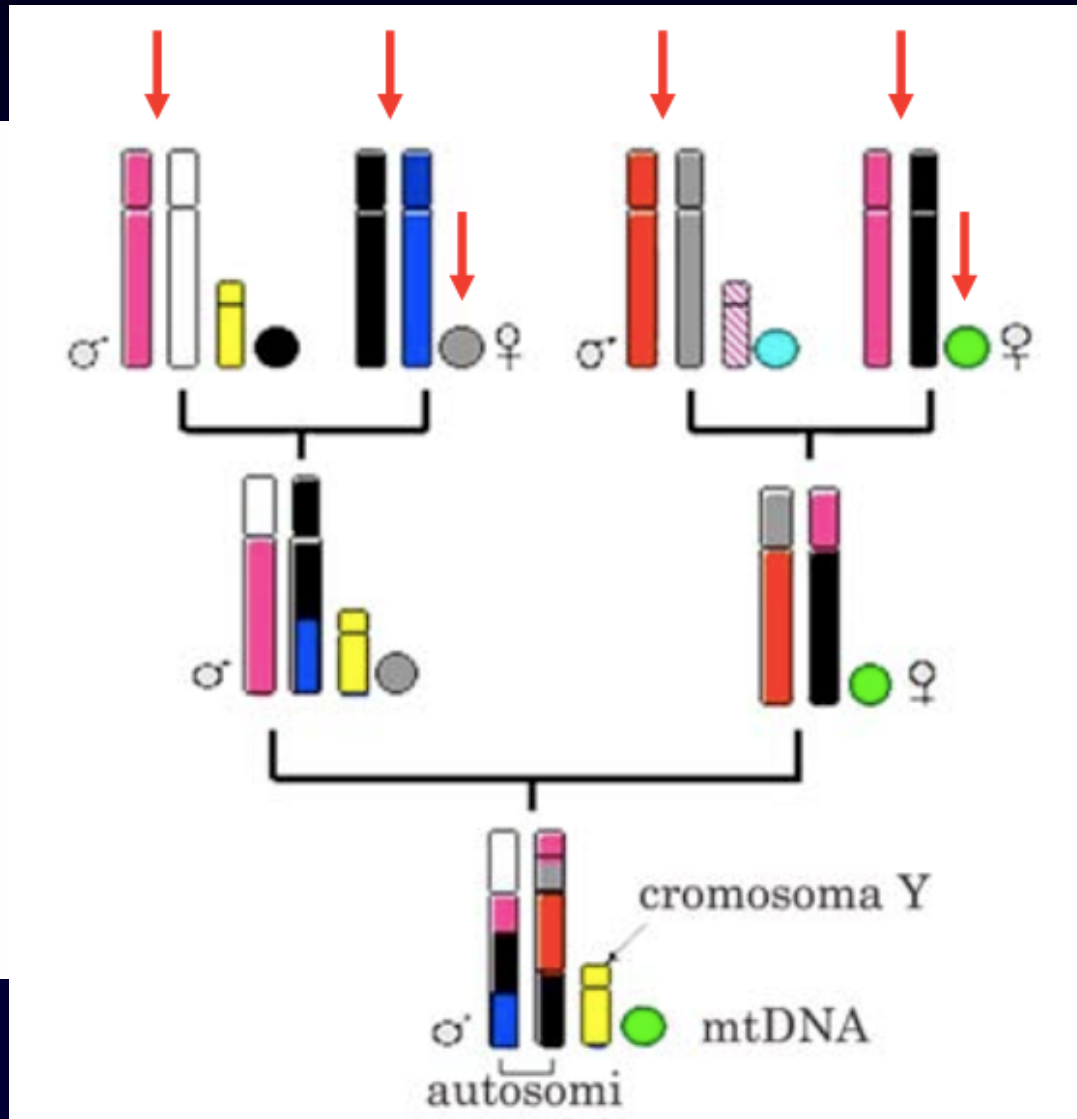
- Delay in development, neotenic behavior
- Early puberty and loss of seasonality
- Attenuated activity of the Hypothalamic-Pituitary-Adrenal axis (stress response and fear)

Epigenetics and genomics!

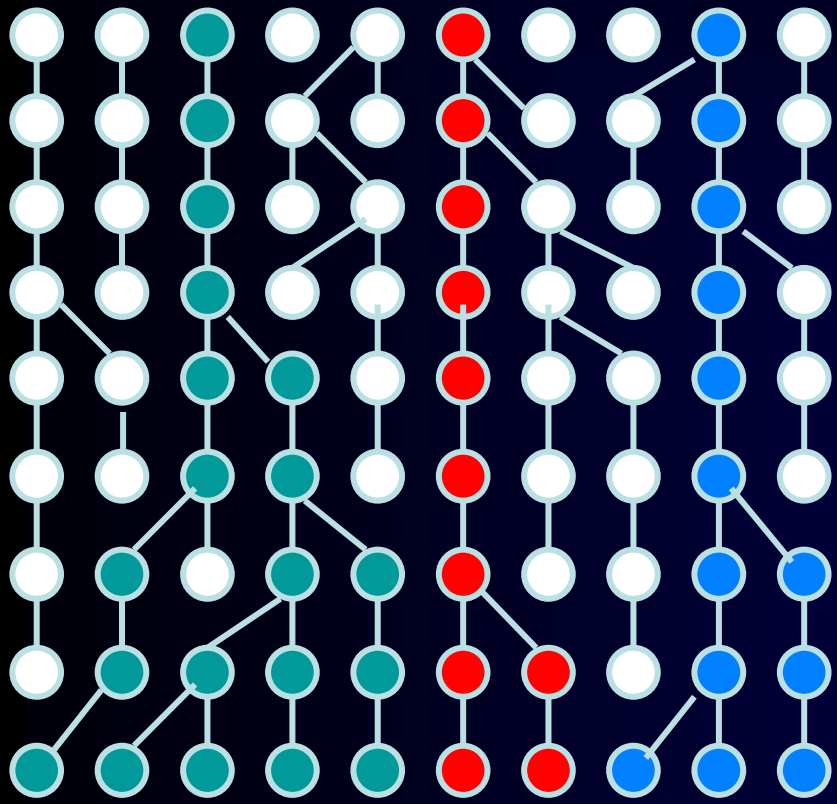
A few DNA glances in the past

Two genomes, three modes of transmitting information

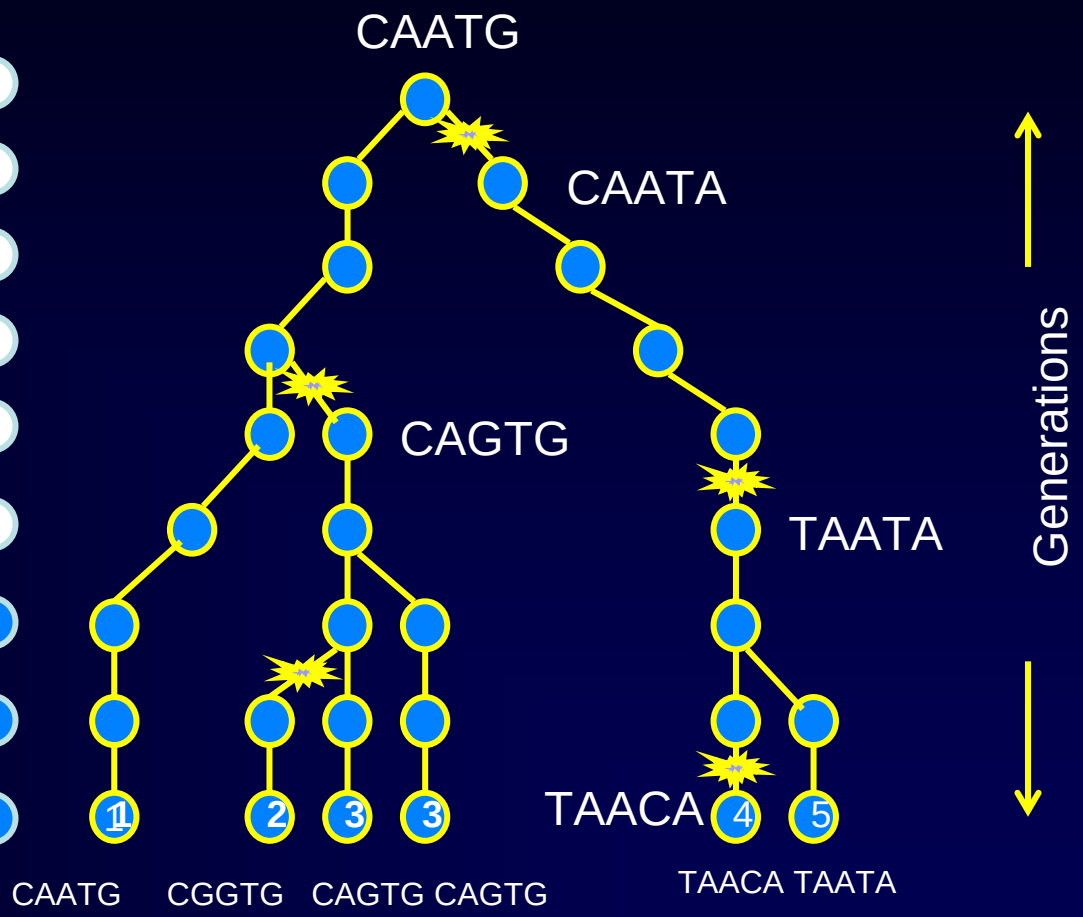




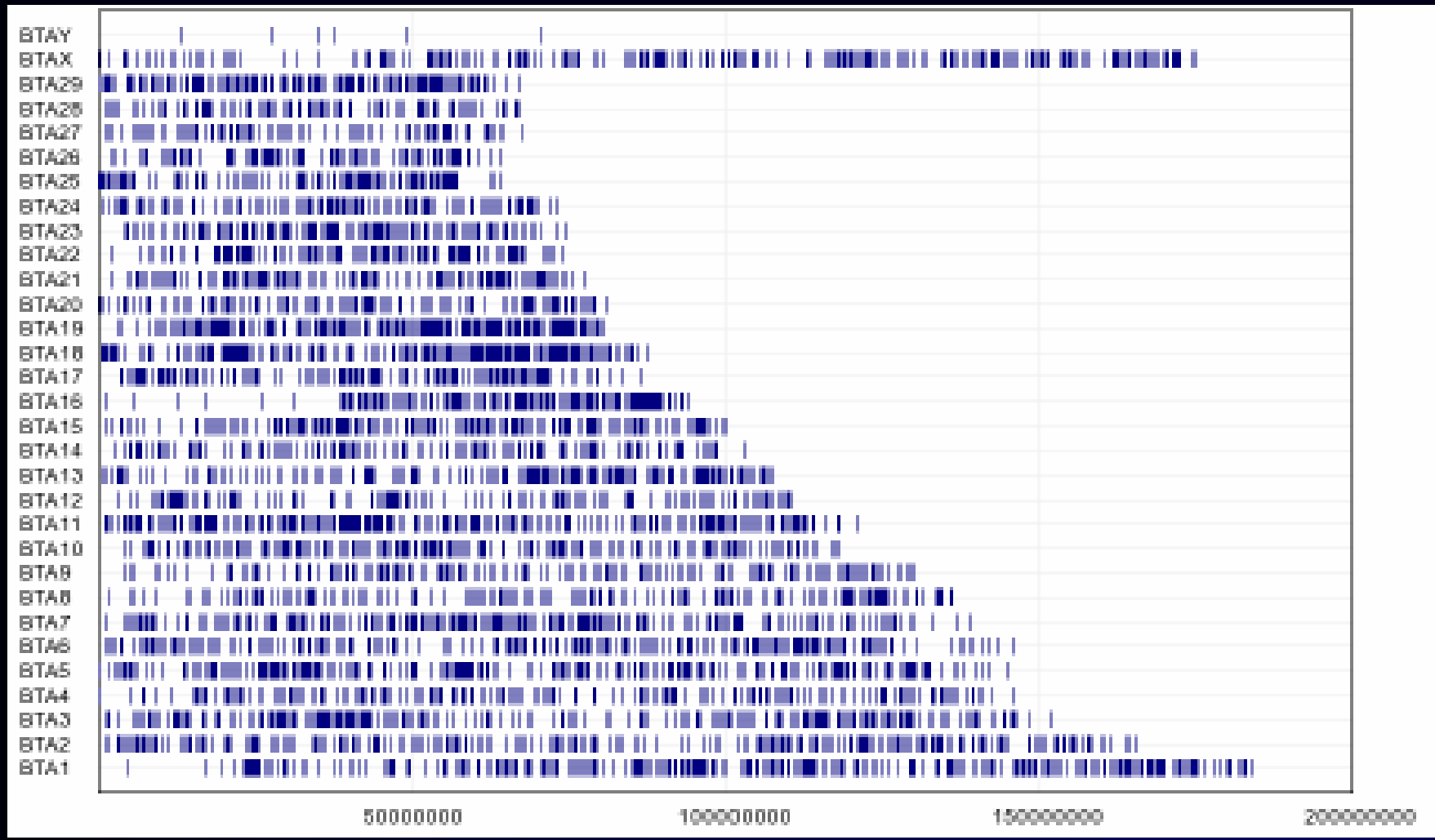
Haplogroups and haplotypes



Groups of sequences descending from a common ancestor



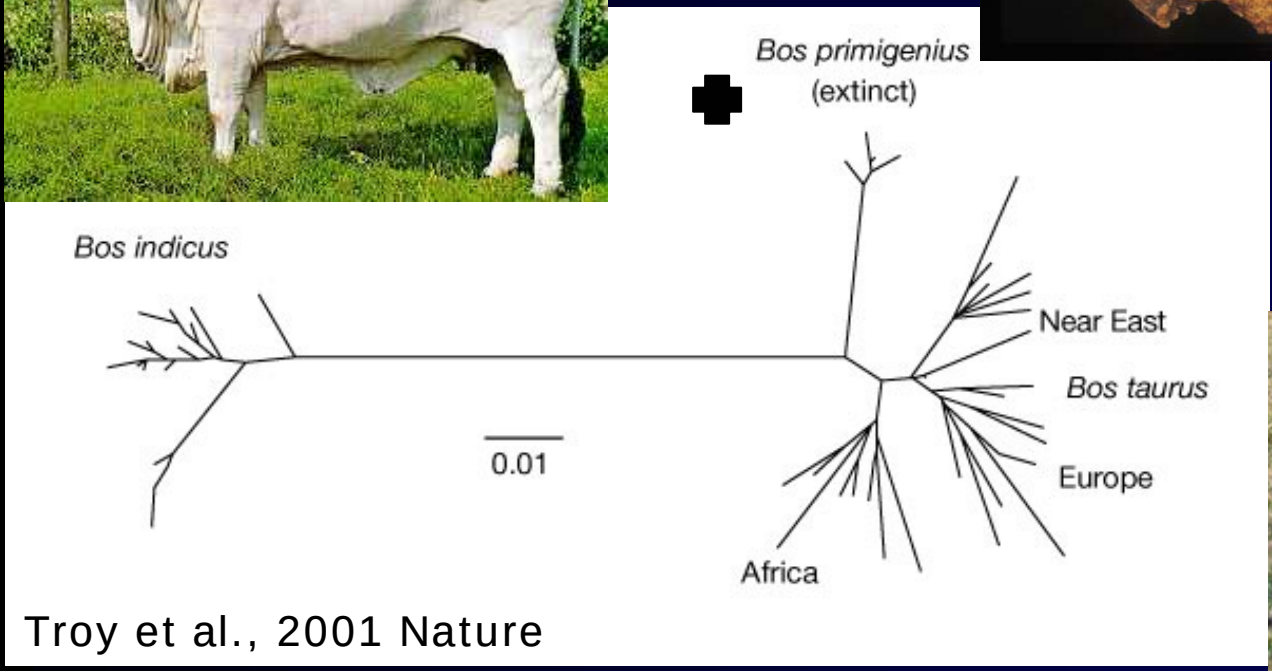
Cattle Genechip ~54001 SNPs



Glance 1: *B. indicus* and *B. taurus* domestication event(s)

B. taurus and B. indicus

Two auroch subspecies domesticated in different geographic areas some 10.000 b.p.

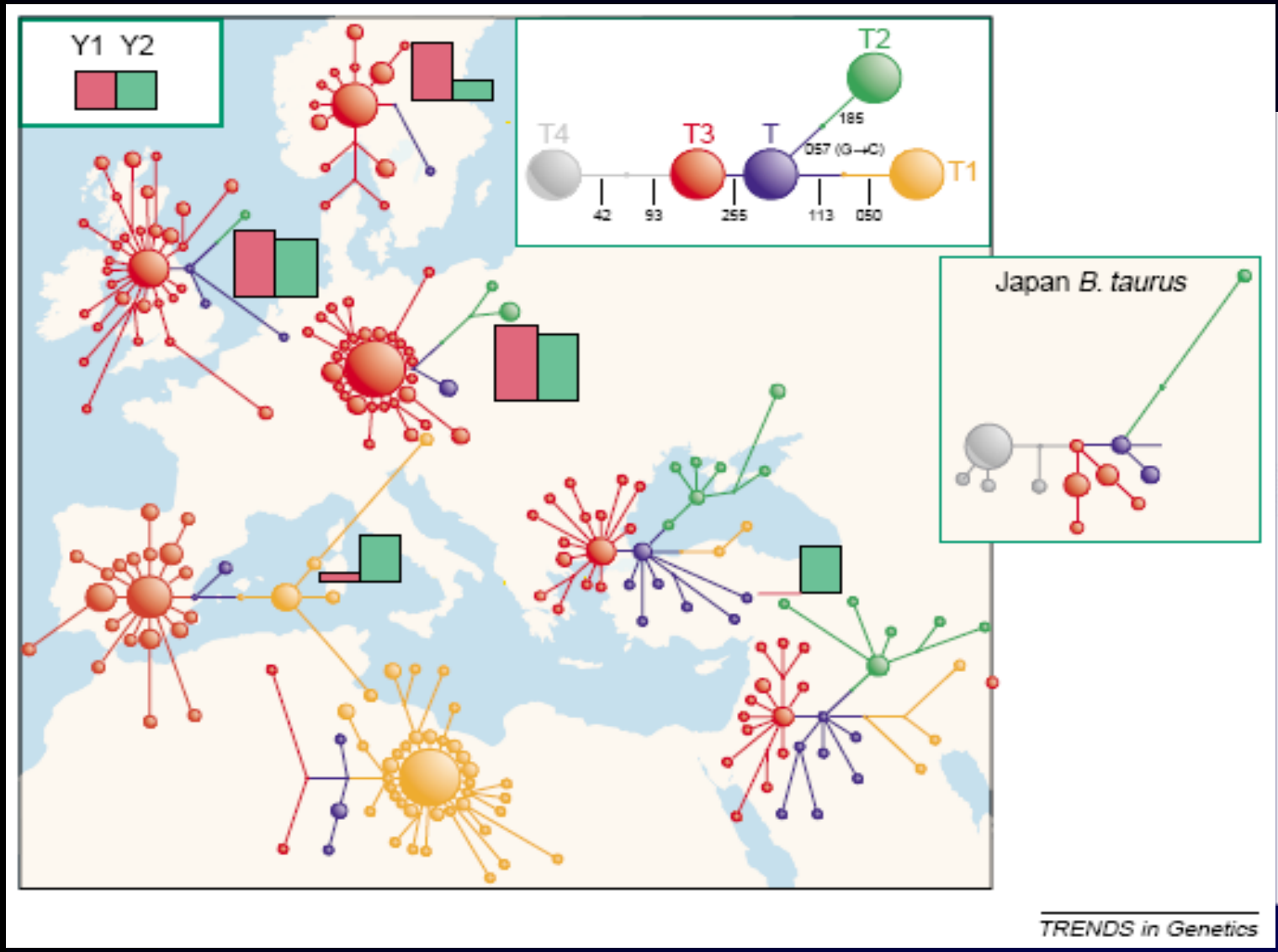


Troy et al., 2001 Nature

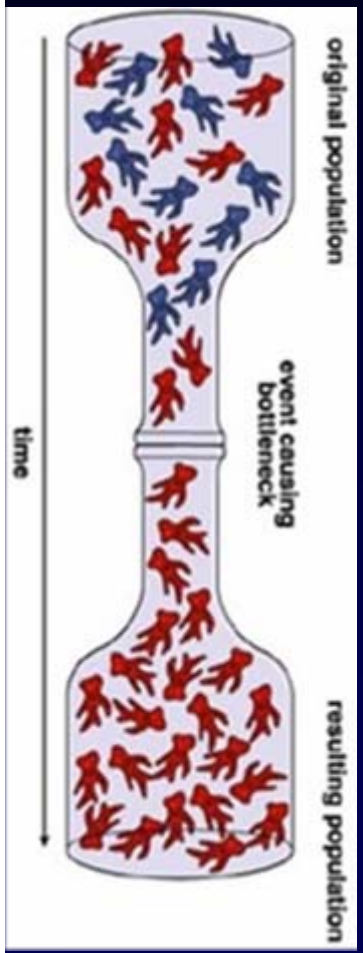
mtDNA: D-loop 281 pb; NJ tree

Divergence between *Bos indicus* and *Bos taurus* dates back at least 100.000 years

Multiple Bos taurus domestication events?

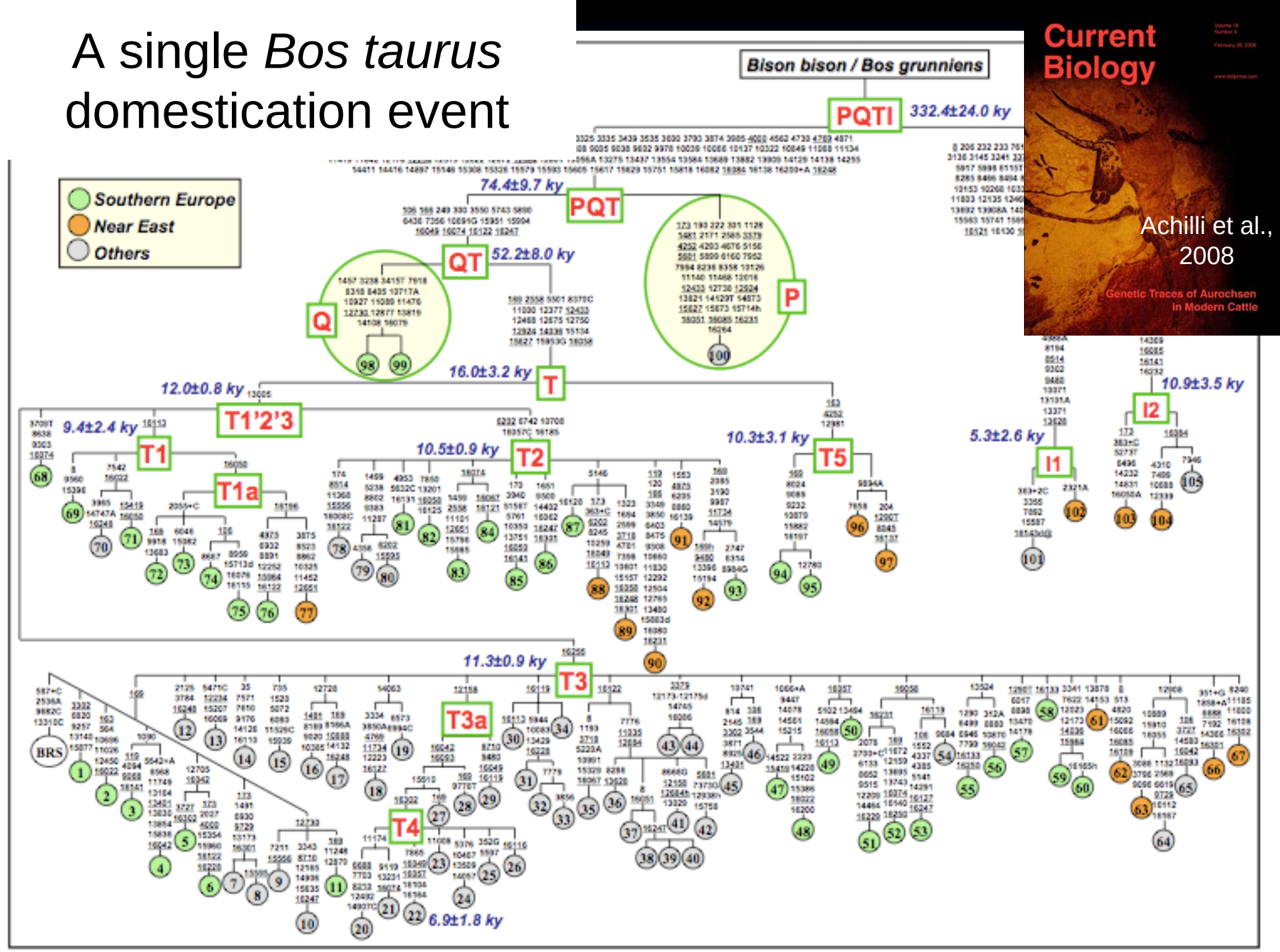


Zeder et al., TIG, 2006



In Africa (T1)? In Eastern Asia (T4)?

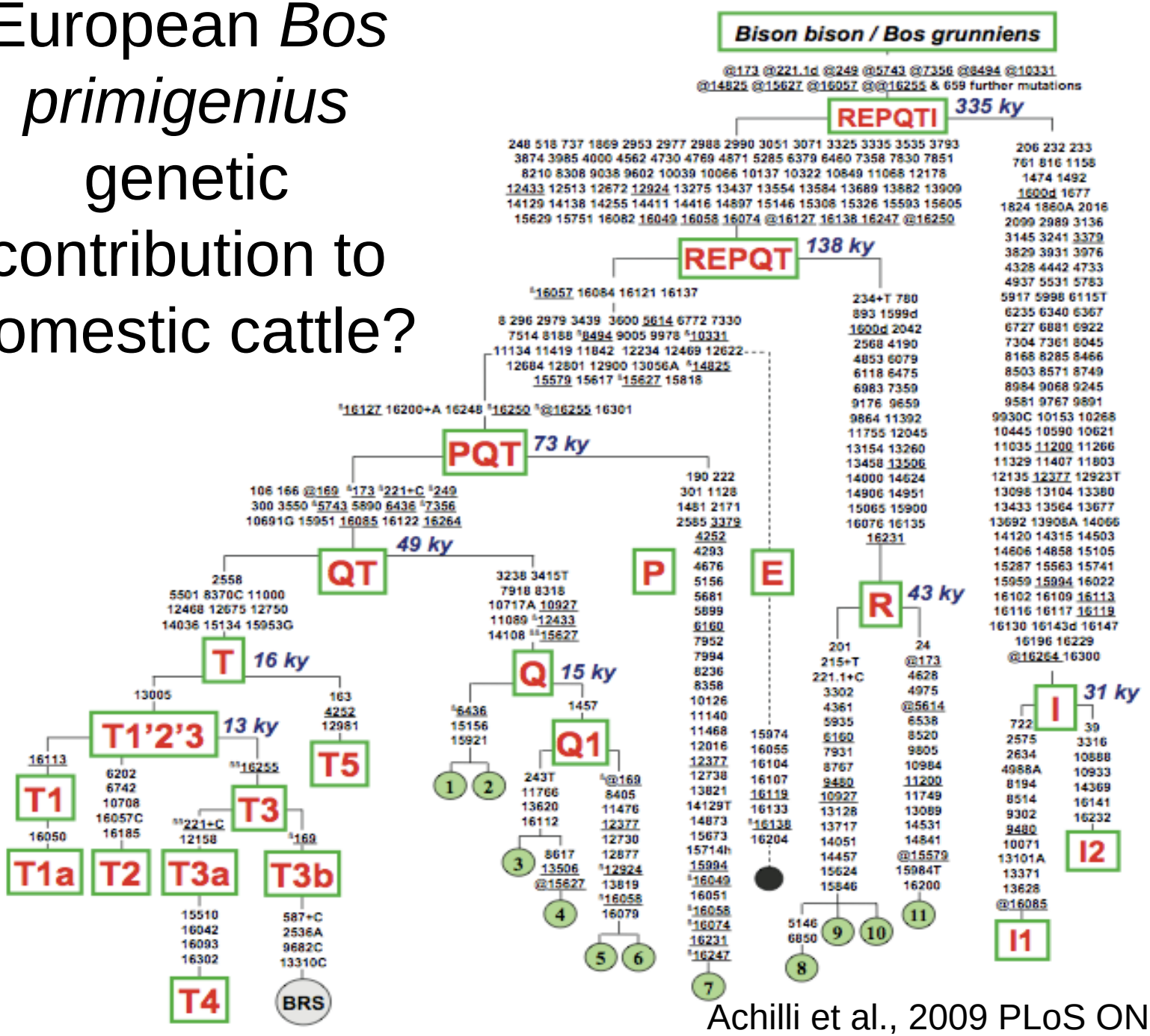
A single *Bos taurus* domestication event



Achilli et al., 2008

Glance 2: European auroch contribution to taurine diversity

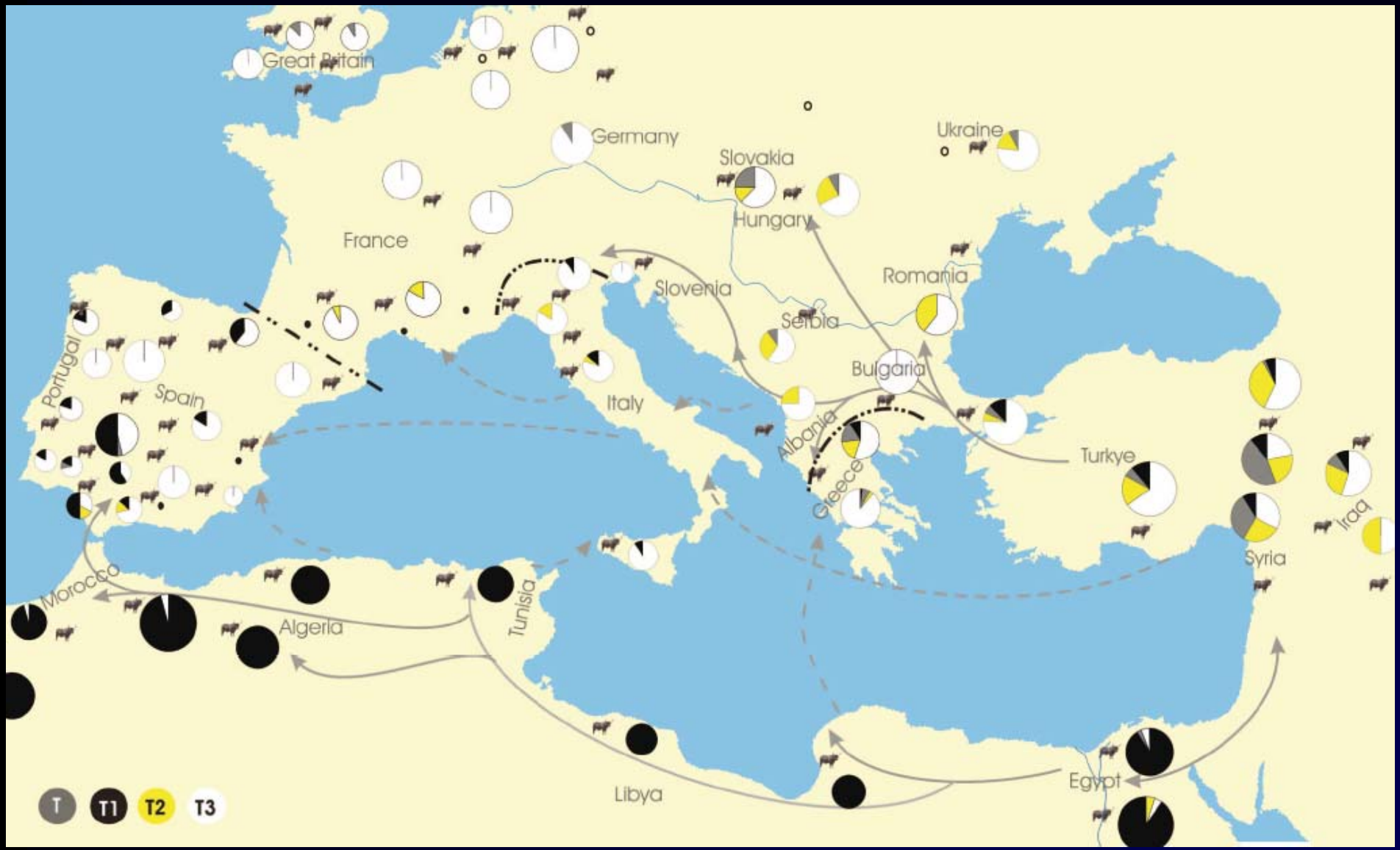
European *Bos primigenius* genetic contribution to domestic cattle?



Achilli et al., 2009 PLoS ONE

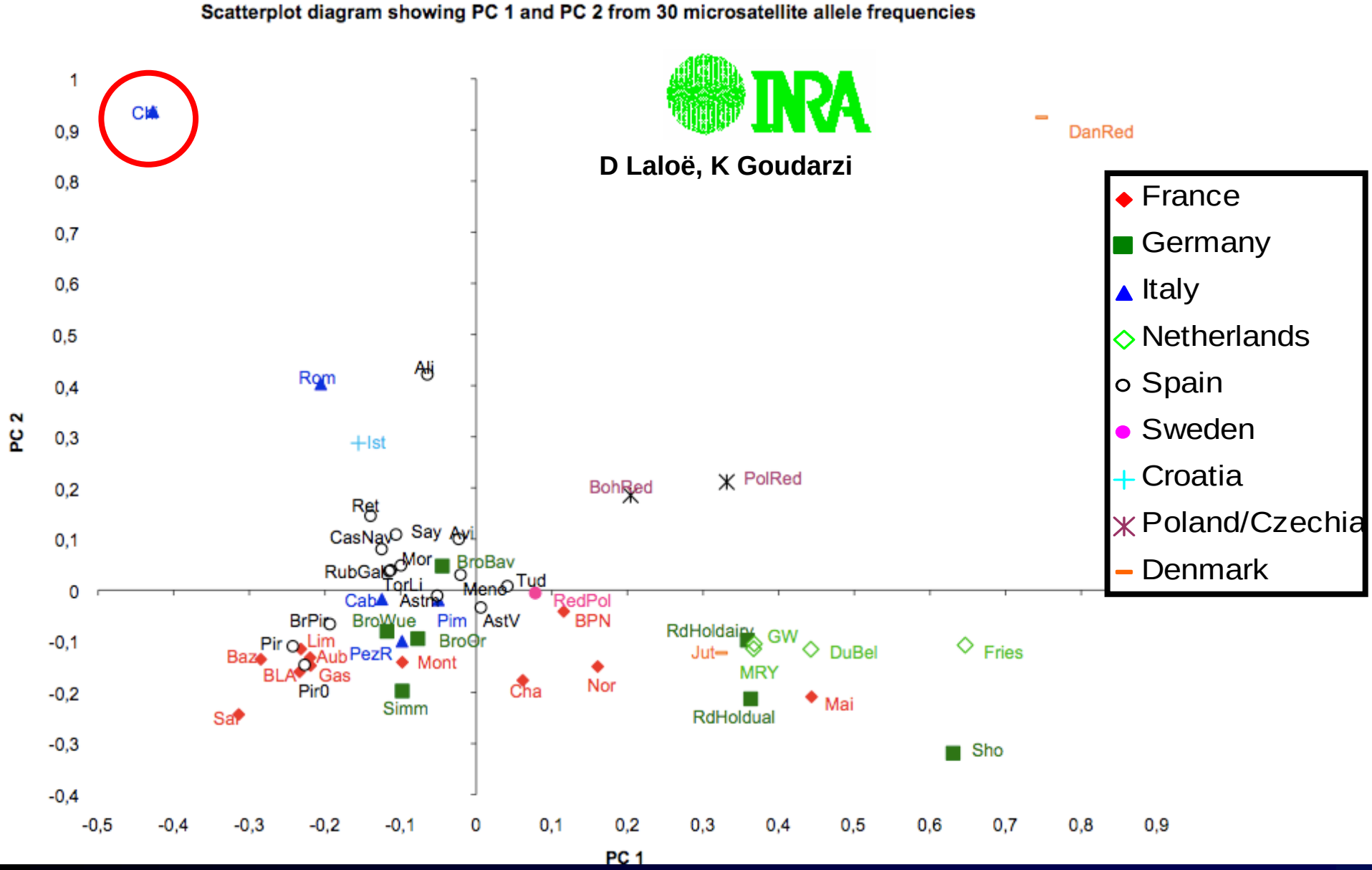
Glance 3: colonization routes

Cattle colonization routes in Europe



Beja-Pereira et al., PNAS 2006

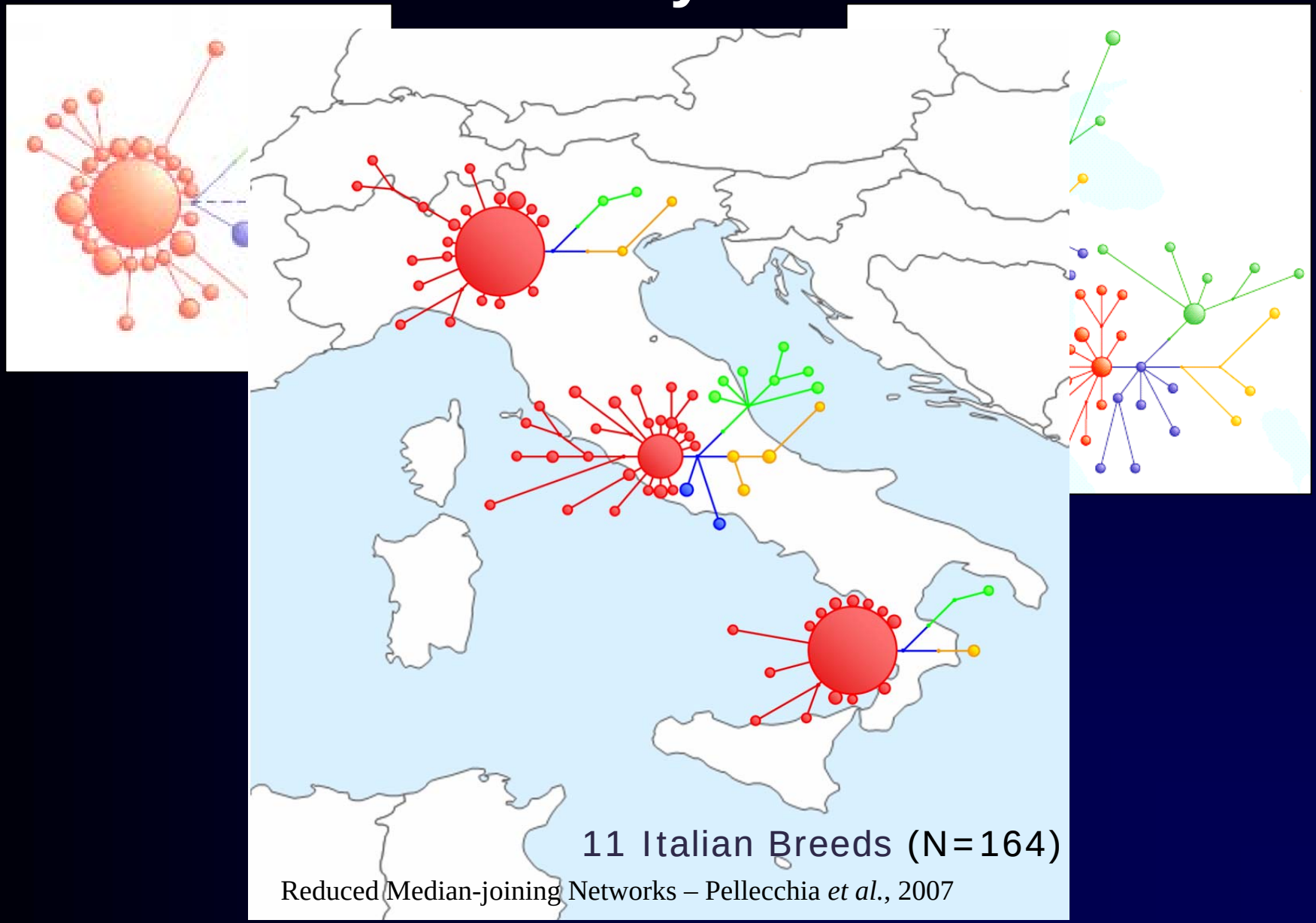
Towards a strategy for the conservation of the genetic diversity of European cattle



Central Europe

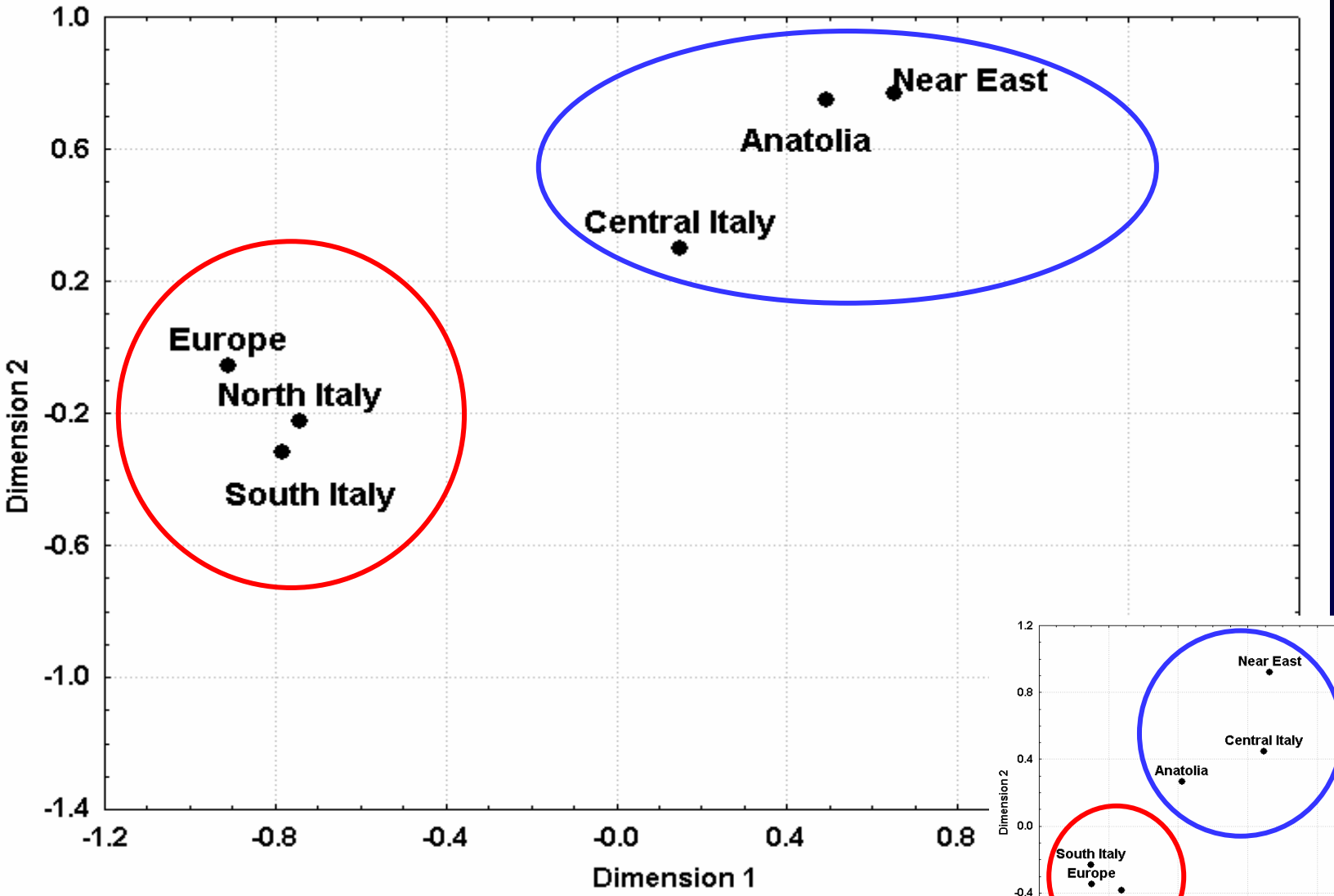
Italy

Near East

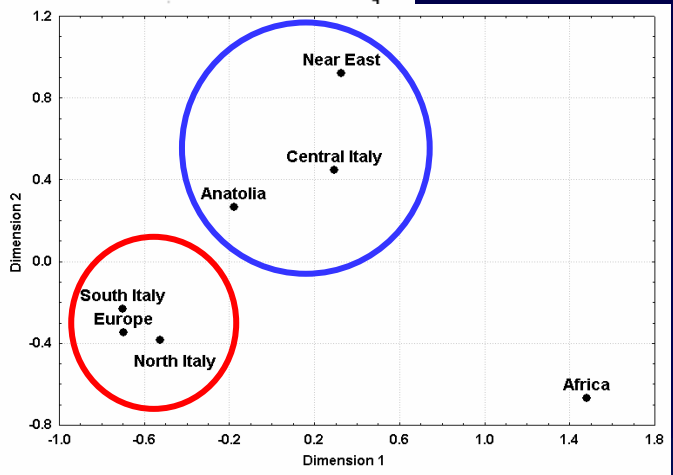


Reduced Median-joining Networks – Pellecchia *et al.*, 2007

All haplogroups (T, T1, T2 and T3)



T3 only



Central Italian cattle breeds

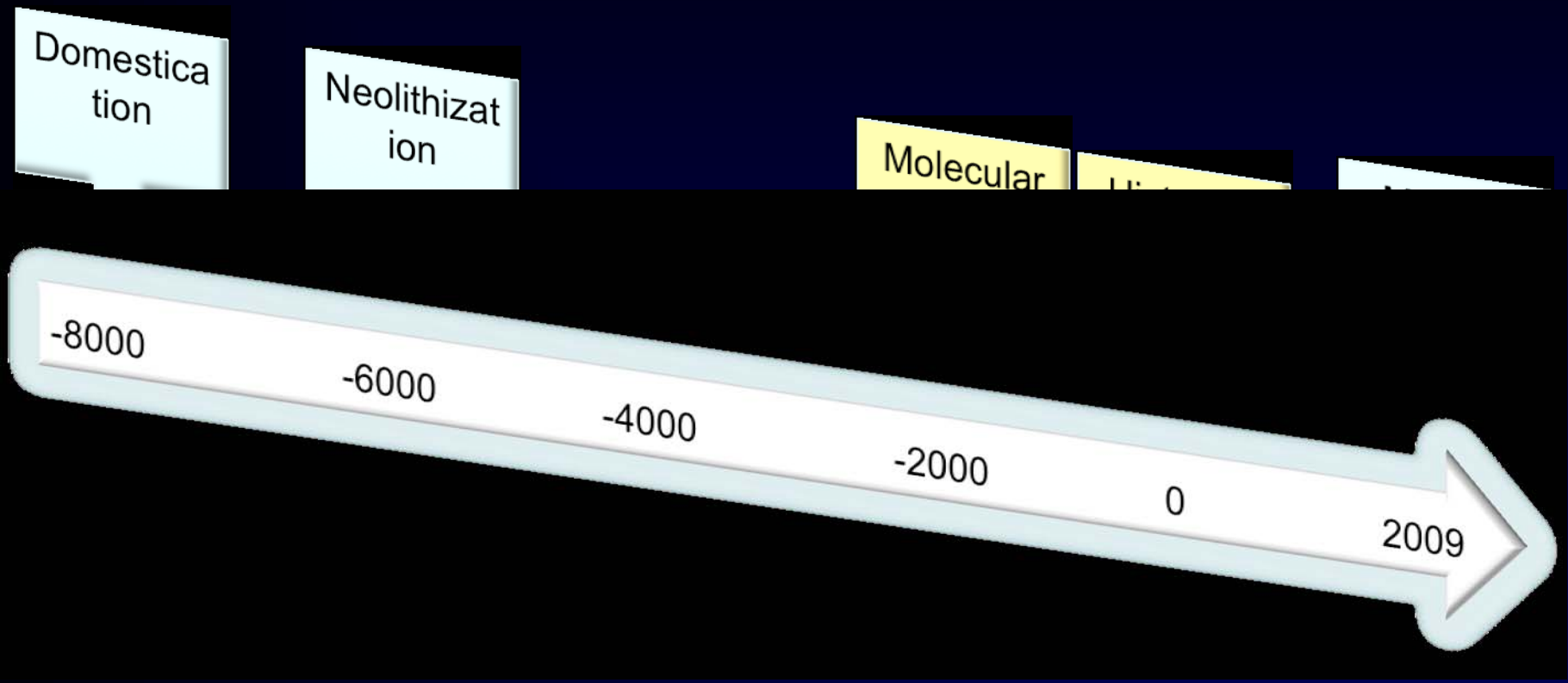
Maremmana

Chianina

Calvana

Cabannina

When did they arrive?



Links with Etruscan civilization

Pellecchia et al 2007
Proc. R. Soc. B

Domesti cation

Neolithi zation

Molecul

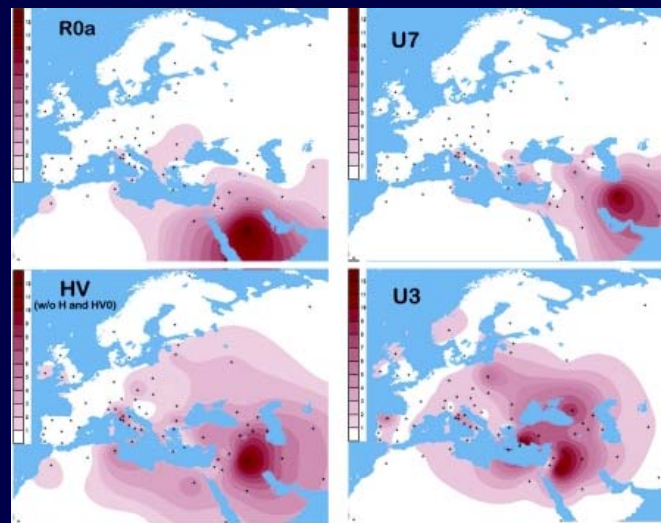
-8000 -6000 -4000 -2000 0 2009

Etruscans onset

Time

Geography

Human data



Achilli et al 2007
Am. J. Human Genet.

ALL ROADS TAKE TO ROME…..?

Before Rome many roads already took nearby, to Tarquinia, Caere, Cerveteri, Chiusi, Murlo…

Glance 4: the signatures of selection

Selection signature

The bovine HapMap Consortium et al., 2009, Science

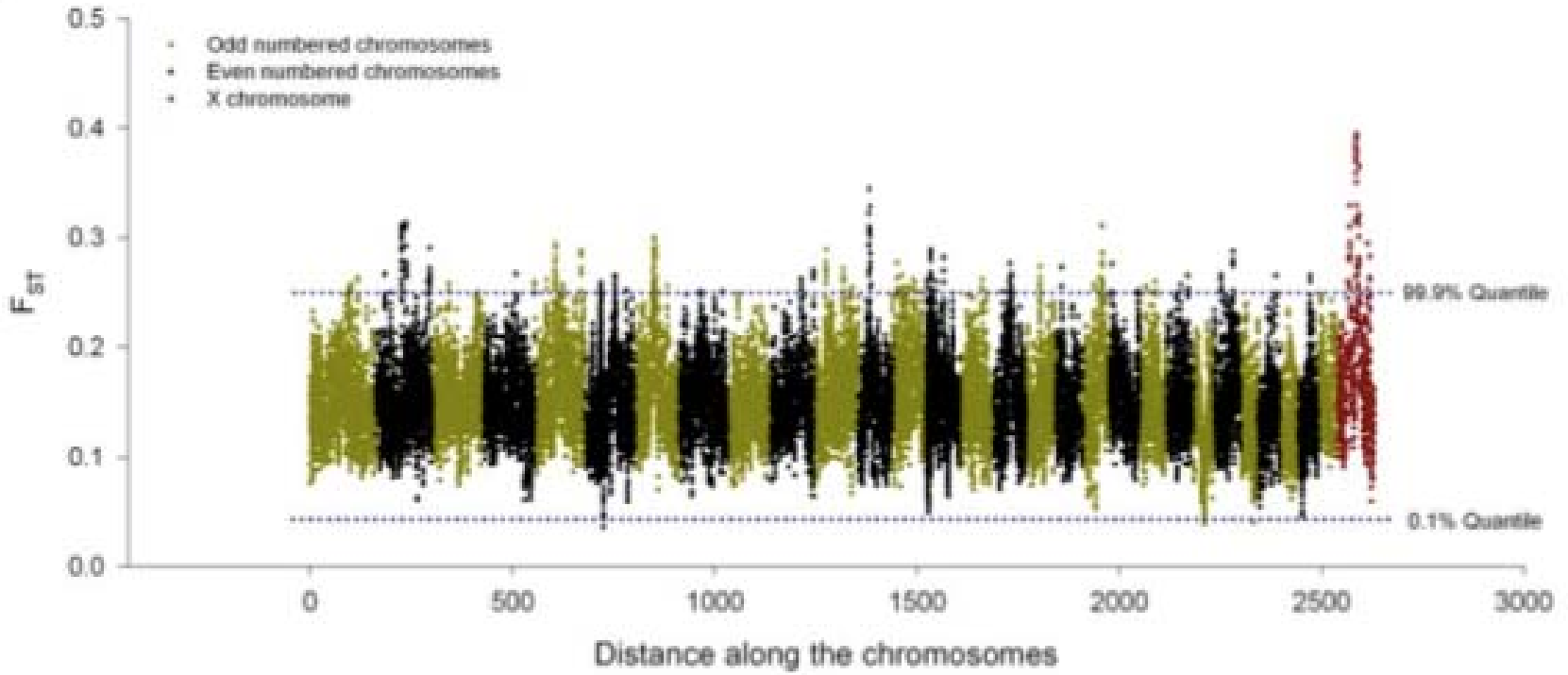


Fig. S21. Genome-wide scan for positive selection. The distribution of F_{ST} averaged across a sliding 8 SNP window is shown for all breeds. Dashed lines represent the 0.1% and 99.9% quantiles for the genome-wide F_{ST} values.

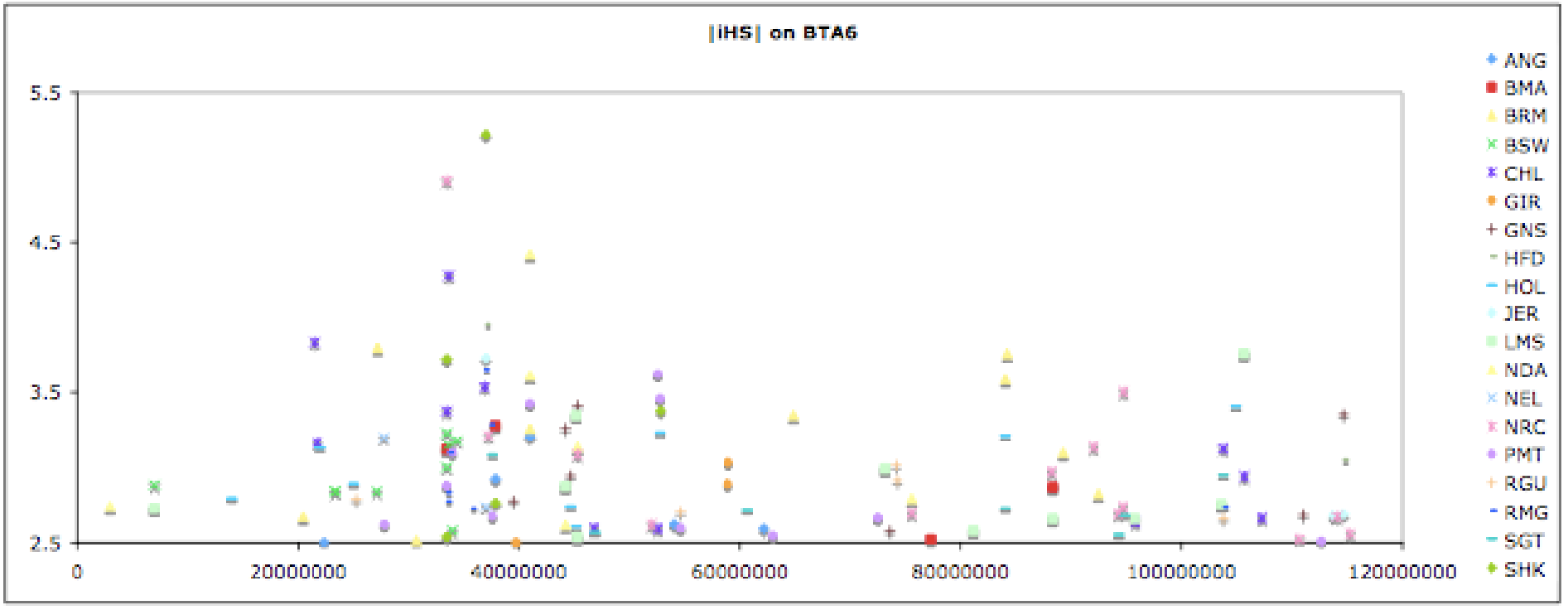
Selection signature

Table 1. Genomic regions associated with extreme F_{ST} values with gene content consistent with domestication. F_{ST} values averaged over eight adjacent SNP. Gene functions from OMIM and NCBI Gene database, except for *R3HDM1* described in (*2*).

Genes	Index SNP	F_{ST}	BTA	Location	Effect or important phenotypes
High values					
ZRANB3, R3HDM1	rs29021800	0.31	2	64740286...64931017	Feed efficiency
WIF1	BTA-27454	0.29	5	52696749...53098507	Mammalian mesoderm segmentation
SPOCK1	BTA-142690	0.30	7	47501122...47899778	Proteoglycan—synaptic fields of the developing CNS
NBEA	BTA-153392	0.34	12	25884192...26189285	Human idiopathic autism
NMT1, DCAKD, C1QL1	BTA-45533	0.31	19	46088946...46157261	Activator of serum complement system
DACH2, CHM, POU3F4, BRWD3	BTA-161991	0.39	X	41471338...44478564	Human mental retardation
NLGN3 to *DGAT2L6*	BTA-164256	0.36	X	49279035...50192452	Severe combined immunodeficiency
Low values					
PPARGC1A, DHX15, SOD3	BTC-039516	0.04	6	45354707...45415844	Antioxidative extracellular protection
No known gene	BTC-049723	0.05	14	4569804...5204473	
DNAH9	rs29018632	0.05	19	30943404...31220868	Multisubunit molecular motor
POU5F1, MHC	BTA-55856	0.05	23	27895932...28145846	Major histocompatibility complex
ZNF187	rs29024230	0.04	23	30241236...30502690	Expressed in olfactory tissues
AUTS2	BTC-074065	0.04	25	31773107...32498861	Human autism susceptibility candidate
RYR2	rs29011563	0.05	28	8736599...8772178	Stress- and exercise-induced sudden cardiac death

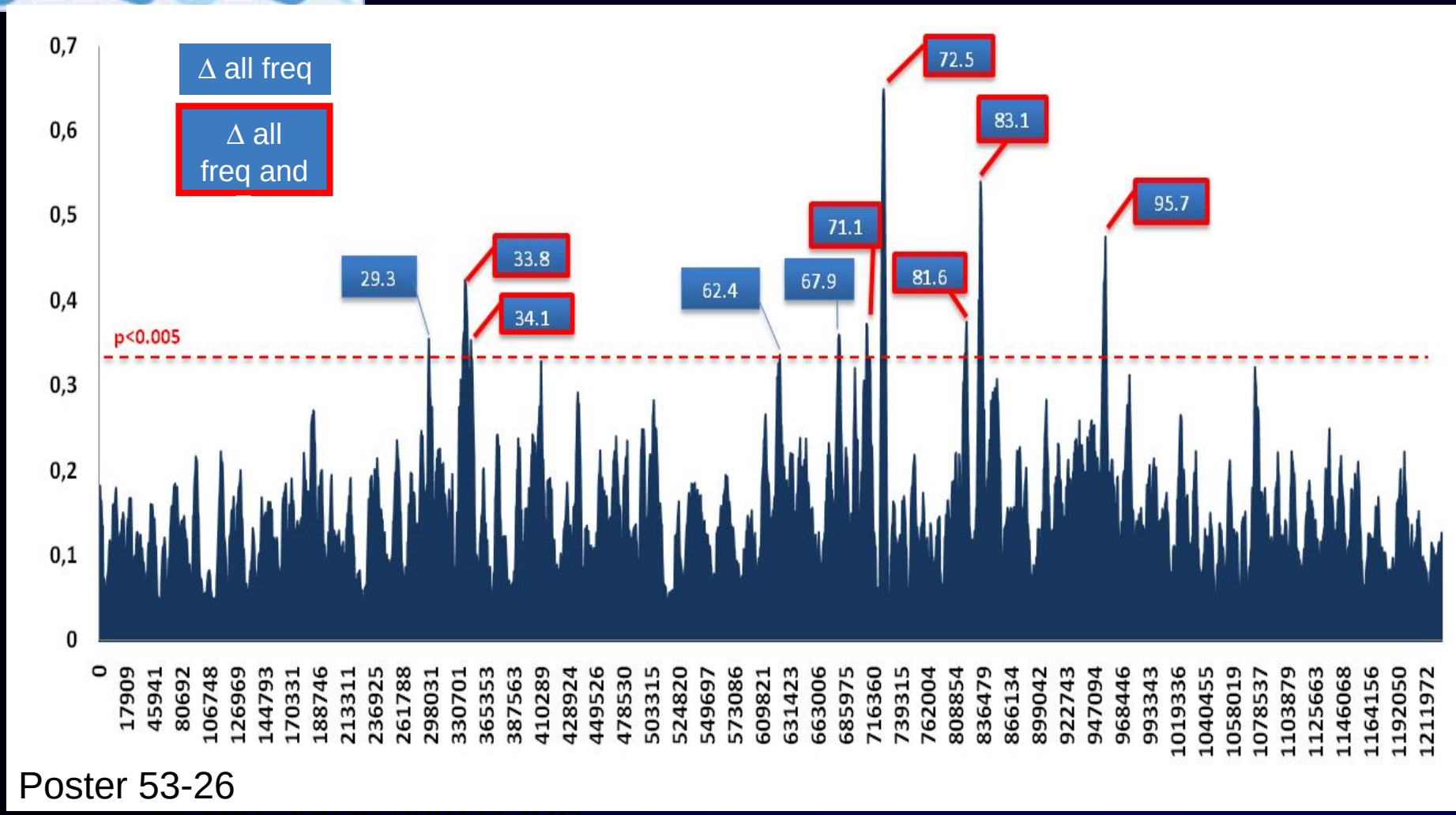
Courtesy of Tad Sonstegard USDA

Selection signature



Courtesy of Tad Sonstegard USDA

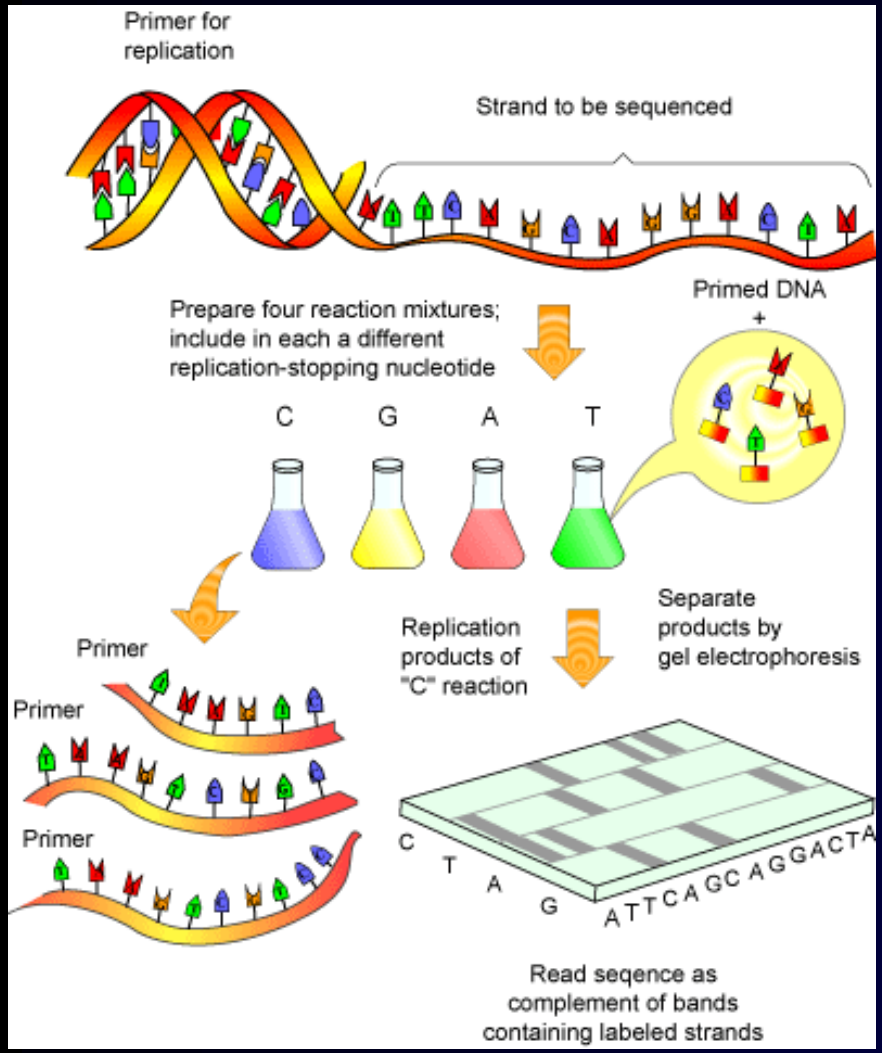
Selection signature



Poster 53-26

What’s Next?

….Sequencing….



New technologies

Saving reagents

10^7 € → 10^5 € → 10^4 € (?)

Highly parallel analyses

Milions SNPs in the cattle genome

A Global View

www.globaldiv.eu

The ultimate glance in the past

Research Centre on Modern and Ancient DNA diversity - BioDNA (Piacenza-IT)

ACKNOWLEDGEMENTS

LAB ANIMAL GENETICS UNICATT (Piacenza-IT)

- Resgen Consortium
- Bovine HapMap Consortium
- SelMol Consortium

- A. Torroni
- A. Achilli
- L. Cavalli-Sforza
- P. Taberlet


Thank you
for your attention
Ch. Darwin
Mand. 7th 1874.