70th EAAP Annual Meeting, Gent 2019

Camelids as emerging food producing species in our changing climate

Phenotypic and genotypic evaluation of camelids, why these species lag behind other livestock.

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Research Institute of Wildlife Ecology

Vetmeduni Vienna, Austria

Elena Ciani, Univ. Bari (IT), CARAVAN

vetmeduni vienna

CARAVAN

TOWARD A CAMEL TRANSNATIONAL VALUE CHAIN



vetmeduni vienna

LARGE CAMELIDS

On the origin of the species

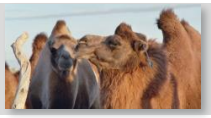
Old World camel genome research

PHENOTYPING

Relevant production phenotypes

Ongoing projects

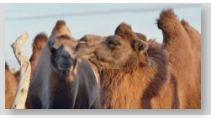
Results of the large camelids questionnaire



So,...
Why do camelids lag behind other livestock species?

- Identify major difficulties
- Provide suggestions for possible next steps

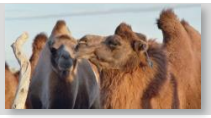



Origin of the Old World camelids

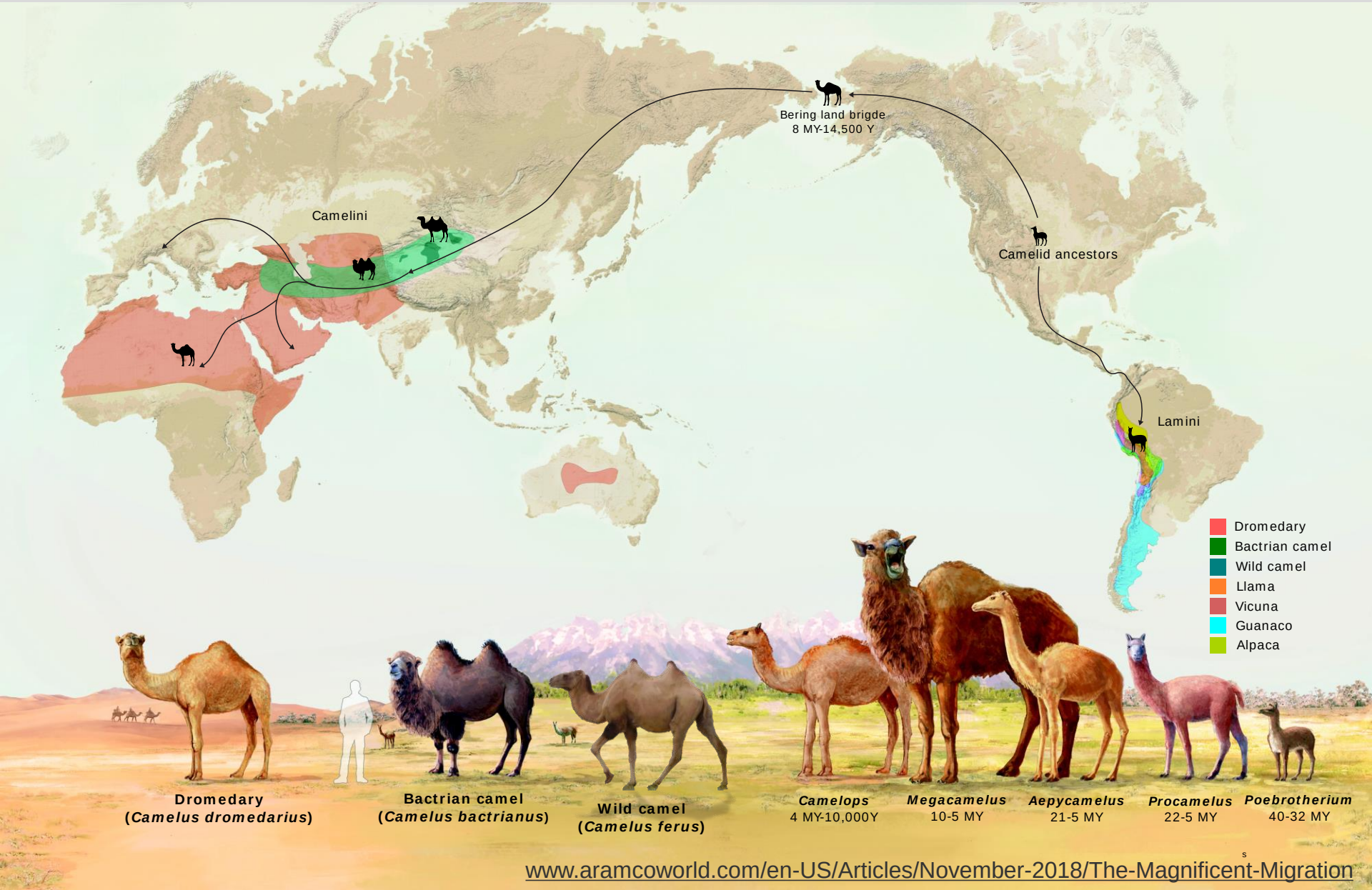
Camelus dromedarius

Camelus bactrianus

Camelus ferus

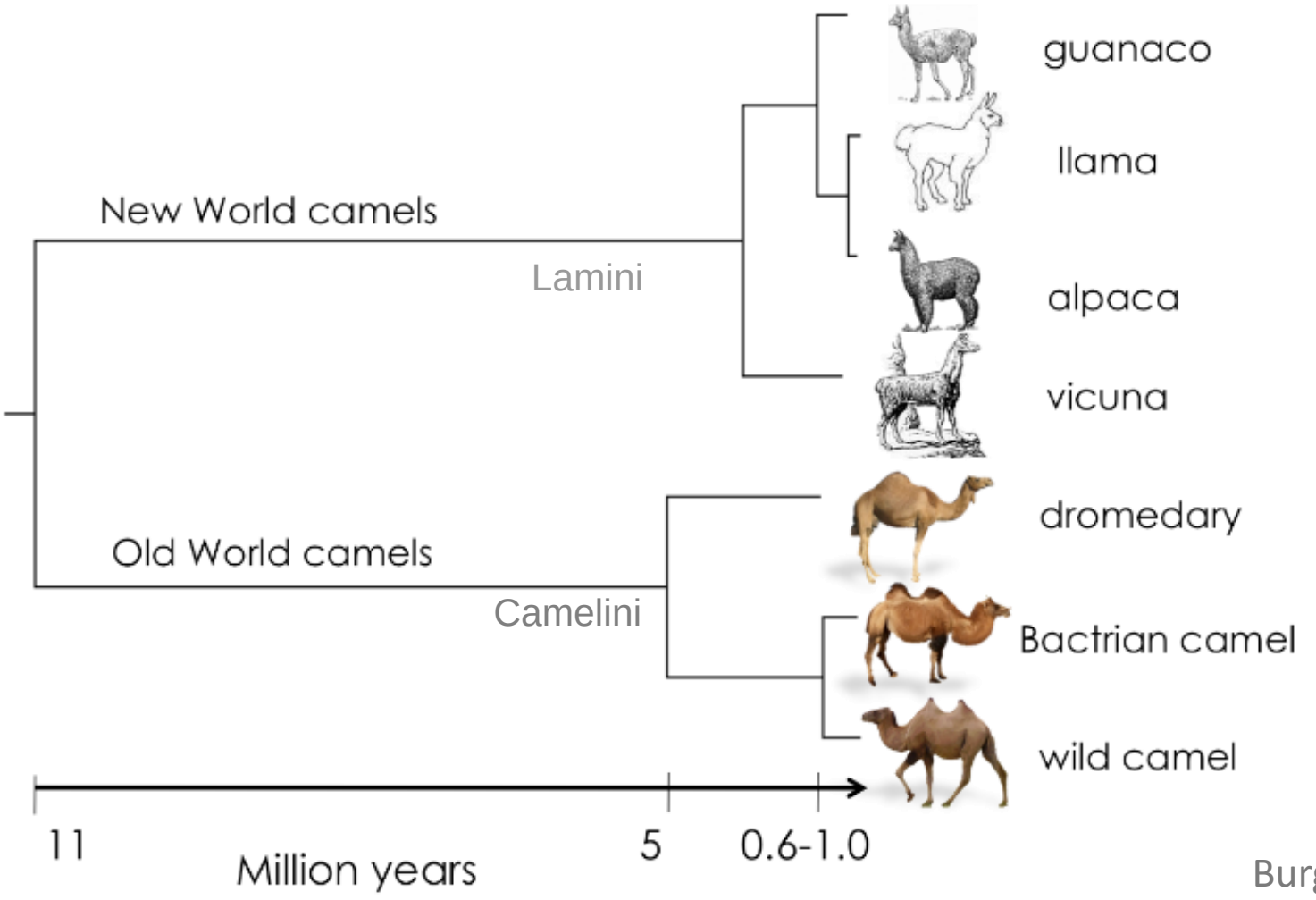


on the origin of the species



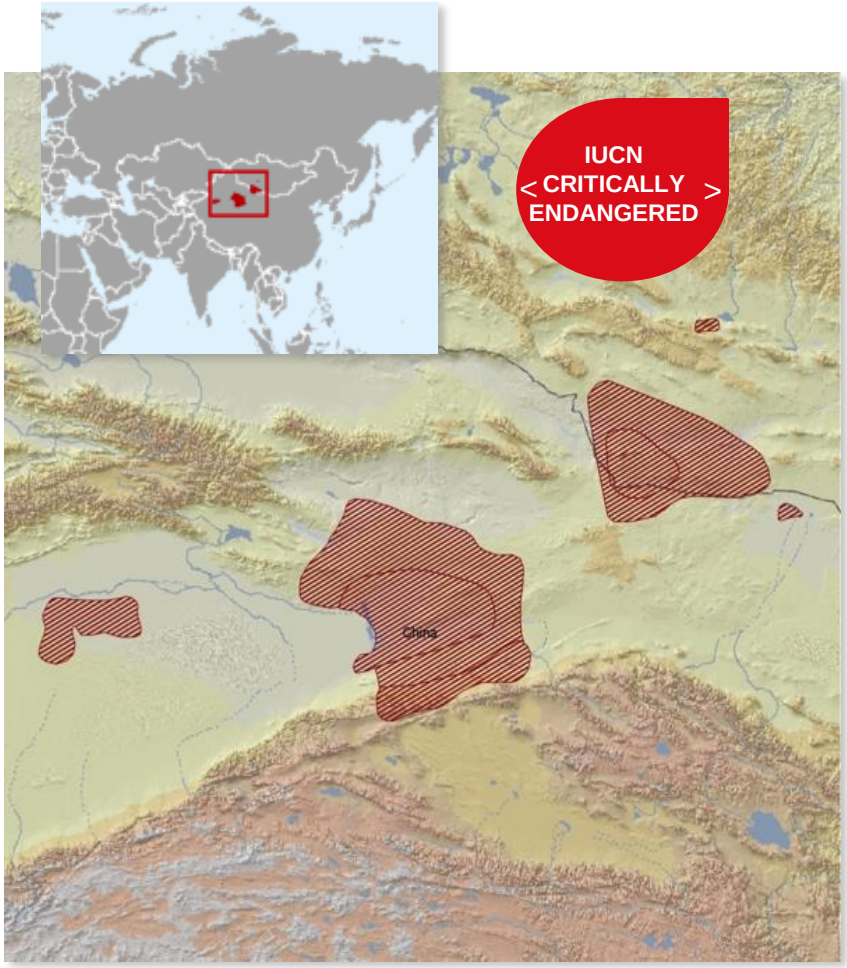
www.aramcoworld.com/en-US/Articles/November-2018/The-Magnificent-Migrations

Phylogenetic tree of New and Old World camels

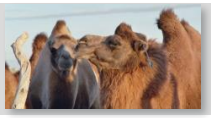


Burger 2012

Camelus ferus



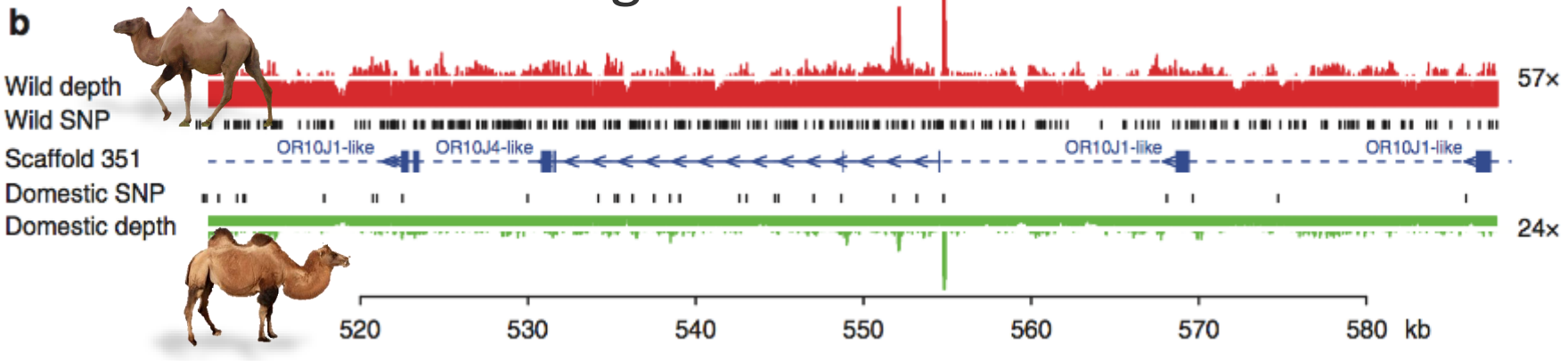
- "*Camelus ferus*" Przewalsky (1878) International Commission for Nomenclature (2004)
- morphology: flat head ('havtagai')
  pointier humps
- population reduction > 80% last 50 y
- 3 natural populations
  Lop Nur (China)
  Taklimakan Desert (China)
  Great Gobi SPA – A (Mongolia)
- ≈ 600 Chinese wild camels
  ≈ 400 Mongolian wild camels



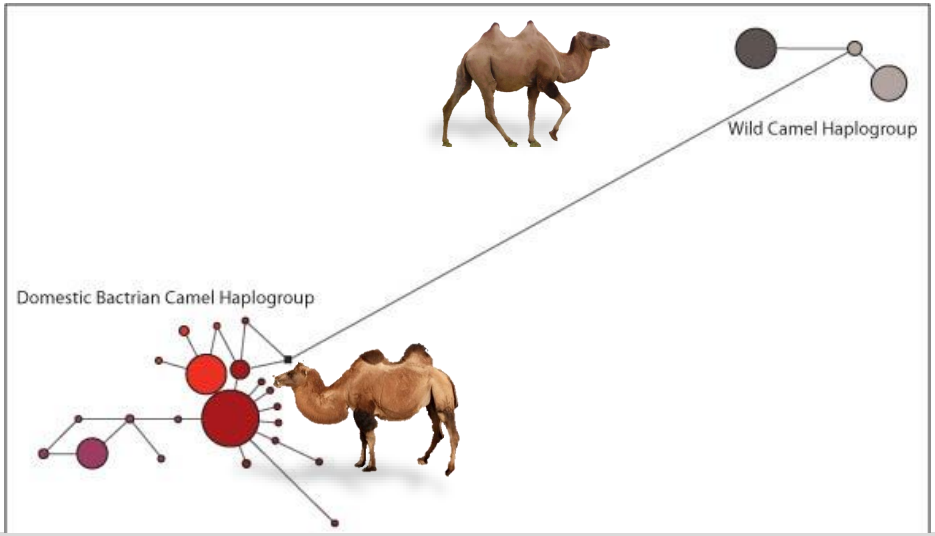
Two-humped camel genomes

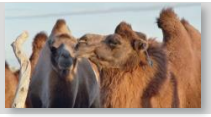
ARTICLE
Received 4 May 2011 | Accepted 8 Oct 2012 | Published 13 Nov 2012
DOI: 10.1038/ncomms2192
Genome sequences of wild and domestic bactrian camels
Wang et al. 2012
The Bactrian Camels Genome Sequencing and Analysis Consortium*

- Genome-wide divergent selection



- Mitochondrial genome high sequence divergence

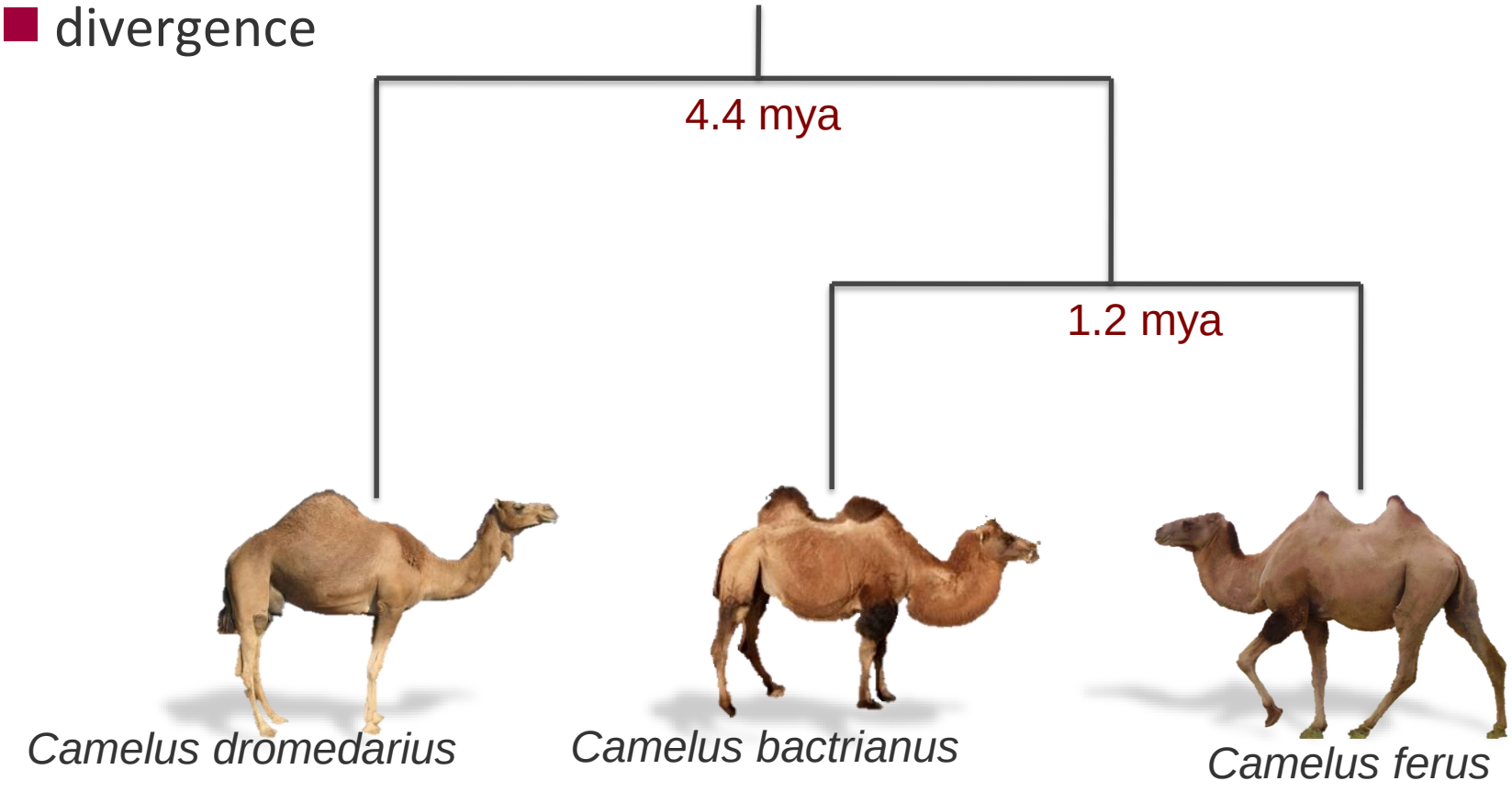


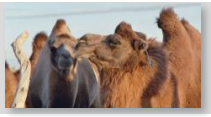


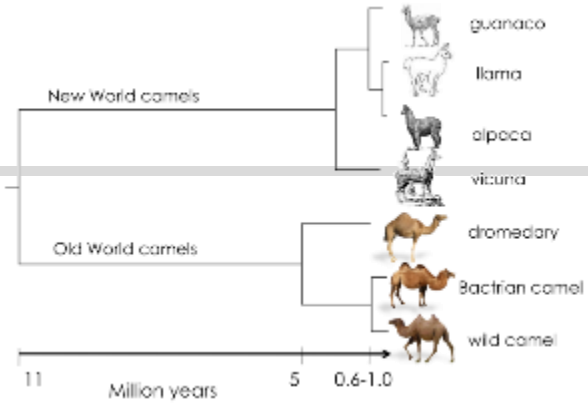
Mohandesan et al.2017. SciRep

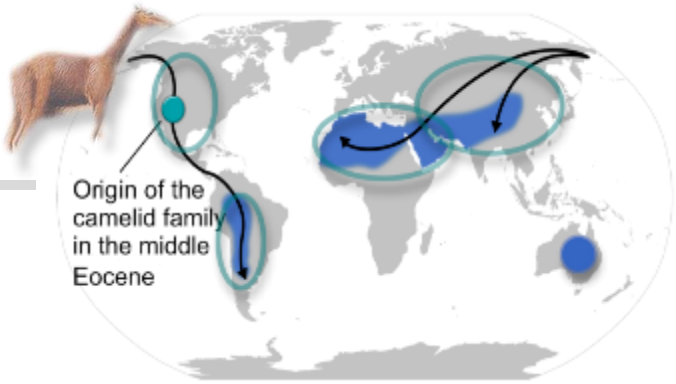
Wild camels are a separate species

- three species of Old World camels exist today
- divergence









Domestication of the Old World camelids

Camelus dromedarius

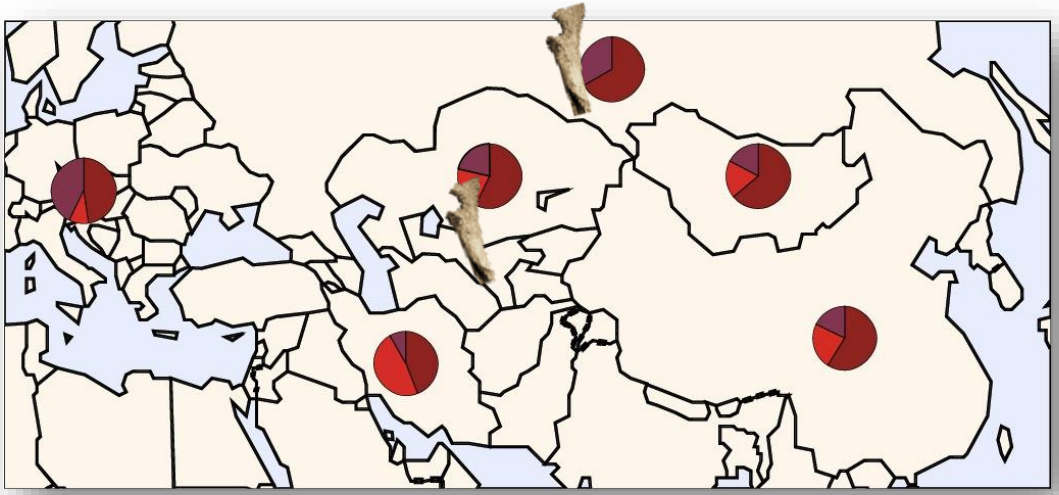
Camelus bactrianus

Camelus ferus

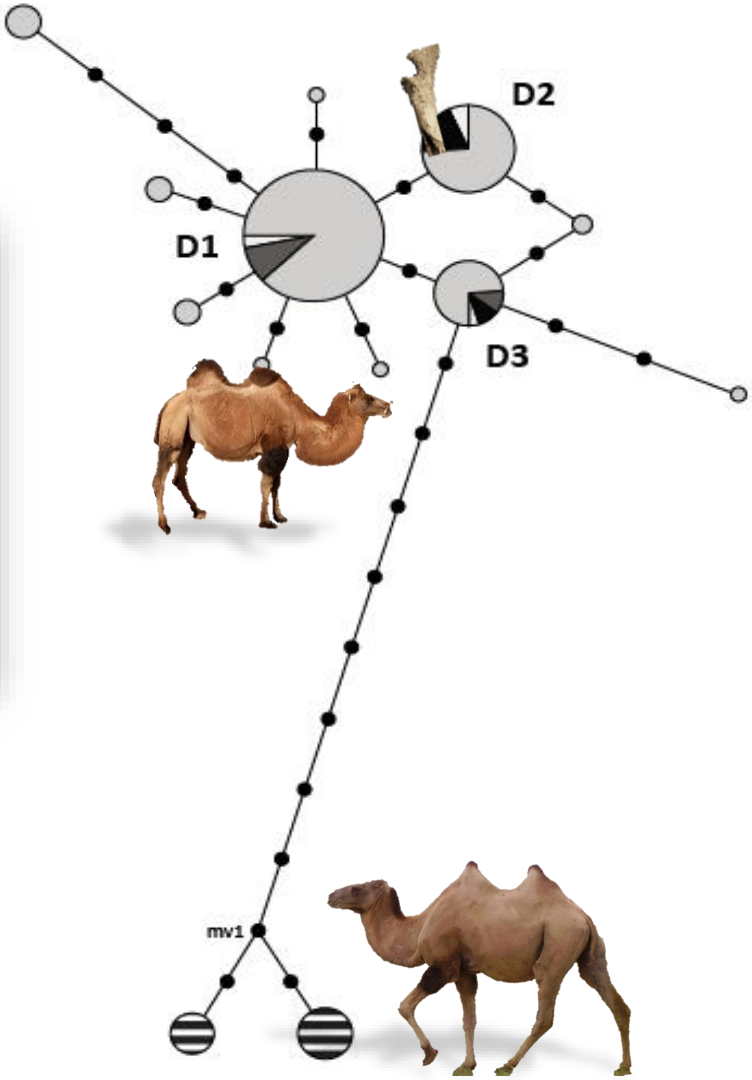
Bactrian camel domestication

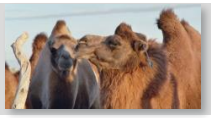
H_I) Centre of domestication in „Bactria“

H_{II}) Domestication further East

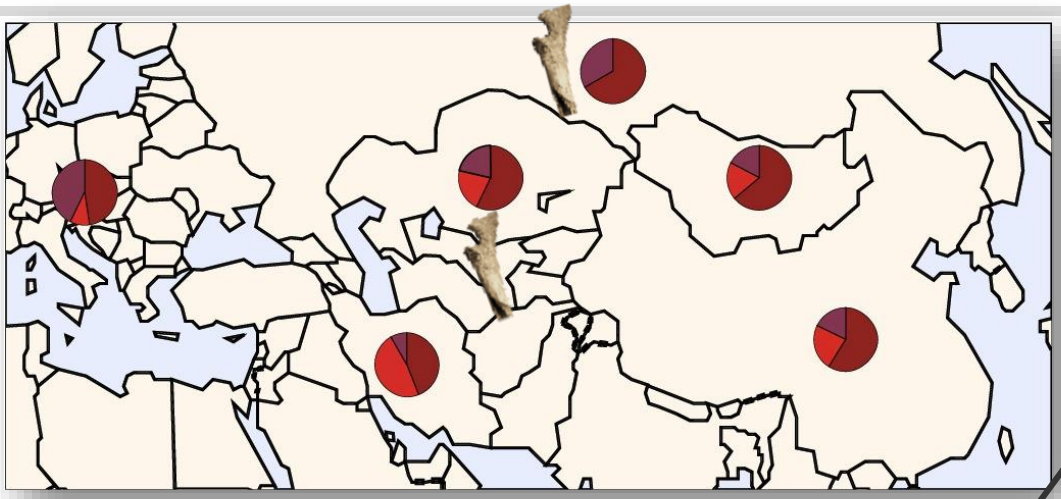


Late Bronze and Eary Iron Age samples
South-Uzbekistan, West-Siberia

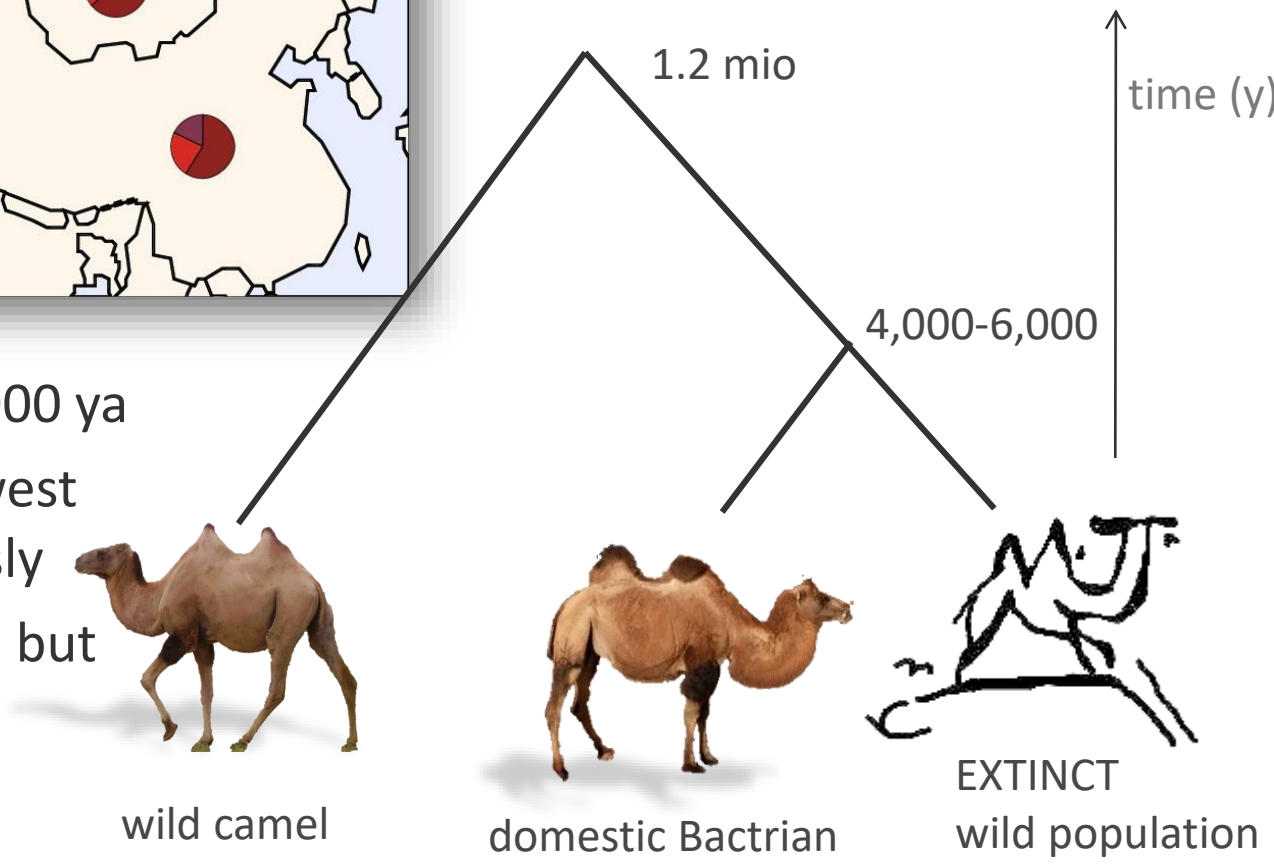


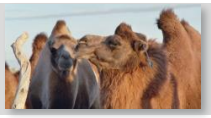


Bactrian camel domestication



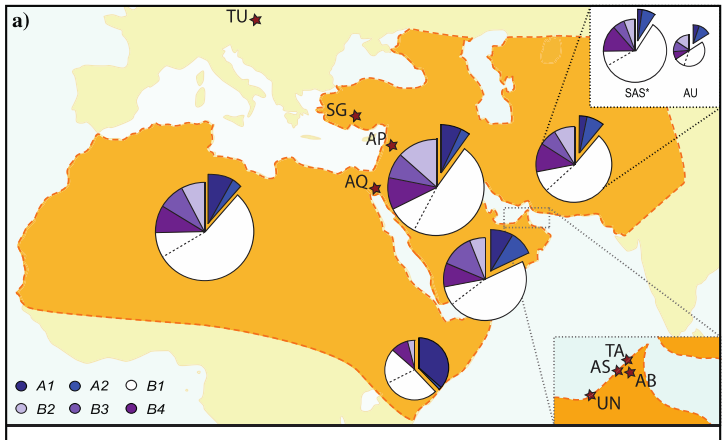
- domestication 4000-6000 ya
- maybe further to the west than assumed previously
- wild camels are related but not the ancestors

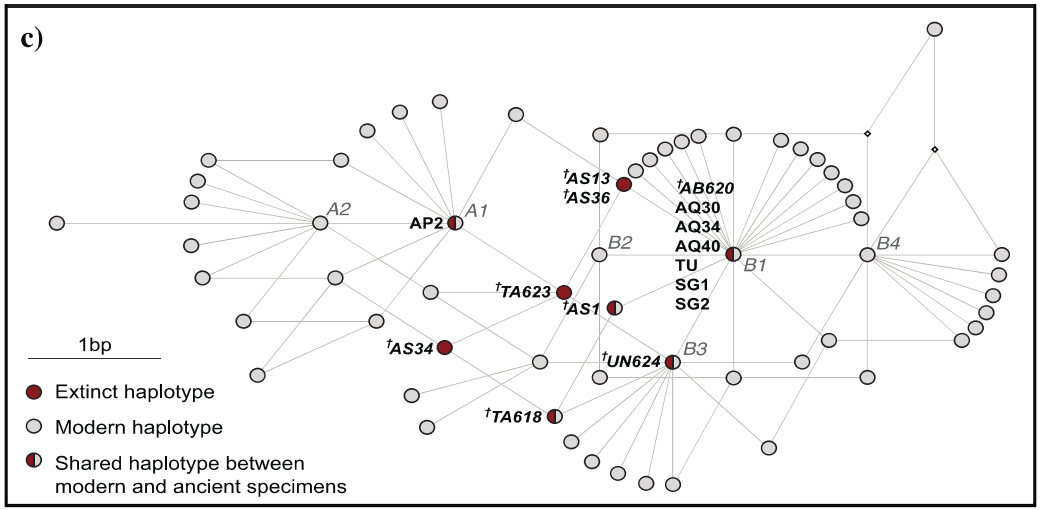




Dromedary domestication

Panmictic dromedary population on mitochondrial level

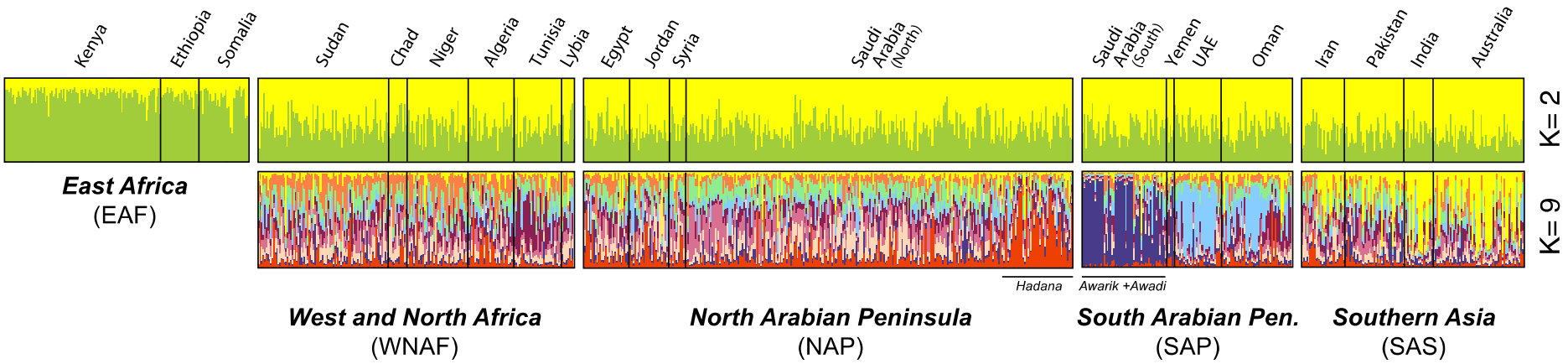


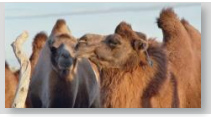


- domestication around 3000 ya
- minimum of 6 maternal lineages
- wild dromedaries from the Southeast coast of the Arabian Peninsula contributed to the modern gene pool

Almathen, Charruau, Mohandesan et al PNAS 2016

Modern dromedary share genetic diversity

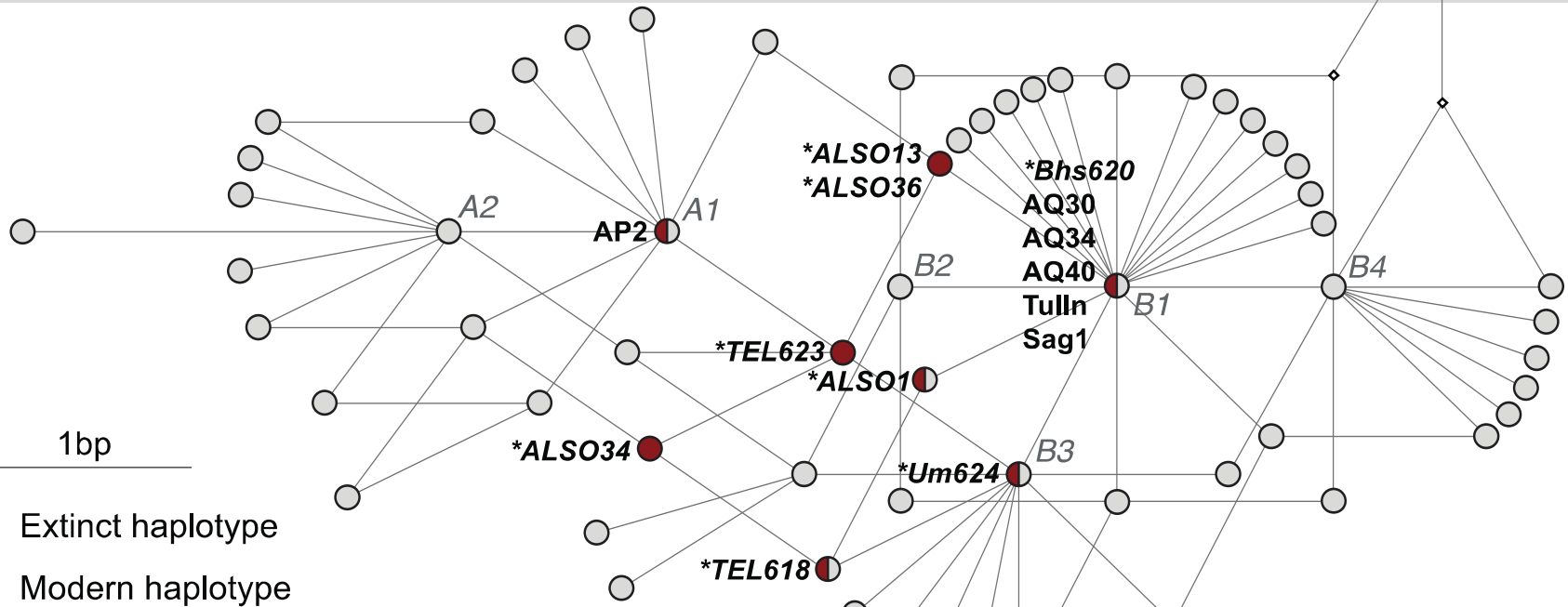




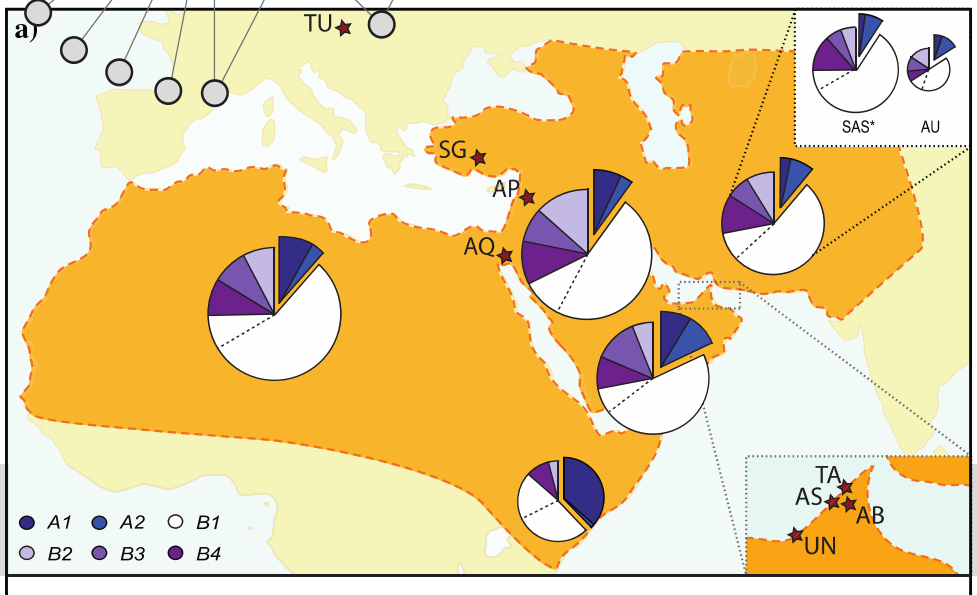
Almathen, Charruau, Mohandesan et al PNAS 2016

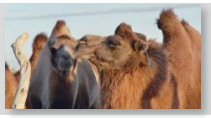
c)

Early-domestic and wild dromedaries share mitochondrial haplotypes



- Extinct haplotype
- Modern haplotype
- Shared haplotype between modern and ancient specimens



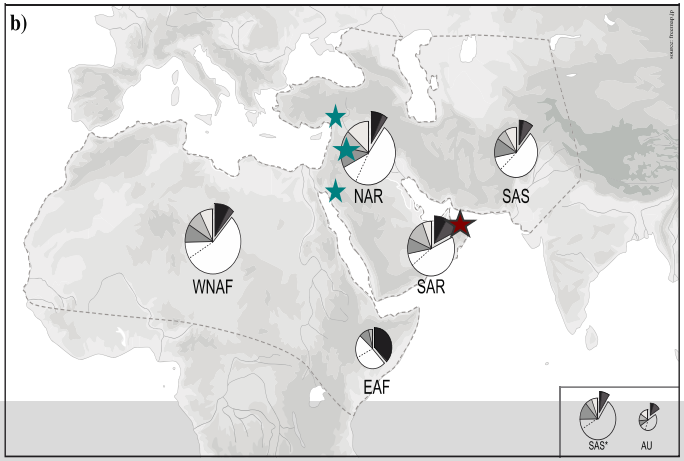


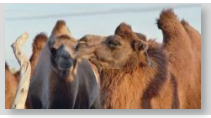
Almathen, Charruau, Mohandesan et al PNAS 2016

domestication – summary

- domestication of Bactrian camels 4000-6000 ya
- wild camels are related but not the ancestors

- domestication of dromedaries around 3000ya
- six maternal lineages
- one place of domestication might be on Southeast coast of the Arabian Peninsula







LARGE CAMELIDS

On the origin of the species

Old World camel genome research

PHENOTYPING

Relevant production phenotypes

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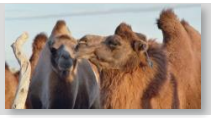
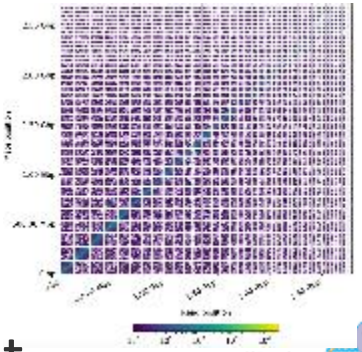
Results of the large camelids questionnaire

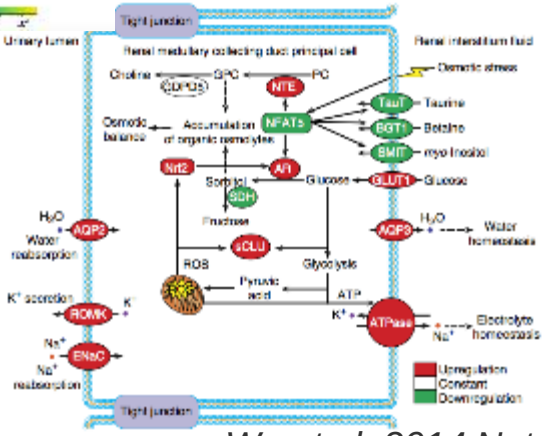
Old World camels genomic resources

- De novo assembly of a female dromedary genome
  - 66-fold coverage, 2.06 GB
  - annotation of 452 (98.7%) CEGs
  - genome-wide heterozygosity 0.74 x 10^{-3}



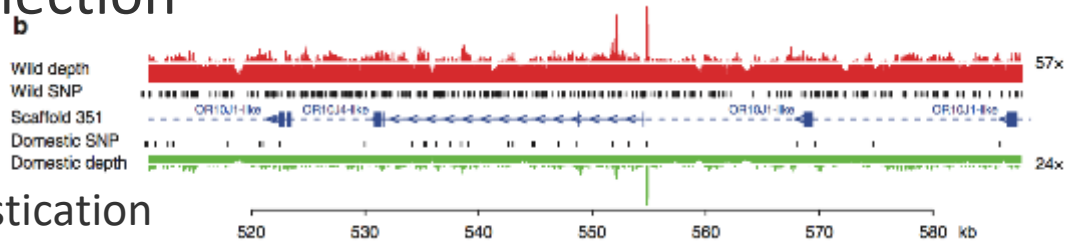
Elbers et al. 2019 Mol Ecol Res
Fitak et al. 2015 Mol Ecol Res

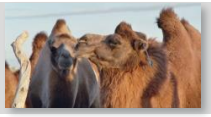
- Adaptation to desert environment
  - Lineage specific accelerated evolutionary rates
  - GO categories enriched genes involved in
    - fat and energy metabolism
    - salt metabolism
    - osmoregulation and water reservation



Wu et al. 2014 Nat Com

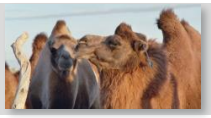
- Genome-wide divergent selection
  - overall lower heterozygosity in the domestic genome
  - artificial selection during domestication





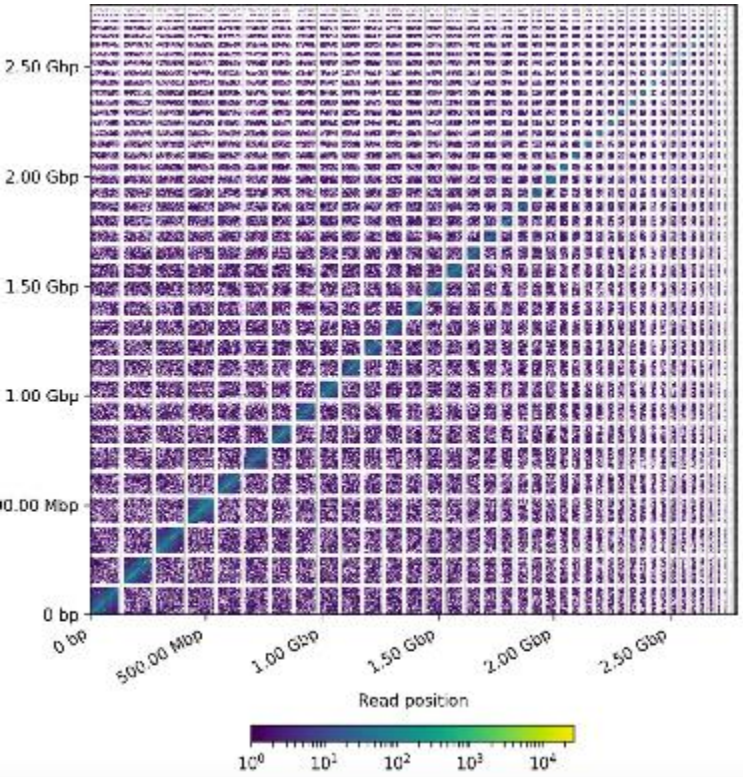
Wang et al. 2012 Nat Com

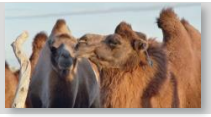
Old World camels genomic resources



	Assembly		
	Original North African Dromedary (CamDro1)	Improved North African Dromedary (CamDro2)	Arabian Dromedary
Total size	2,055,063,633	2,154,386,959	2,004,047,047
Gap length	53,035,436	20,341,506	22,407,814
Scaffolds			
Number	35,752	23,439	32,572
Longest	9,719,801	124,992,380	23,736,781
N90[a]	260,185	24,922,612	689,795
L90[b]	1,592	31	594
N50[a]	1,482,444	75,021,453	4,188,677
L50[b]	393	11	132
Contigs[c]			
Number	133,158	45,969	93,701
Longest	413,938	9,491,684	896,174
N90	11,508	177,667	17,513
L90	42,697	1,944	25,175
N50	50,278	1,333,231	88,36
L50	11,378	423	6,074
Single-copy BUSCOs[d]	3,820	3,851	3,811
Duplicated BUSCOs	22	24	19
Fragmented BUSCOs	164	133	178
Missing BUSCOs	98	96	96
Proportion of complete BUSCOs	0.936	0.944	0.933

Old World camels genomic resources





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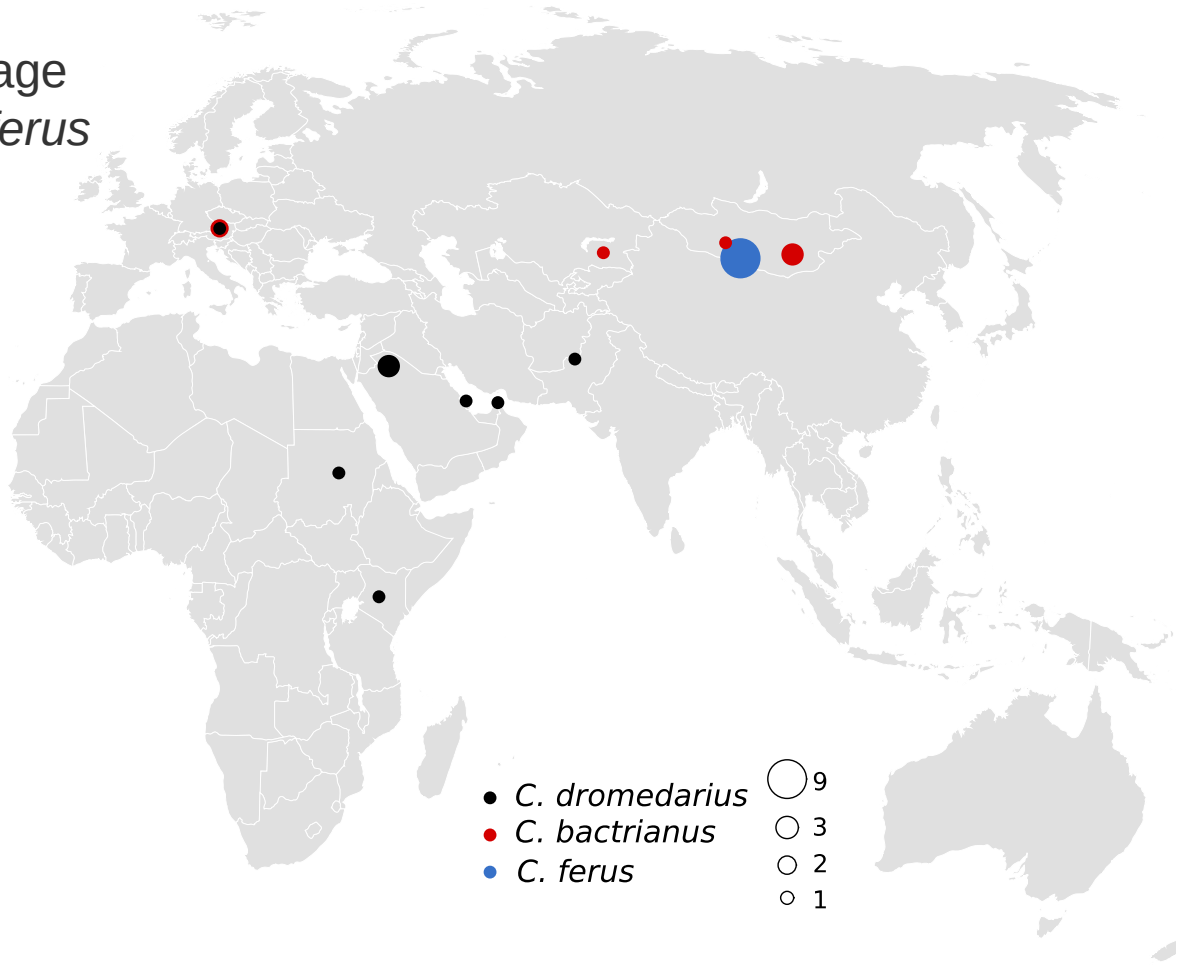
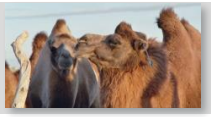
Re-sequencing projects

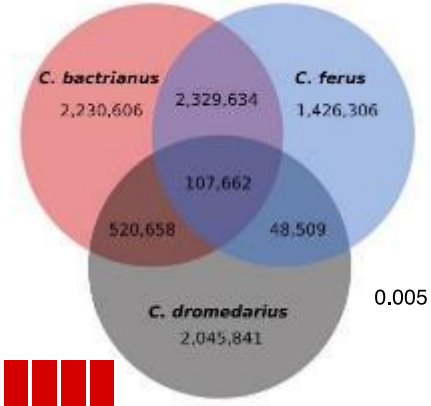
25 Genomes
~15-60x coverage
Mapped to *C. ferus*

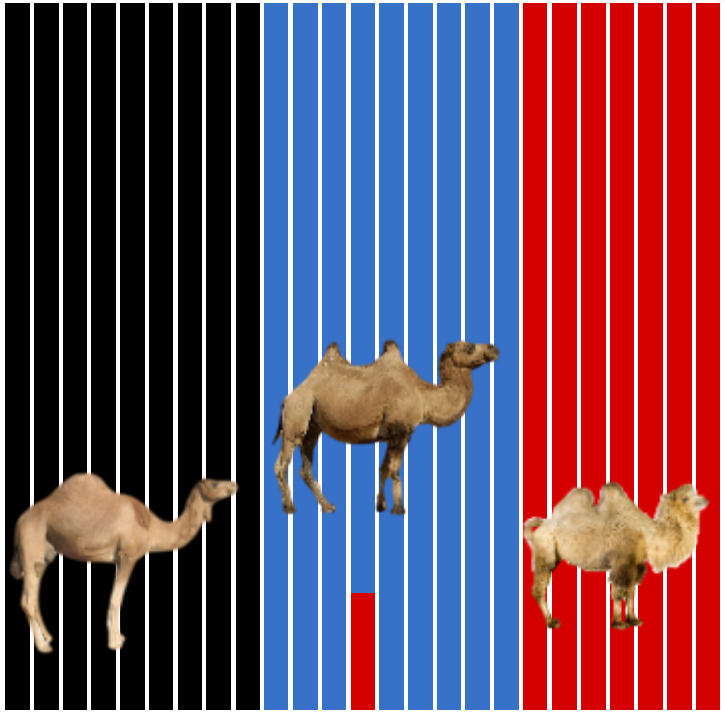


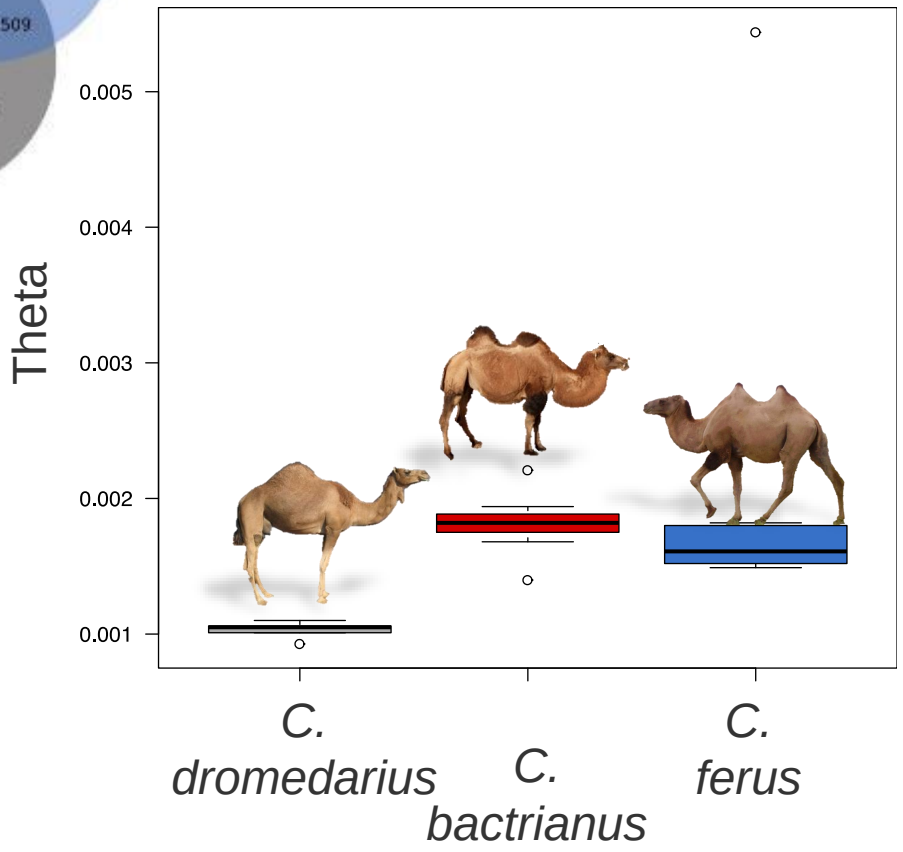


Fitak et al. & Burger submitted

Genomic Variation and hybridization







Other (Re)sequencing projects

The Largest Ag-Genomics Meeting in the World.

PLANT & ANIMAL GENOME CONFERENCE XXVI

www.intlpag.org January 13 - 17, 2018 San Diego, CA

ABSTRACT

Samantha Brooks et al 2018

W132: A *de novo* Hybrid Assembly of a Dromedary Camel

CSH Cold Spring Harbor Laboratory

bioRχiv

Whole-genome sequencing of 128 camels across Asia provides insights into origin and migration of domestic Bactrian camels

Liang Ming, Liyun Yuan, Li Yi, Guohui Ding, Surong Hasi, Gangliang Chen, Tuyatsetseg Jambl, Nemat Hedayat-Evright, Mijiddorj Batmunkh, Garyaeva Khongr Badmaevna, Tudeviin Gan-Erdene, TS Batskh, Wenbin Zhang, Azhati Zulipikaer, Hosblig, Erdemt, Arkady Natyrov, Prmanshayev Mamay, Narenbatu, Gendalai Meng, Choijilsuren Narangerel, Orgodol Khongorzul, Jing He, Le Hai, Weili Lin, Sirendalai, Sarentuya, Aiyisi, Yixue Li, Zhen Wang, Jirimutu

doi: https://doi.org/10.1101/656231

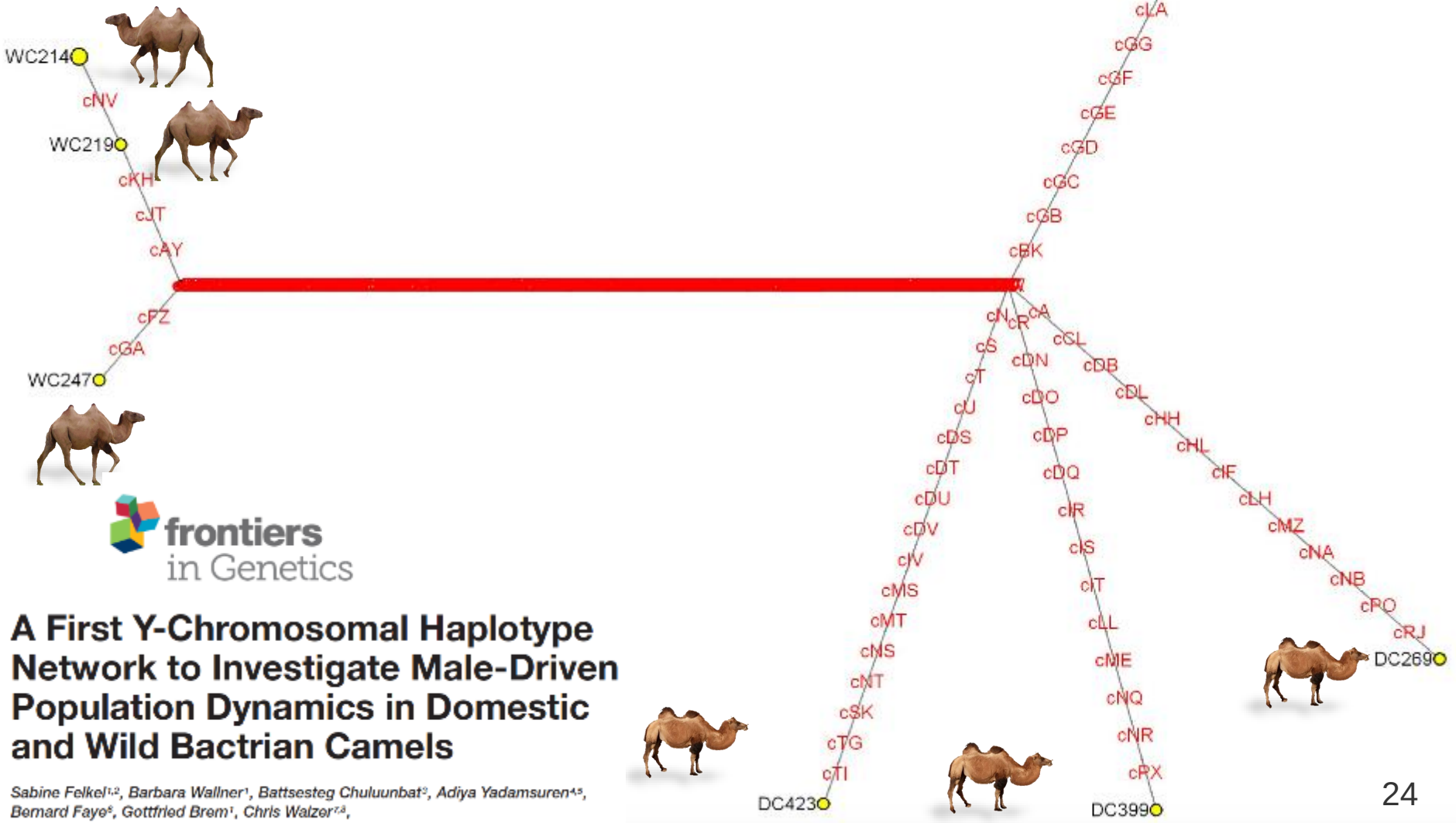
PLOS ONE

RESEARCH ARTICLE

Genetic variants analysis of three dromedary camels using whole genome sequencing data

Reza Khalkhali-Evrigh[1], Seyed Hasan Hafezian[1], Nemat Hedayat-Evrigh[2]*, Ayoub Farhadi[1], Mohammad Reza Bakhtiarizadeh[3]

Y-Chromosome haplotype network
Old World camels



frontiers in Genetics

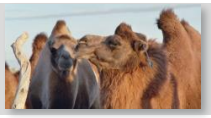
A First Y-Chromosomal Haplotype Network to Investigate Male-Driven Population Dynamics in Domestic and Wild Bactrian Camels

*Sabine Felkel[1,2], Barbara Wallner[1], Battsesteg Chuluunbat[2], Adiya Yadamsuren[4,5], Bernard Faye[6], Gottfried Brem[1], Chris Walzer[7,8], on behalf of the International Camel Consortium[†] and Pamela A. Burger[7]**



Old World camel genome research

- Dromedary genome at chromosome level
- Domestic and wild Bactrian genomes at scaffold levels
- Multiple re-sequencing projects ~180 genomes



Old World camel genome research

- Dromedary genome at chromosome level
- Domestic and wild Bactrian genomes at scaffold levels
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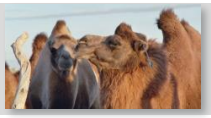
Why camels lag behind other livestock species…

- ~2000 cattle genomes
- few hundred sheep and pig genomes
- thousands of low and high density SNPchip data

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AREAS OF INTEREST TECHNIQUES SYSTEMS PRODUCTS & SERVICES INFORMATICS SCIENCE & EDUCA

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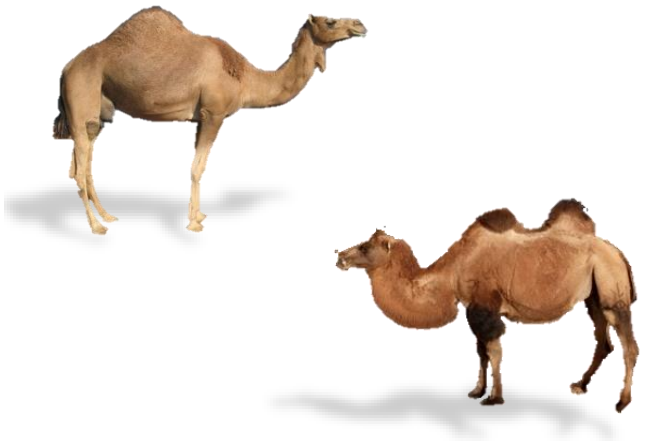
Illumina Announces Eleventh Agricultural Greater Good Initiative Grant Winner

Recipient Focused on Genetics Research of Camels



- next step: sequencing of 400 camel genomes

ICC-GIC

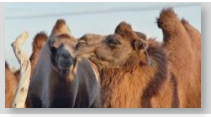
International Camel Consortium for genetic improvement and conservation

www.ICC-GIC.weebly.com

Mission:

support at various levels the network of involved scientists and professionals to boost, harmonize, coordinate and share activities on camel genetic conservation, management, animal phenotypic recording and genetic improvement.

Riyadh, Workshop April 2015





LARGE CAMELIDS

On the origin of the species

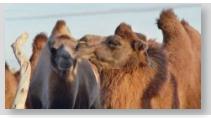
Old World camel genome research

PHENOTYPING

Relevant production phenotypes

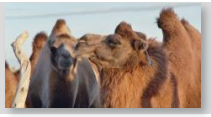
Ongoing projects

Results of the large camelids questionnaire

Relevant phenotypes

- Milk yield and content
- Growth, meat, carcass
- Reproduction
- Wool/ fiber
- Health, immunity
- Beauty
- Racing
- Animal behaviour



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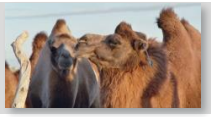
- No animal ID system in place





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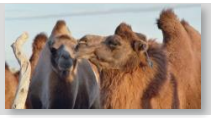


Reproduction

Contents lists available at ScienceDirect

Animal Reproduction Science

journal homepage: www.elsevier.com/locate/anireprosci

The use of some assisted reproductive technologies in old world camelids

Julian A Skidmore

- Semen collection and storage
- Aritificial insemination
- In vitro fertilization
- Embryo transfer

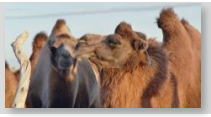
Theriogenology

Volume 134, August 2019, Pages 24-33

Pregnancy and parturition in dromedary camels I. Factors affecting gestation length, calf birth weight and timing of delivery

Péter Nagy, Judit Juhász

- Calf birth weight primarily affected by female camel, parity, year and month of parturition.
- Environment has a decisive role in the variation of length of gestation, timing of parturition and calf birth weight.



Ecology and Evolution
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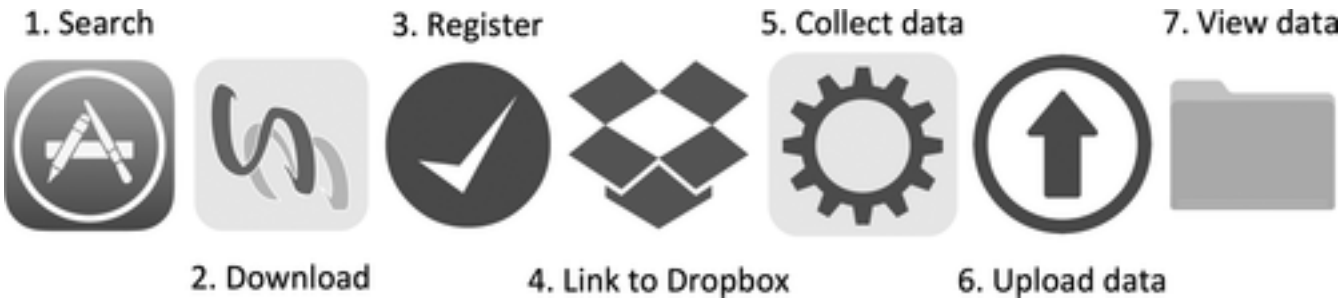
ORIGINAL RESEARCH | Open Access

SamplEase: a simple application for collection and organization of biological specimen data in the field

Hasan Alhaddad, Bader H. Alhajeri

First published: 17 September 2018 | https://doi.org/10.1002/ece3.4503 | Cited by: 1



Towards a rational camel breed judging: a proposed standard of a camel (*Camelus dromedarius*) milk breed

Dioli M.

Journal of Camel Practice and Research 2016

Table 2. Suggested body areas that should be subjected to assessment during an evaluation of a lowland camel breed specialising in milk production in a semi-intensive production husbandry system. Females over 4 years, males over 7 years.

Body areas	Desired Characteristics	Undesired Characteristics (if excessive may warrant disqualification)	Points that may be assigned	Comments on evaluating
1	2	3	4	5
Coat colour	According to the prevalent colour existing for that breed	Large differences with the agreed breed colour	**up to 1**	➢ *If various colour varieties in the breed exists they* ***should not be considered as poor conformation.***
Hair distribution	Smooth, uniform and/or with localised hair growth in specific body areas	Large areas without hair and/or with thickened and wrinkled skin (indicating an active or past scabies infestation)	**up to 1**	➢ *Active or past episodes of mange can be responsible for large body areas to be without hair and with thickened and profusely wrinkled skin. Such animals* ***should be considered as poor conformation.*** ➢ *Females with clear and well demarcated hairless areas on the back/top of the hump* ***should be considered as poor conformation,*** *since this is a sign of poor fertility; the airless area is caused by mechanical pressure and friction of the pedestal of the male during mating. Overly frequent mating sessions cause these typical skin traumas.* ➢ *Camel kept in areas with cold seasons will grow longer coats even if their original breed type has short smooth coats.*

Withers height	females over 185 cm males over 210 cm Wither clearly higher than the lumbar area	females 175 cm or less males 200 cm or less Wither with same height of lumbar area	**up to 4**	➢ *Excessively tall females **should be considered as poor conformation** points since they may have reached such height only because of sterility or manmade prevention of breeding.*
Body weight *(females > 4 years males > 7 years)*	Females: 550-700 kg Males: 750-900 kg	450 kg or less for females 650 kg or less than for males	**up to 5**	➢ *Watering regime **should not be over 3 days** otherwise body weight may be significantly affected.* ➢ *Obviously obese males **should be considered as poor conformation** since they are probable not experiencing a long rut season.* ➢ *Obviously obese females **should be considered as poor conformation** and if with small udder must be **considered as** since such animals are often sterile or with poor reproductive or milking capabilities.* ➢ *Males at the end of rut season may be considerably lighter in weight and should not **be considered as poor conformation**.*
Head size (*Measured from nose to occipital crest*) and conformation	Length approx 45-55 cm (higher values for males) Males with a well marked forehead. Lips may be pendulous or completely without hair	Small: 40 cm or less Males with flat forehead Mandible undershot or overshot Presence of "wry face" (lateral deviation of the face)	**up to 2**	➢ *The presence of any firing scar around the orbit without obvious eye lesions **should be considered as poor conformation** since it may be an indication of a tentative to correct idiopathic blindness with a traditional treatment.* ➢ *"Wry face" is a genetic abnormality so affected animals **should be considered as poor conformation** and their progeny penalised.*
Neck (*Measured from base of the jaw to base of the neck in front of the chest. Circumference measurement taken in the middle of the neck*)	Length 110-120 cm or more (higher values for males) Circumference 90-100 cm or more (higher values for males)	Length 90 cm or less in females 110 cm or less in males Circumference: 70 cm or less in females 80 cm or less in males	**up to 2**	➢ *The presence of any firing scar **should be considered as blemish** since could be an indication of past pathologies such as "wry neck" or "impacted dulaa".* ➢ *A thick neck in male camel is a sign of masculinity and therefore capacity to breed a high number of females. It is also probably related to fertility.*

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Why camels lag behind other lifestock…

- ➢No standardized phenotype recording
- ➢No animal ID system in place
- ➢No estimation of breeding values

- No standardized phenotype recording
- No animal ID system in place

- Suggested next step:

Development of standardized phenotyping guidelines

  - EAAP camelid working group
  - ICAR sheep, goats and camelids WG

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- Involve STAKEHOLDERS
  - Breeding associations
  - Local governments



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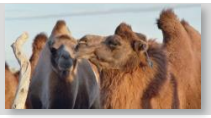
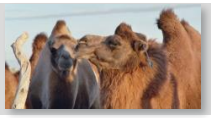


Large camelids questonaire

Content

1. GENERAL PERFORMANCE OF THE SURVEY
2. INFORMATION ON THE RESPONDENT
3. SPECIES INCLUDED
4. ANIMAL IDENTIFICATION
5. TRAIT RECORDING
6. SELECTION PROGRAMMS

- Implementation in 3 languages!

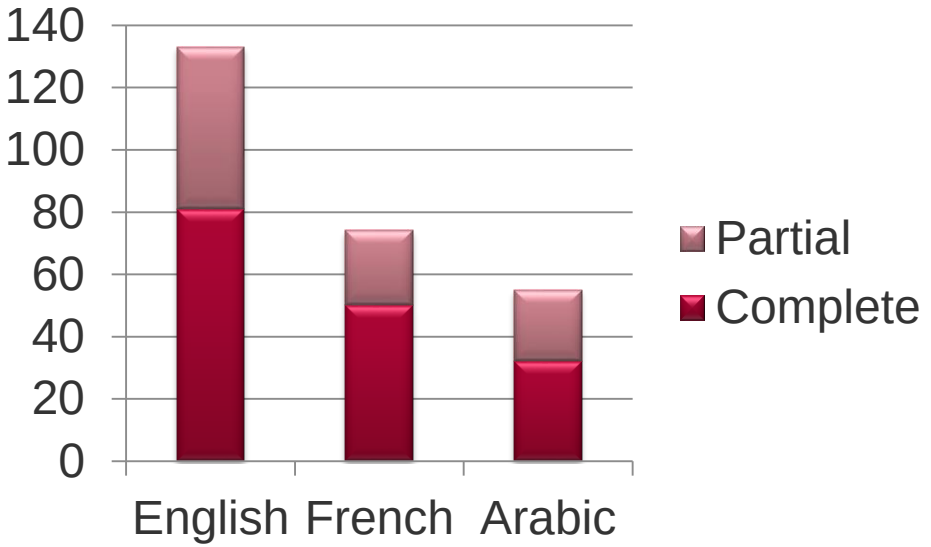


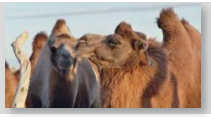
Total responses

- Total responses: 264
  - Complete: 163
  - Partial: 101

In 3 different languages

- English: 133/ 81/ 52
- French: 74/ 50/ 24
- Arabic: 57/ 32/ 25





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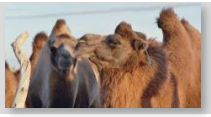
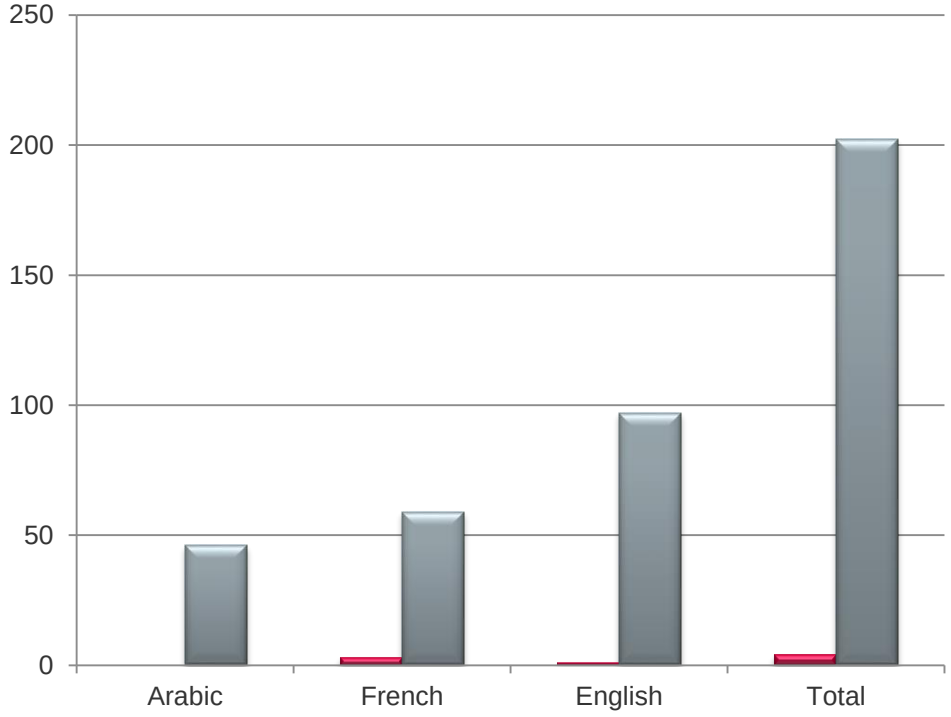
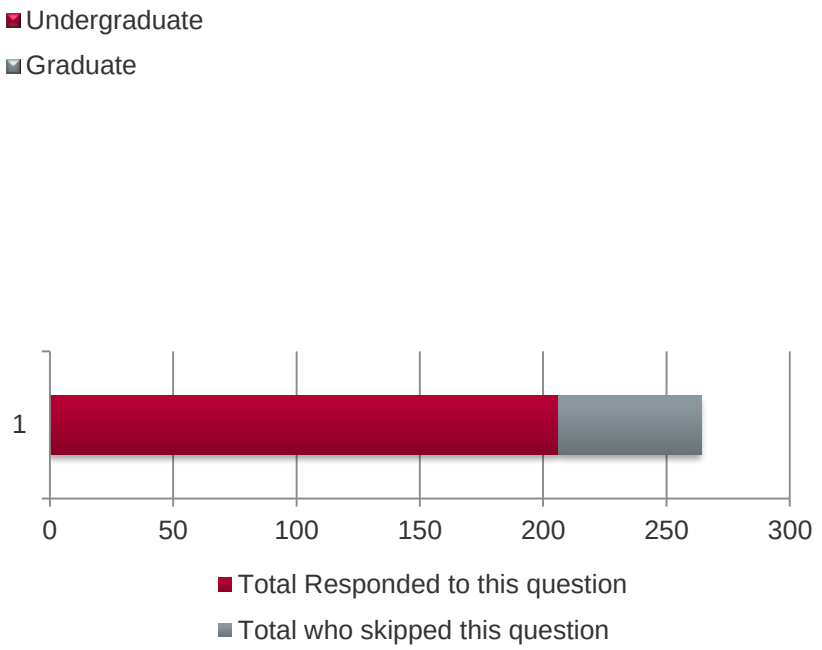
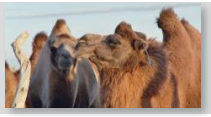


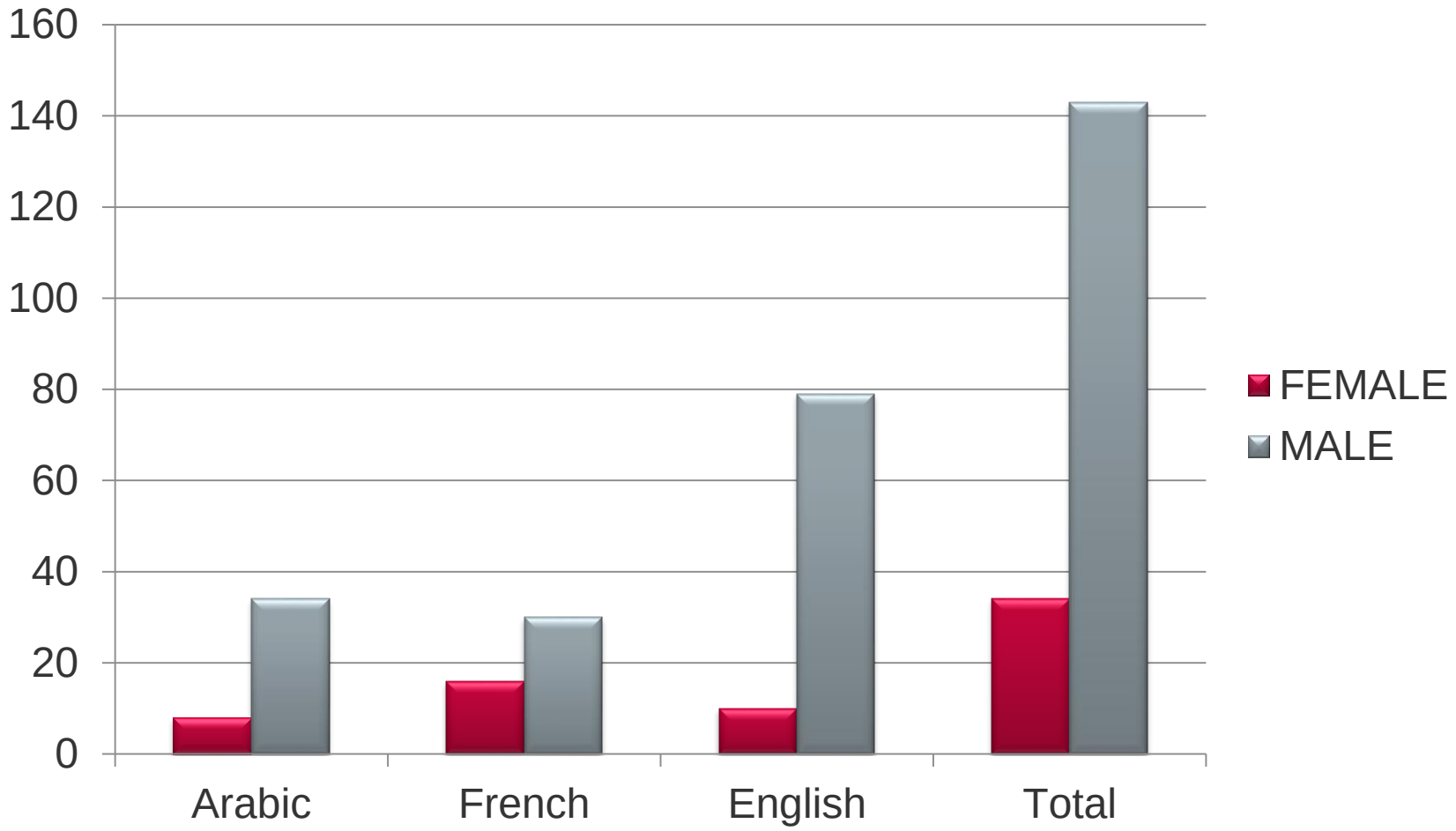
Education Level (67.5% responded)

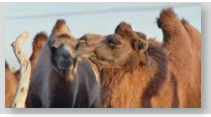






Sex (67% responded)



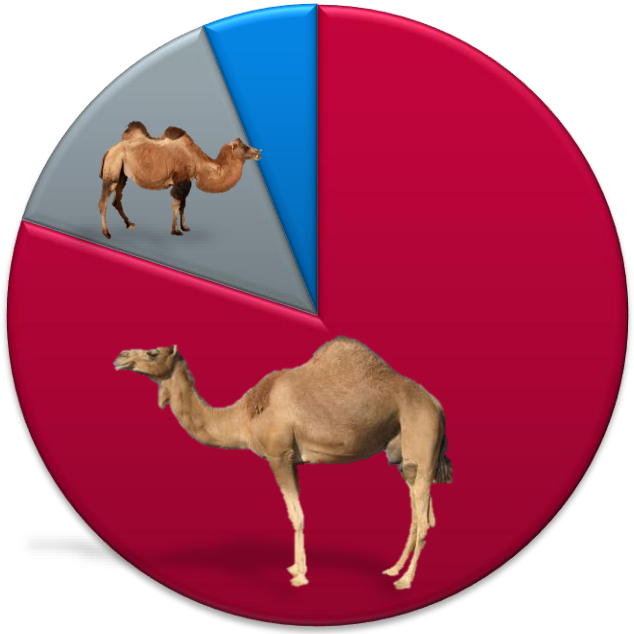


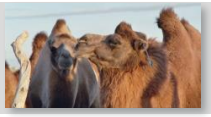
3. SPECIES INCLUDED

Dromedary 80%

Bactrian camel 14%

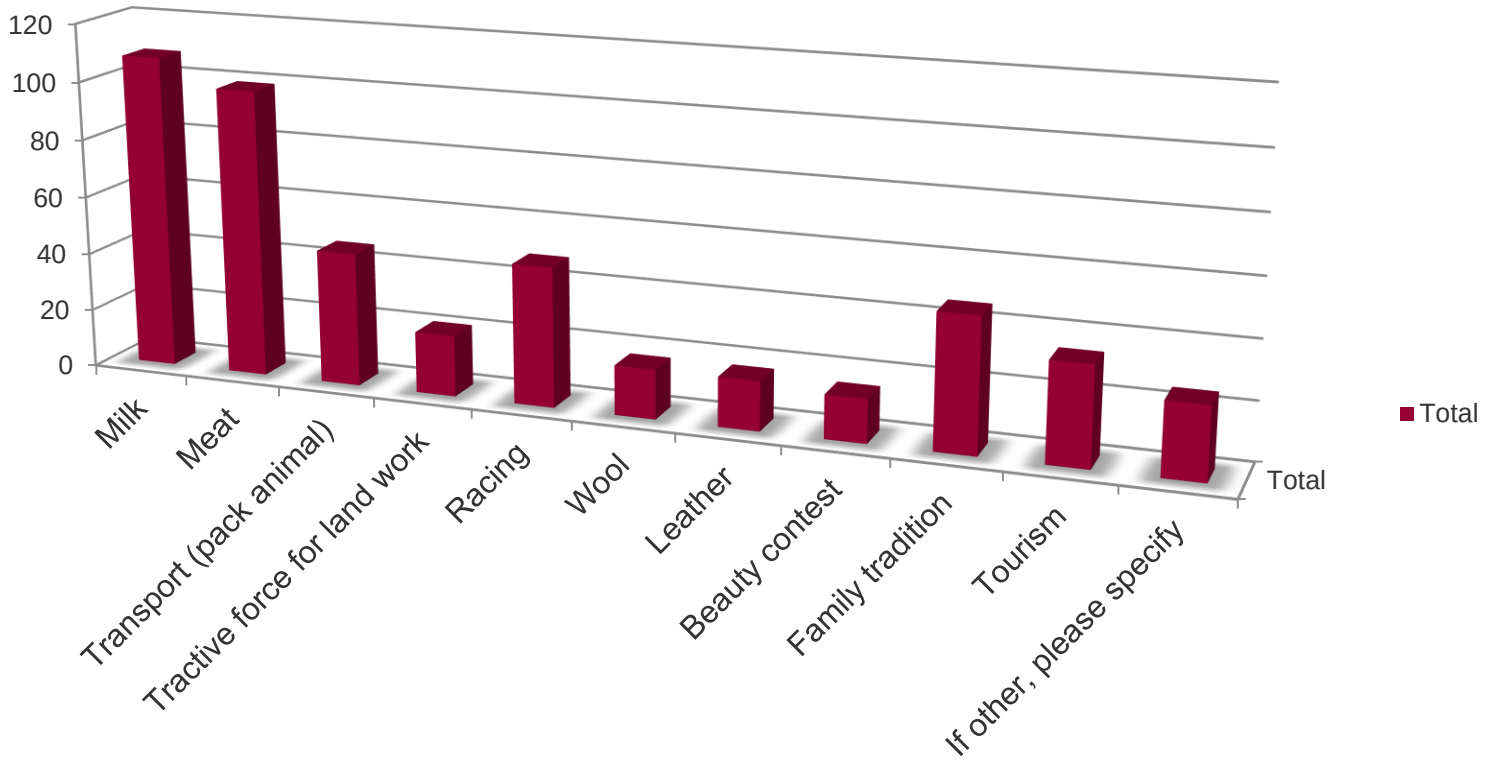
Hybrid 6%





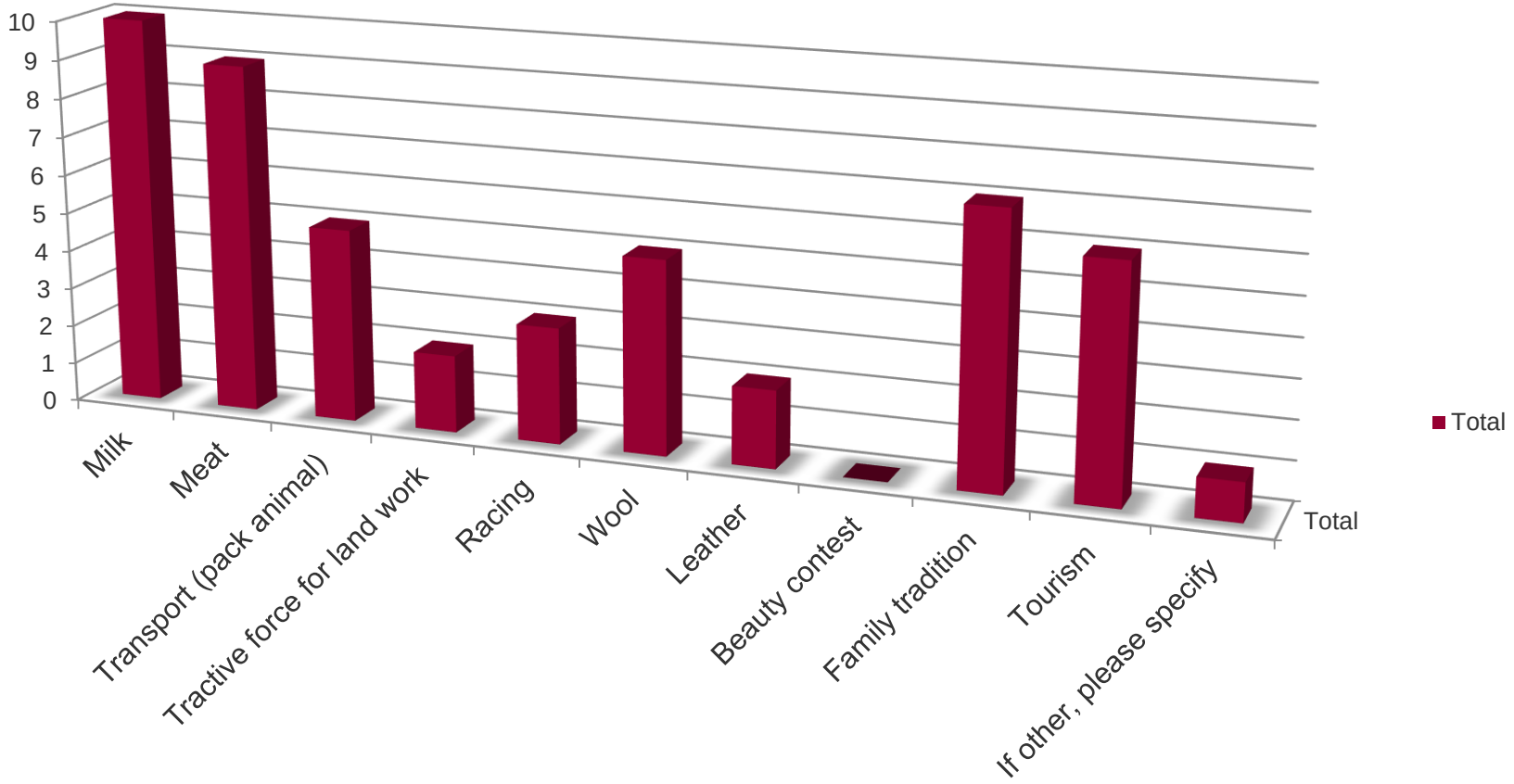
3. SPECIES: DROMEDARY

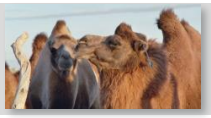
Main breeding reasons



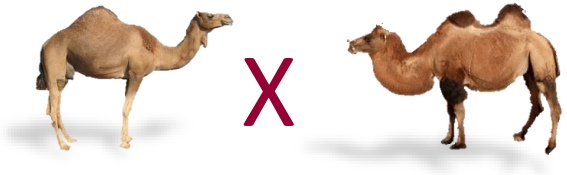
3. SPECIES: BACTRIAN CAMEL

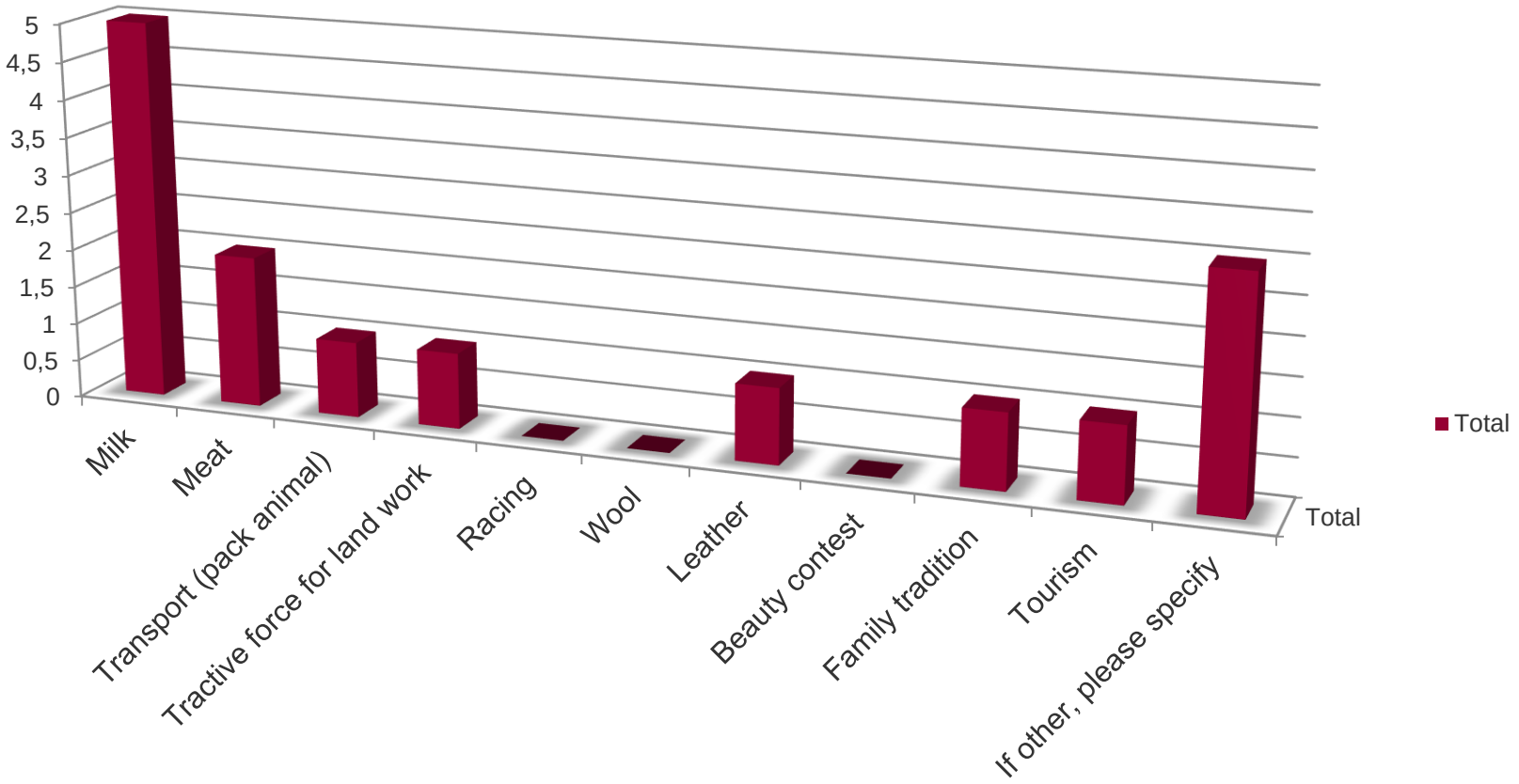
Main breeding reasons





3. SPECIES: Hybrids





24.

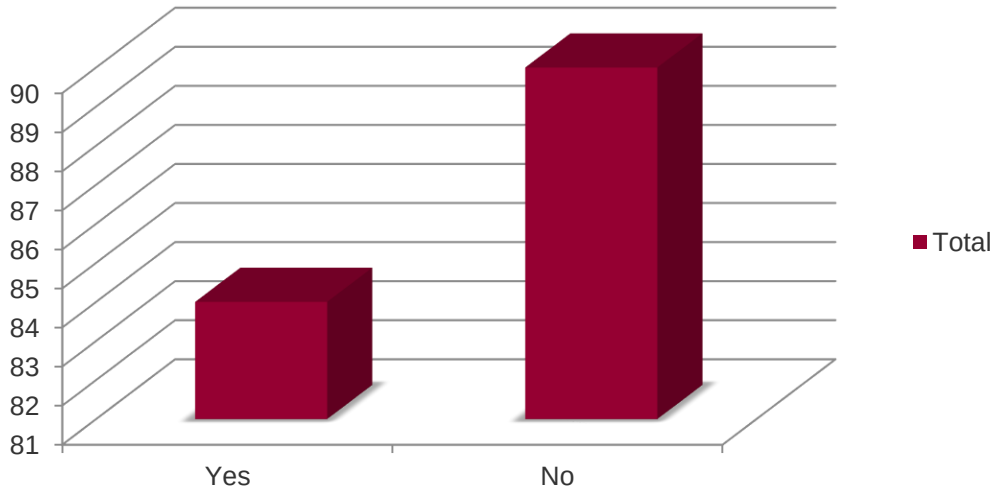
Please indicate the reasons for rearing animals referring exclusively to the TERRITORIAL LEVEL you selected by ticking all that apply

Response	Comments
1	wrestling
2	Male F1 hybrid for camel wrestling

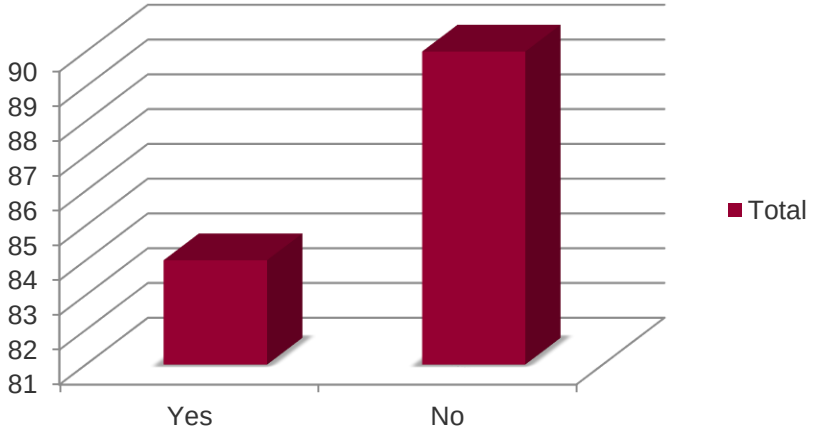
Camel wrestling @Selçuk, Turkey

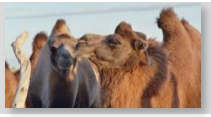
4. ANIMAL IDENTIFICATION

ID system available?



ID system mandatory?





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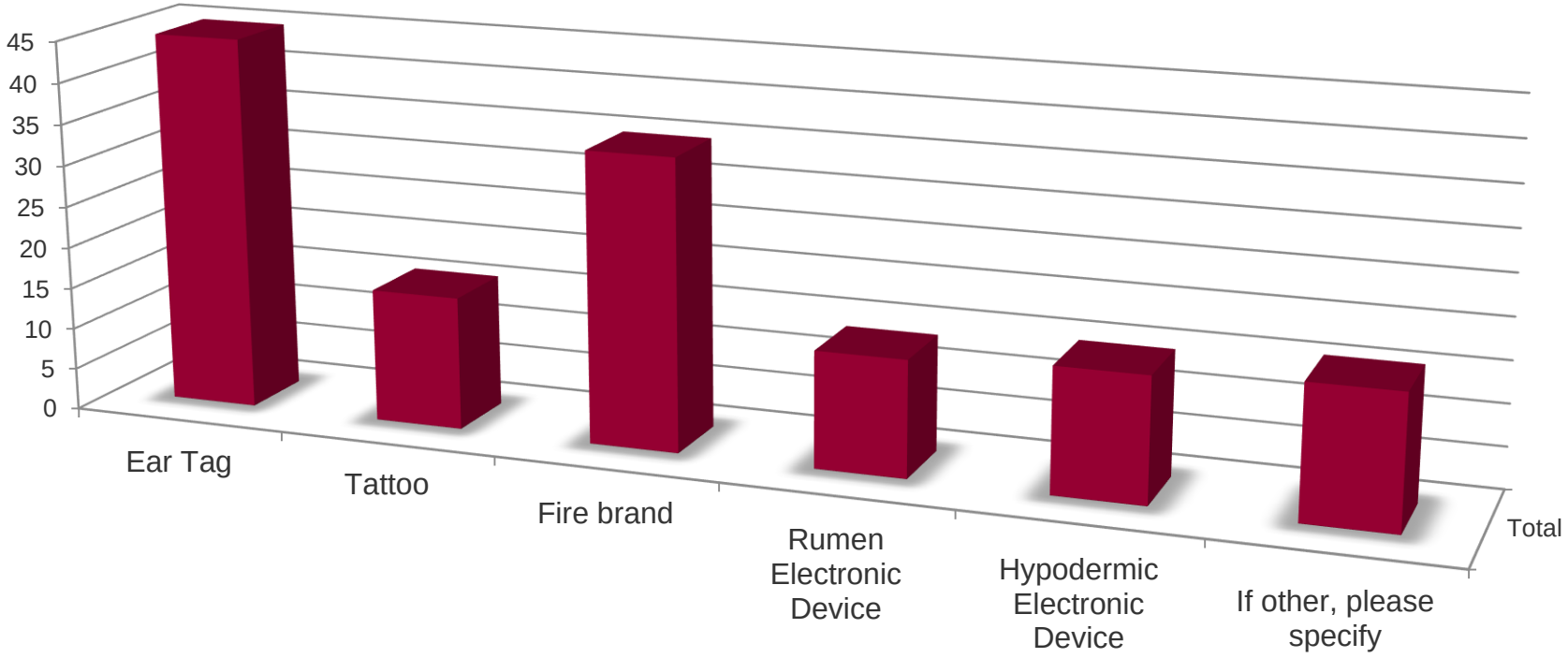
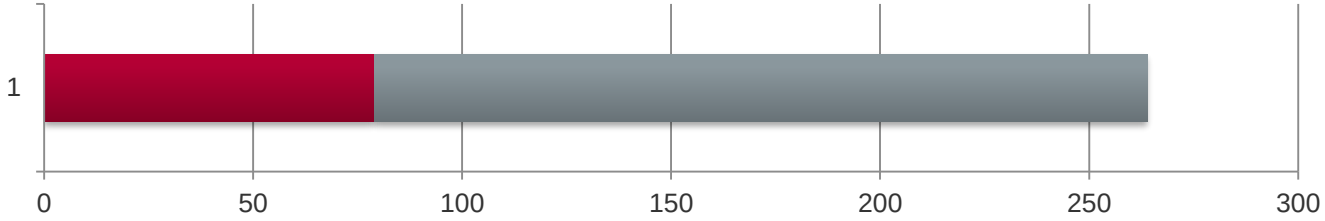
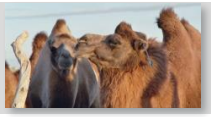
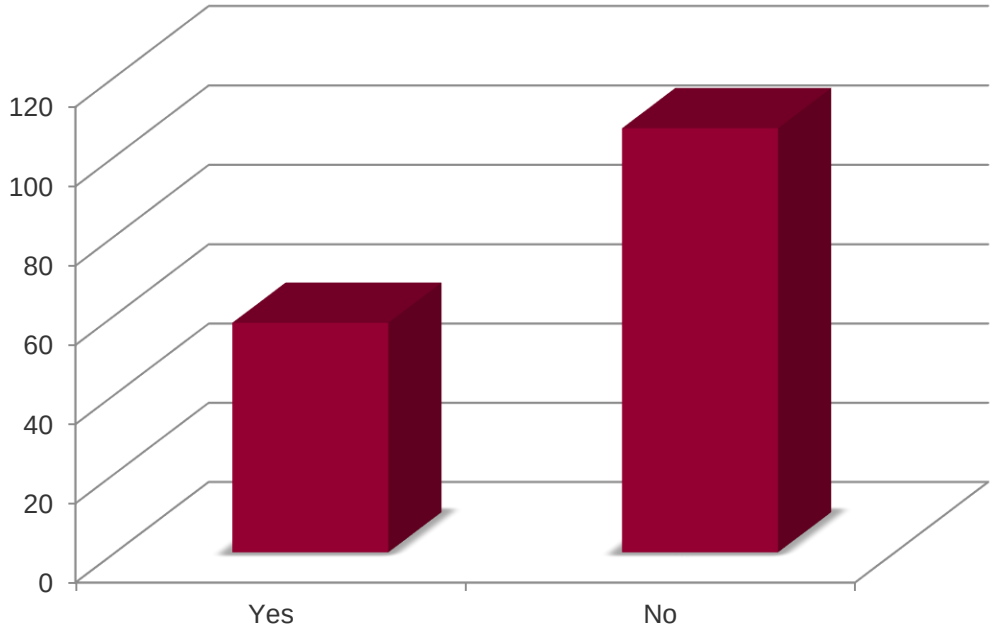
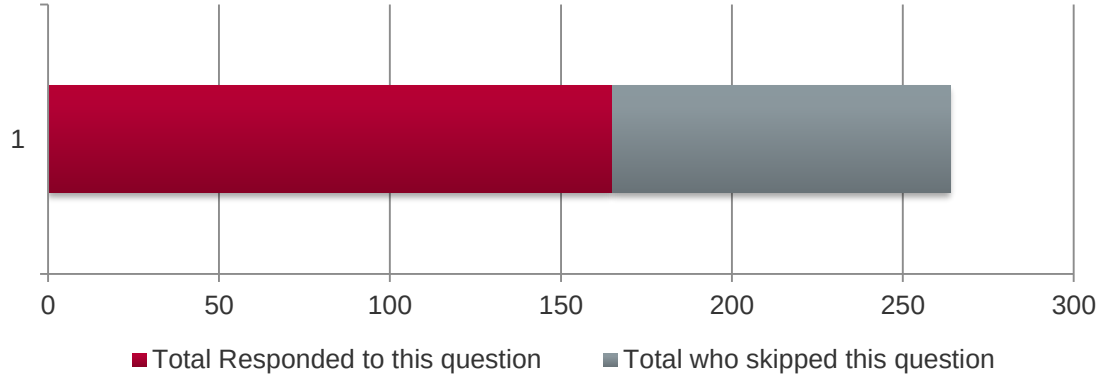


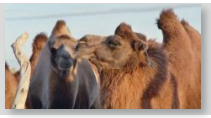




5. TRAIT RECORDING

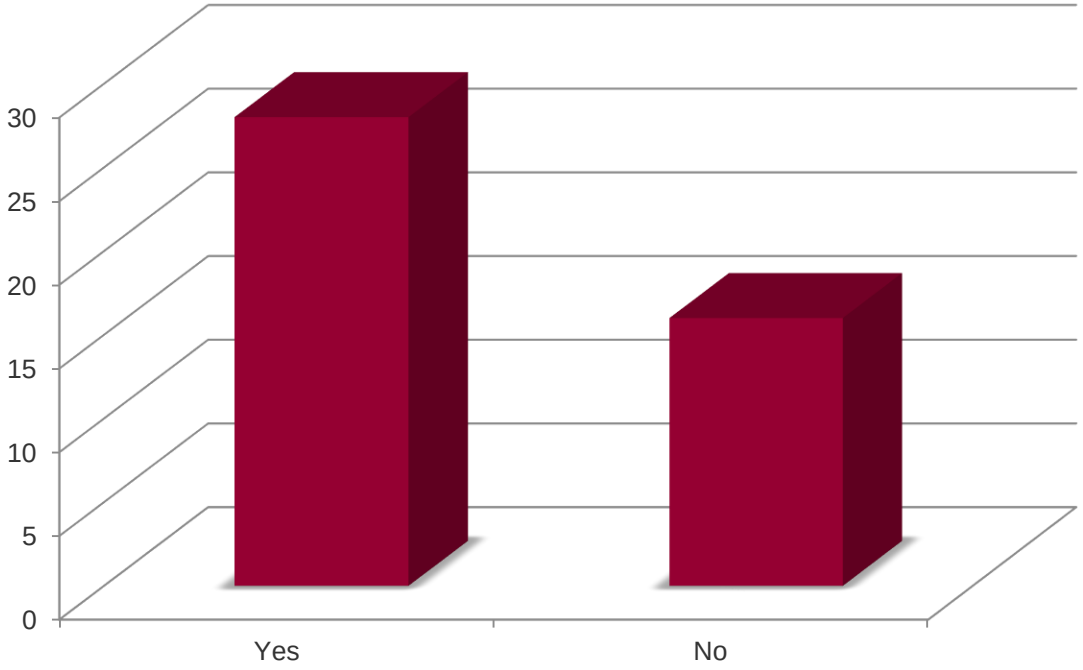


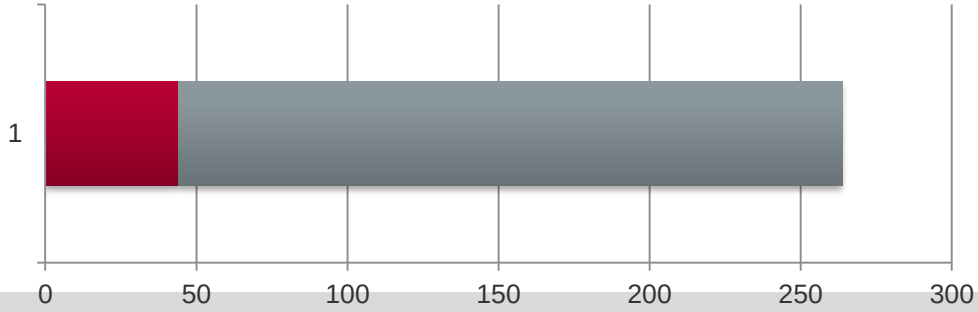


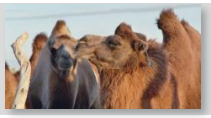


5. TRAIT RECORDING

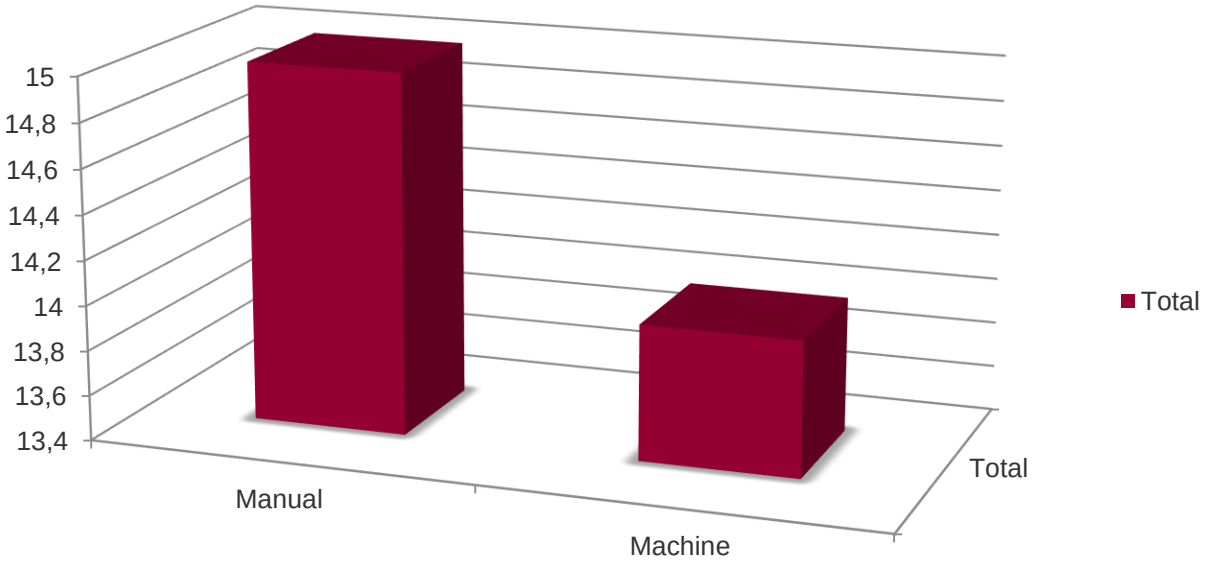
Milk recording

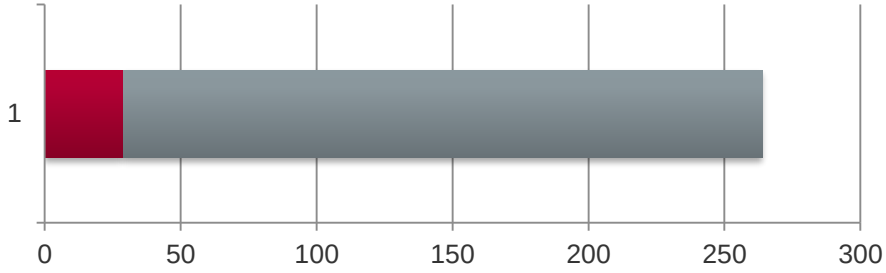


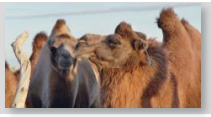


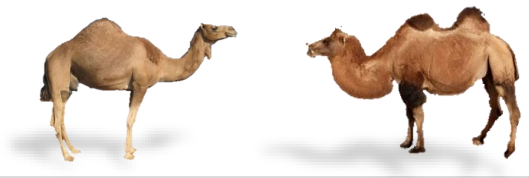


Milking type recording

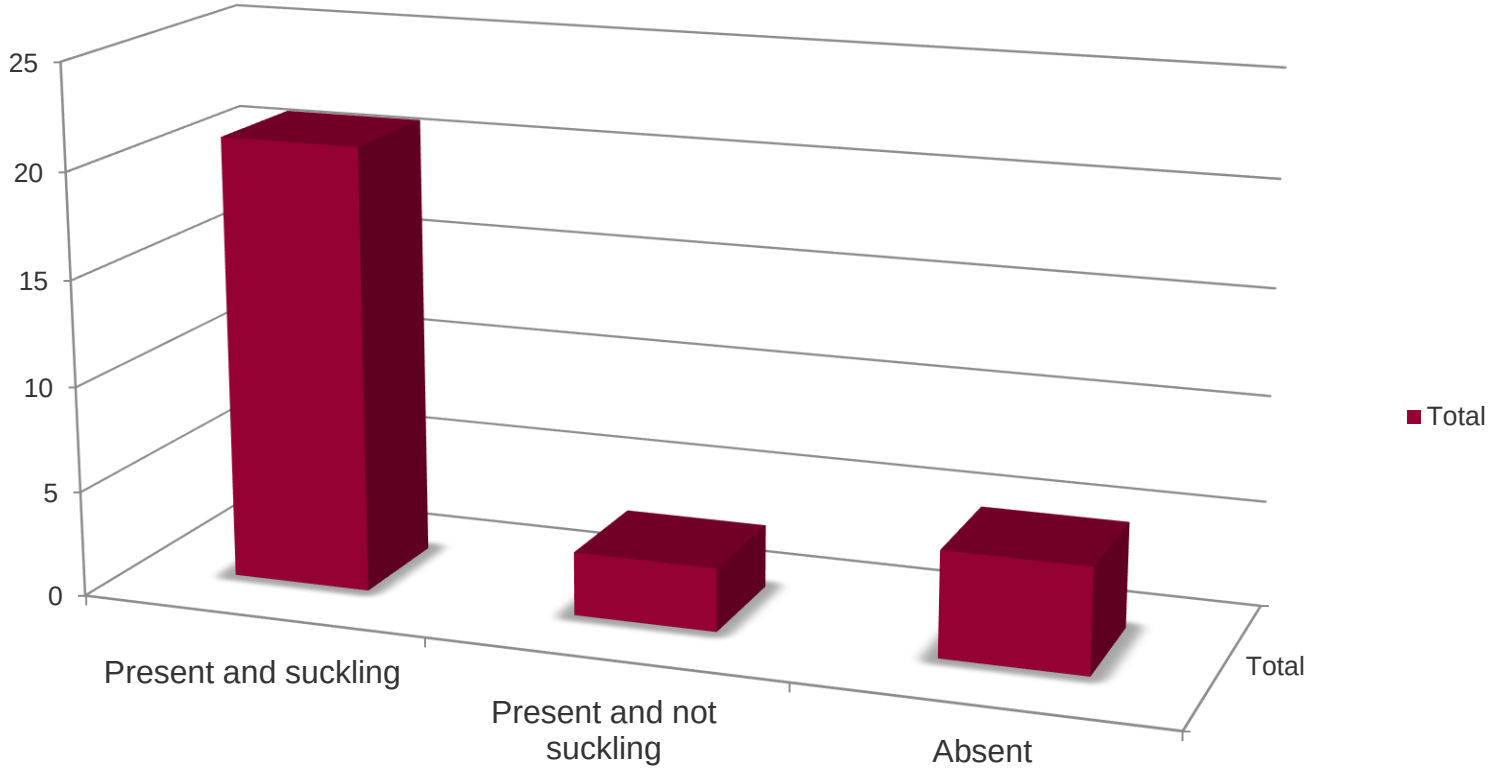


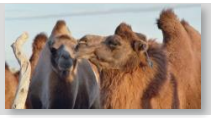






Milking and suckling





5. TRAIT RECORDING

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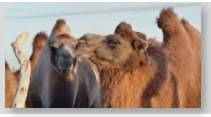
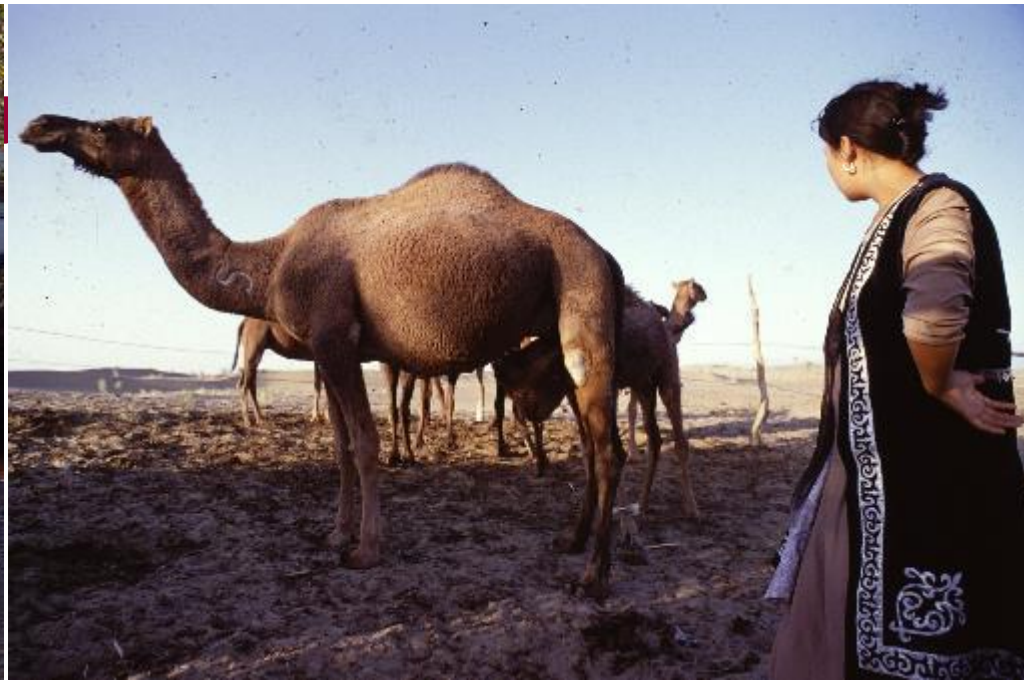
5. TRAIT RECORDING

Milking and suckling



SUMMARY: camels are MULTI-PURPOSE animals



c) Dual-purpose camel

d) Racing camel

e) Bactrian camel

SUMMARY: camels are MULTI-PURPOSE animals

- extensive management in the desert

versus

- semi-intensive management in peri-urban areas
- European market is interested in camels

- Keep high animal welfare standards and genetic diversity
- alongside genomic improvement/ selection

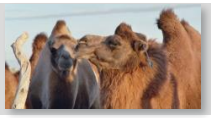
Where to go from here

- Identify breeders for developing recording guidelines
- Animal Identification
- Collaboration with stakeholders
  - FAO
  - national governments
  - Breeders associations

- Evaluate newly measured phenotypes
- Initiate first GWAS study(ies)

- Develop further genomic tools

TOWARD A CAMEL TRANSNATIONAL VALUE CHAIN



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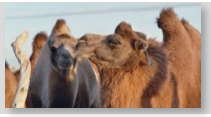
why improving camels...

- Improvement of livestock is always an improvement for people
- Camels are one of the most promising livestock species for sustainable utilization
- Conservation of the last wild camels and of locally adapted diversity



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