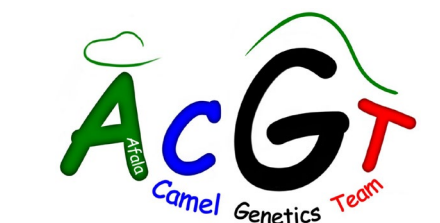




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Genome-wide association study of hair shape variation in dromedaries from Kuwait



Hasan Alhaddad, Silvia Bruno, Kawther M. Akbar, and Elena Ciani

EAAP

September 1st 2024



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Industry

Variation

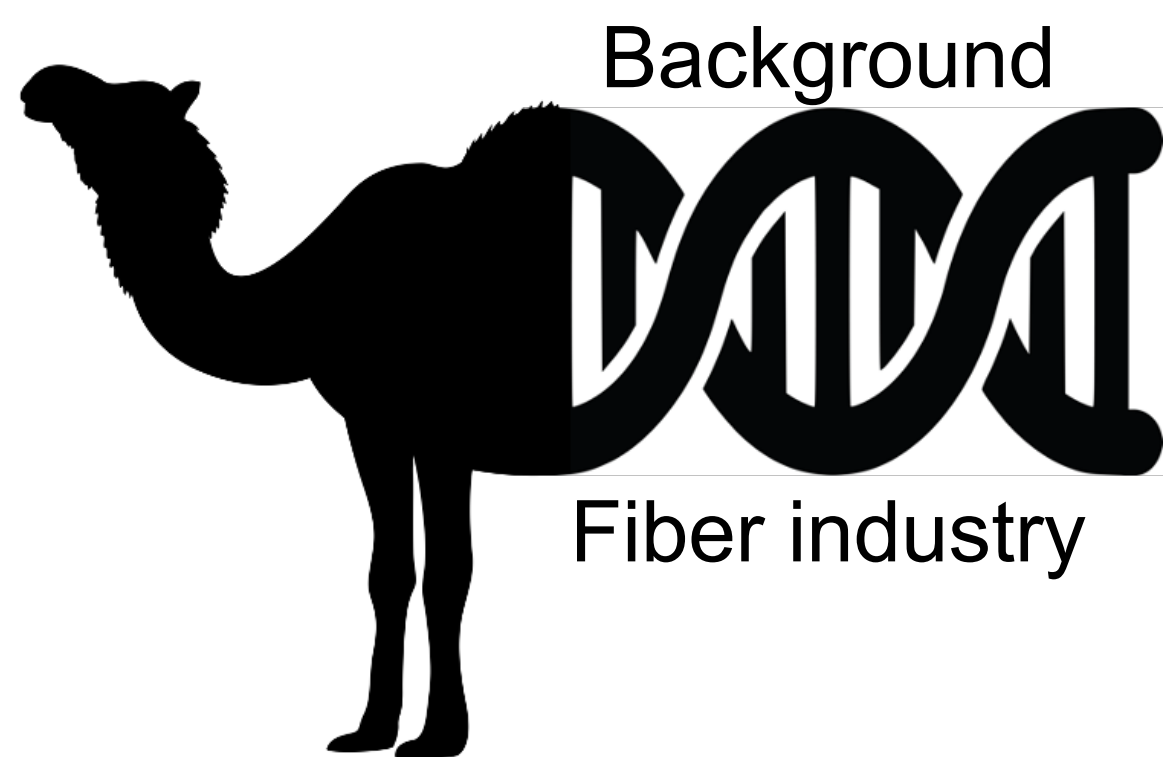
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



What are the industrial uses of camel hair (i.e., wool)?





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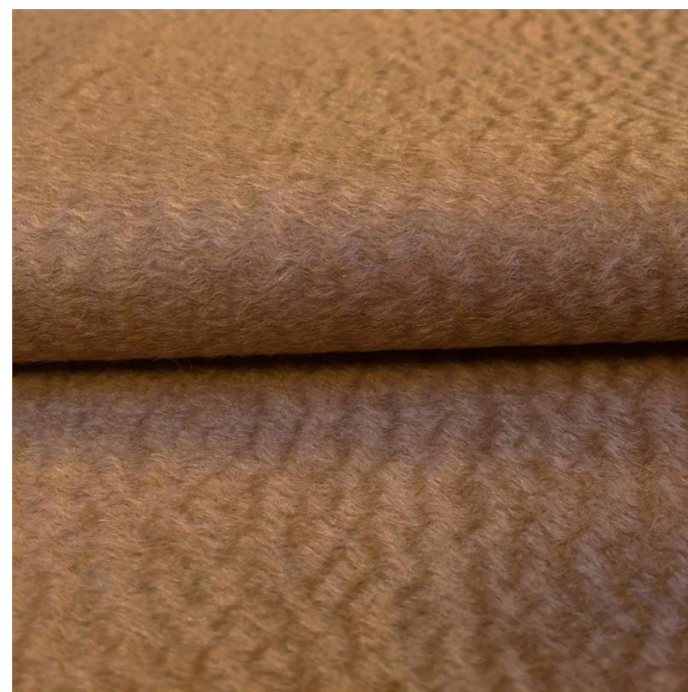
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2





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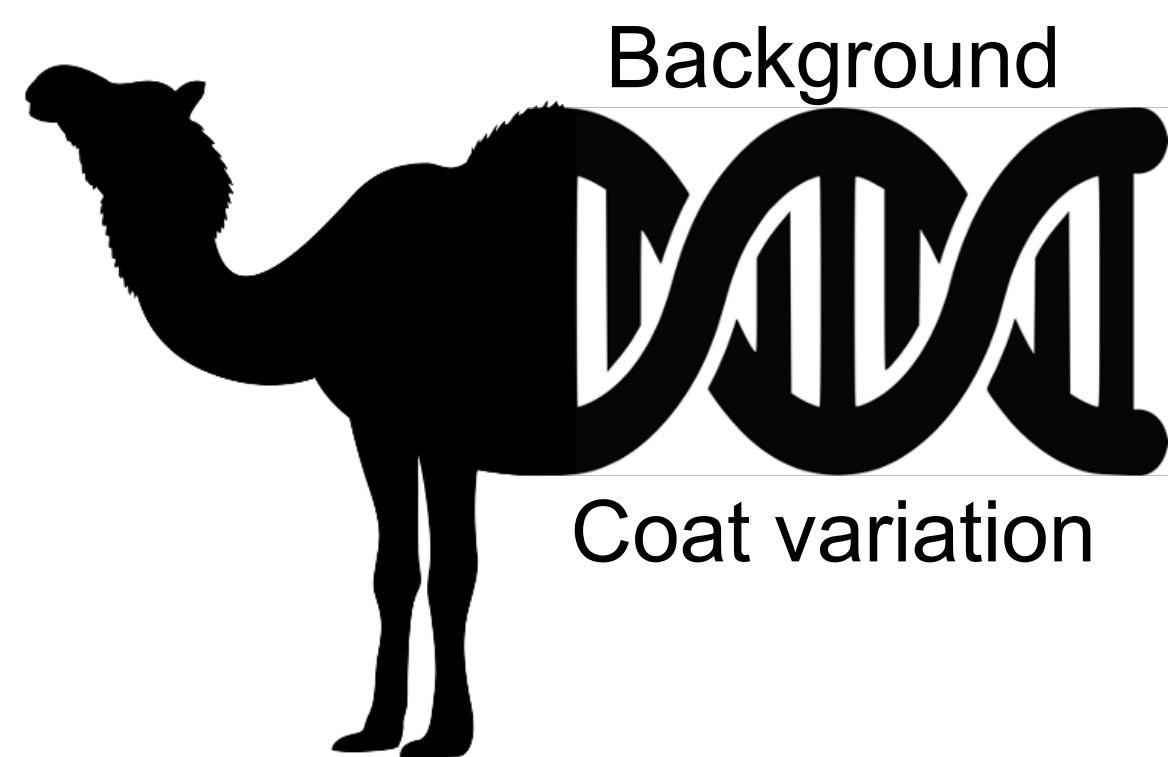
Attributes

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Crimp-types

GWA Study 1

GWA Study 2



Do dromedary camels in Kuwait
(Show-camels) vary in hair attributes?



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Attributes

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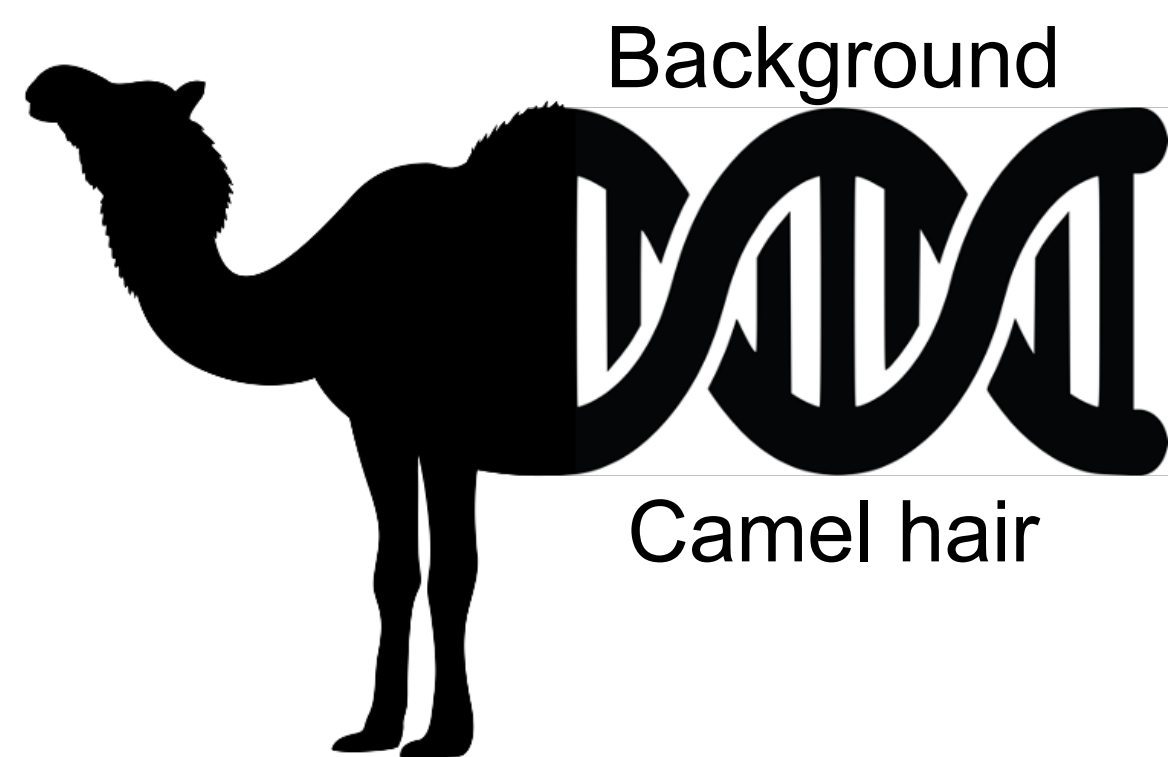
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



What are the characteristics and shape classes of camel hair fibers?



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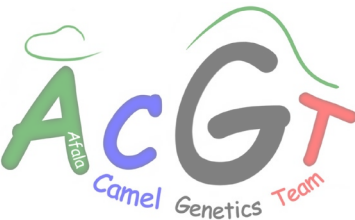
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



Small Ruminant Research 235 (2024) 107276



Contents lists available at ScienceDirect

Small Ruminant Research

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



Fiber characteristics of the dromedary camel in the Arabian Peninsula

Kawther M. Akbar , Bader H. Alhajeri , Hasan Alhaddad *

Department of Biological Science, Kuwait University, P.O Box 5969, Safat 13060, Kuwait

Individual fibers	Fiber strands	Torso photo	Camel photo	Crimp category	Description
				 Straight	• Luster: very smooth and shiny. • Hair tips: protrude downwards. • Hair strands: wide, layered on top of one another, and not distinguishable. • Individual hairs: straight or slightly bent.
				 C-shaped	• Luster: smooth and shiny. • Hair tips: protrude inwards towards the skin or outwards at different directions. • Hair strands: wide, mostly closely packed and easily distinguishable. • Individual hairs: mostly C-shaped.
				 Wavy	• Luster: frizzy and not shiny. • Hair tips: protrude outwards or downwards. • Hair strands: narrow, mostly well defined, closely packed, easily distinguishable. • Individual hairs: multiple bends of varying amplitudes.
				 Ringed	• Luster: frizzy and not shiny. • Hair tips: protrude outwards. • Hair strands: narrow, well defined, closely packed, easily distinguishable. • Individual hairs: nearly regular bends at the bases with circular or sickle shaped tips that revolves around its axis.
				 Kinky	• Luster: very frizzy and not shiny. • Hair tips: protrude downwards. • Hair strands: wide from the base and narrow at the tip and easily distinguishable. • Individual hairs: appear straight with very small nearly regular bends.

Fig. 1. An illustration of the different crimp categories with a detailed description of each. A scaled drawing is shown for each crimp category, assigned by analyzing whole body photos, close-up torso photos, along with strand and individual fiber scans. The photos were selected as examples of the most representative fibers in each crimp category.



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Phenotyping

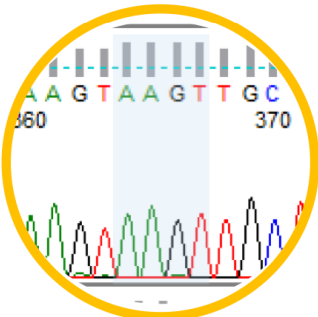
Crimp-types

GWA Study 1

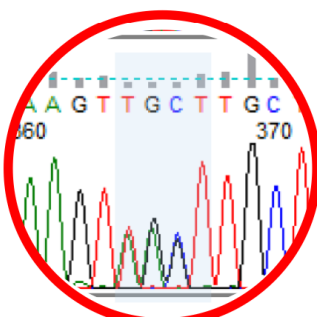
GWA Study 2



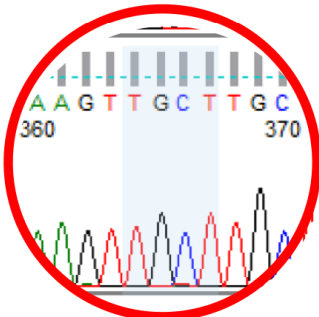
FGF5 (g.364-366delAAGT)



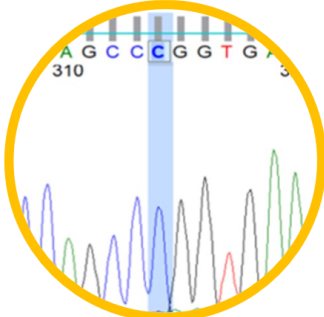
Wt/Wt



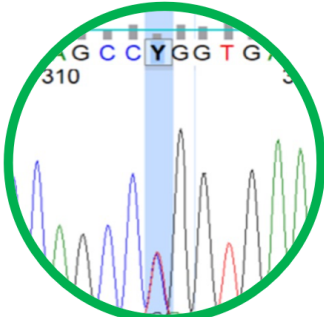
WT/Del



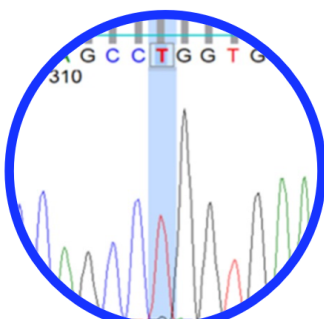
Del/Del



C/C

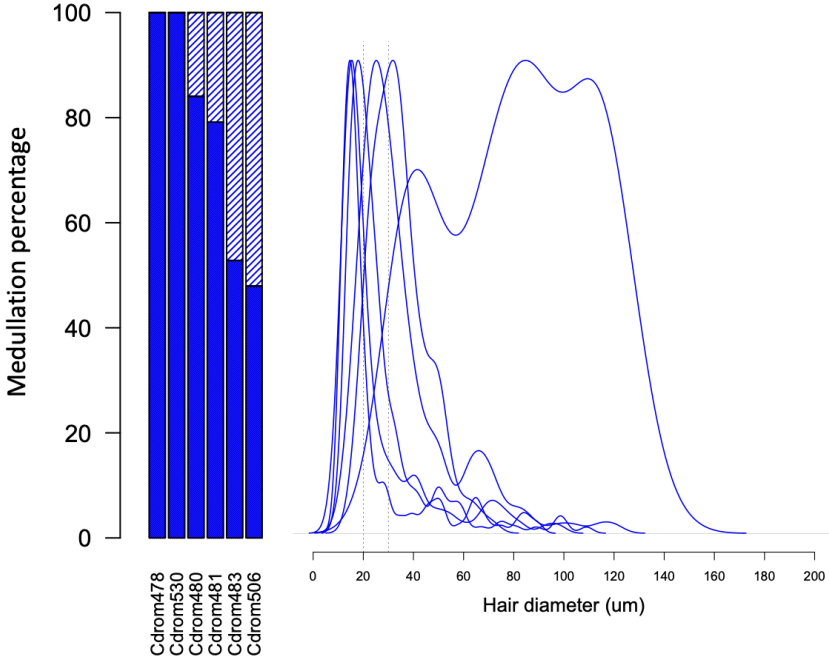
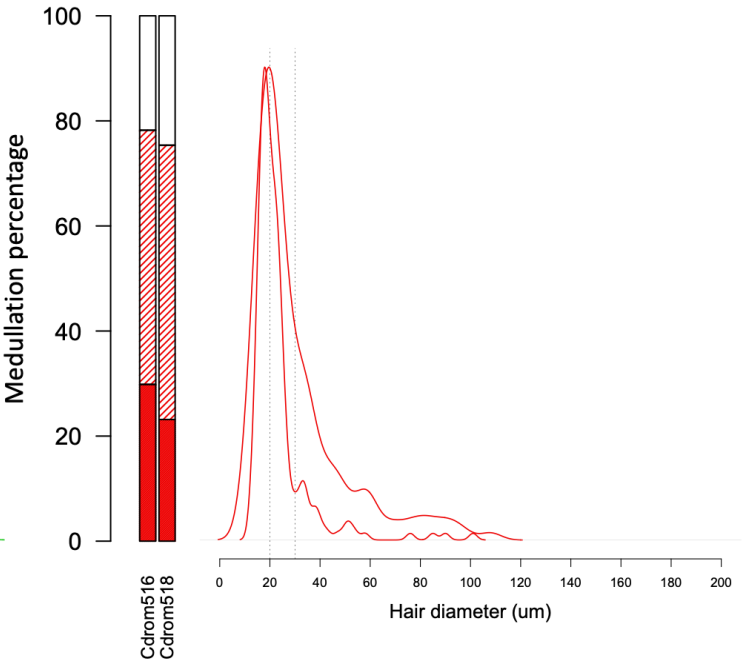
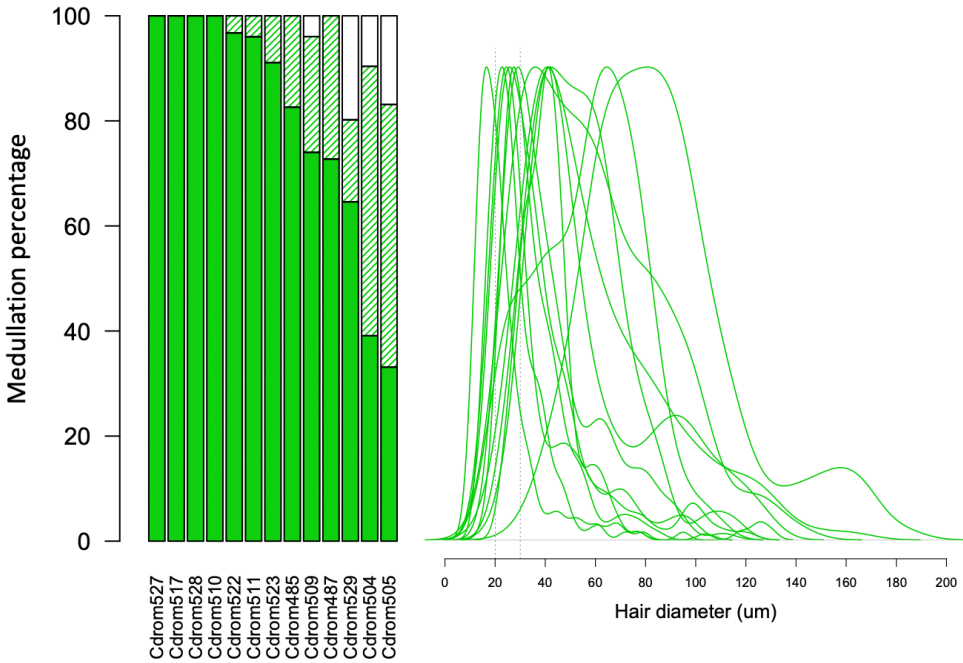
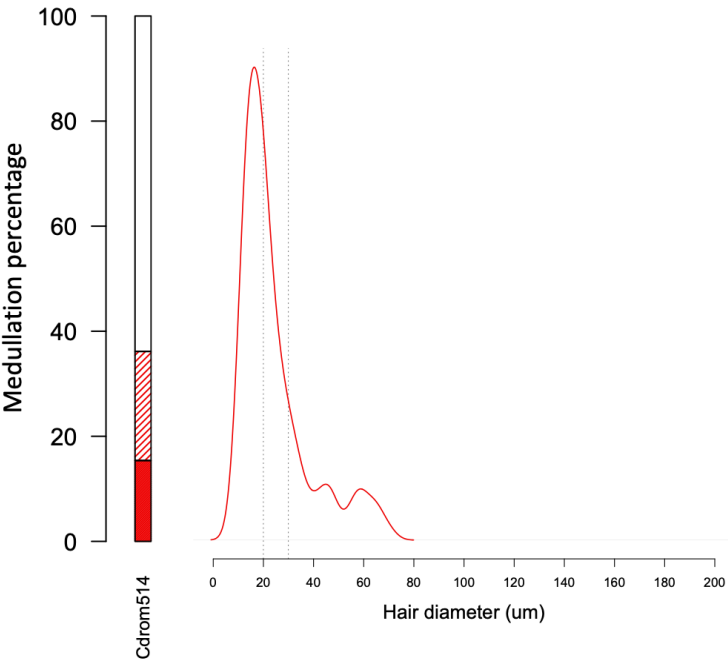
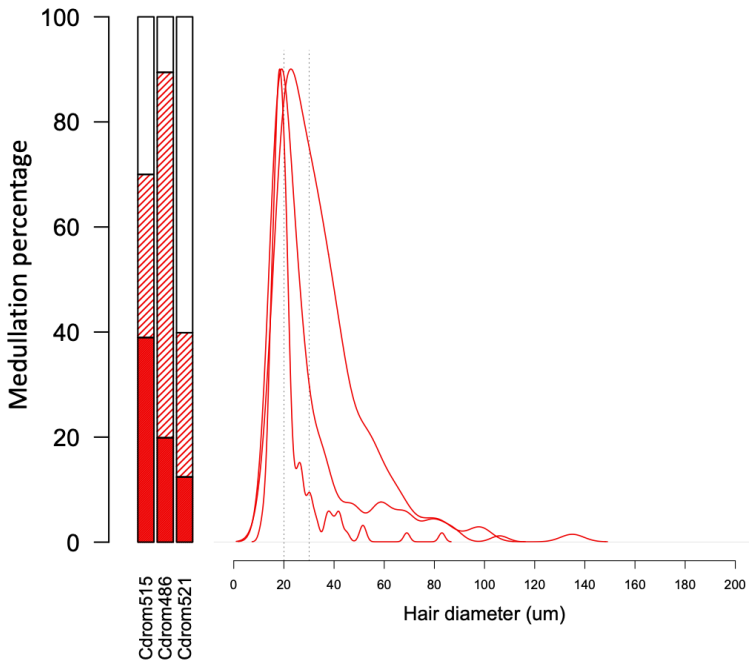
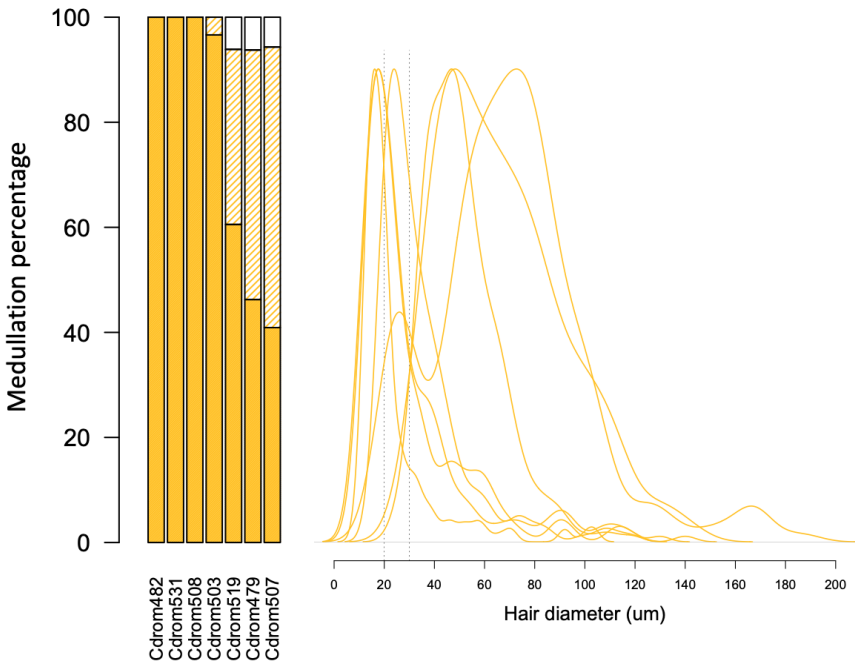


C/T



T/T

FGF5 (c.779 C>T)



Hair length
Short
Intermediate
Long
Extremely long



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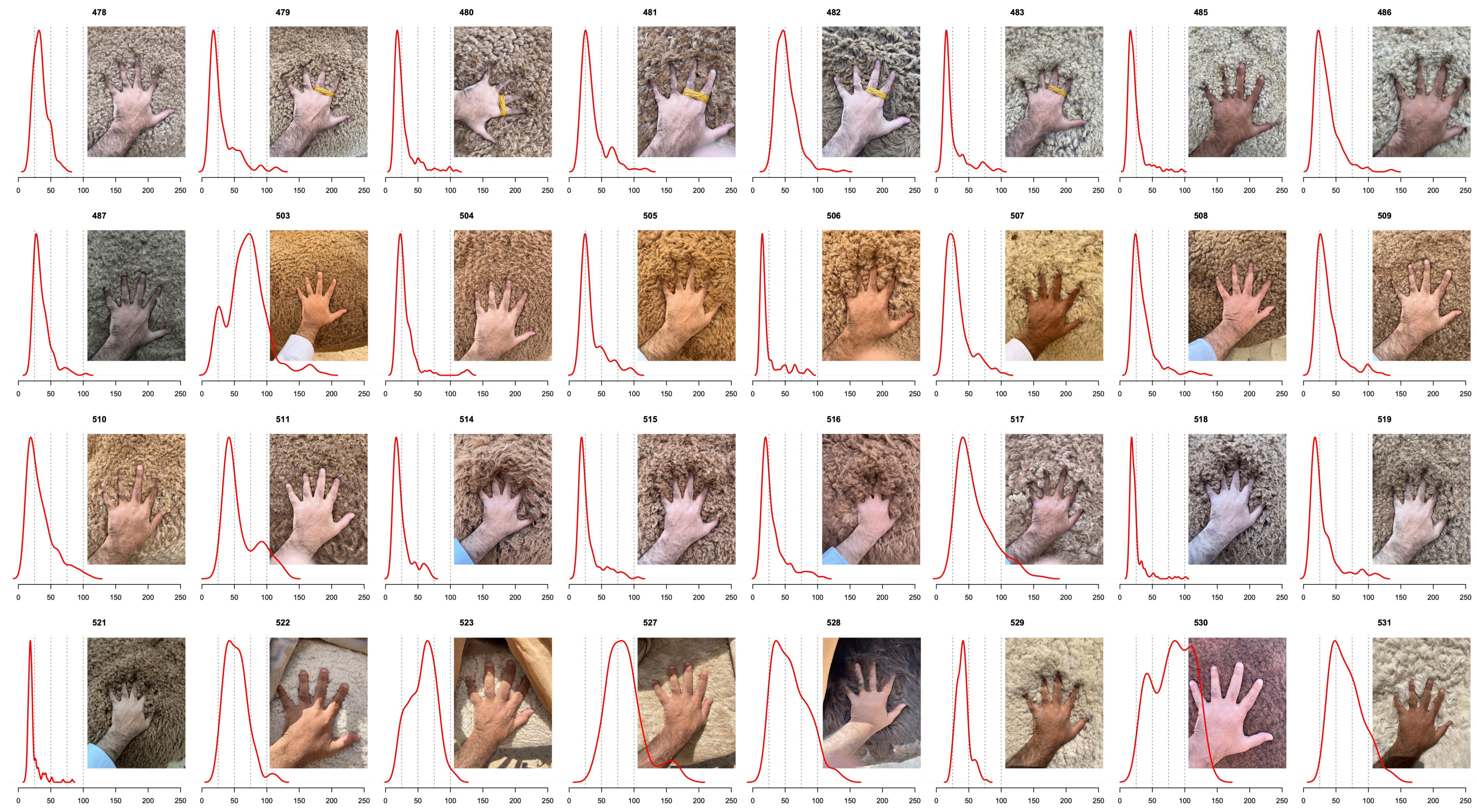
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2





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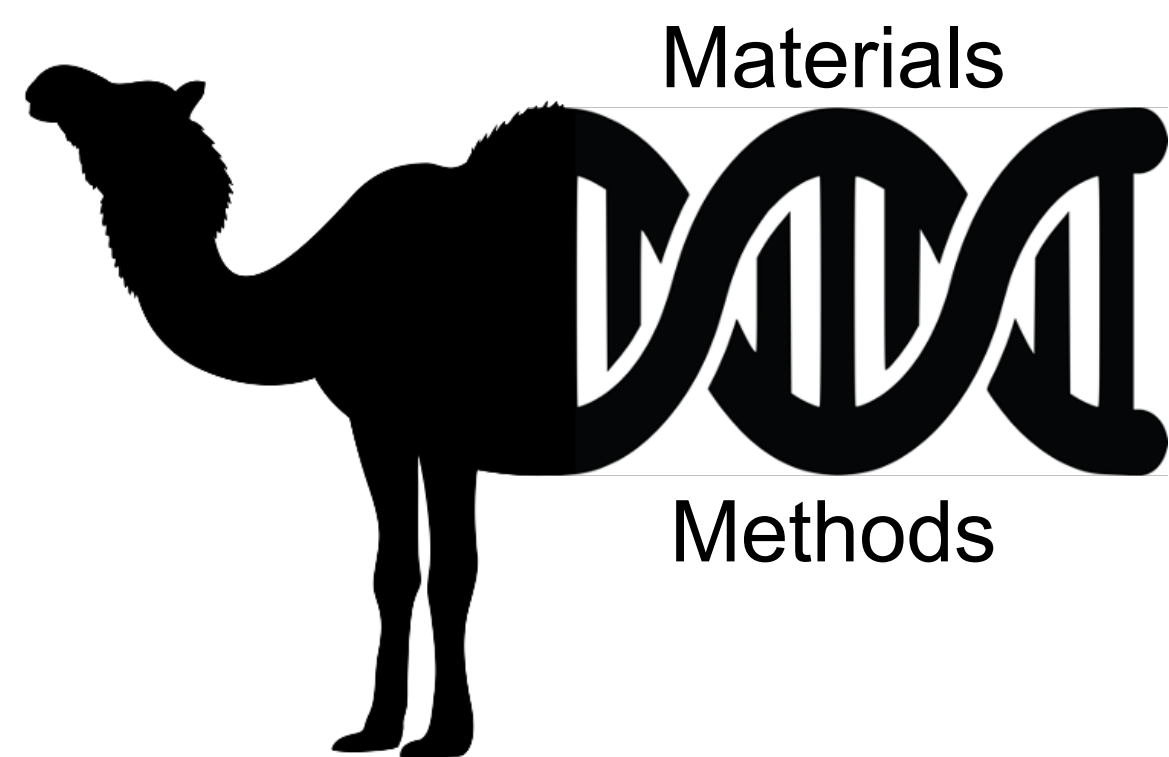
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



How do we phenotype camel hair shape variation and other qualities?



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Attributes

Phenotyping

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GWA Study 1

GWA Study 2





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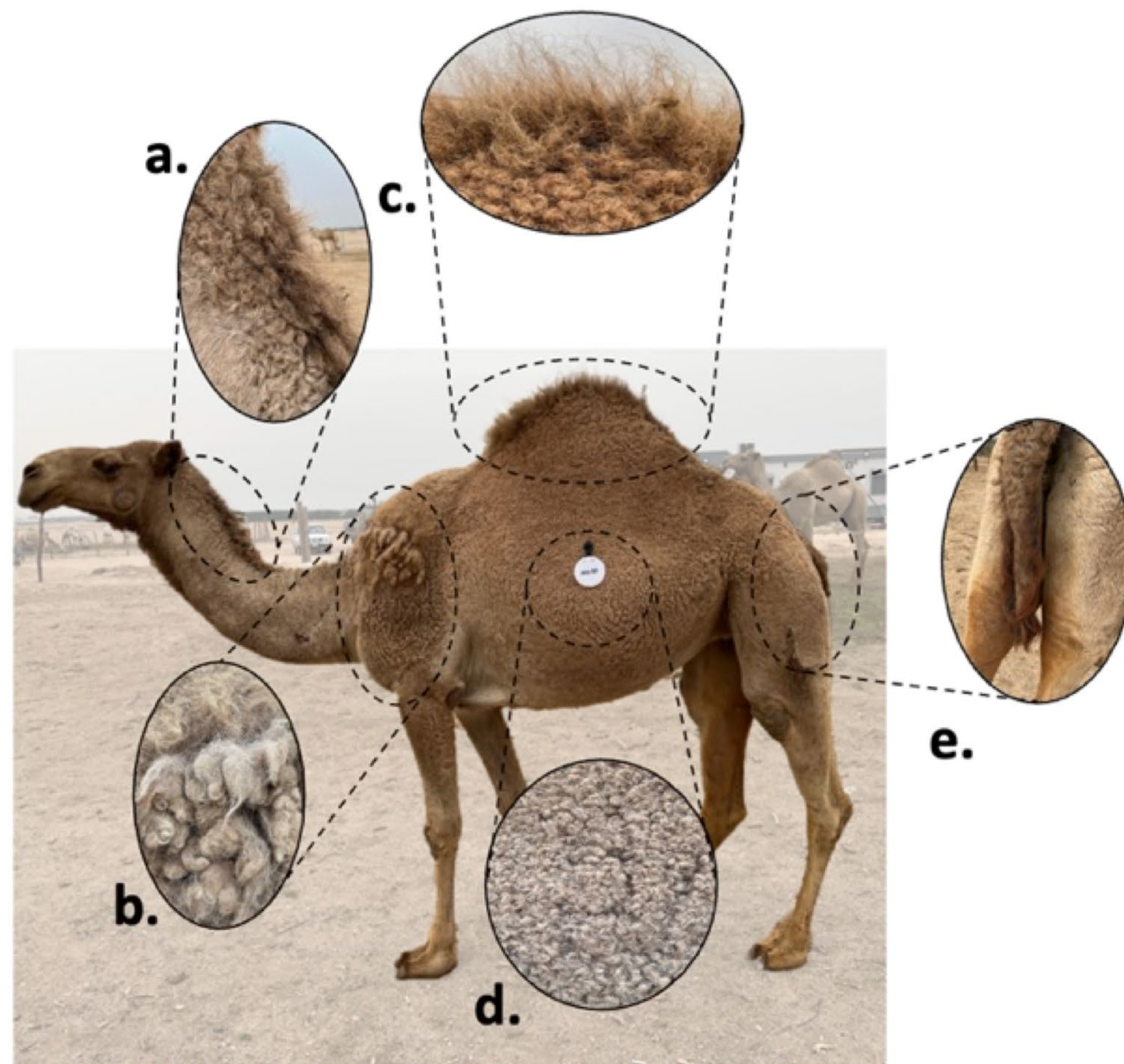
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2





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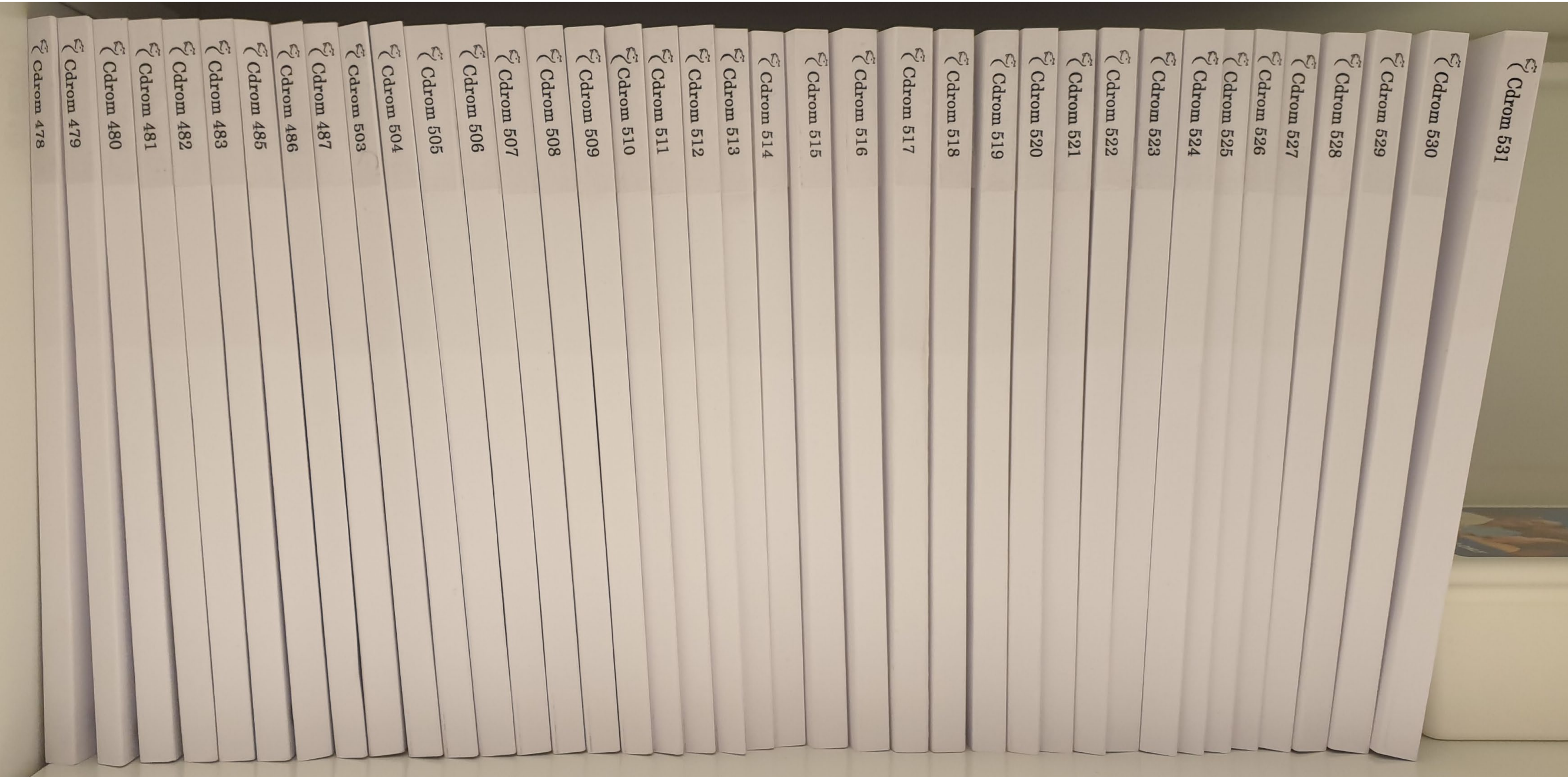
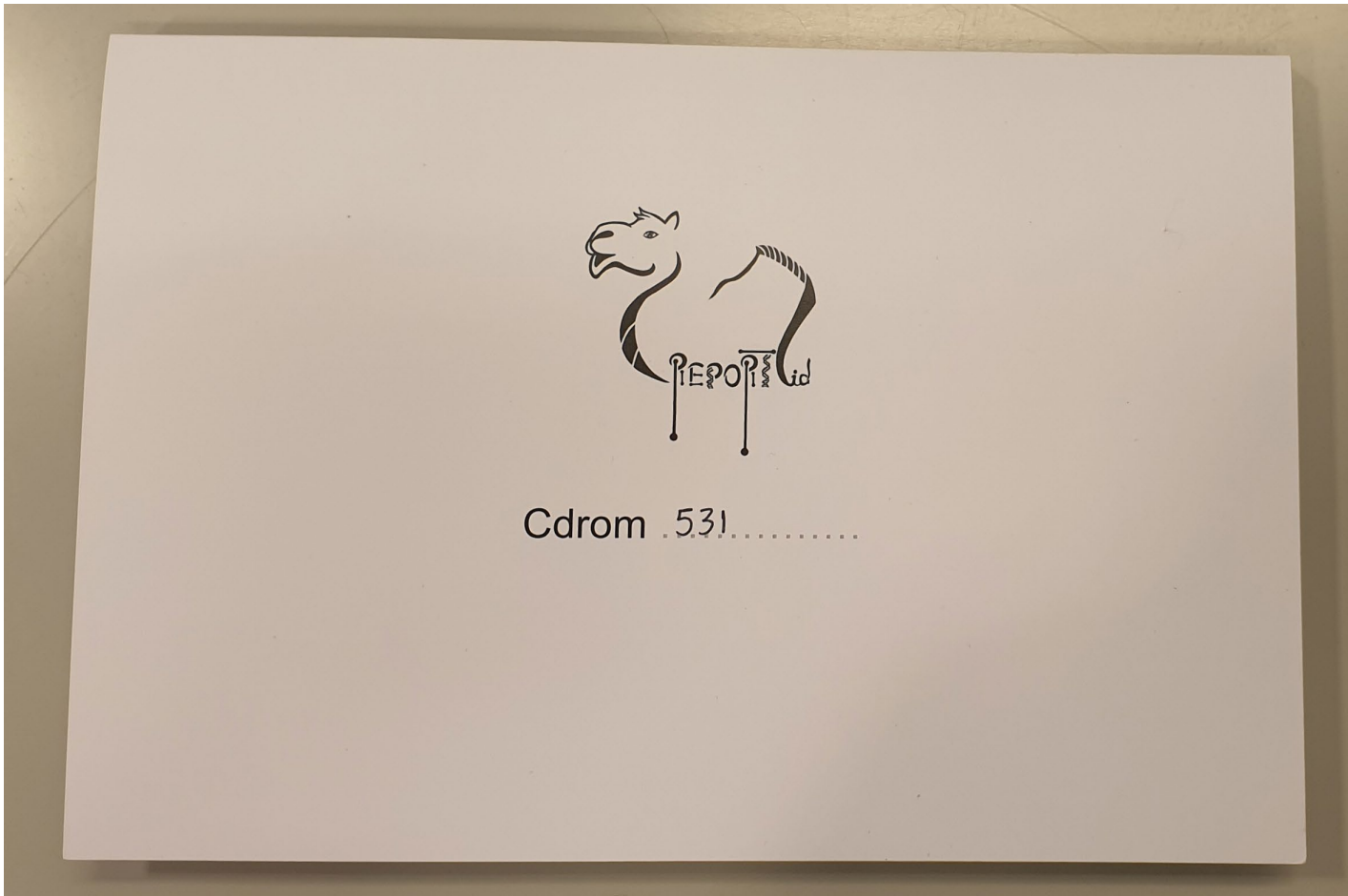
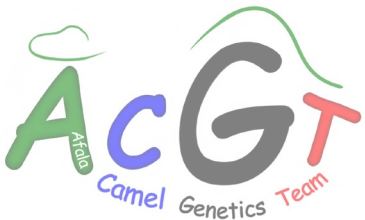
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2





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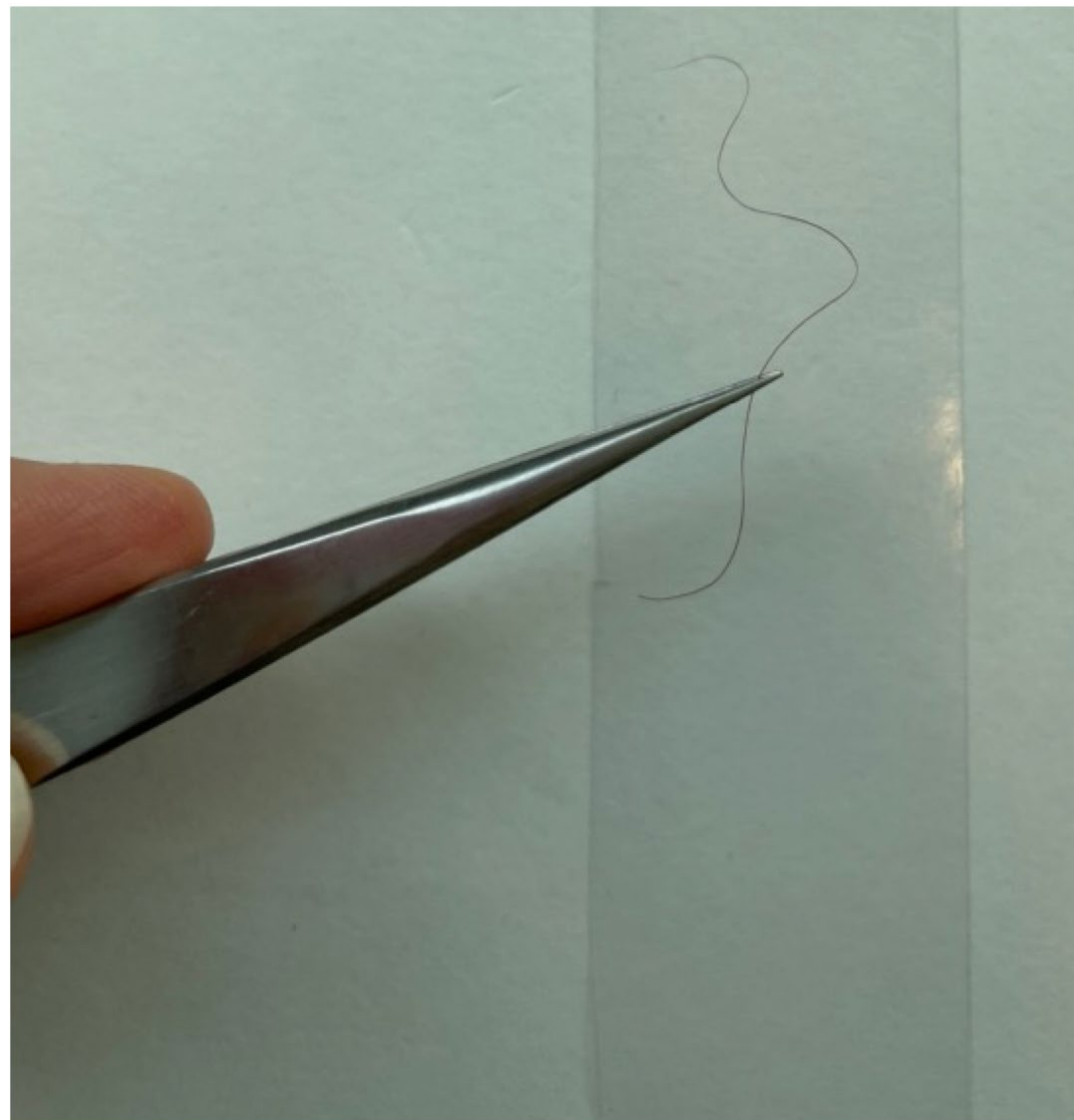
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2





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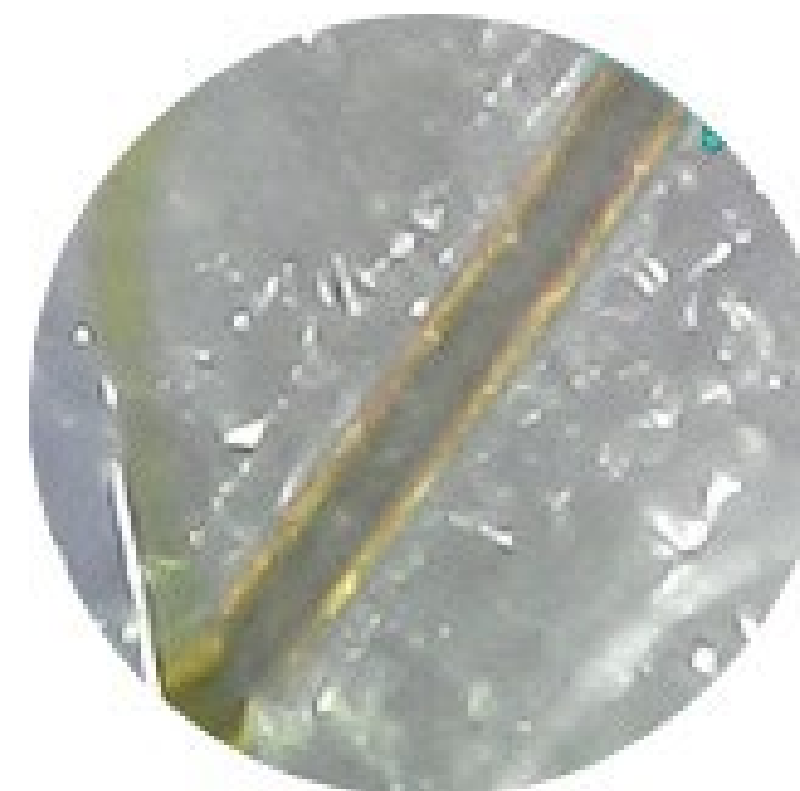
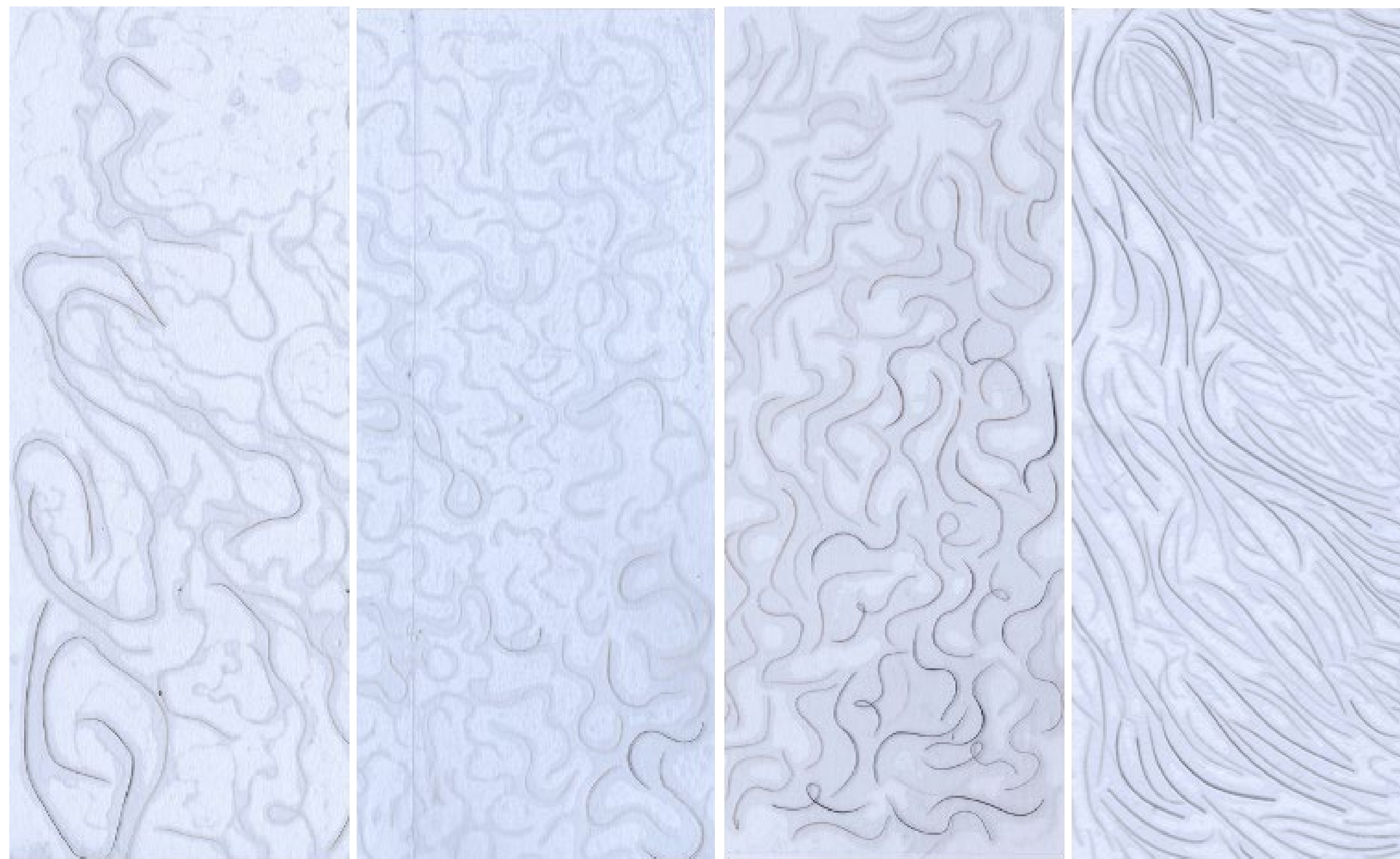
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



Medullation



Fiber diameter



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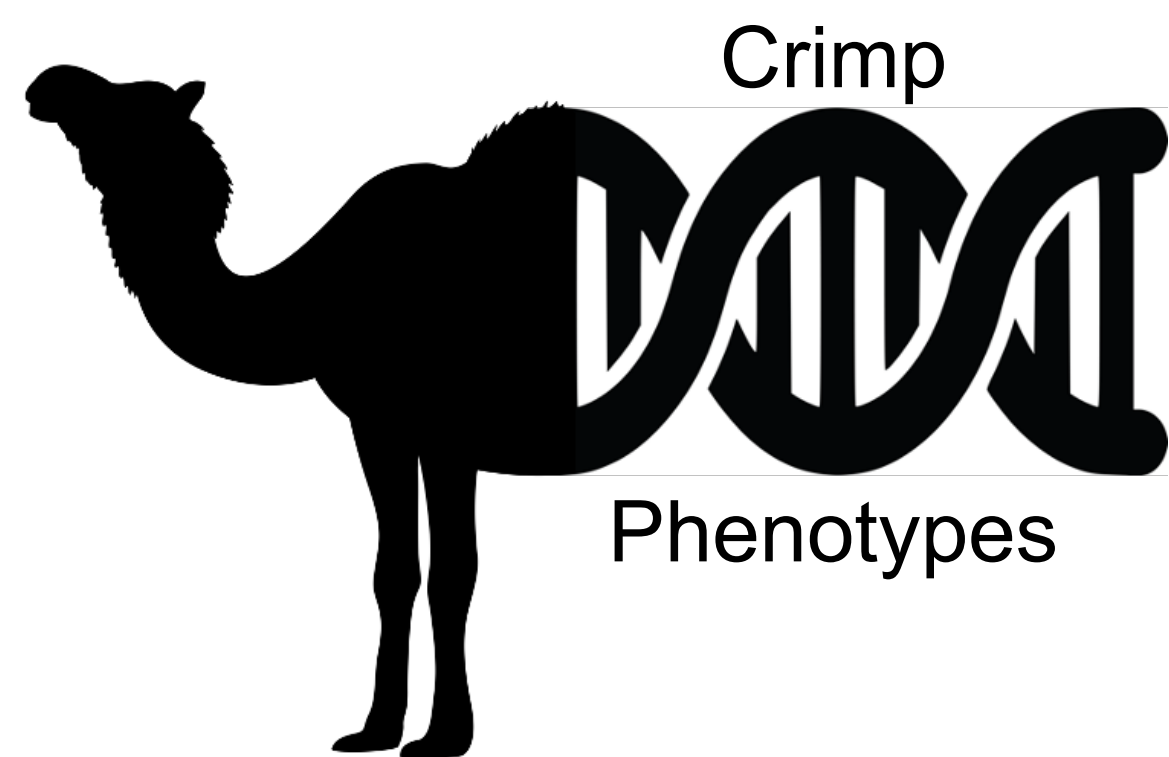
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



What are the categories of camel hair shape (i.e., crimp)?



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Attributes

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Crimp-types

GWA Study 1

GWA Study 2



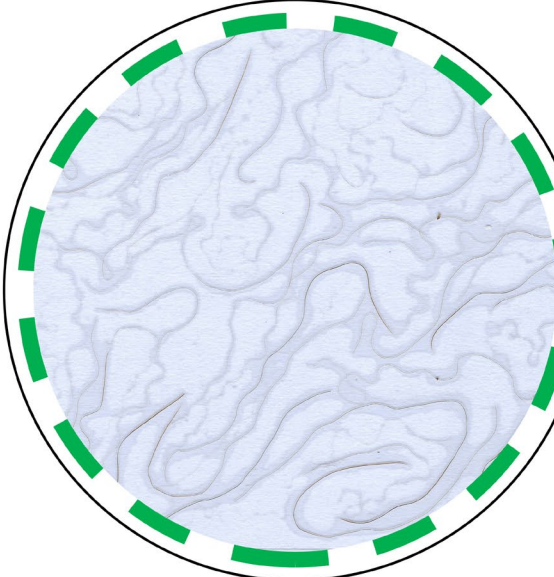
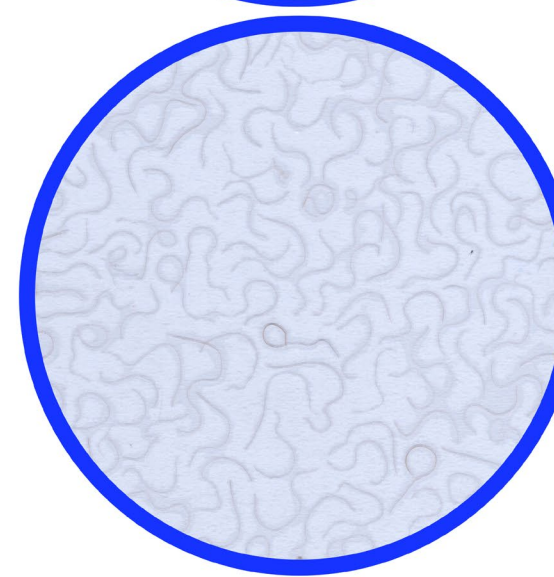
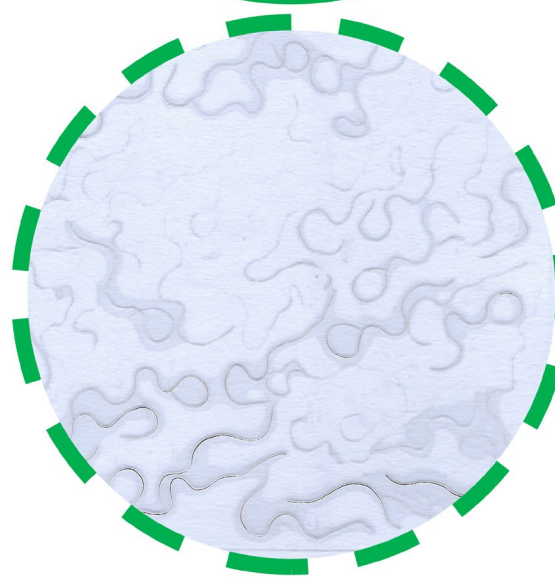
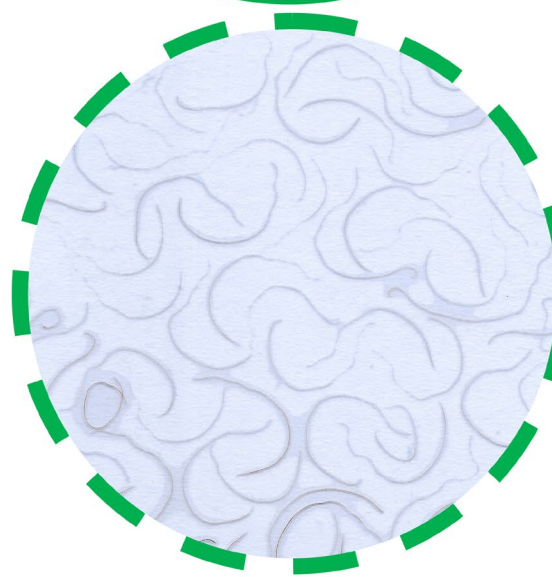
Photo-based phenotype



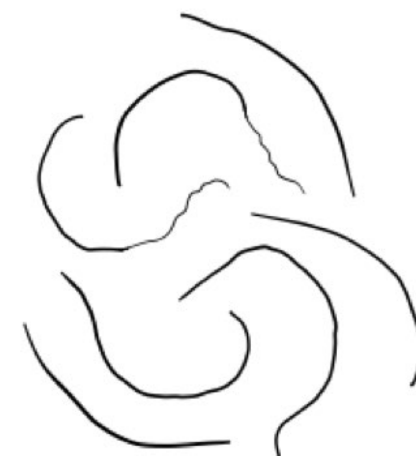
Strand-based phenotype



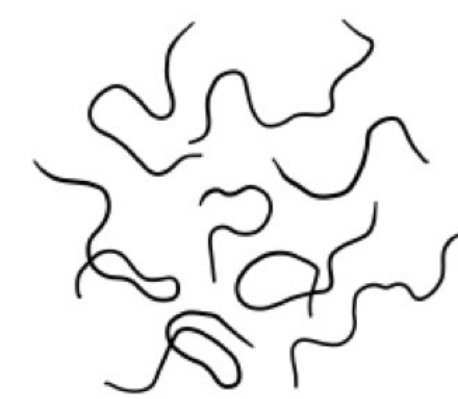
Fiber-based phenotype



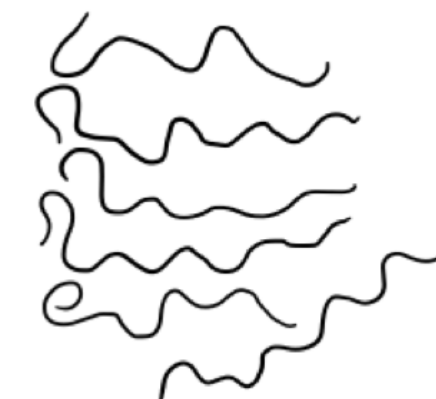
Straight



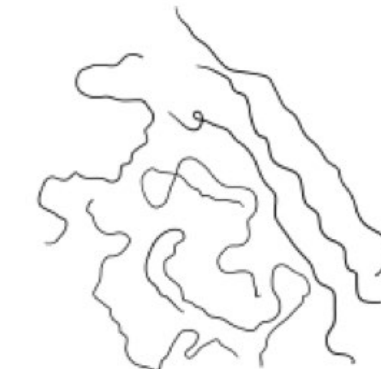
C-shaped



Wavy



Ringed



Kinky



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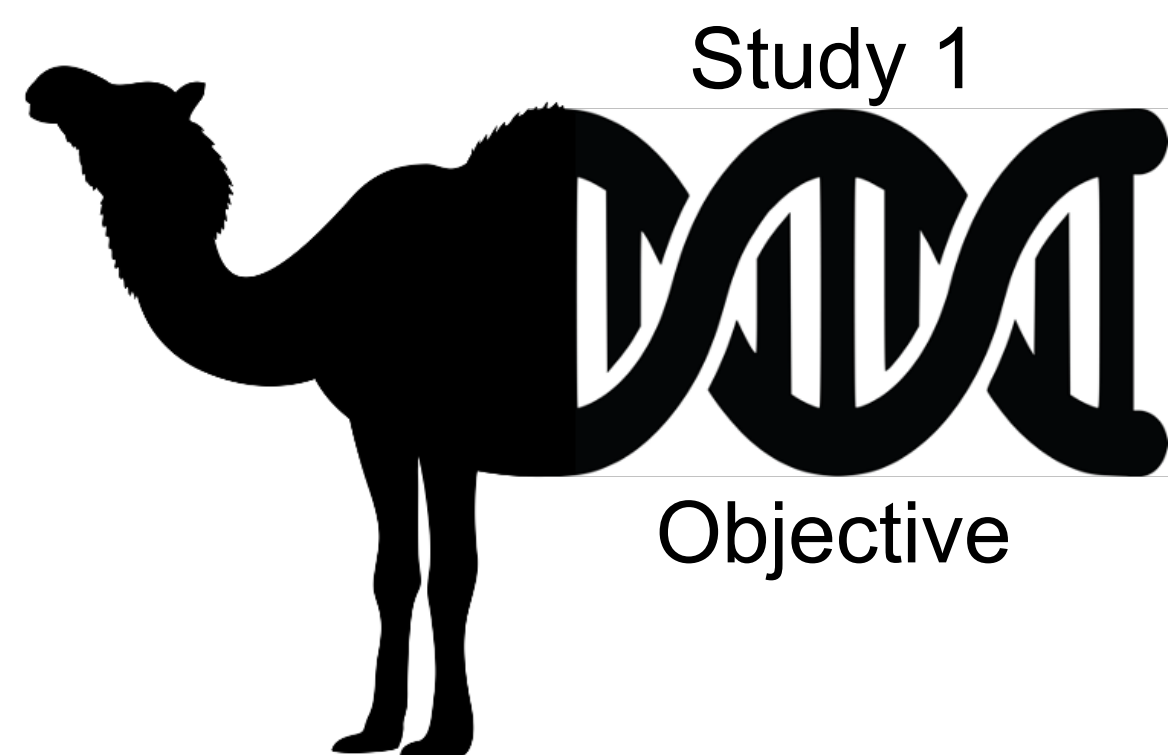
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



Perform GWAS between straight and
wavy crimp-types using WGS data



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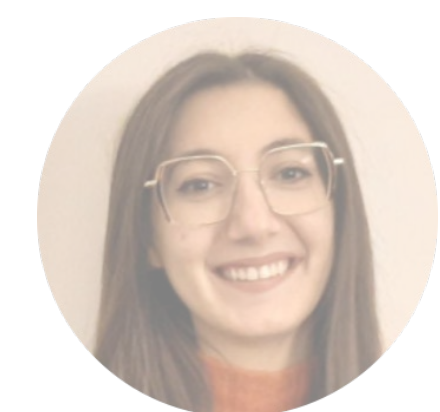
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



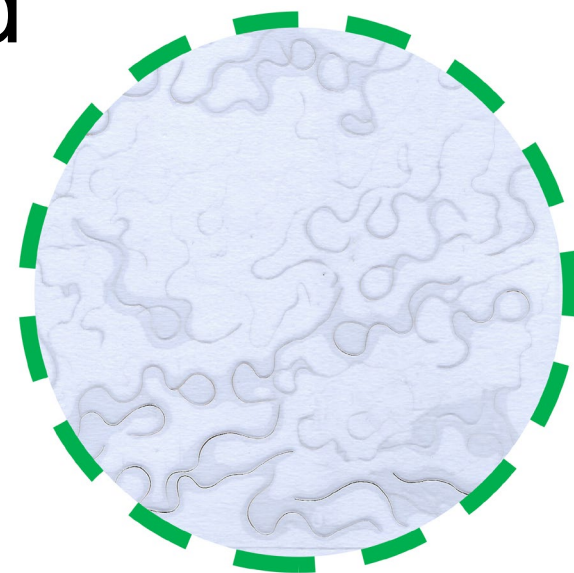
Phenotypes



Fiber-based
phenotype

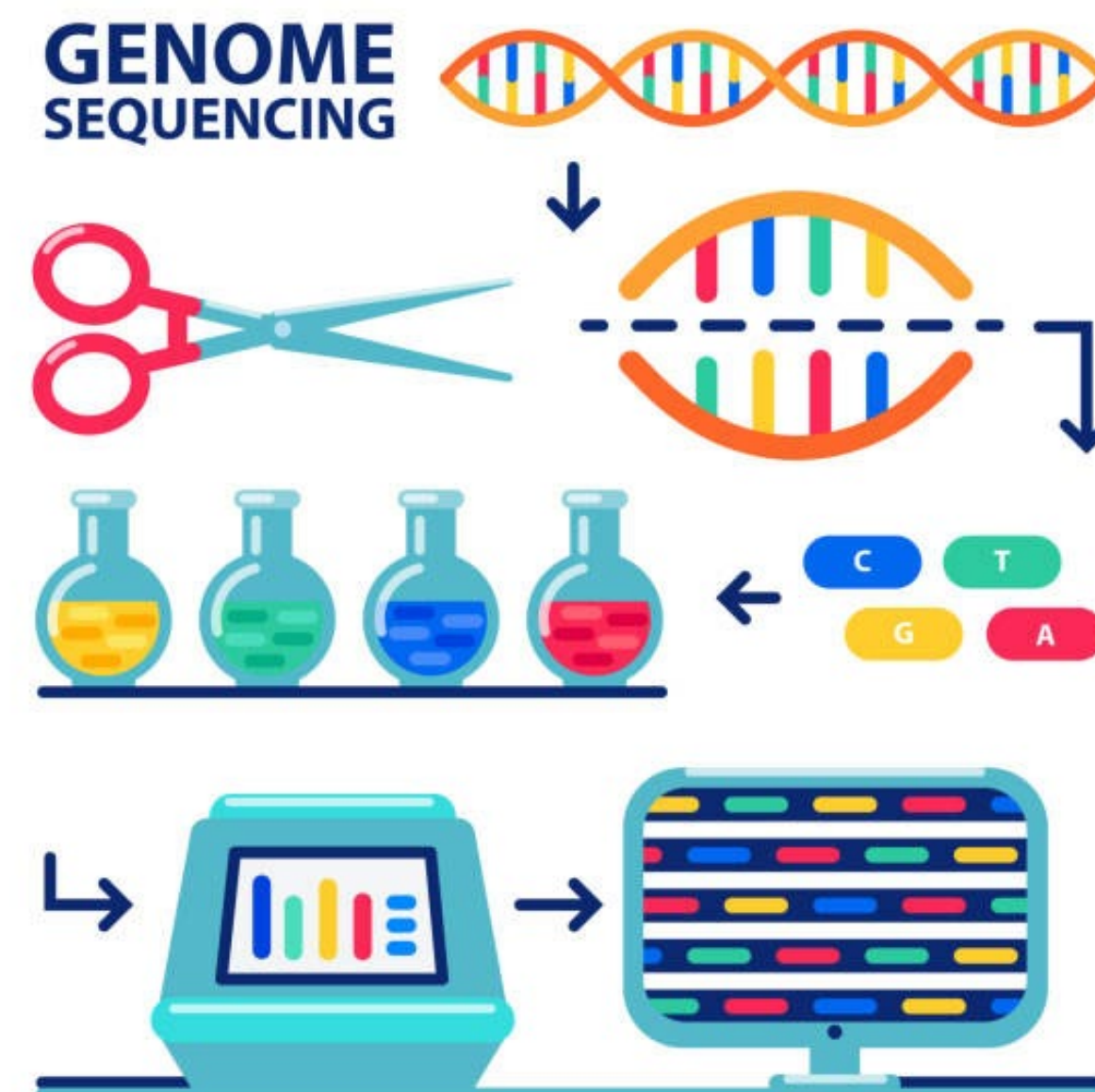


Straight
n=8



Wavy
n=14

Genotypes



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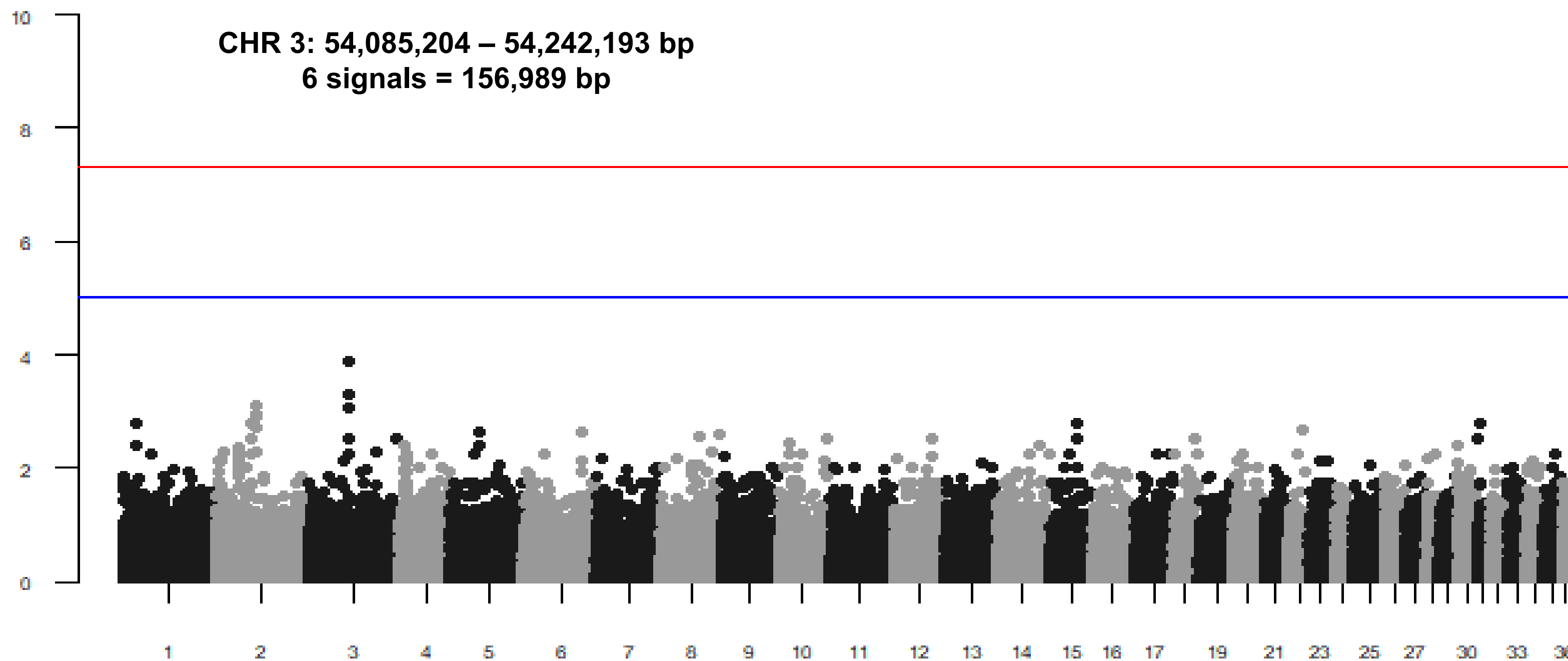
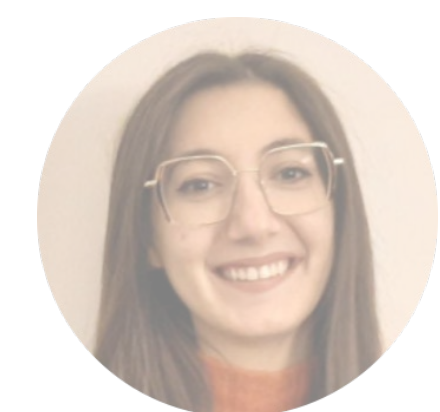
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Phenotyping

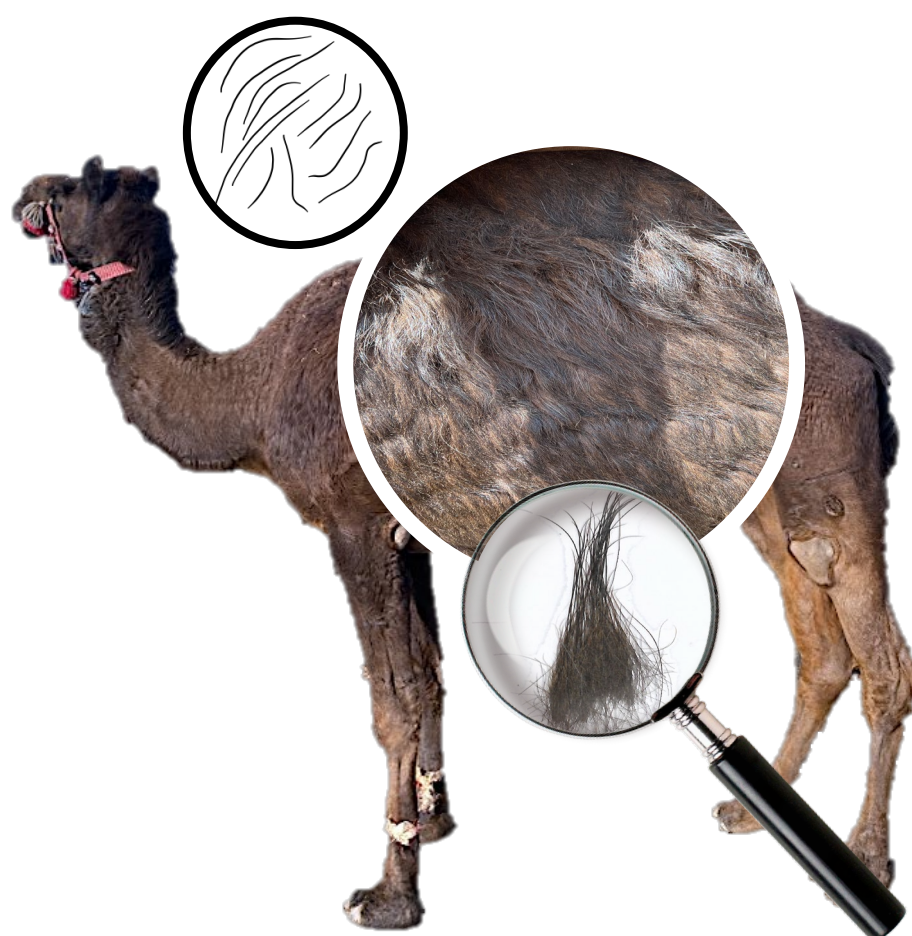
Crimp-types

GWA Study 1

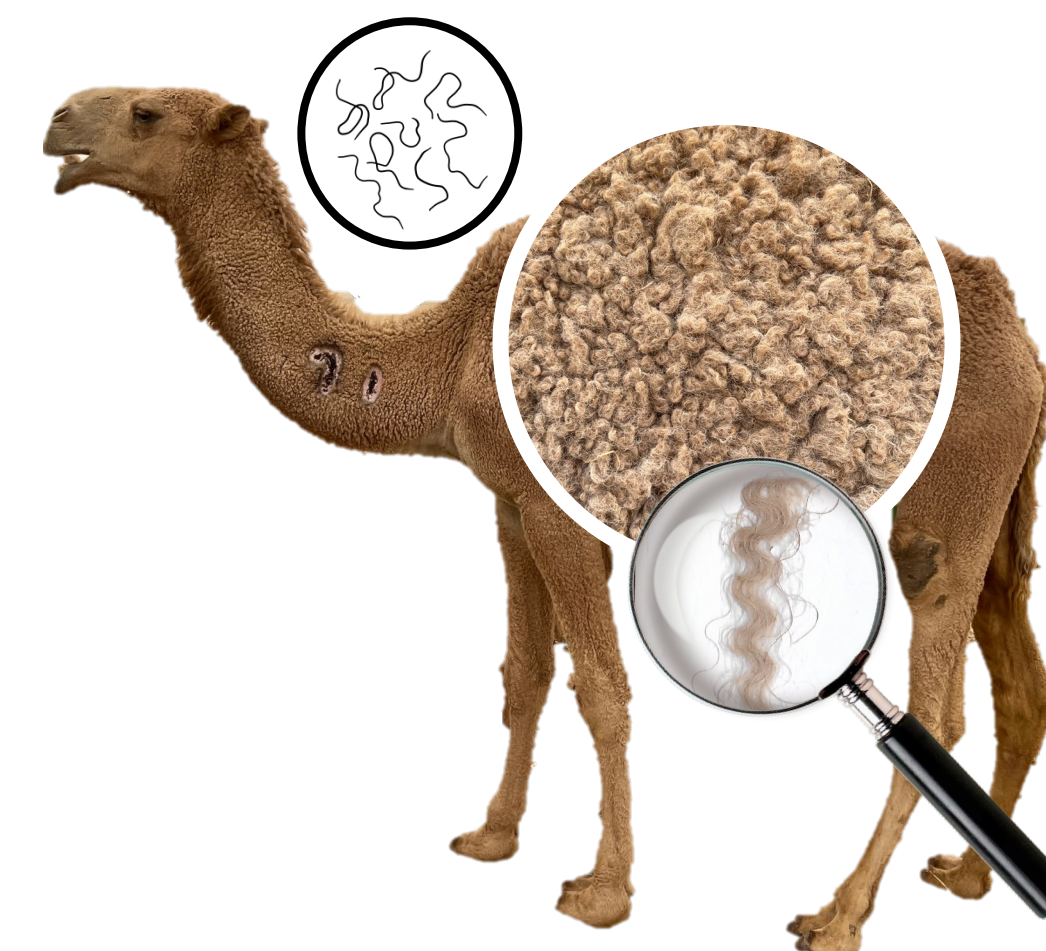
GWA Study 2



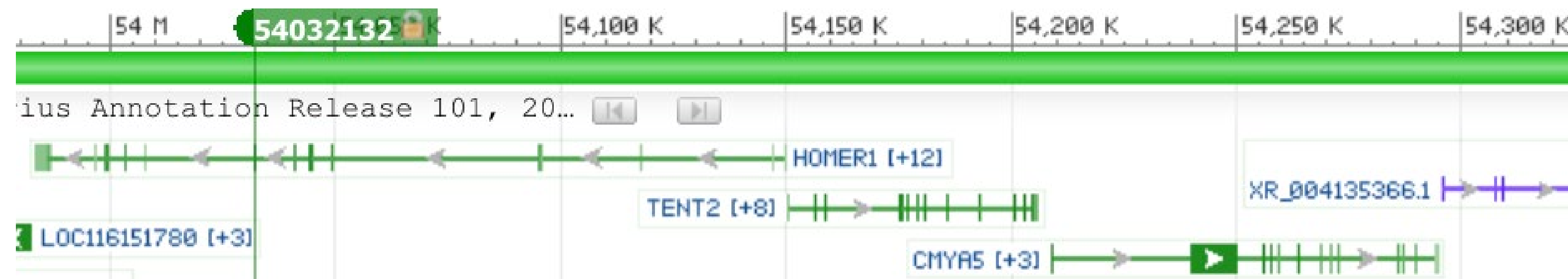
Chromosome



Straight n=8



Wavy n=14





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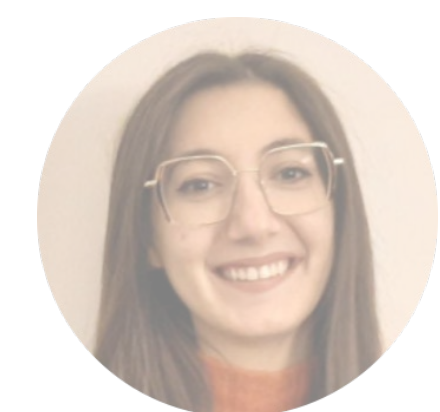
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



[Front Genet.](#) 2023; 14: 1184015.

Published online 2023 Jun 7. doi: [10.3389/fgene.2023.1184015](#)

PMCID: PMC10282778

PMID: [37351343](#)

Altered hair root gene expression profiles highlight calcium signaling and lipid metabolism pathways to be associated with curly hair initiation and maintenance in Mangalitza pigs

[Nadia Khaveh](#), ^{1, 2} [Kathrin Schachler](#), ² [Jan Berghöfer](#), ^{1, 3} [Klaus Jung](#), ² and [Julia Metzger](#)^{✉ 1, 2, *}



Curly Mangalitza pigs

[Front Genet.](#) 2019; 10: 1263.

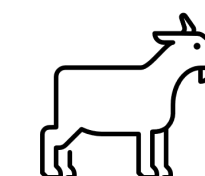
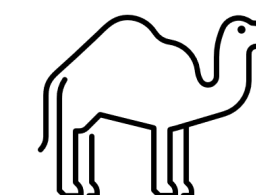
Published online 2020 Jan 8. doi: [10.3389/fgene.2019.01263](#)

PMCID: PMC6960231

PMID: [31969898](#)

Integrated Analysis of Methylome and Transcriptome Changes Reveals the Underlying Regulatory Signatures Driving Curly Wool Transformation in Chinese Zhongwei Goats

[Ping Xiao](#), ^{1, 2} [Tao Zhong](#), ² [Zhanfa Liu](#), ³ [Yangyang Ding](#), ¹ [Weijun Guan](#), ¹ [Xiaohong He](#), ¹ [Yabin Pu](#), ¹ [Lin Jiang](#), ¹ [Yuehui Ma](#), ^{1, *} and [Qianjun Zhao](#) ^{1, *}



Curling vs non-curling
Chinese goats

[Cell.](#) Author manuscript; available in PMC 2011 Apr 16.

Published in final edited form as:

[Cell.](#) 2010 Apr 16; 141(2): 331–343.

doi: [10.1016/j.cell.2010.03.013](#)

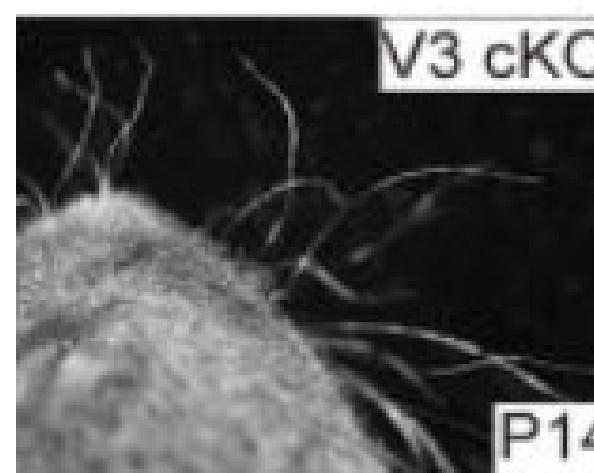
PMCID: PMC2858065

NIHMSID: NIHMS190910

PMID: [20403327](#)

TRP Channel regulates EGFR signaling in Hair Morphogenesis and Skin Barrier Formation

[Xiping Cheng](#), ^{1, #} [Jie Jin](#), ^{2, 3, #} [Lily Hu](#), ¹ [Dongbiao Shen](#), ¹ [Xian-ping Dong](#), ¹ [Mohammad A. Samie](#), ¹ [Jayne Knoff](#), ¹ [Brian Eisinger](#), ¹ [Mei-ling Liu](#), ¹ [Susan M. Huang](#), ⁴ [Michael J. Caterina](#), ⁴ [Peter Dempsey](#), ⁵ [Lowell Evan Michael](#), ⁶ [Andrzej A. Dlugosz](#), ⁶ [Nancy C. Andrews](#), ^{2, 7} [David E Clapham](#), ^{3, *} and [Haoxing Xu](#) ^{1, 3, *}



Wavy hairs in mice



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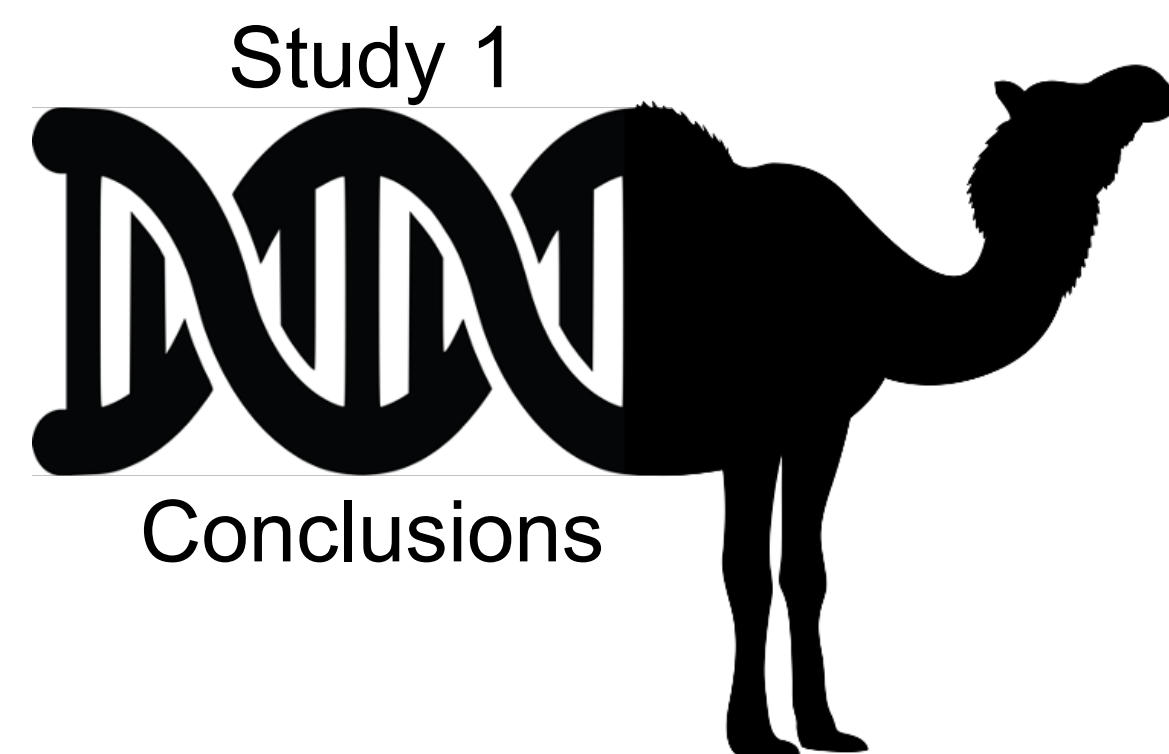
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



1. Sample sizes are insufficient to get a statistical significance.
2. Multiple markers associated (6 SNPs).
3. Not random association (single SNP).
4. Individual hair-based phenotyping is adequate to ensure phenotypes homogeneity.
5. HOMER1 is a likely candidate gene given similarities in phenotypes with other species.
6. WGS data suggests a 3' splice site mutation in intron 4 - Not validated.



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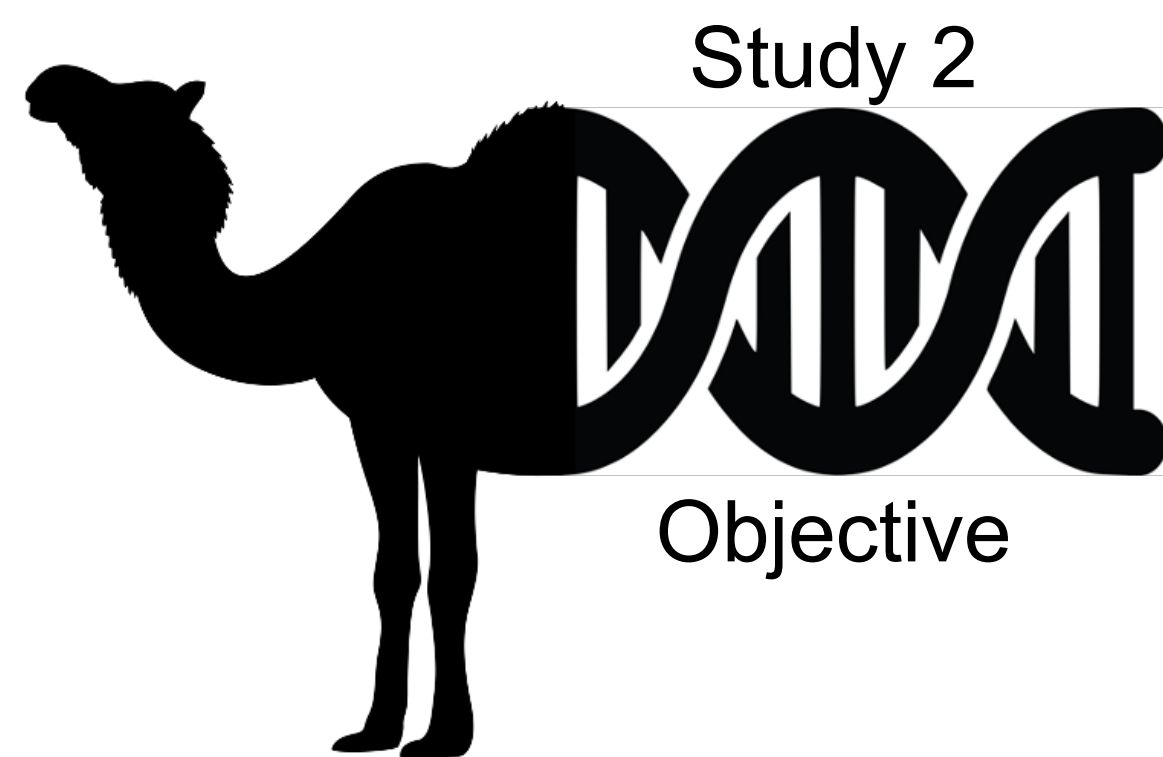
Attributes

Phenotyping

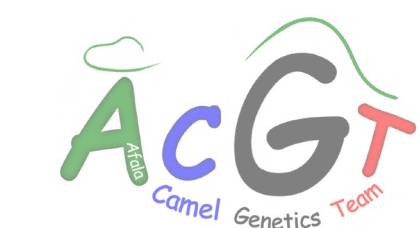
Crimp-types

GWA Study 1

GWA Study 2



Perform GWAS between all crimp-
types using SNP array data





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Variation

Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2

Phenotypes



Photo-based phenotype

Genotypes

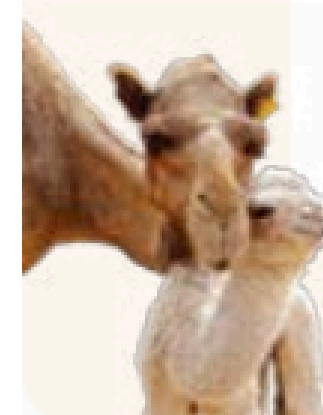
Camel Array



Markers
~56,000

Array format
HTS-24

Autosomes:	~55,000
Chromosome X:	721
mtDNA:	71
Markers in genes of interest [47]:	~800



CamelSNP60



Applications

GWAS

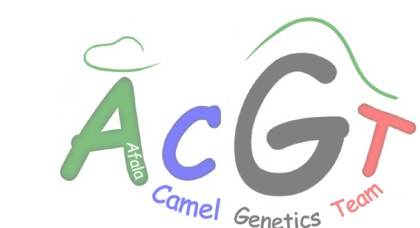
Genomic Selection

Population Genetics

Carrier Screening

Parentage verification

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Variation

Attributes

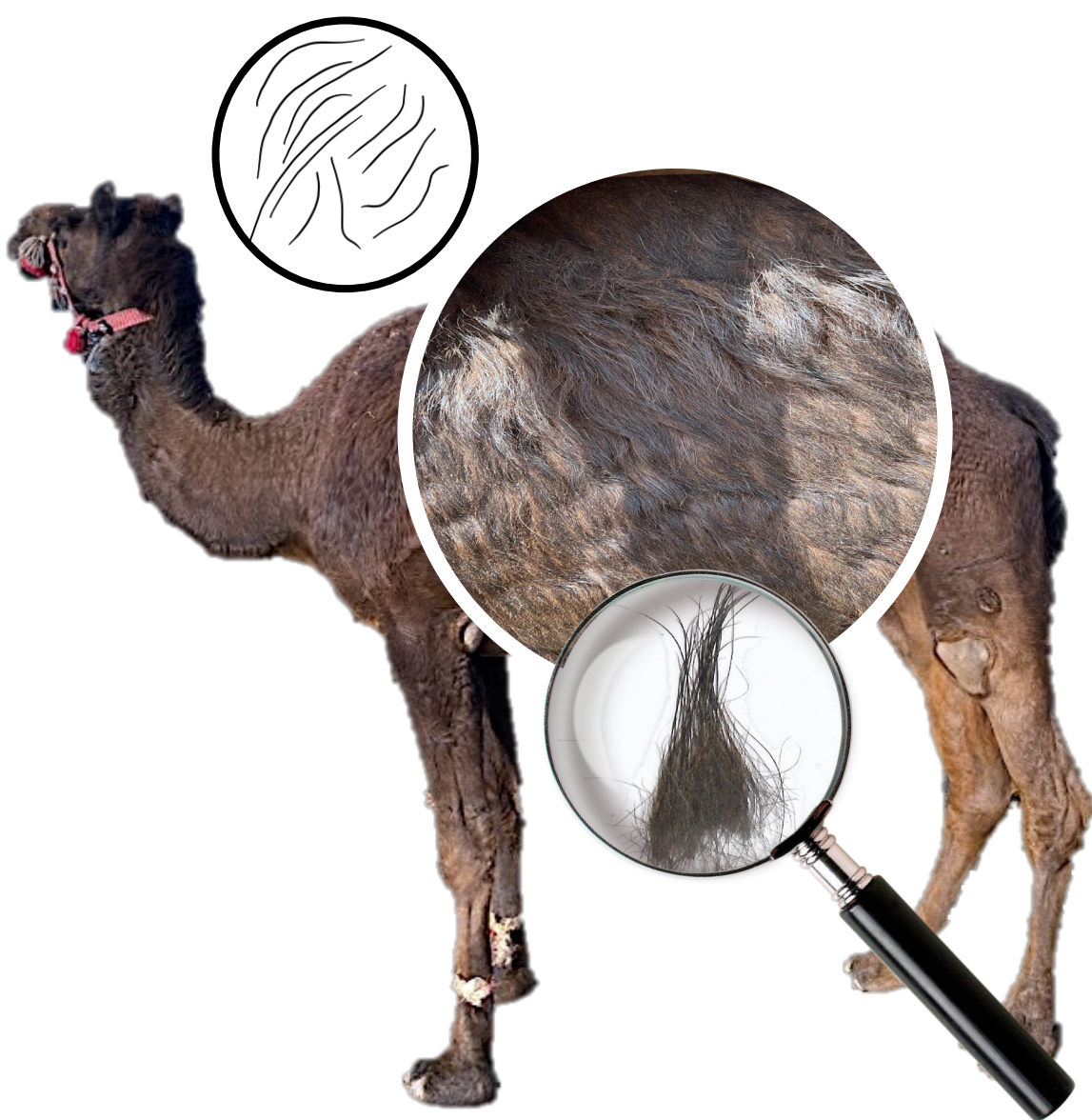
Phenotyping

Crimp-types

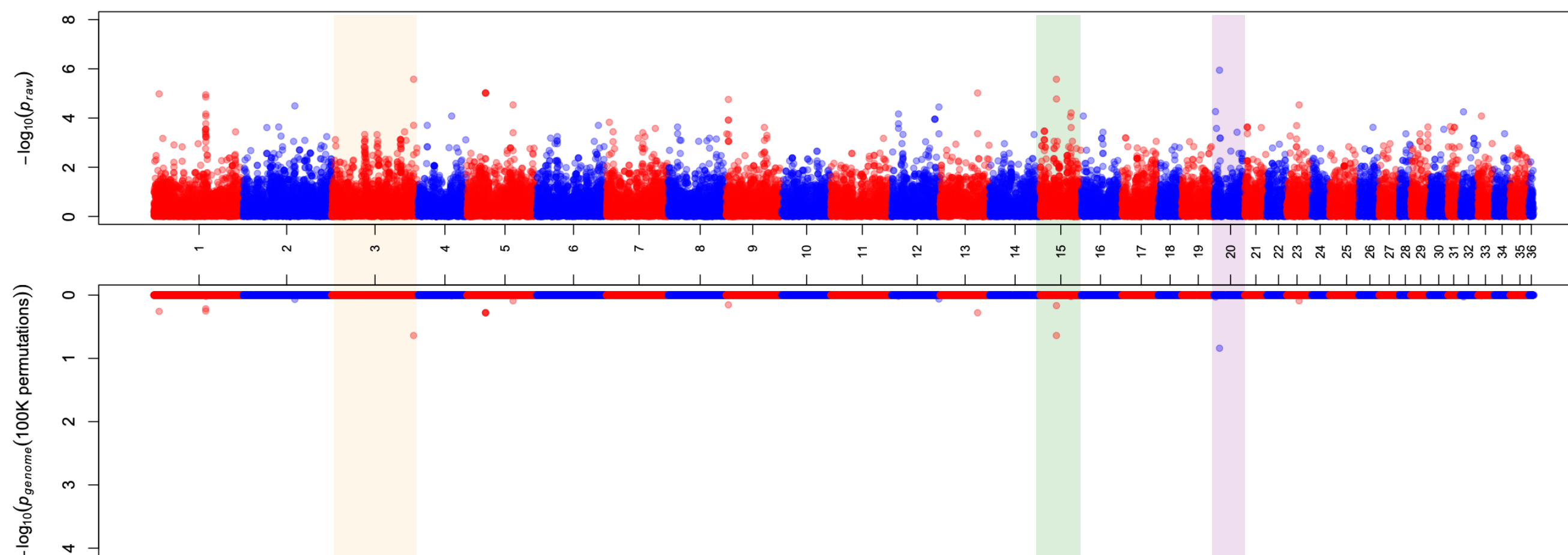
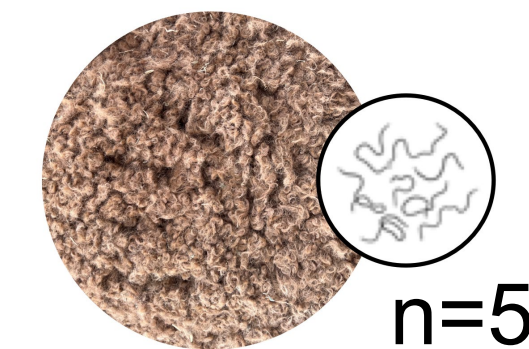
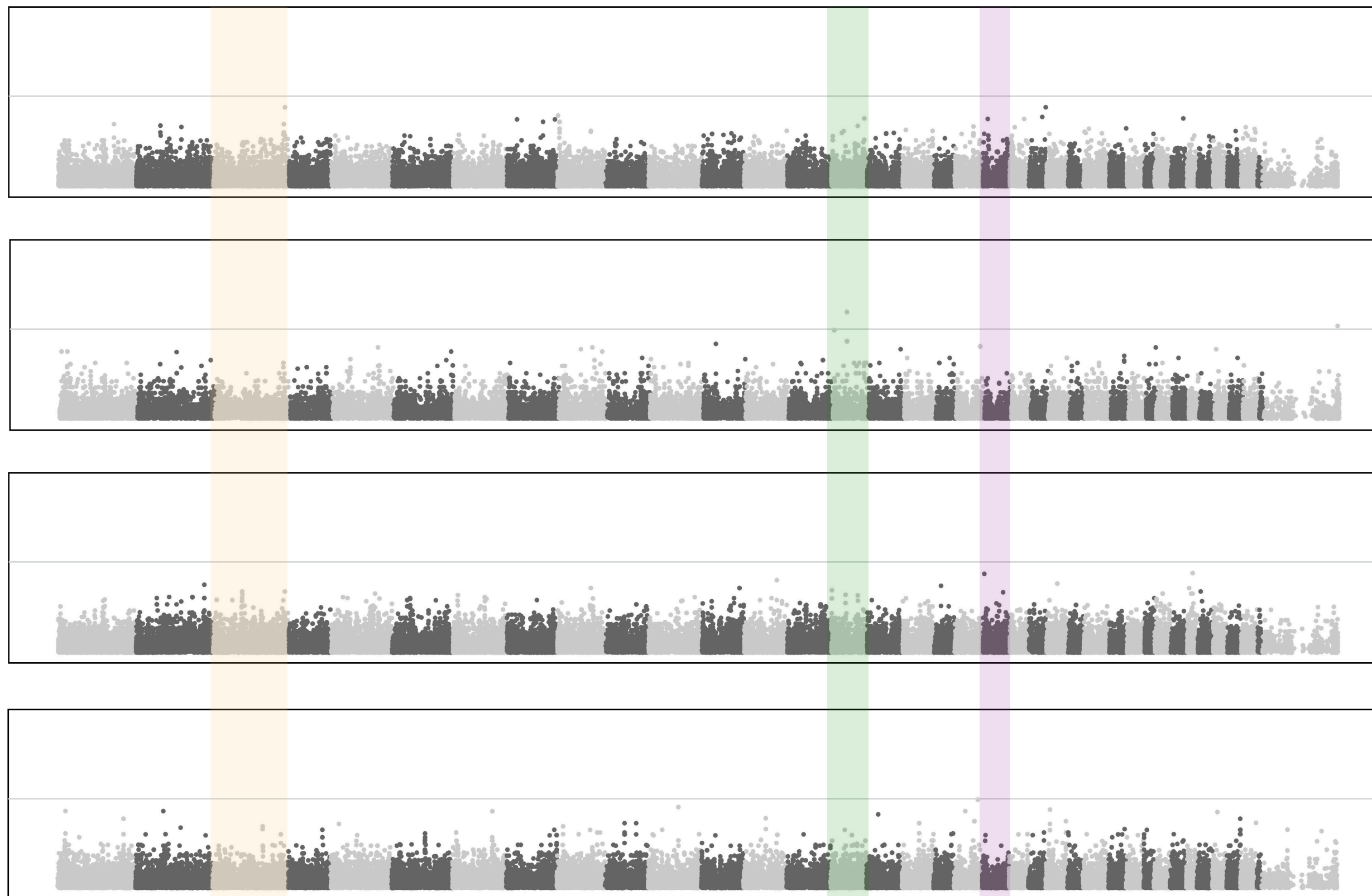
GWA Study 1

GWA Study 2

Straight Crimp-type



n=17



n=62





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ALDO MORO

Industry

Variation

Attributes

Phenotyping

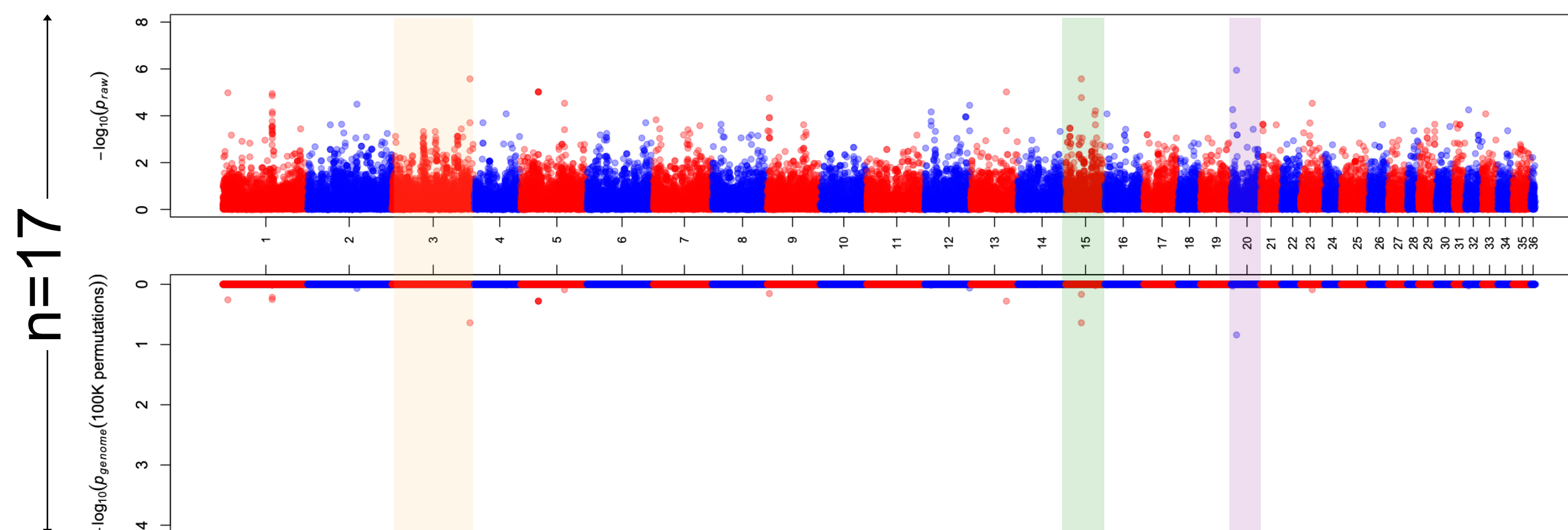
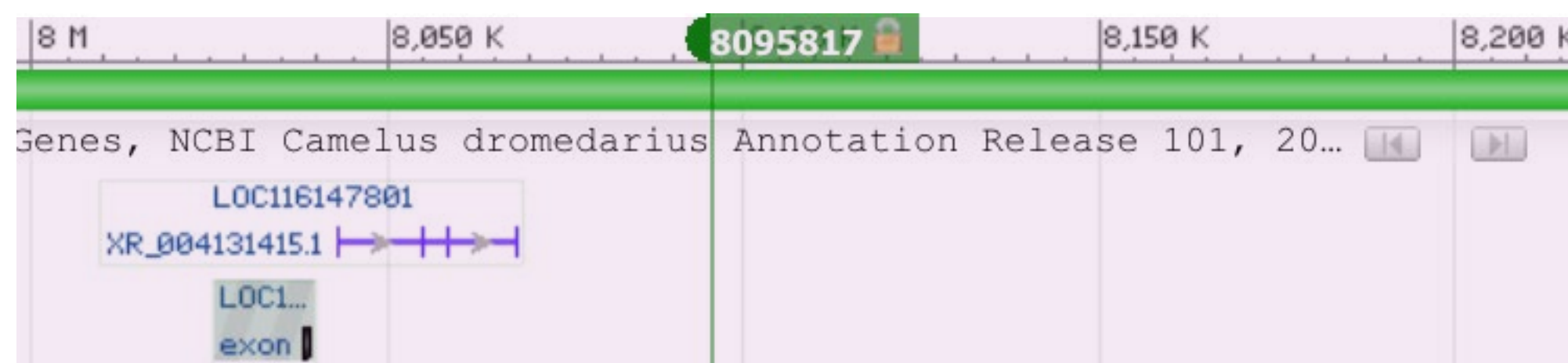
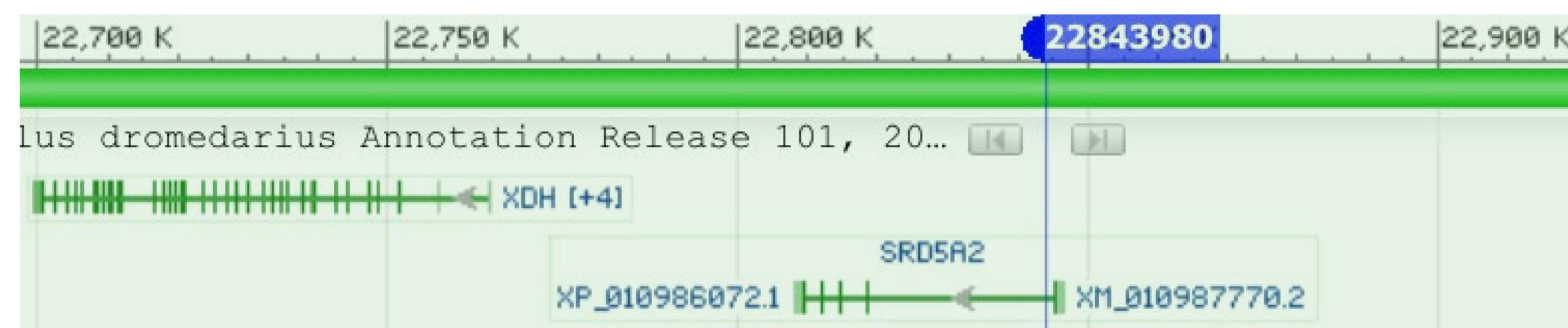
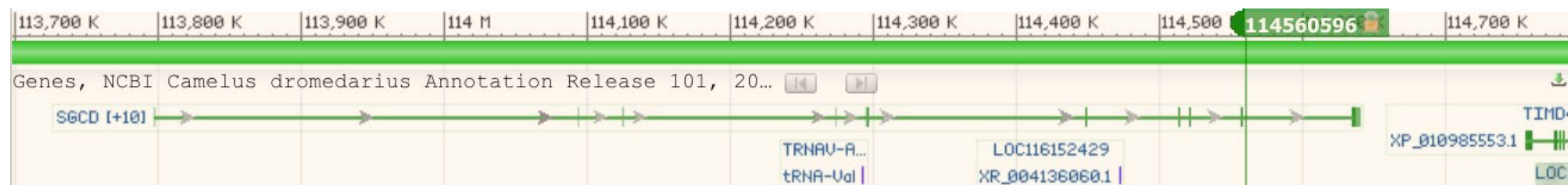
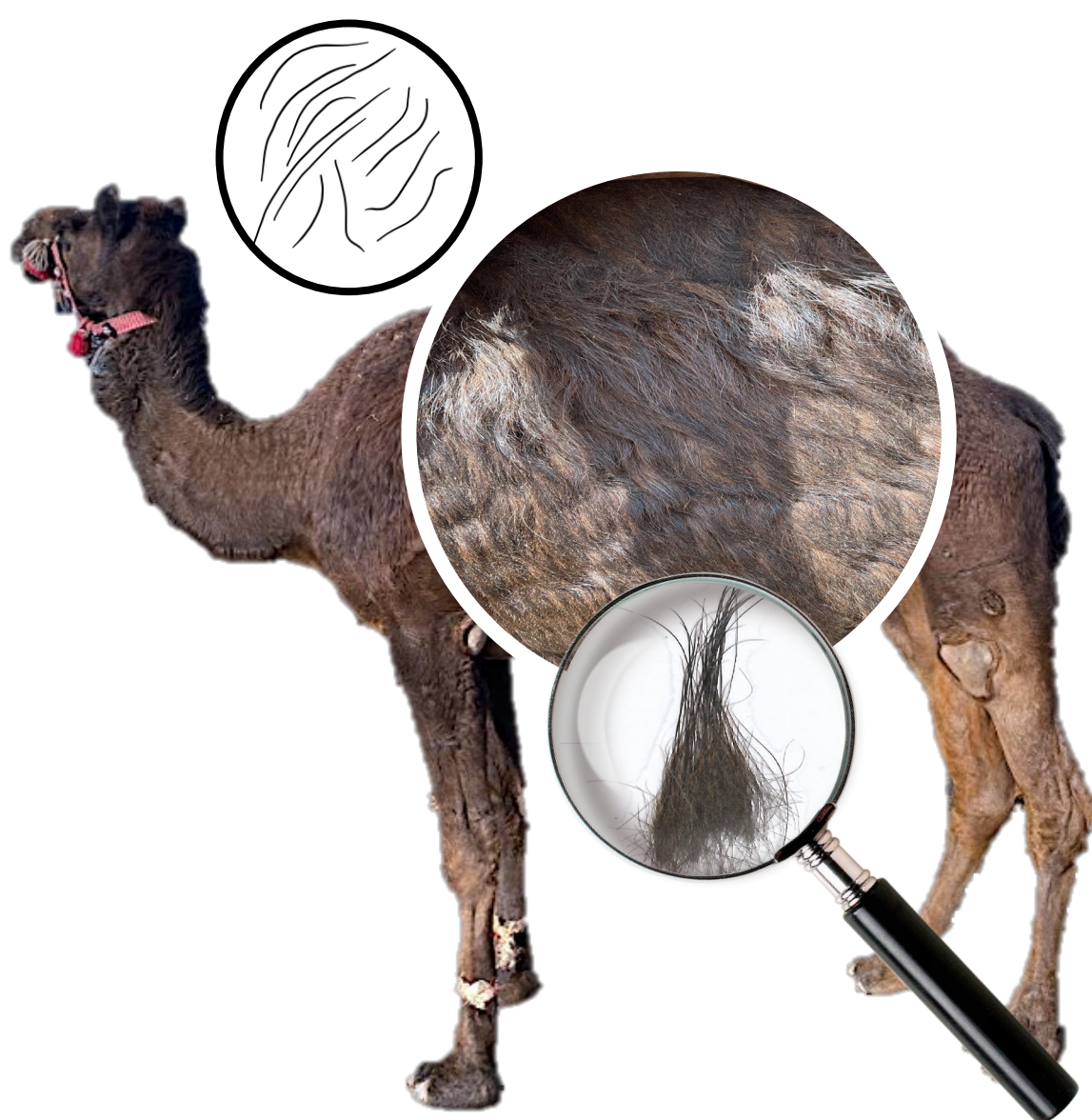
Crimp-types

GWA Study 1

GWA Study 2



Straight Crimp-type



n=62



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Attributes

Phenotyping

Crimp-types

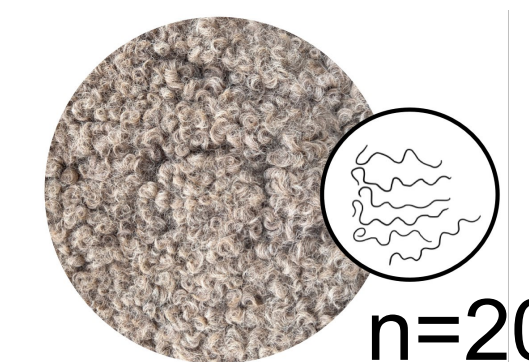
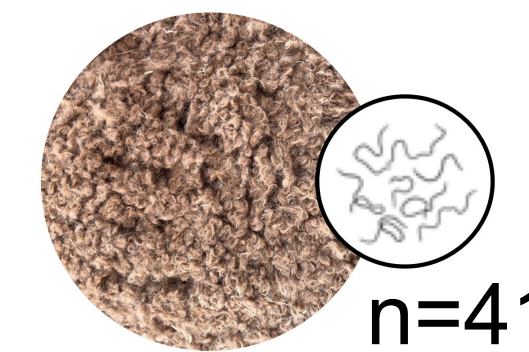
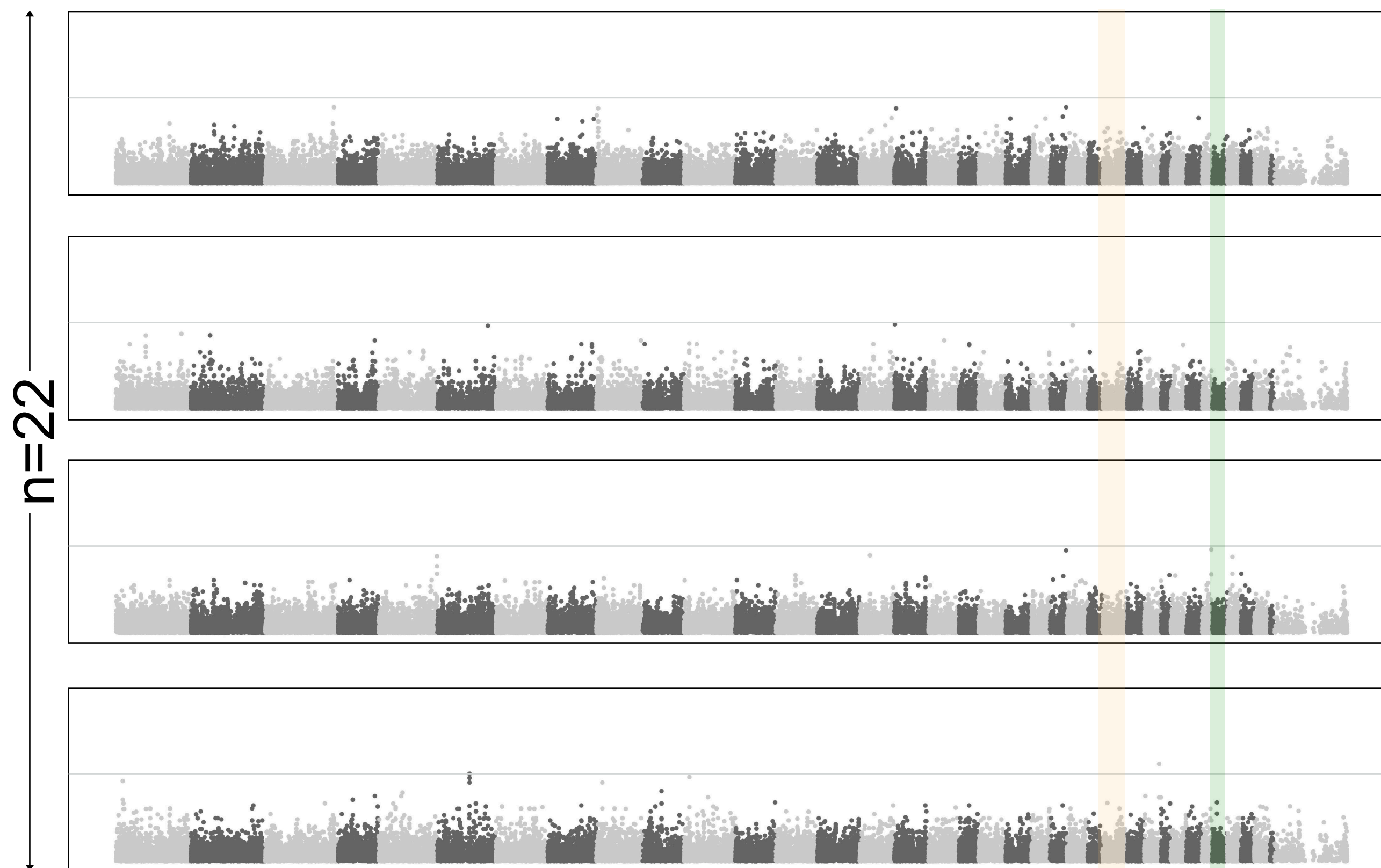
GWA Study 1

GWA Study 2

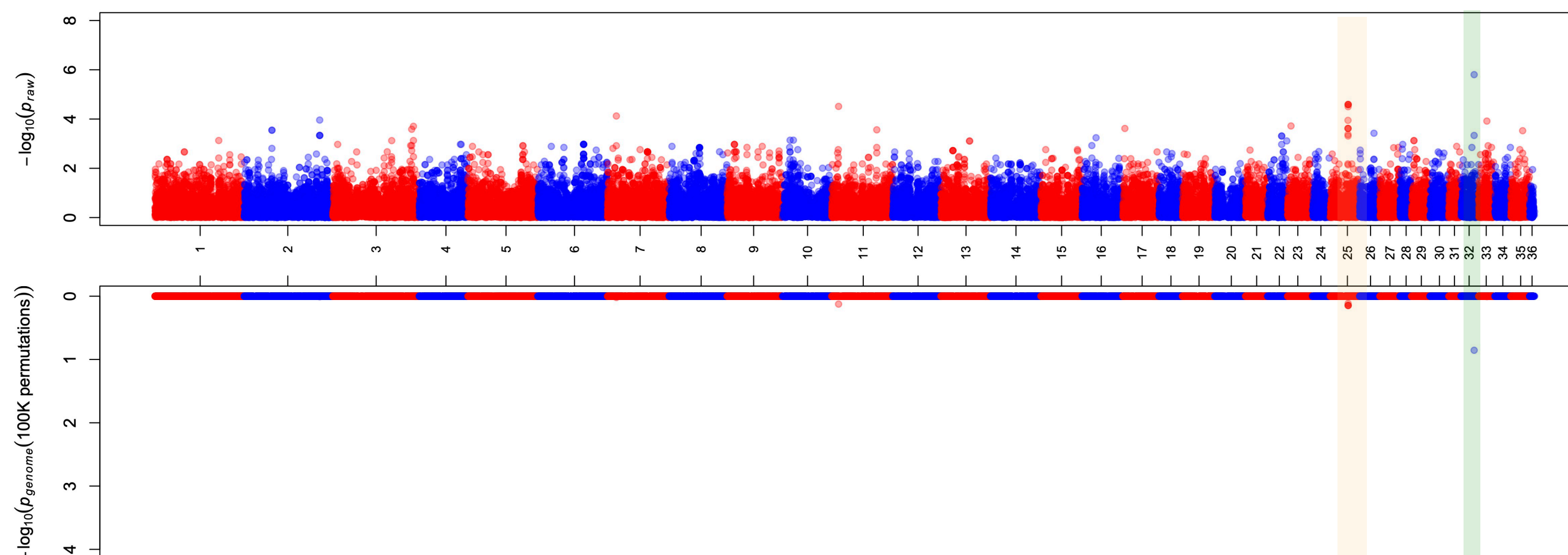
C-shaped Crimp-type



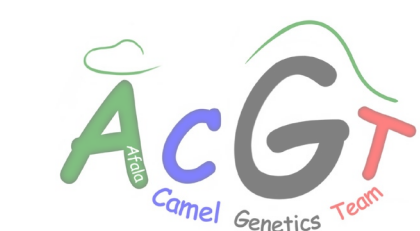
n=22



n=15



n=43





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Attributes

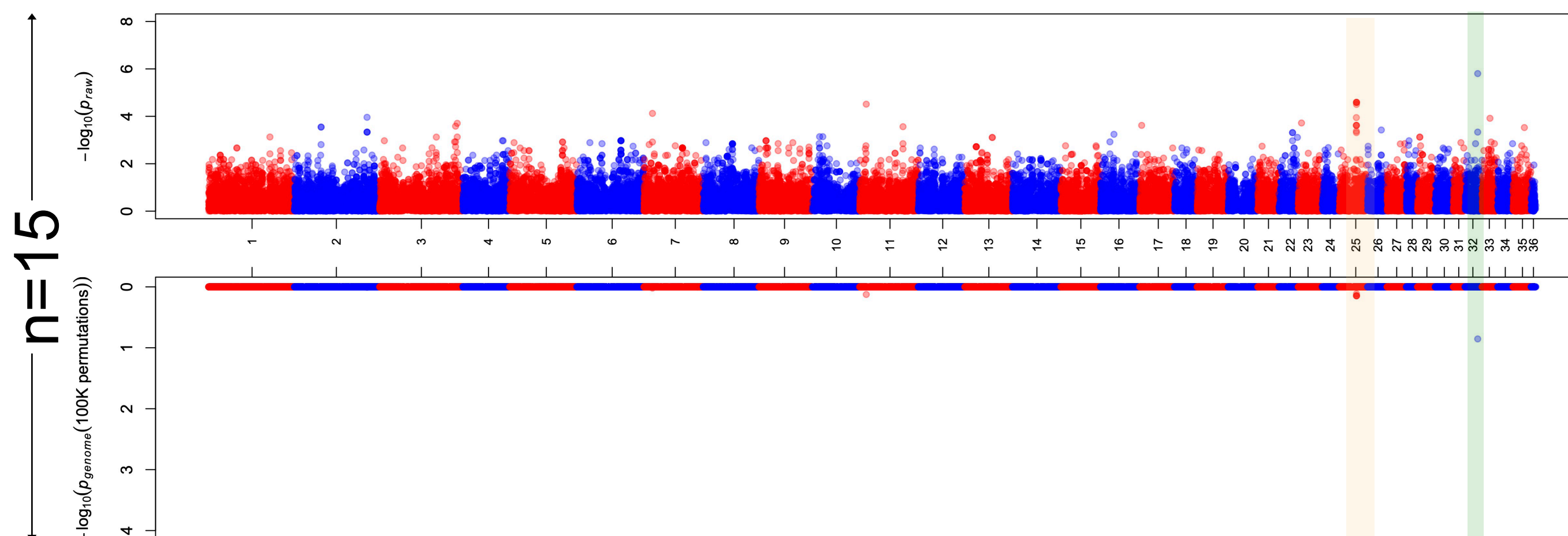
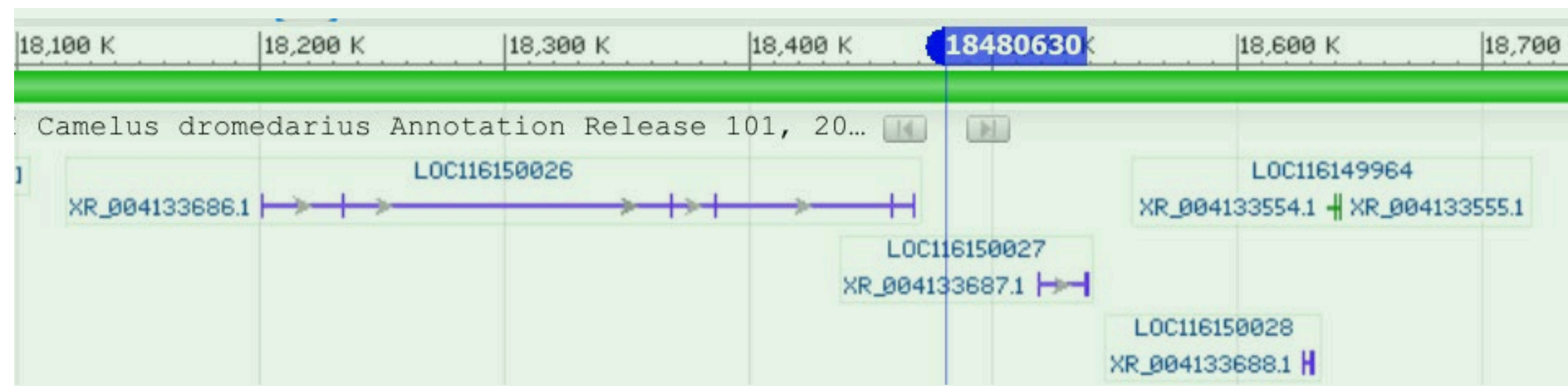
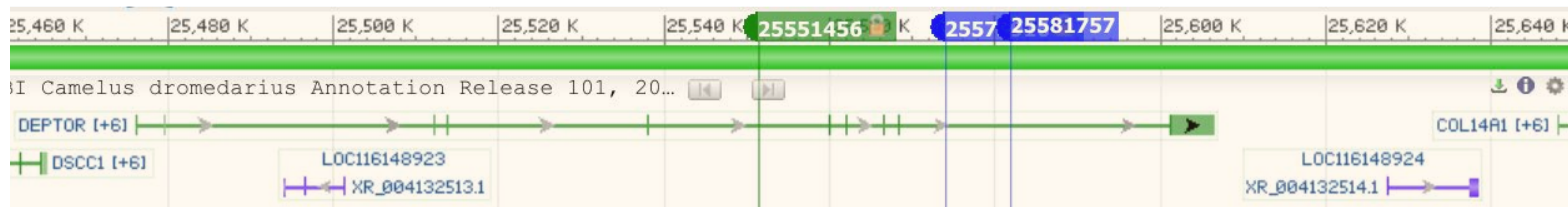
Phenotyping

Crimp-types

GWA Study 1

GWA Study 2

C-shaped Crimp-type



n=43



ACGT
Camel Genetics Team



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Variation

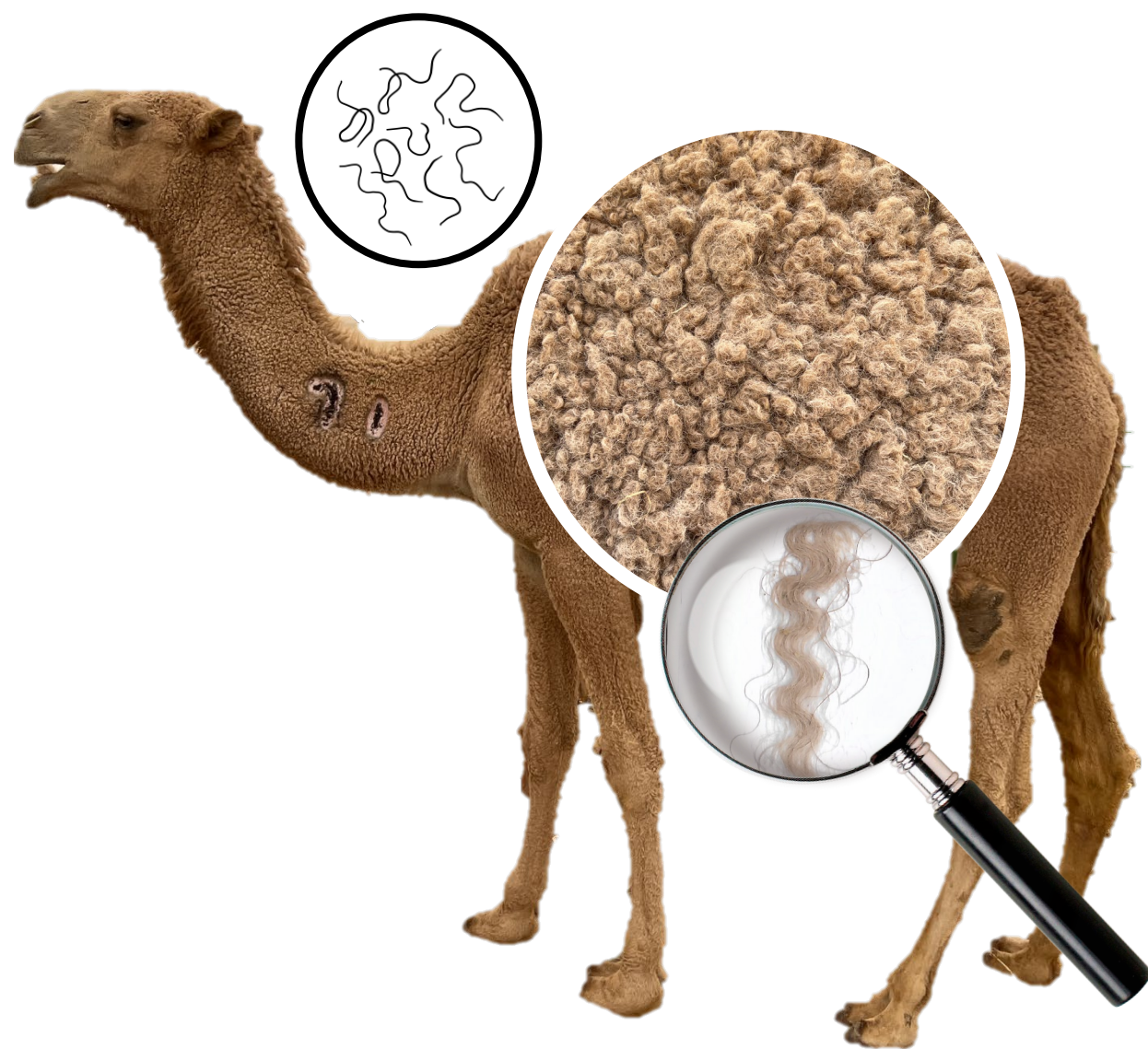
Attributes

Phenotyping

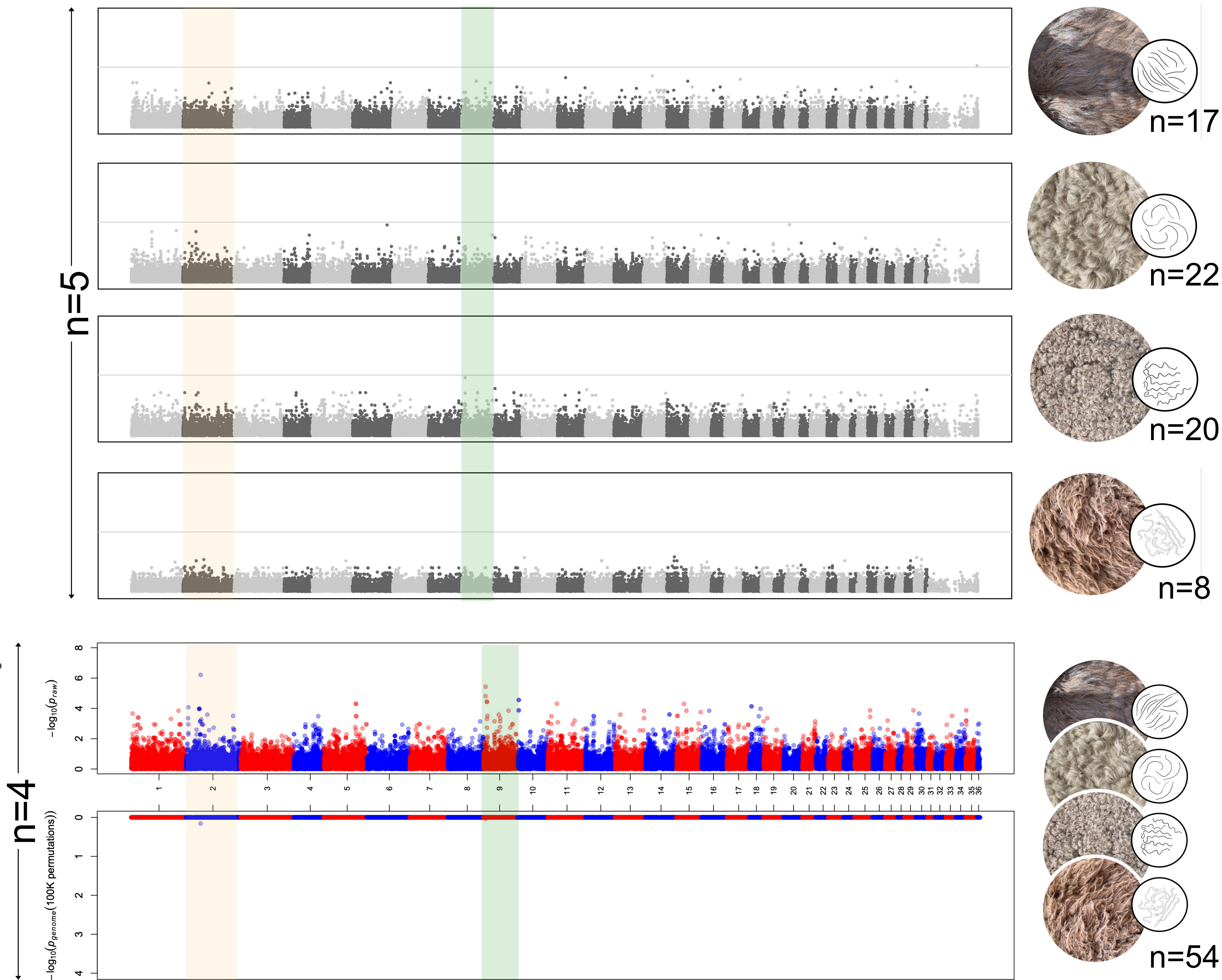
Crimp-types

GWA Study 1

GWA Study 2



Wavy Crimp-type





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Variation

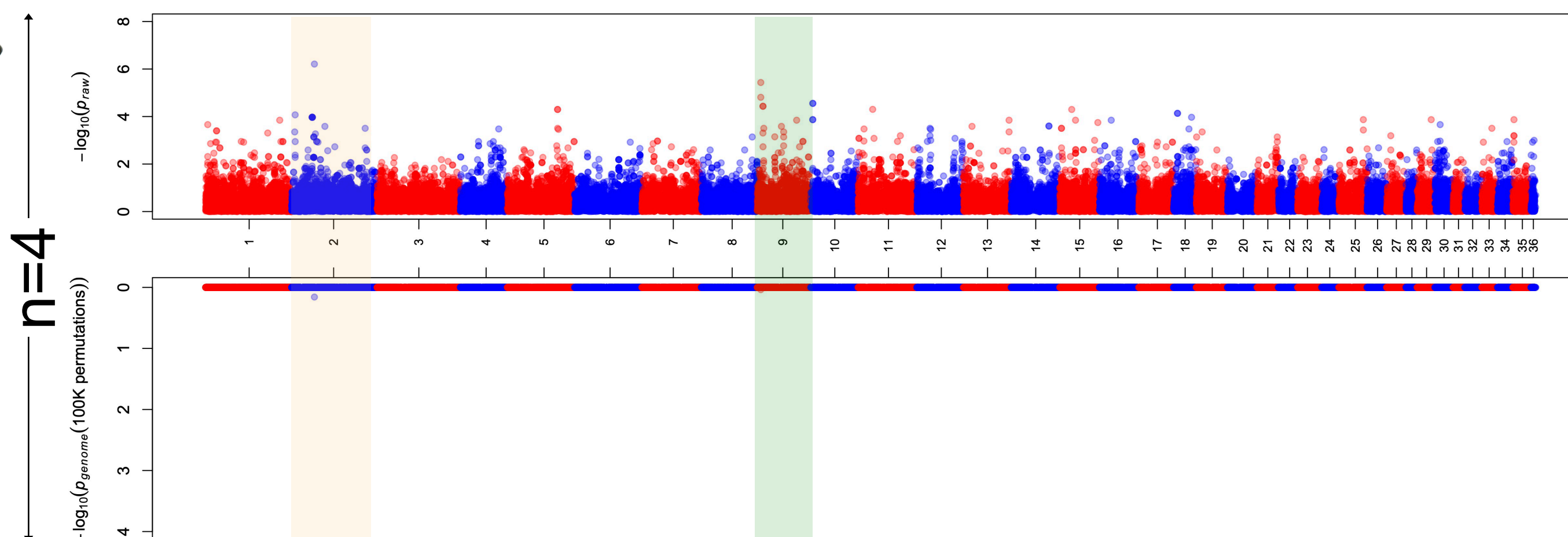
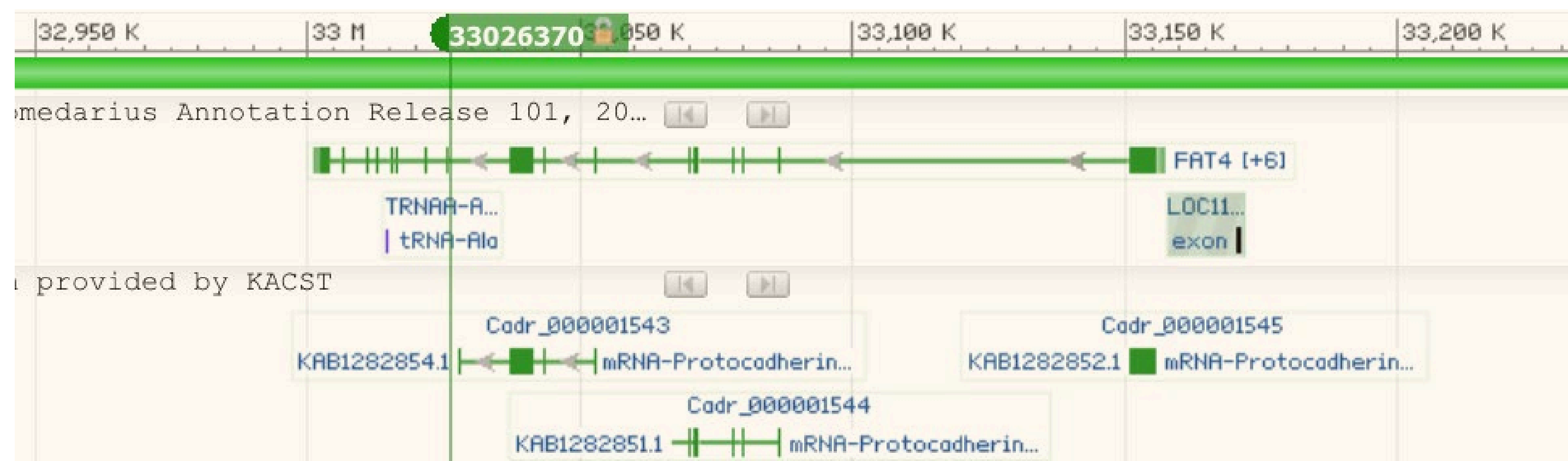
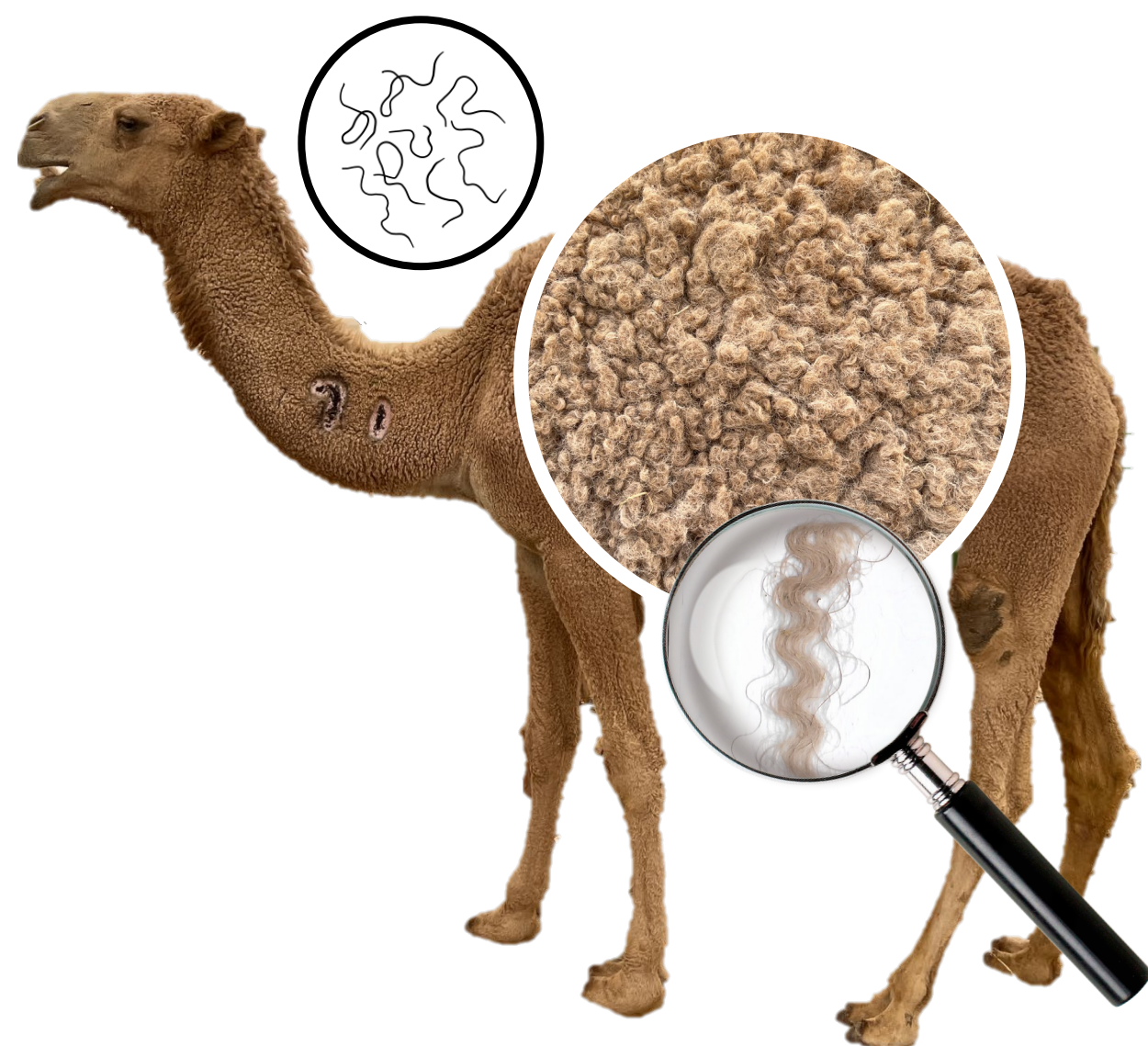
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



n=54





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Variation

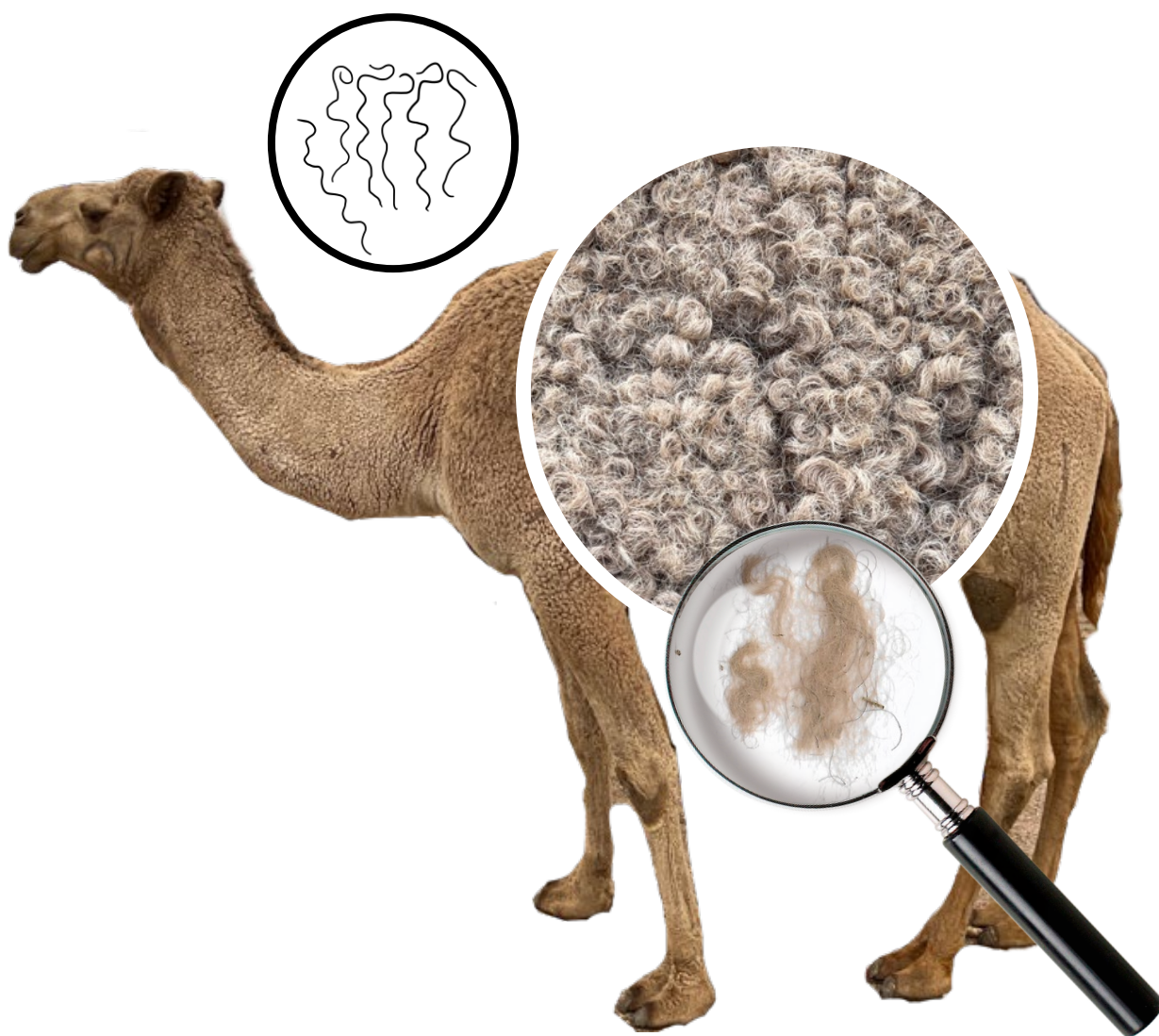
Attributes

Phenotyping

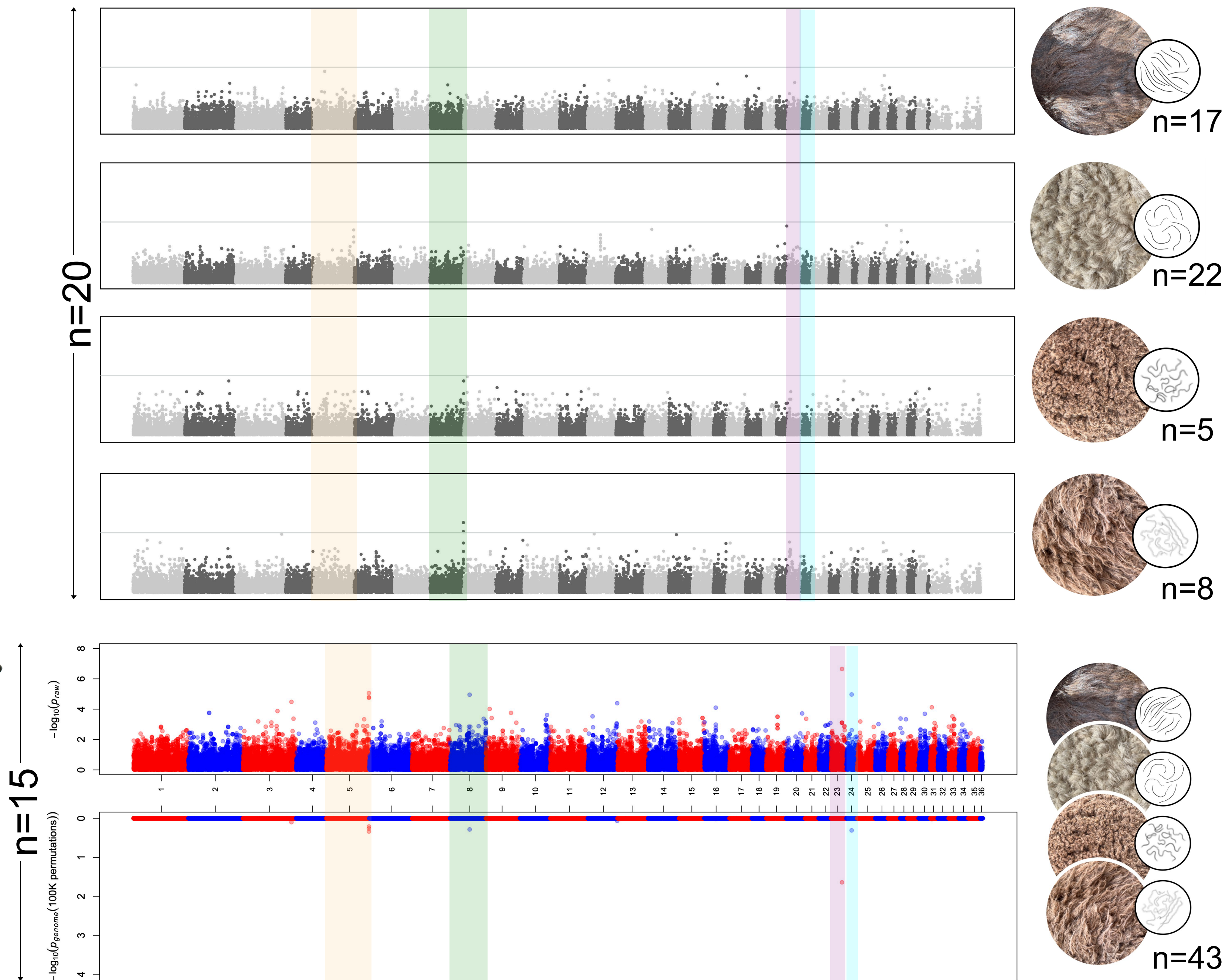
Crimp-types

GWA Study 1

GWA Study 2



Ringed Crimp-type





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Variation

Attributes

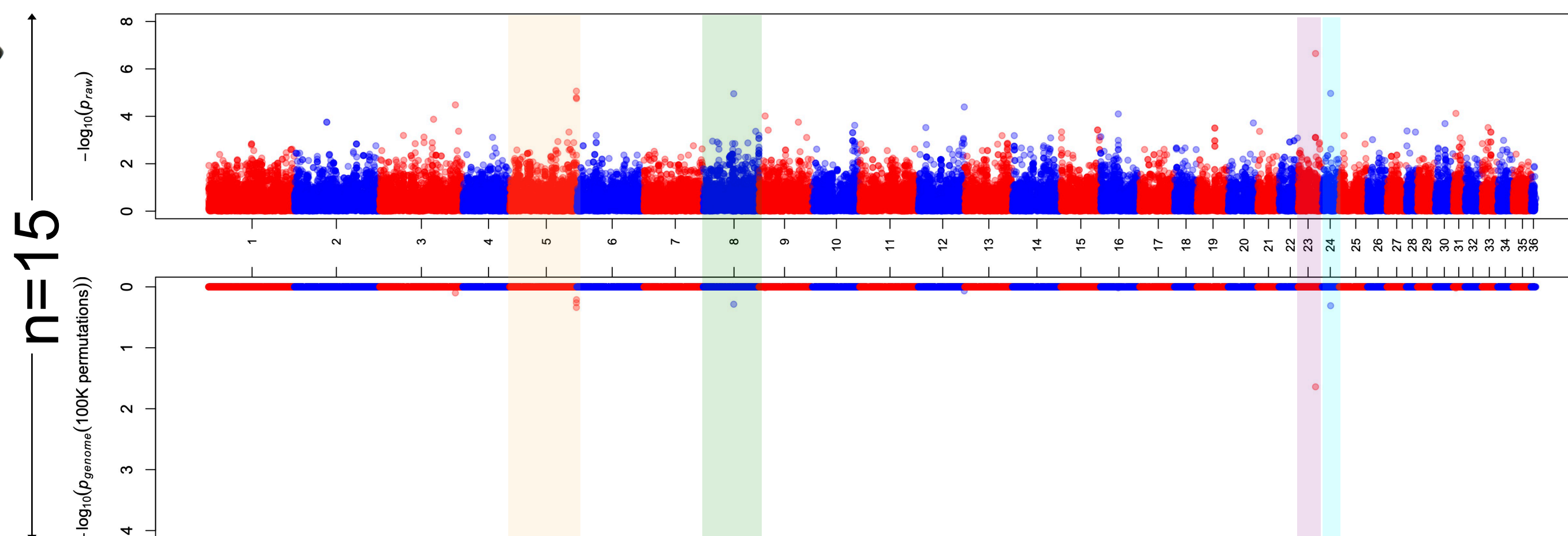
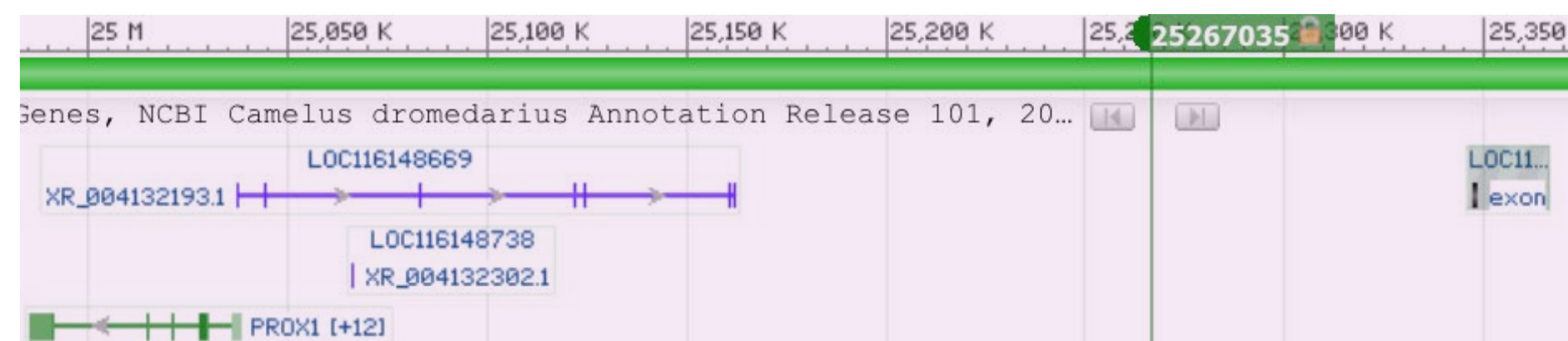
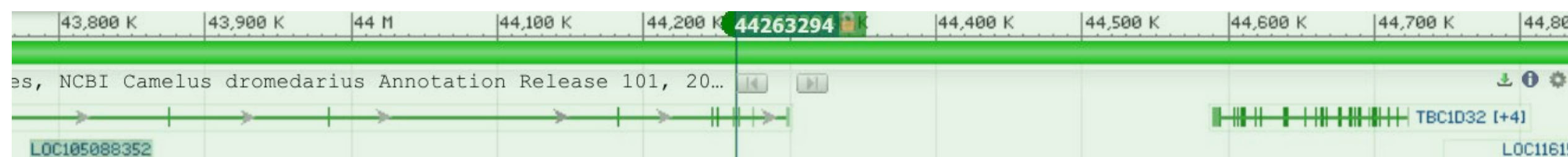
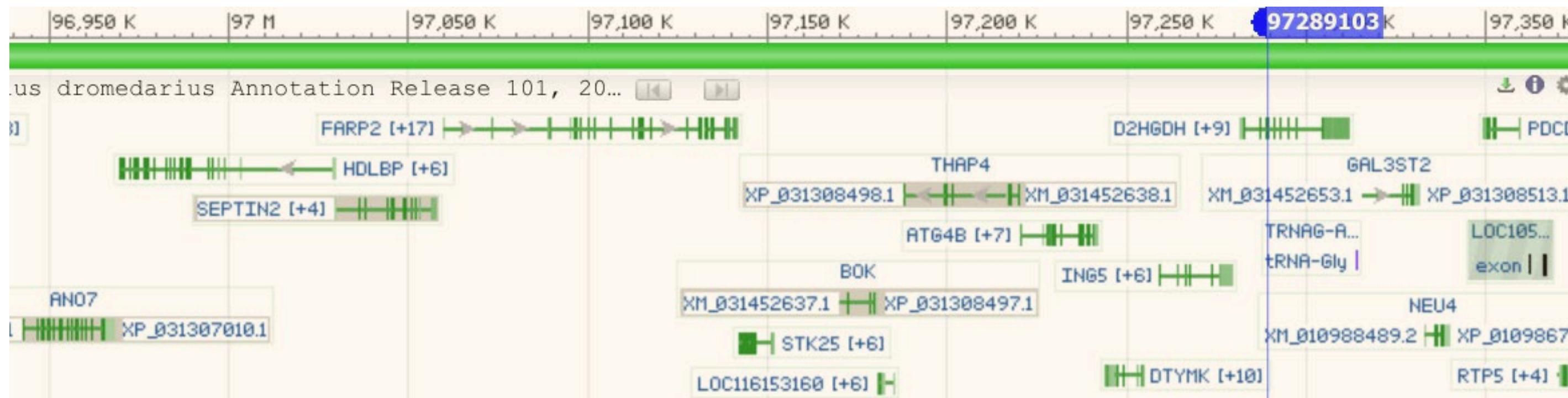
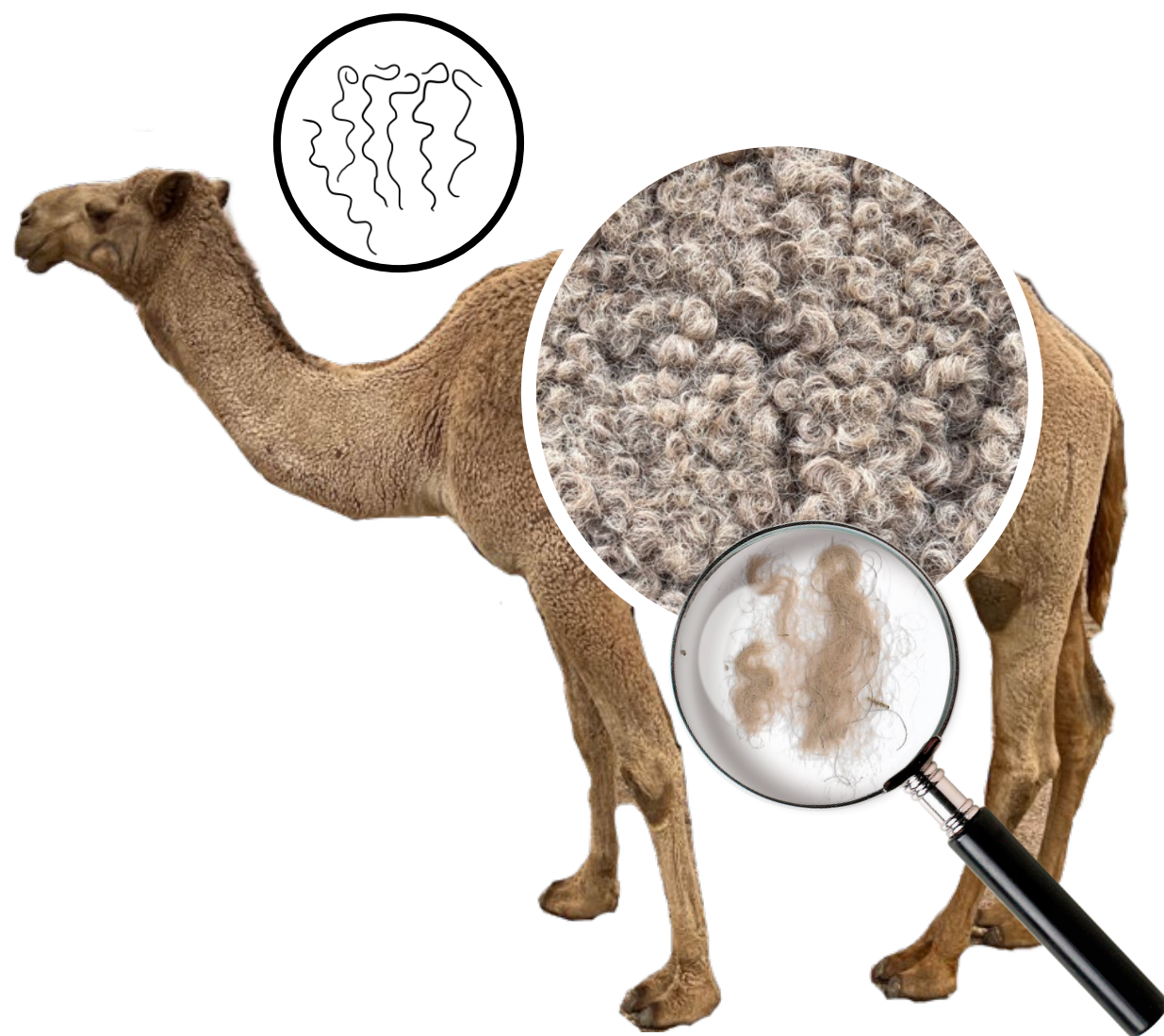
Phenotyping

Crimp-types

GWA Study 1

GWA Study 2

Ringed Crimp-type



n=43





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Variation

Attributes

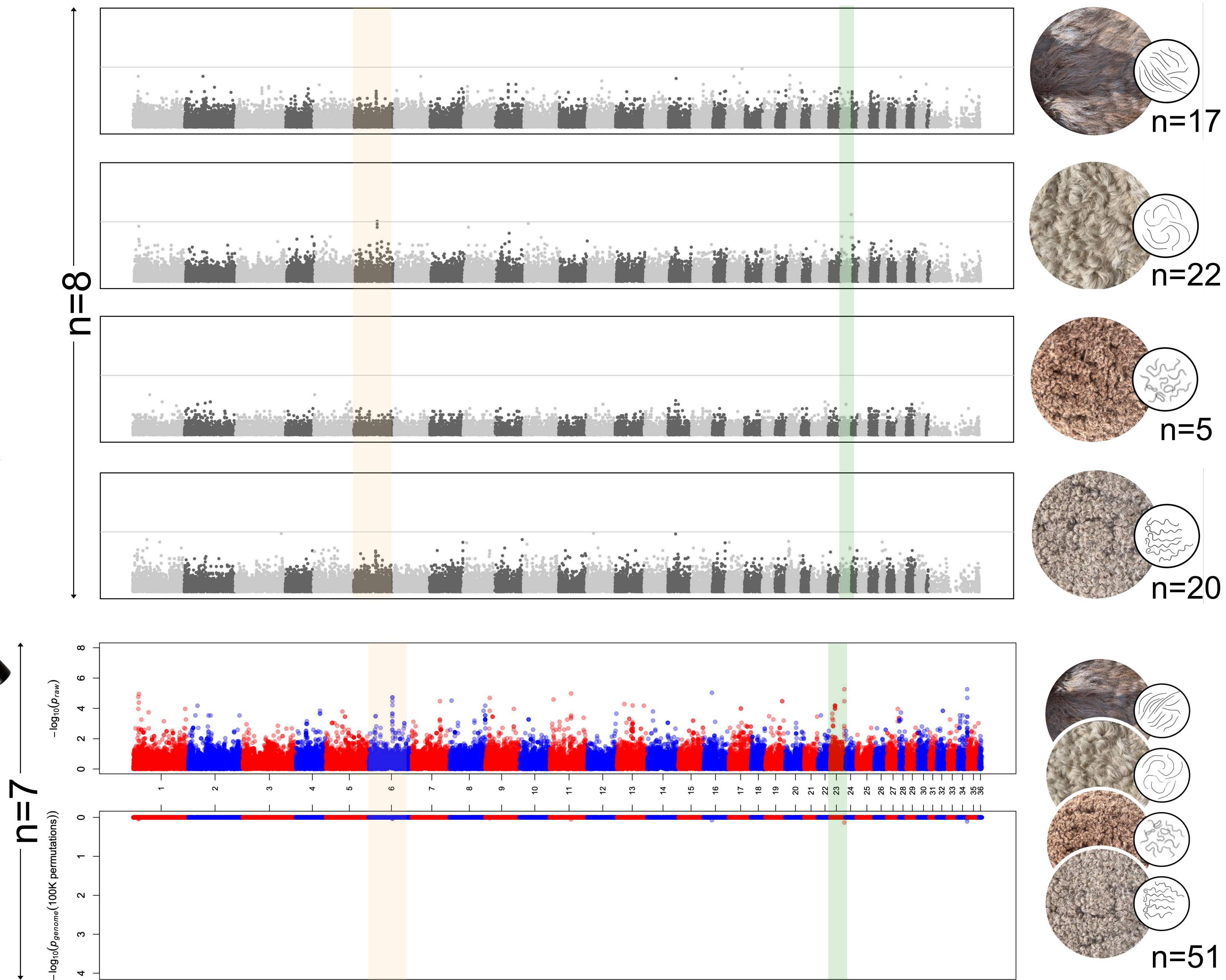
Phenotyping

Crimp-types

GWA Study 1

GWA Study 2

Kinky Crimp-type





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Variation

Attributes

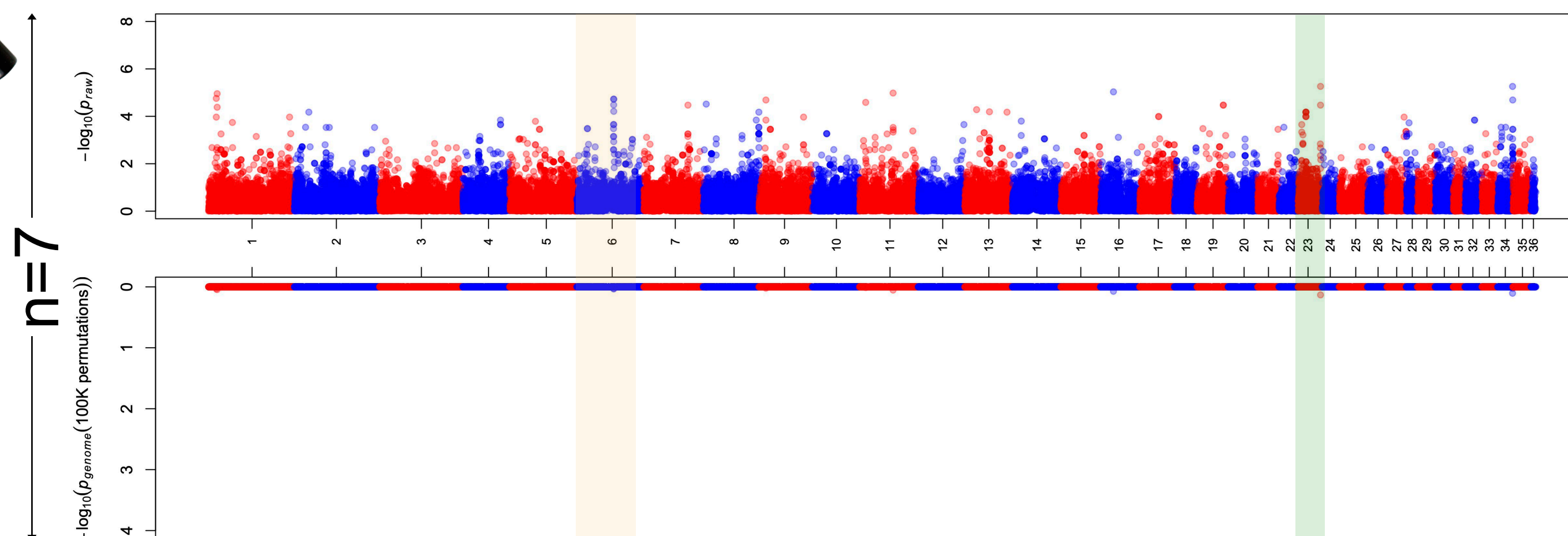
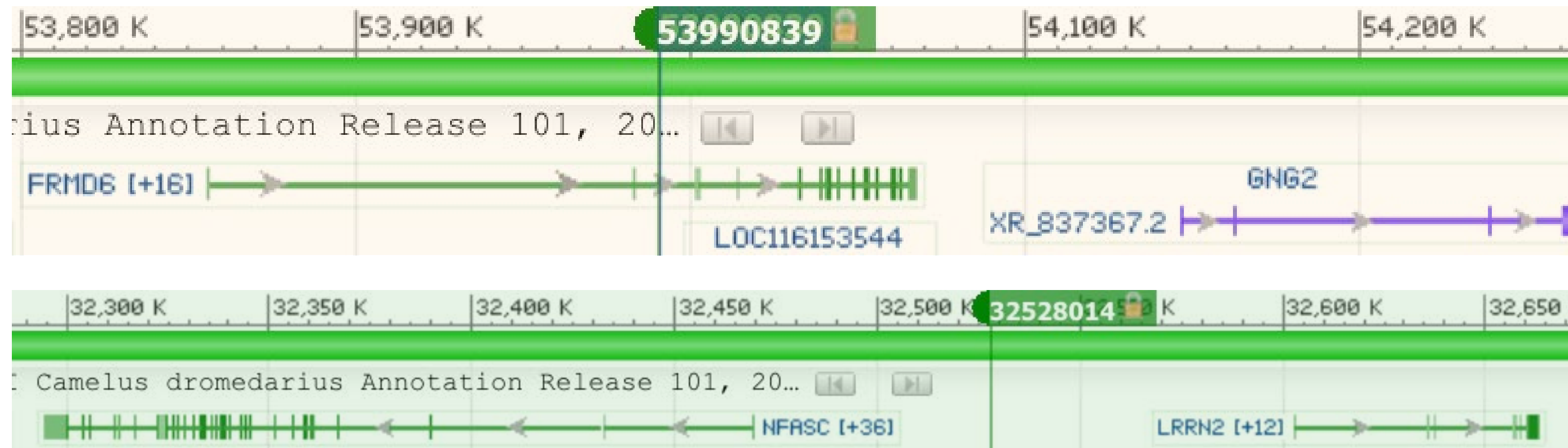
Phenotyping

Crimp-types

GWA Study 1

GWA Study 2

Kinky Crimp-type



n=51





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Variation

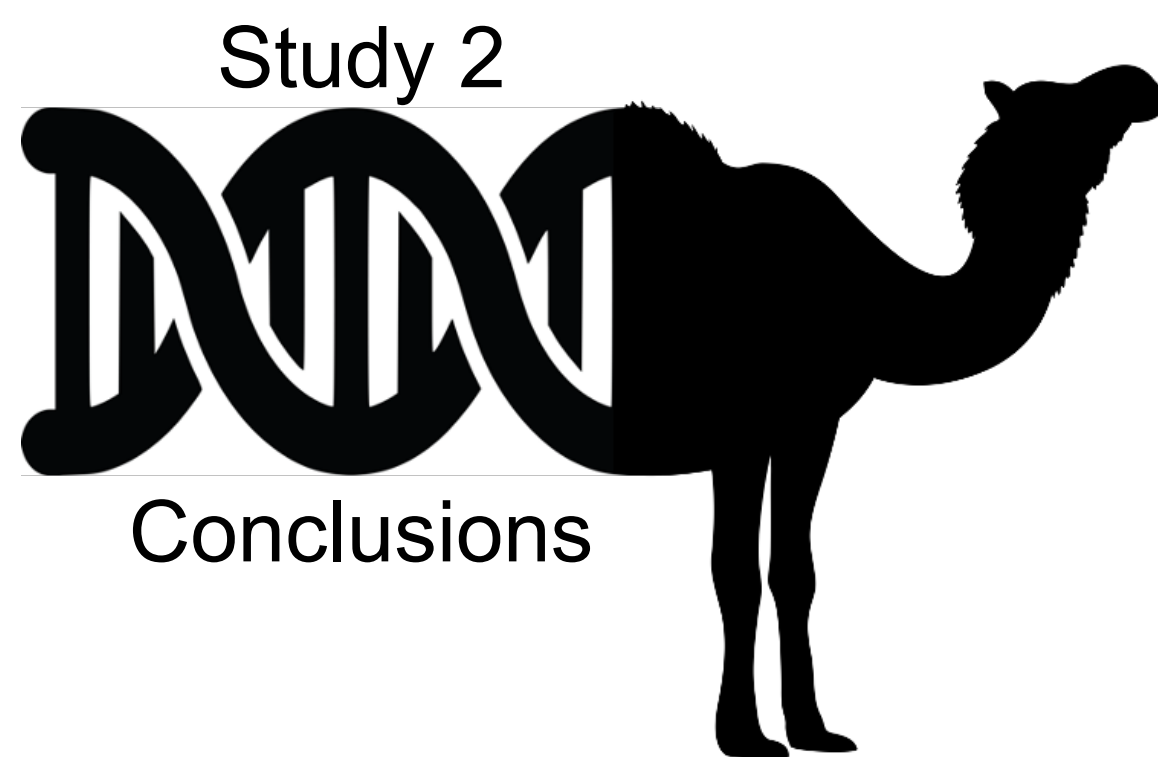
Attributes

Phenotyping

Crimp-types

GWA Study 1

GWA Study 2



1. Sample sizes are insufficient to get a statistical significance.
2. Mostly single marker associations suggesting random associations.
3. No obvious candidate genes in any of the associated regions.
4. Associated region on for straight vs. wavy could not be identified.
5. Photo-based phenotyping likely results in phenotype heterogeneity.
6. Are the crimp-type classes a result of variation in other hair qualities (e.g., diameter, length).

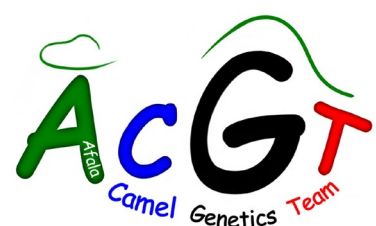




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Acknowledgments

illumina®

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Zhiliang Chen: Bioinformatics

André Eggen: Coordination

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Theyab Alhajeri

Saree Alhajeri

Fahad Alharbi

Adnan Alshawaf

Atallah Almutairi

Marzouq Alotaibi

Mutlaq Alseqyani

Saud Alshemmeri

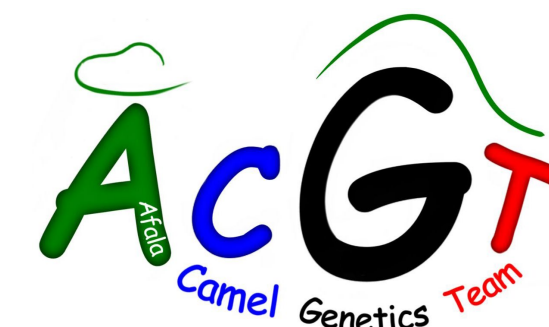
Mubarak Alothman

Saqer Zuraij Alazmi

Nawaf Marji Alenizi

Mohammed Alfanoosh

Abdulkareem Aladwani



Co-PI: Bader Alhajeri

Current Team

Tasneem Maraqa

Kawthar Akbar

Afnan Khaled

Hoda Alotaibi

Sara Alashqar

فريق
أفلا
لدراسة الإبل