

Aberystwyth University

Population structure and history of the Welsh sheep breeds determined by whole genome genotyping

Beynon, Sarah E.; Slavov, Gancho T.; Farré-Belmonte, Marta; Sunduimijid, Bolormaa; Waddams, Kate; Davies, Brian; Haresign, William; Kijas, James; Macleod, Iona M.; Newbold, C. Jamie; Davies, Lynfa; Larkin, Denis M.

Published in:
BMC Genetics

DOI:
[10.1186/s12863-015-0216-x](https://doi.org/10.1186/s12863-015-0216-x)

Publication date:
2015

Citation for published version (APA):

Beynon, S. E., Slavov, G. T., Farré-Belmonte, M., Sunduimijid, B., Waddams, K., Davies, B., Haresign, W., Kijas, J., Macleod, I. M., Newbold, C. J., Davies, L., & Larkin, D. M. (2015). Population structure and history of the Welsh sheep breeds determined by whole genome genotyping. *BMC Genetics*, *16*(1), [65].
<https://doi.org/10.1186/s12863-015-0216-x>

Document License
CC BY

General rights

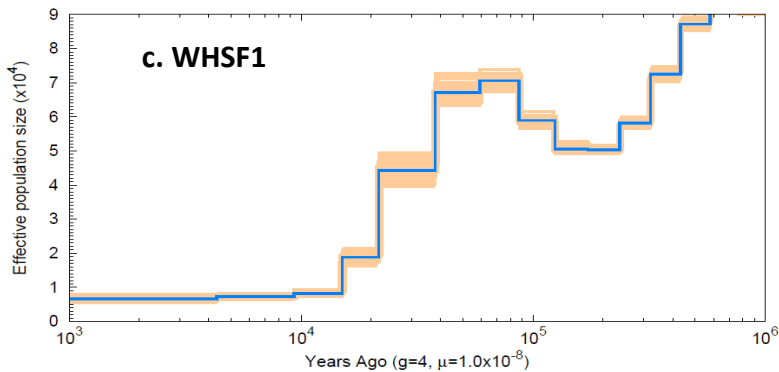
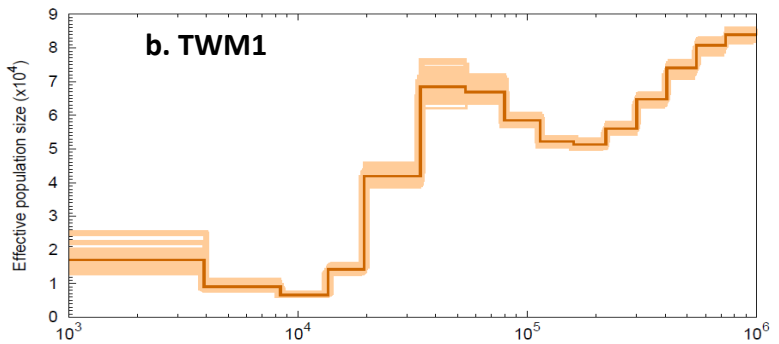
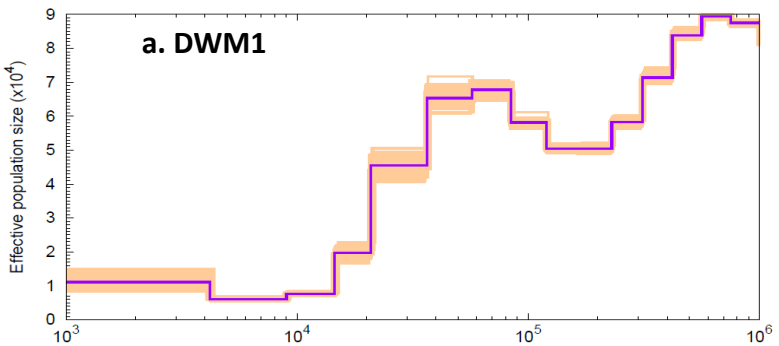
Copyright and moral rights for the publications made accessible in the Aberystwyth Research Portal (the Institutional Repository) are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

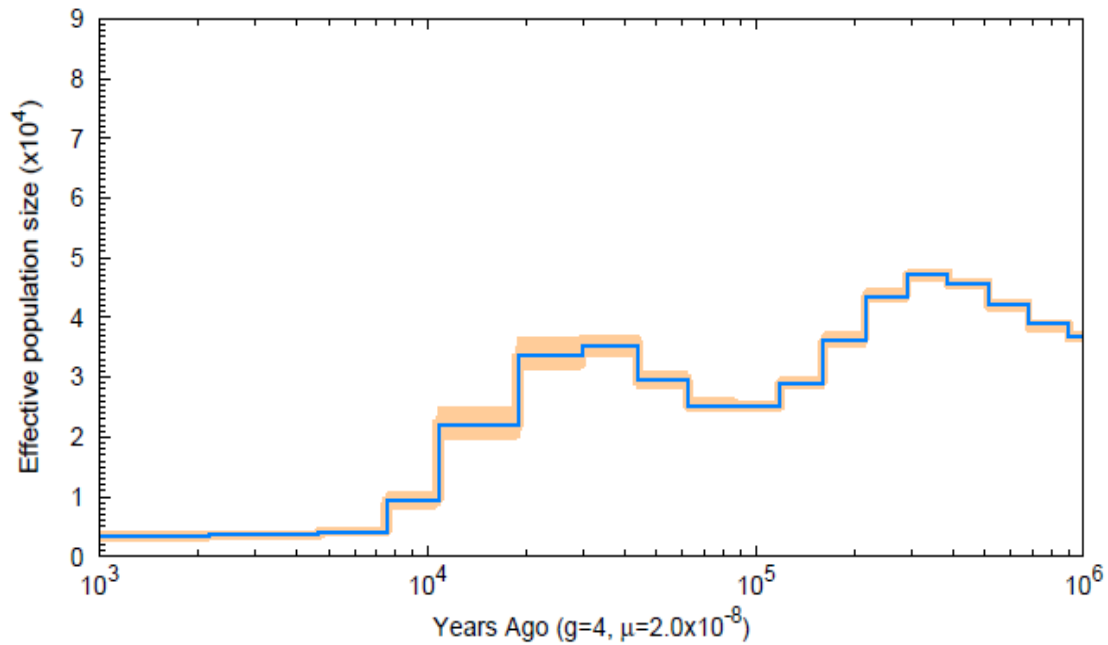
- Users may download and print one copy of any publication from the Aberystwyth Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Aberystwyth Research Portal

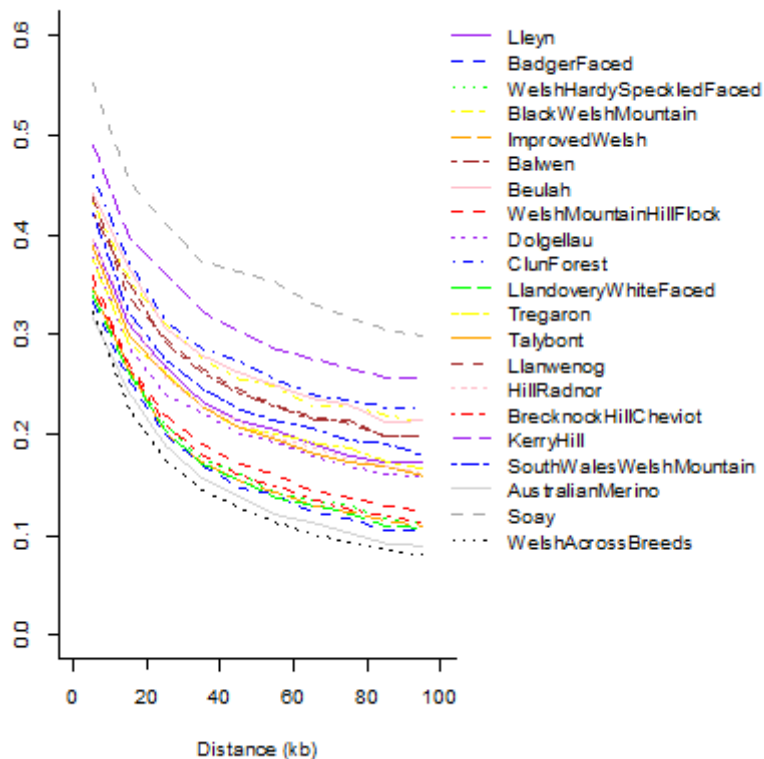
Take down policy

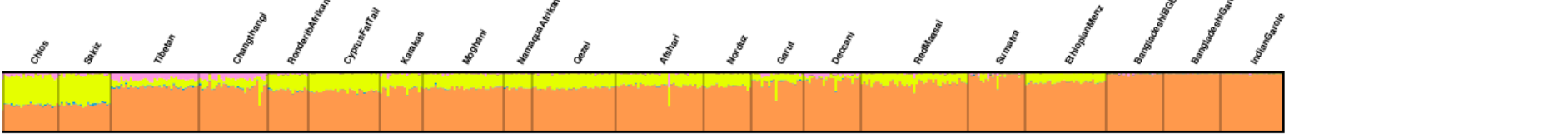
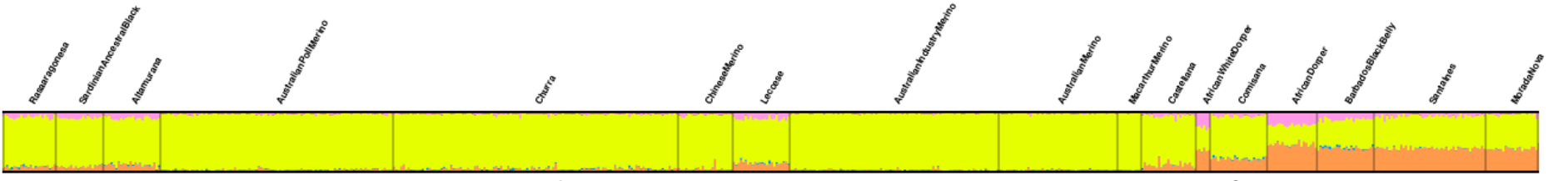
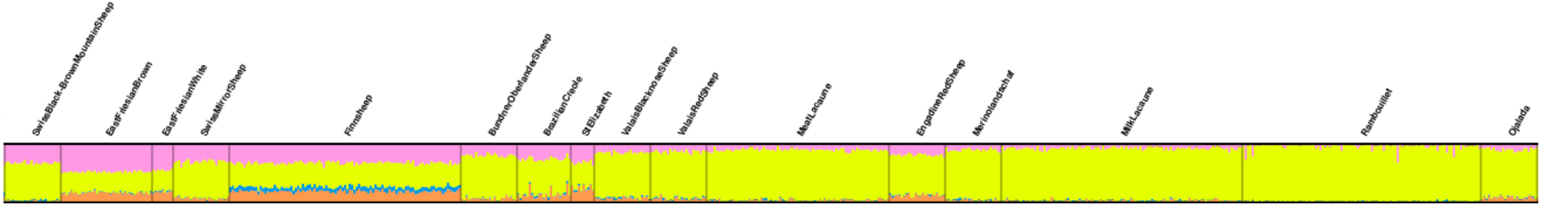
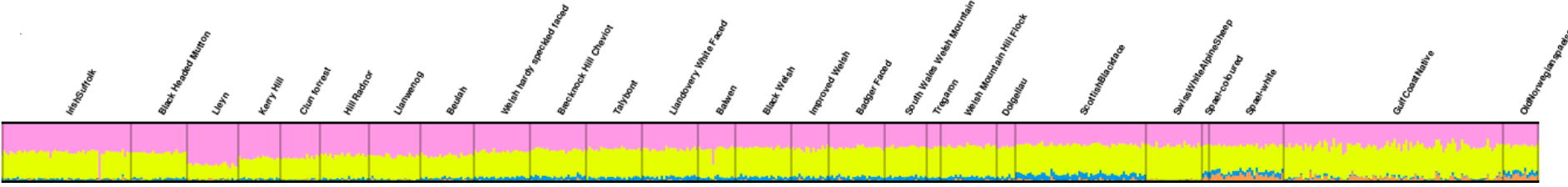
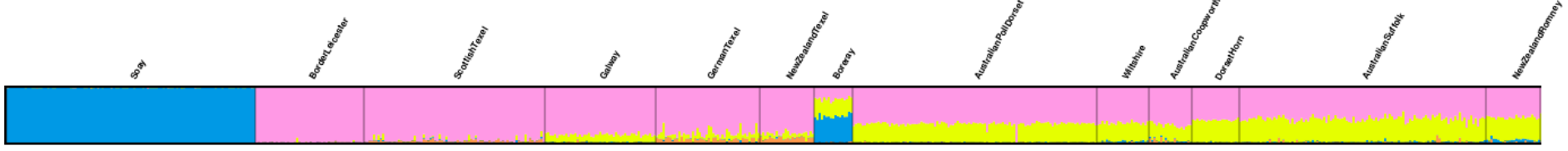
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

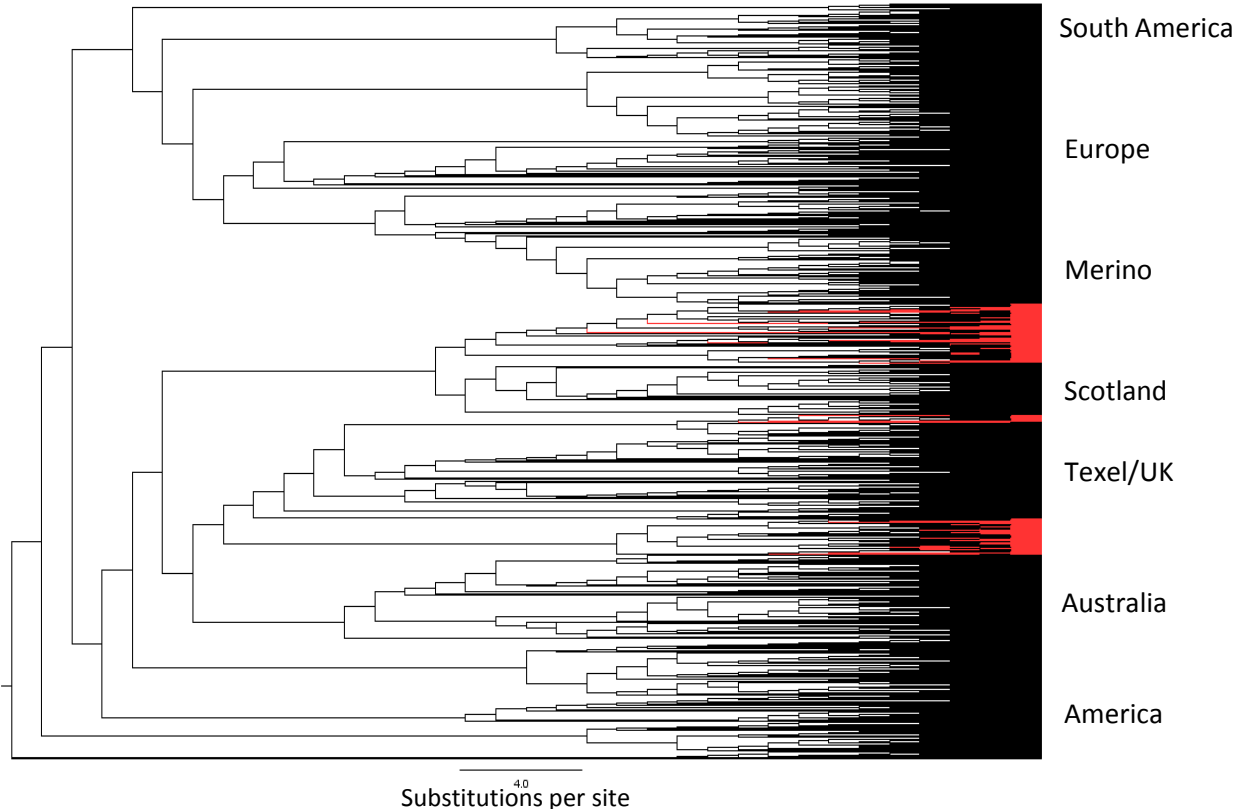
tel: +44 1970 62 2400
email: is@aber.ac.uk

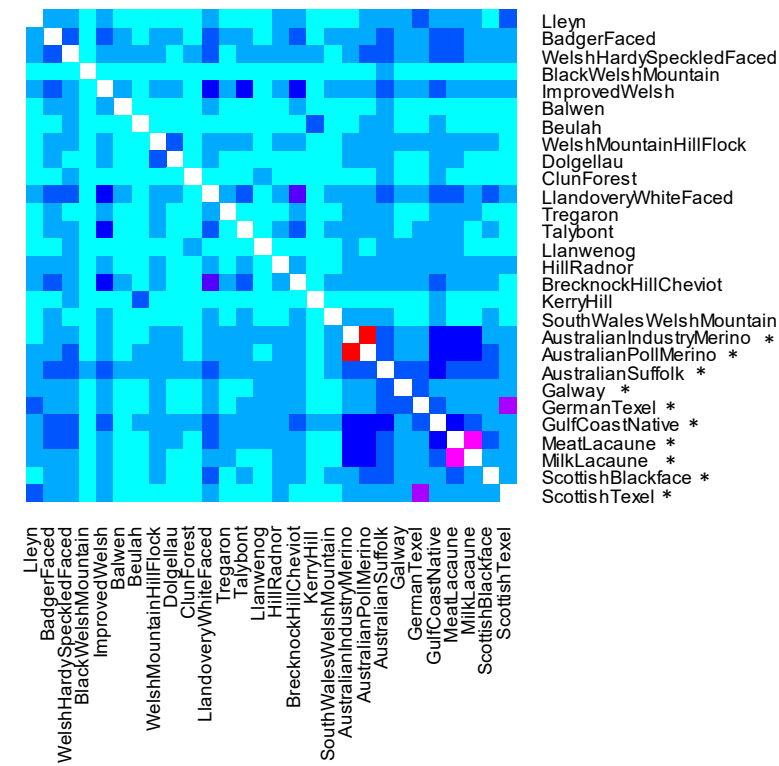
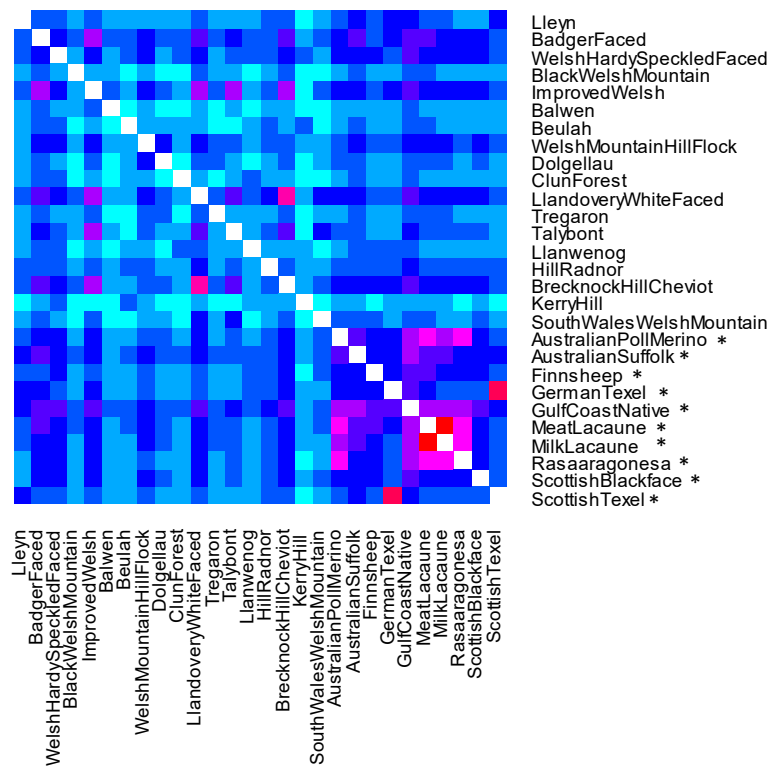
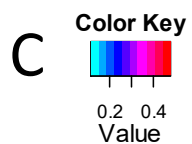
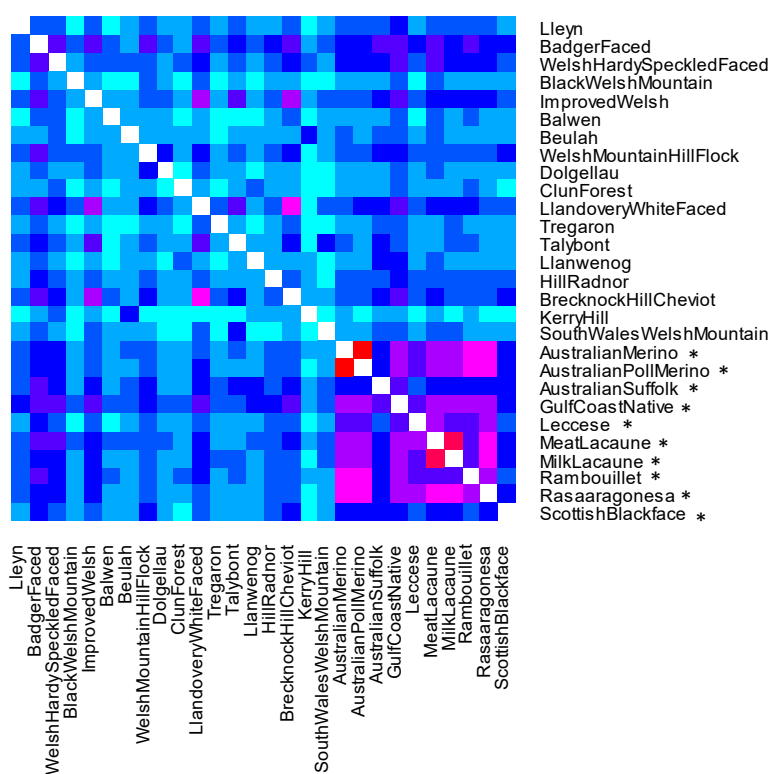
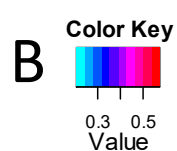
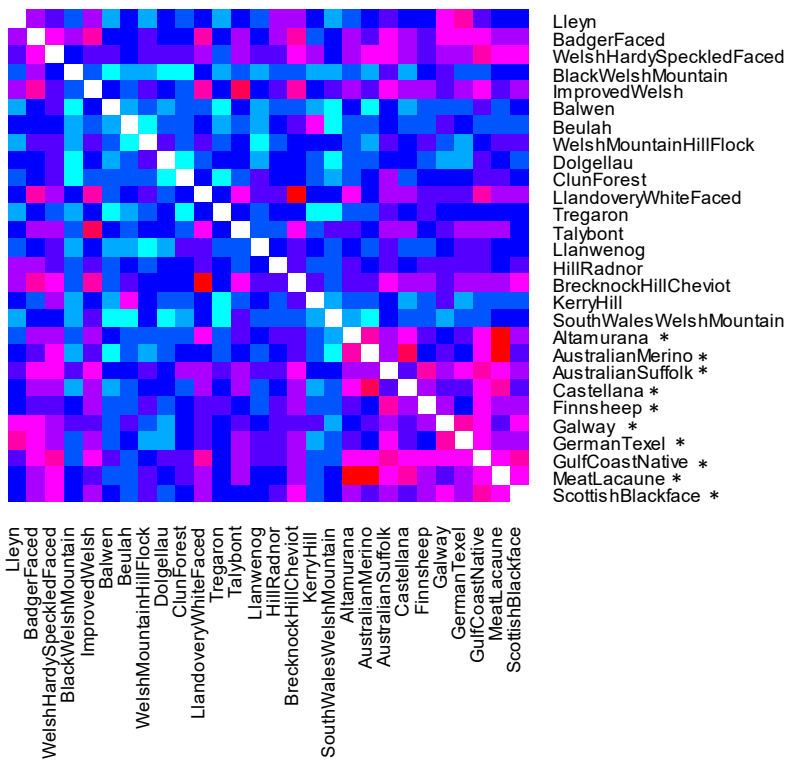










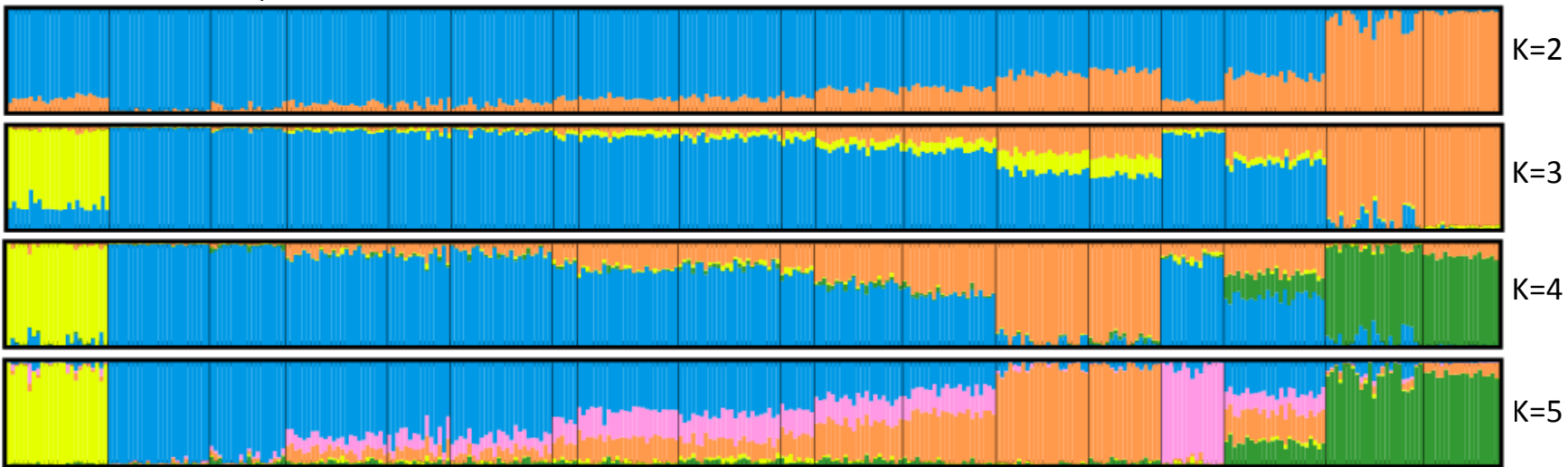


Supplementary Table 1. Haplotype sharing between the 18 Welsh and 10 top worldwide breeds summarised by geographical origin.

| | European breeds | | | | | | | USA | Iranian | New Zealand/ Australian |
|----------------------------|-----------------|----------------------------|-------|--------|----------------|--------|-------|-----|---------|----------------------------|
| | Scandinavian | Spanish/Portuguese/Italian | Irish | French | UK (non-Welsh) | German | Swiss | | | |
| Beulah | | | + | | + | | | + | | + |
| Kerry Hill | | + | + | | | | | | | + |
| Black Welsh Mountain | + | | + | + | + | | | | | |
| Clun Forest | | | | + | + | | | + | | + |
| Llanwenog | | + | | | + | + | | + | | + |
| Badger Faced | | | + | | | | | + | | + |
| Hardy Speckled Faced | | + | | + | + | + | | + | | + |
| Improved Welsh Mountain | + | + | | | + | + | | + | | + |
| Balwen | | + | | | + | | | + | | + |
| Hill Flock Welsh Mountain | + | + | | + | | | | | | + |
| Dolgellau Welsh Mountain | | + | | + | | | | + | | + |
| Llandovery White Faced | | + | | | + | | + | + | | + |
| Tregaron Welsh Mountain | + | | | + | | | | + | + | |
| Talybont Welsh Mountain | | + | | + | | + | | + | | + |
| Hill Radnor | | + | + | | + | | | + | | + |
| Brecknock Hill Cheviot | + | | | | + | + | | + | | + |
| South Wales Welsh Mountain | | | | + | + | | | | | + |
| Lleyn | | | + | | + | + | | + | | + |

The International Sheep Genome Consortium (ISCG) breeds with the highest levels of haplotype sharing (top 10) with each of the Welsh breeds are summarised by geographical origin, based on 0-10Kb resolution.

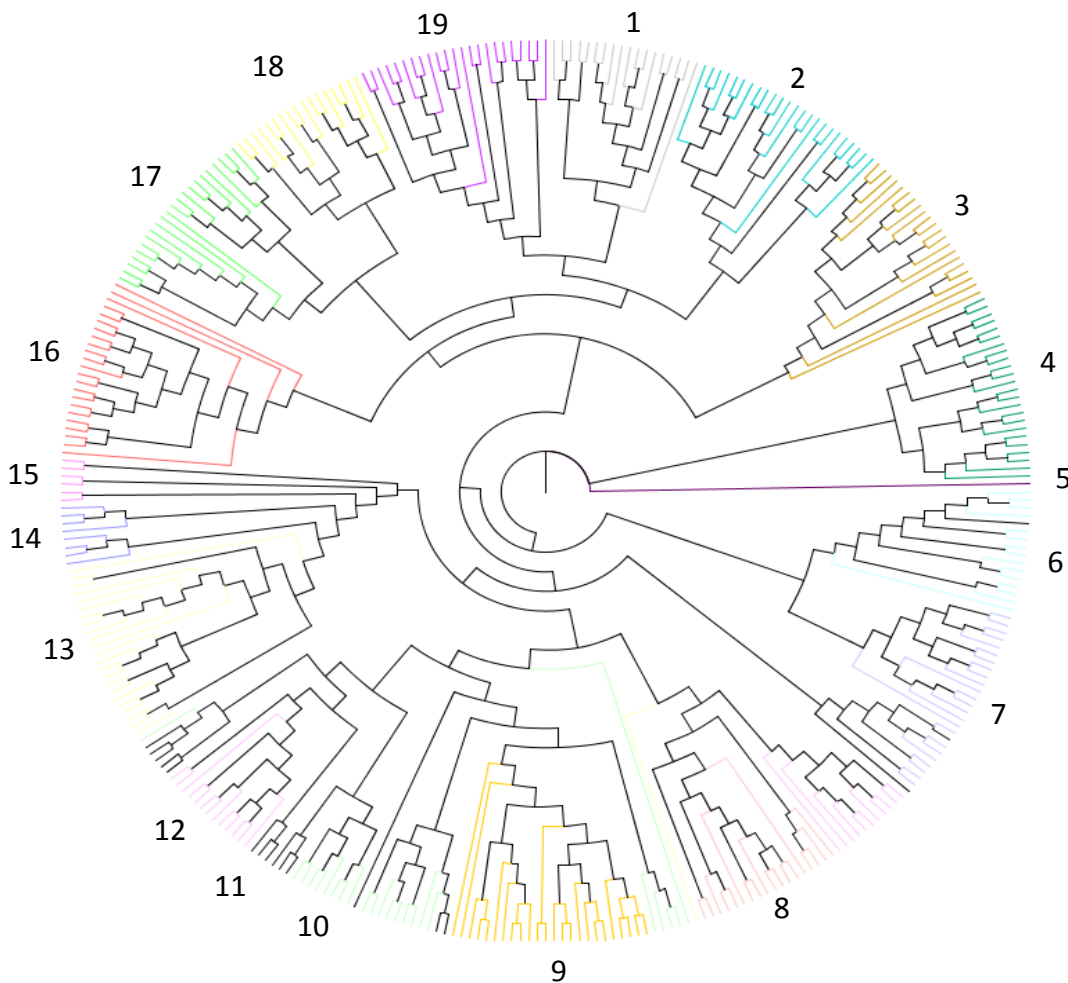
Black Welsh
 Talybont Welsh Mountain
 South Wales
 Welsh Mountain
 Llandovery White Faced
 Improved Welsh Mountain
 Brecknock Hill Cheviot
 Tregaron Welsh Mountain
 Welsh Mountain
 Hill Flock
 Badger Faced
 Dolgellau Welsh Mountain
 Hill Radnor
 Llwyn
 Llanwenog
 Clun Forrest
 Balwen
 Welsh Hardy
 Speckled Faced
 Beulah
 Kerry Hill



Supplementary Table 2. Pairwise genetic differentiation (F_{ST}) between Welsh, British and Asian breeds, Scottish Texel and Indian Garole.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|----|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 | Lleyn | 0 | 0.078 | 0.082 | 0.144 | 0.072 | 0.130 | 0.141 | 0.097 | 0.088 | 0.130 | 0.080 | 0.072 | 0.109 | 0.123 | 0.108 | 0.085 | 0.159 | 0.126 | 0.202 | 0.099 |
| 2 | Badger Faced | 0.078 | 0 | 0.051 | 0.106 | 0.030 | 0.091 | 0.112 | 0.057 | 0.047 | 0.110 | 0.040 | 0.031 | 0.068 | 0.099 | 0.078 | 0.045 | 0.137 | 0.084 | 0.170 | 0.105 |
| 3 | Welsh Hardy Speckled | 0.082 | 0.051 | 0 | 0.118 | 0.047 | 0.108 | 0.102 | 0.068 | 0.057 | 0.106 | 0.056 | 0.043 | 0.084 | 0.097 | 0.084 | 0.060 | 0.113 | 0.098 | 0.177 | 0.108 |
| 4 | Black Welsh Mountain | 0.144 | 0.106 | 0.118 | 0 | 0.104 | 0.162 | 0.177 | 0.126 | 0.117 | 0.174 | 0.113 | 0.102 | 0.140 | 0.163 | 0.146 | 0.118 | 0.201 | 0.155 | 0.234 | 0.171 |
| 5 | Improved Welsh Mountain | 0.072 | 0.030 | 0.047 | 0.104 | 0 | 0.085 | 0.109 | 0.054 | 0.044 | 0.104 | 0.020 | 0.022 | 0.036 | 0.095 | 0.074 | 0.026 | 0.132 | 0.074 | 0.168 | 0.100 |
| 6 | Balwen | 0.130 | 0.091 | 0.108 | 0.162 | 0.085 | 0 | 0.170 | 0.116 | 0.105 | 0.168 | 0.104 | 0.090 | 0.133 | 0.155 | 0.137 | 0.108 | 0.193 | 0.146 | 0.223 | 0.161 |
| 7 | Beulah | 0.141 | 0.112 | 0.102 | 0.177 | 0.109 | 0.170 | 0 | 0.131 | 0.119 | 0.163 | 0.117 | 0.105 | 0.146 | 0.156 | 0.144 | 0.121 | 0.130 | 0.159 | 0.237 | 0.168 |
| 8 | Hill Flock Welsh Mountain | 0.097 | 0.057 | 0.068 | 0.126 | 0.054 | 0.116 | 0.131 | 0 | 0.039 | 0.127 | 0.065 | 0.040 | 0.091 | 0.116 | 0.096 | 0.070 | 0.155 | 0.103 | 0.186 | 0.125 |
| 9 | Dolgellau Welsh Mountain | 0.088 | 0.047 | 0.057 | 0.117 | 0.044 | 0.105 | 0.119 | 0.039 | 0 | 0.118 | 0.054 | 0.025 | 0.081 | 0.105 | 0.086 | 0.061 | 0.144 | 0.094 | 0.176 | 0.114 |
| 10 | Clun Forest | 0.130 | 0.110 | 0.106 | 0.174 | 0.104 | 0.168 | 0.163 | 0.127 | 0.118 | 0 | 0.113 | 0.102 | 0.141 | 0.129 | 0.135 | 0.116 | 0.176 | 0.155 | 0.232 | 0.157 |
| 11 | Llandovery White Faced | 0.080 | 0.040 | 0.056 | 0.113 | 0.020 | 0.104 | 0.117 | 0.065 | 0.054 | 0.113 | 0 | 0.027 | 0.055 | 0.102 | 0.082 | 0.023 | 0.139 | 0.082 | 0.174 | 0.108 |
| 12 | Tregaron Welsh Mountain | 0.072 | 0.031 | 0.043 | 0.102 | 0.022 | 0.090 | 0.105 | 0.040 | 0.025 | 0.102 | 0.027 | 0 | 0.057 | 0.092 | 0.071 | 0.034 | 0.129 | 0.074 | 0.160 | 0.099 |
| 13 | Talybont Welsh Mountain | 0.109 | 0.068 | 0.084 | 0.140 | 0.036 | 0.133 | 0.146 | 0.091 | 0.081 | 0.141 | 0.055 | 0.057 | 0 | 0.131 | 0.111 | 0.061 | 0.170 | 0.086 | 0.203 | 0.137 |
| 14 | Llanwenog | 0.123 | 0.099 | 0.097 | 0.163 | 0.095 | 0.155 | 0.156 | 0.116 | 0.105 | 0.129 | 0.102 | 0.092 | 0.131 | 0 | 0.126 | 0.106 | 0.171 | 0.145 | 0.221 | 0.149 |
| 15 | Hill Radnor | 0.108 | 0.078 | 0.084 | 0.146 | 0.074 | 0.137 | 0.144 | 0.096 | 0.086 | 0.135 | 0.082 | 0.071 | 0.111 | 0.126 | 0 | 0.087 | 0.163 | 0.127 | 0.205 | 0.135 |
| 16 | Brecknock Hill Cheviot | 0.085 | 0.045 | 0.060 | 0.118 | 0.026 | 0.108 | 0.121 | 0.070 | 0.061 | 0.116 | 0.023 | 0.034 | 0.061 | 0.106 | 0.087 | 0 | 0.144 | 0.094 | 0.180 | 0.113 |
| 17 | Kerry Hill | 0.159 | 0.137 | 0.113 | 0.201 | 0.132 | 0.193 | 0.130 | 0.155 | 0.144 | 0.176 | 0.139 | 0.129 | 0.170 | 0.171 | 0.163 | 0.144 | 0 | 0.184 | 0.257 | 0.186 |
| 18 | South Wales Welsh Mountain | 0.126 | 0.084 | 0.098 | 0.155 | 0.074 | 0.146 | 0.159 | 0.103 | 0.094 | 0.155 | 0.082 | 0.074 | 0.086 | 0.145 | 0.127 | 0.094 | 0.184 | 0 | 0.215 | 0.154 |
| 19 | Indian Garole | 0.202 | 0.170 | 0.177 | 0.234 | 0.168 | 0.223 | 0.237 | 0.186 | 0.176 | 0.232 | 0.174 | 0.160 | 0.203 | 0.221 | 0.205 | 0.180 | 0.257 | 0.215 | 0 | 0.223 |
| 20 | Scottish Texel | 0.099 | 0.105 | 0.108 | 0.171 | 0.100 | 0.161 | 0.168 | 0.125 | 0.114 | 0.157 | 0.108 | 0.099 | 0.137 | 0.149 | 0.135 | 0.113 | 0.186 | 0.154 | 0.223 | 0 |

^a Scottish Texel and Indian Garole breeds were included in this table to demonstrate F_{ST} ranges with non-Welsh European and Asian breeds.



Supplementary Table 3. Summary statistics for the whole genome sequence of three Welsh sheep after strict quality control.

| Animal ID | Uniquely aligned (Mb) | Heterozygous false negative error rate^a | Heterozygous false positive error rate | Mean read depth | Estimated true heterozygosity^b |
|--------------------------|------------------------------|---|---|------------------------|--|
| DWM1^c | 30,767 | 0.422 | 4.95×10^{-5} | 12 | 0.002773 |
| TWM1^d | 27,245 | 0.533 | 4.50×10^{-5} | 11 | 0.002836 |
| WHSF1^e | 32,368 | 0.364 | 6.24×10^{-5} | 13 | 0.002816 |

^a Calculated as the proportion of heterozygous sites that are missed in the sequence data.

^b True heterozygosity estimated from the observed heterozygosity and corrected for false negative error rate: True heterozygosity = observed heterozygosity/[1-False Negative Error Rate]).

^c Dolgellau Welsh Mountain, ^d Tregaron Welsh Mountain, ^e Welsh Hardy Speckled Faced