

## 1. Limited Insight into Recent Human Adaptations

Rapid environmental shifts in the past 300–400 years (urbanization, Industrial Revolution) have influenced many human traits, potentially driving new adaptations and creating evolutionary mismatch, leading to diseases of modernity. However, detecting recent natural selection is challenging, as allele frequencies change slowly. Different genomic signatures are required to identify recent adaptations.

## 2. An Alternative Signature of Recent Selection

Stabilizing and directional selection favor chromosomes with a mix of trait-increasing (+) and trait-decreasing (-) alleles. This mix creates **negative covariance** between like-effect alleles, reducing genetic variance, known as the **Bulmer effect** (Bulmer 1971). Thus, negative covariance in sampled genomes hints at recent selection.

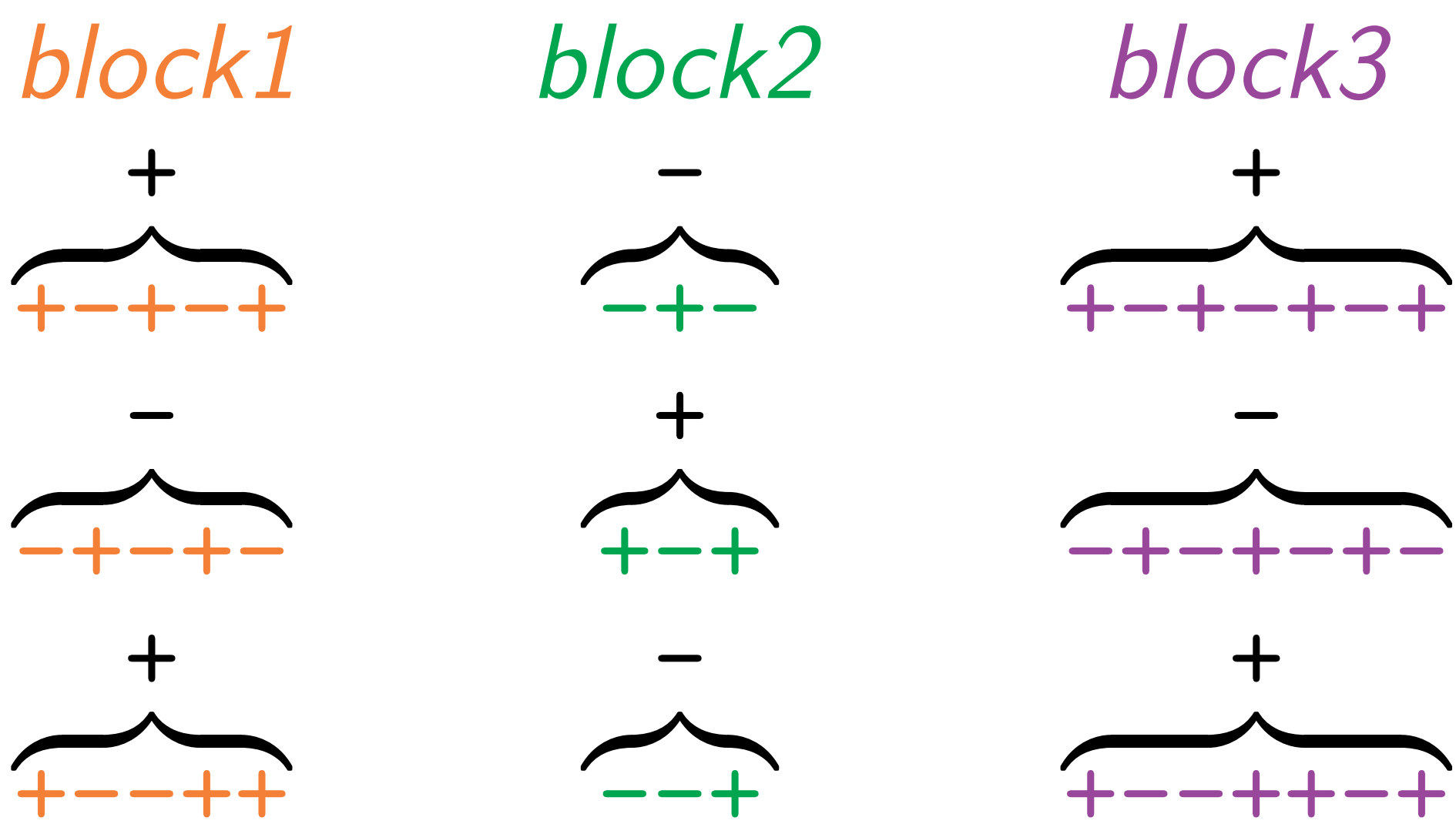
Chromosome	Phenotype
++++	large
----	small
+--+	intermediate
-+-+	
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## 3. Uncertainty in Assigning +/- Alleles

Under selection, (+) and (-) alleles counteract each other, leading to underestimated allelic effect sizes in genome-wide association studies and reducing the power to detect selection.

## 4. The New Method: BULMER

Our method is based on the insight that negative correlations between like-effect alleles also result in negative correlations between like-effect linkage disequilibrium (LD) blocks.



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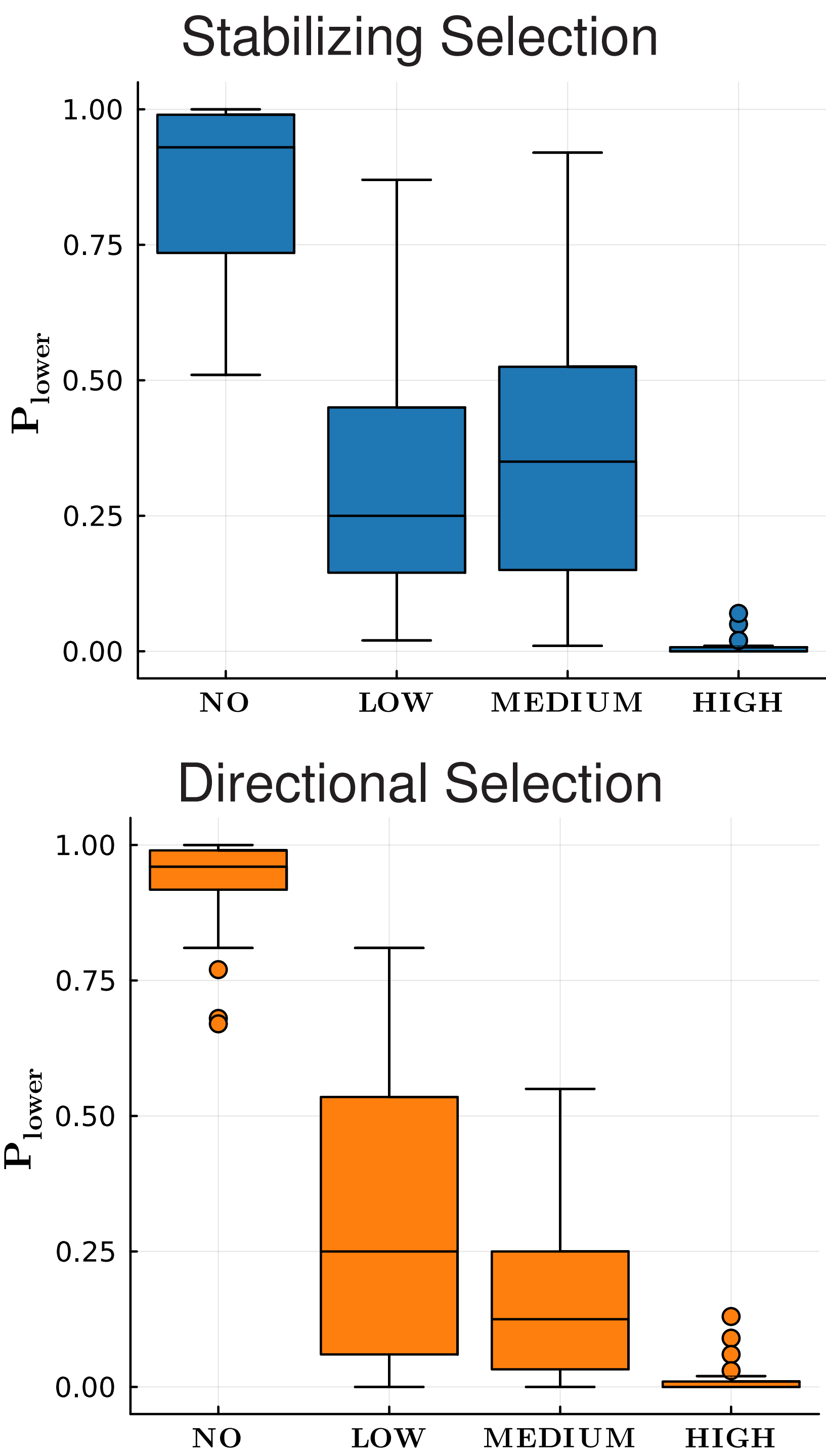
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We use the most significant loci from each block in a multivariate regression to estimate the net effects of individual blocks. This reduces the number of loci analyzed, lowering the required sample size.

## 5. Selection Amid Drift and Structure

- Genetic drift creates correlation with random sign. We use **randomization** to test the hypothesis of selection against drift.
- Population structure masks Bulmer effect; we correct for it using a **clustering** approach.

## 6. Forward Simulations with SLiM



P-values from 30 downsampled bootstrap replicates. BULMER can detect selection **within the last 300–400 years** (15 generations) in large biobank datasets, **even with population structure**.

## 7. Conclusions

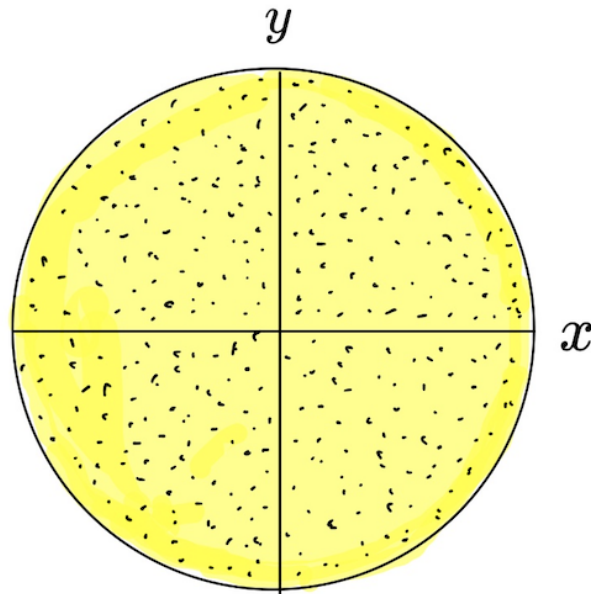
- Bulmer effect detects recent stabilizing and directional selection.**
- The method corrects for population stratification.**
- Simulations show selection is detectable in the last 300–400 years.**

## 8. Future Work

- Distinguish stabilizing from directional selection.**
- Detect ongoing selection.**
- Analyze anthropometric, molecular, and life-history traits in the UK Biobank.**

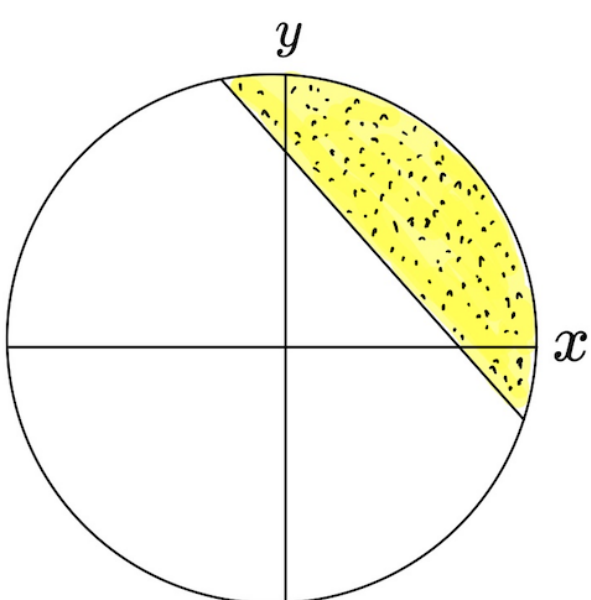
## Appendix: Bulmer Effect

Consider a quantitative trait, such as height, determined by two loci ( $x$  &  $y$ ), whose effects combine additively.



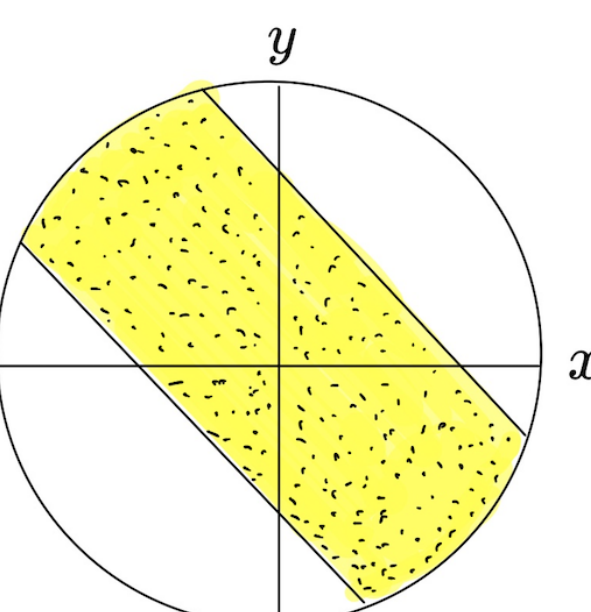
The yellow circle shows all possible heights under neutrality. All heights have equal fitness.

$Cov[x, y] = 0$



Taller heights in yellow strip have higher fitness under directional selection.

$Cov[x, y] < 0$



Intermediate heights in yellow strip have higher fitness under stabilizing selection.

$Cov[x, y] < 0$

## Acknowledgements

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## Scan Me!!

