Supergenes

Maddie Ore
Overview

• What is a supergene

• The Evolution of a Supergenes

• Restrictions against Supergenes
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What is a supergene

• A complex phenotype of multiple co-adapted elements that act like a single allele, maintained as a polymorphism
  • Multiple genes that act on a phenotype
  • Genes function together
  • Polymorphism: 2+ Alternate Forms/Morphs
  • Suppressed recombination
  • Intermediate forms are lethal or very unfit

Felsenstein, 2016
Thompson & Jiggins, 2014
Requirements

• **Strong Epistasis**
  • Epistasis is the strength of genetic interaction
  • Must be so strong that it functions like a simple Mendelian trait

• **Selection against Intermediate Forms**
  • Allele must be advantageous together AND deleterious alone or in any other combination
  • Adaptive advantage stronger than recombination

Felsenstein, 2016
Charlesworth & Charlesworth, 1975
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Location Matters

Two possible scenarios:

A. Component genes arise on separate chromosomes

B. Component genes arise on same chromosome
Overcoming Recombination

Suppressing recombination can occur through:

• Genomic location
• Modifiers that prevent recombination
• Inversions

• Often there are chromosomal rearrangements that facilitate tighter linkage
  • this can create LD without strongly-positive epistasis

• Inversion on the chromosome drastically reduce the recombination rate

Huynh et al, 2011
Schwander et al, 2014
How do they arise?

Local Adaptation

- A collective suite of characteristics are favorable in a local area

- Characteristics only beneficial when presented together

Joron et al, 2006
Morphological Polymorphism

Mimetic Butterflies

- 200 kb with high LD
- *Heliconius numata* populations have adapted to match the local *Melinaea sp.*
  - Strong selective forces act to maintain this polymorphism
- Spatial heterogeneity of morphs

Joron et al, 2006
Joron et al, 2011
How do they arise?

Negative Frequency-dependent Selection

• A specific set of behavioral/morphological characteristic are controlled by a suite of genes

• There is some selective benefit of being the rarer or opposite morph

Schwander et al, 2014
Social Polymorphism

White-throated Sparrows
- 104/110 Mb with high LD
- Two morphs: Tan-stripe and White-Stripe
  - Tan morph: less aggressive, more parental care
  - White morph: more aggressive, less parental care

Huynh et al, 2011
• Negative assortative mating
  • Homozygous ZAL2\textsuperscript{m}/ZAL2\textsuperscript{m} is lethal

Huynh et al, 2011
Other examples of Supergenes

Fire Ants and Alpine Silver Ant:
- Two types of colonies: Polygynous or monogynous
- Controlled by a large linked region
- Suppressed recombination and inversion

Heterostyly and self-incompatibility
- Region of genes that act to prevent self-pollination
- Inhibited growth of self pollen, Incompatible proteins, Mismatched stamen and anther lengths

Sex chromosomes
- Y-chromosome inverted to prevent recombination with X-chromosome

*Cepaea nemoralis* snails
- Color and pattern of shells maintained in a polymorphism

Thompson & Jiggins, 2014
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Why aren’t supergenes more common?

• Recombination has a lot of benefits
  • ex. Ability to adapt to a changing environment

• Interactions that are not physically linked will not establish

• Selection and/or epistasis must be strong

• Chromosomal rearrangements like inversions can incur accumulation of deleterious alleles and genetic degradation

Charlesworth & Charlesworth, 1975
Maynard Smith, 1977
Conclusions

• Supergene is commonly defined as a set of genes that are co-adapted and inherited together

• This concept contrasts the typical paradigm of recombination to create variability in offspring

• There are a number of examples of this phenomenon, but can come at a cost
References


