Sexual conflict at the genetic level

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When to mate?
How often to mate?
Whether to remate with a different individual?
How much to invest in current offspring?

Conflict arises because males and females...

... face different costs of reproduction (starting with anisogamy)
... are more related to their offspring than they are to each other
... may be subject to differing selection pressures (sexual and natural)

The take-home message

Sexual conflict can have a significant impact on morphology, physiology, behaviour, life history and genetics

Trade-offs in sexual and natural selection: cichlids in rocky areas of Lake Malawi

Structure of lecture

1. Sexually antagonistic selection
   - On genes at different loci
   - On alleles at the same locus
   - How to detect it
   - Its effects: coevolutionary arms races & mate choice

2. Case study: SAS in humans

3. Genetic imprinting and conflicts of interest
   - Genetic imprinting and fetal growth
   - Is imprinting really due to parental conflict?
First key point!

The fittest allele at a given locus may be different for males and females

⇒ intra-locus sexual conflict

Intra-locus antagonism

- A sex*genotype interaction for fitness

- Can lead to:
  - trade-offs in mean phenotype values
  - maintenance of polymorphism in a population.
  - high frequencies of low-fitness alleles (later!)

- Can lead to the evolution of sex-specific gene expression and/or new sex determination mechanisms (pollywogs)

Cox & Calsbeek (2009)

Detecting intra-locus SAS


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Detecting intra-locus SAS

- More sexual dimorphism/sexual selection ⇒ more opportunity for SAS? (Red deer)
- Could compare juvenile vs. adult - Drosophila experiment showed strong genotype*sex interaction in adult but not juvenile fitness (egg-adult survival & LRS)


Differing reproductive interests

A. Male-fundamental betardenial relationship

B. Female-fundamental betardenial relationship

Reproductive success (no. offspring)

Number of mates
Second key point!

We may see a coevolutionary ‘arms race’ where each sex is selected to exploit the other but also defend against exploitation.

Inter-locus conflict and imprinting

Inter-locus antagonism

- Insemination reaction mass in some Drosophila spp.
- Females do not oviposit or remate until it has subsided - paternity assurance tactic by male
- Rapid evolution of seminal proteins

Knowles, LL & Markow, TA (2001) PNAS 98:8692-6

Inter-locus antagonism & reproductive isolation

- A biochemical mismatch between males and females of different species
- Did isolated populations follow different paths of antagonistic coevolution, leading to post-mating, pre-zygotic isolation?
- Inter-specific matings lead to bigger masses and delayed oviposition, i.e. a cost of such matings.

Knowles & Markow (2001) PNAS 98:8692-6

Where are antagonistic loci?

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Role of the X chromosome

- Another Drosophila experiment.
- Cloned 20 X chromosomes and compared their fitness variation with genome-wide levels.
- At the juvenile stage, the X chromosome made no detectable contribution to genome-wide fitness variation.
- At the adult stage, the X chromosome was estimated to harbour 45% of the genome-wide fitness variation and 97% of the genome-wide sexually antagonistic variation.


(Also Lercher, MJ et al. (2003) Evidence that the human X chromosome is enriched for male-specific but not female-specific genes. Nature 421:1113-1116)

Antagonism & mate choice

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Antagonism & mate choice

- Clearly, they are related. We've already seen that a female's mate choice may result in a trade-off between the fitness of her daughters and the fitness of her sons.
- But how does the interaction of SAS and mate choice influence the evolution of fitness / phenotypes?
- Does the location of loci under SAS have an effect?

Inter-locus antagonism & mate choice

- Antagonism can select for changes in intercept and/or slope of female response function
  
  
  (19(2) is a special issue on sexual conflict)

Intra-locus antagonism & mate choice

- XY (male heterogametic) species
  - Y-linked traits that are beneficial to males are never expressed in daughters - no problem here.
  - But X-linked male traits are never passed from an attractive male to his sons, only to his daughters
  - So... no increase in offspring fitness if females prefer males with extreme values of an X-linked trait.
  - No benefit to sons, and if SAS operates there's a cost to daughters
  - But X-linked traits that increase female fitness can rise to fixation
  

- WZ (female heterogametic) species
  - Both mother and father contribute a Z chromosome to sons. (Daughter gets W from mother)
  - So females who prefer males with a Z-linked display trait get sexy sons - even if their daughters pay a cost.
  - Simulations show that with a Z-linked sexually antagonistic trait and Z-linked preference locus, females evolve to prefer males carrying alleles beneficial to sons.
  

SAS in humans: male homosexuality

- Accepted that there is a considerable genetic component to male homosexuality (twin studies)
- Surely the ultimate example of a low-fitness genotype?
  - So why is it maintained at appreciable frequencies? (very approximately 10% from e.g. Kinsey studies)
  - In the 1990s, people started to theorise:
    - Social conformity/still have a desire for children
    - Heterozygote advantage
    - "Sneaky males"
    - Homosexuals as non-breeding helpers
    - Birth order/immunisation
    - Sexually antagonistic selection - same allele increases female fitness
  
  MacIntyre & Estep (1993) *Sperm competition and the persistence of genes for male homosexuality* *discSystems* 31:223-233

- 2004: 98 homosexual and 100 heterosexual Italian men provided pedigrees - family trees with data on relatives’ sexuality
  - Maternal relatives of homosexual men have higher fecundity than do maternal relatives of heterosexual men.
  - Even if only first-born homosexual men are included
  - 2007, 2008: Slightly larger, cross-cultural studies produced similar results - mothers and maternal aunts showed significantly increased fecundity

- 2008: Two new studies and an excellent modelling paper
  - Where in the genome is this locus (loci?)?
  - Two loci, at least one of which is X-linked, produce a model which fits the empirical data.


**SAS: summary**

- Can have significant consequences for evolution of phenotypes/fitness
- And evolution of mate choice
- Inter-locus antagonism can lead to coevolutionary 'arms races'
- We can detect SAS by observation and by experiment
- The location of genes under SAS is important

**Conflicts of interest over offspring**

**Imprinting**

- Genetic imprinting: switching genes off by heavily methylating the DNA
- Whole chromosomes or individual genes - latter only in mammals, flowering plants & some insects
- Different loci may be imprinted in male and female germline
- A textbook classic: IGF2 and IGF2R in mice
  - UPD2s: two maternal IGF2 small, two paternal IGF2 large
  - IGF2R paternal - no effect. But IGF2R maternal: 30% growth increase, lethal
  - e.g. Heg, G & Groffen, G (1991) Cell 64:1045
- An obvious case of sexual antagonism (& parent-offspring conflict)
- Humans too

**Imprinting: is it really due to parental conflict?**

- What does conflict theory predict?
  - Growth enhancers should be maternally imprinted, growth suppressors should be paternally imprinted
  - Antagonistic coevolution between enhancer and suppressor loci
- Are these predictions supported by evidence?
  - Uniparental disomies
    - Survey of 15 UPDs in humans and mice. 8 had effects in expected direction, 7 were in opposite direction.
    - e.g. Angelman’s syndrome underweight, Prader-Willi obese
  - Molecular evolution
    - IGF2 and IGF2R are very highly conserved at mutual binding site
    - Rate of molecular evolution in 7 imprinted genes in mouse & rat not significantly different from non-imprinted receptors (and much lower than immune genes)
Summary of lecture

• Sexual conflict - it's in the genes
• The fitness of a given allele can depend on its genomic background
• And its location in the genome can be crucial in determining its fate
• These factors can lead to really interesting evolutionary dynamics
• Sexual antagonism at the genetic level may be involved in post-mating reproductive isolation
• And in the maintenance of apparently unfit genotypes over long periods of time
• Gene regulation by imprinting has been a cause celebre in sexual conflict theory - but remember critically to assess evidence

More references

Background

Examples

Imprinting

Popular science
• Baker, C (2005) Sperm Wars: Infidelity, Sexual Conflict, and Other Bedroom Battles (Thunder's Mouth)

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