The fragile biology of social genes and the evolution of human societies

Professor Keith Kendrick
What is social behaviour?

Mutually beneficial interactions among individuals within the same species

Evolved because it promoted 'survive and reproduce'
Sociability in female baboons promotes infant survival
Silk et al 2003

Fig. 1. Effects of sociability on infant survival.
What is social behaviour?

Can be seen in species from amoeba...
What is social behaviour?

Can be seen in species from amoeba... through to humans
What is social behaviour?

Can be seen in species from amoeba through to humans

Must have strong genetic basis hence 'Sociobiology'

Many find this hard to square with 'free-will'

Edward O Wilson
"...it is quite possible that the relative strength of these two drives is, in the main, fixed by inheritance. But the personality that finally emerges is largely formed by the environment in which a man happens to find himself during his development, by the structure of the society in which he grows up, by the tradition of that society, and by its appraisal of particular types of behavior."

What are the advantages of being social?

Co-operation and altruism have a price
What are the advantages of being social?

Parental behaviour - nurturing offspring at cost to oneself!
What are the advantages of being social?

Sometimes even males get involved
What are the advantages of being social?

Eusocial insects - 'queens' and 'workers'
What are the advantages of being social?

Eusocial mammals

The naked mole rat (*Heterocephalus glaber*)
What are the advantages of being social?

Eusocial mammals

The naked mole rat (*Heterocephalus glaber*)

The Damaraland mole rat (*Cryptomys damarensis*)
So what might lead to these behaviours?

Selfish genes can lead to co-operation and altruism – kin selection
So what might lead to these behaviours?

Selfish genes can lead to co-operation and altruism – kin selection

Social co-operation in many species extends beyond kin

WD Hamilton

Robert Trivers
So what might lead to these behaviours?

‘Altruistic punishment’ of non-cooperators
Ernst Fehr and Simon Gächter 2002
So what might lead to these behaviours?

There must be significant costs associated with cheating!
Social genes

Solitary vs. social across species
Social genes

Solitary vs. social across species

Solitary vs. social within the same species
Social genes

Solitary vs. social across species

Solitary vs. social within the same species

Often a single gene polymorphism or deletion alters social behaviour
Hard and soft inheritance

Hard inheritance: Nucleotide based genes inherited bi-allelically

Inheritance of Cystic Fibrosis (CF)

Father (Carrier of CF Gene)
Mother (Carrier of CF Gene)

Child (Does Not Have CF)
Child (Carrier of CF Gene)
Child (Carrier of CF Gene)
Child (Has Cystic Fibrosis)

Normal Gene
Defective Gene
Hard and soft inheritance

Hard inheritance: Nucleotide based genes inherited bi-allelically

Inheritance of acquired traits?

Jean-Baptiste Lamarck (1744 - 1829)
Hard and soft inheritance

Hard inheritance: Nucleotide based genes inherited bi-allelically

Inheritance of acquired traits?

Jean-Baptiste Lamarck (1744 - 1829)
Hard and soft inheritance

Hard inheritance: Nucleotide based genes inherited bi-allelically

Inheritance of acquired traits?

Trofim Denisovitch Lysenko (1898 - 1976)
Hard and soft inheritance

Soft inheritance: the epigenome and epigenetics

Extra layer of modification instructions passed down from parent to child
Epigenetic marks - methylation changes and histone modifications

These modifications are not usually passed on to the next generation

Fraga et al. 2005
Hard and soft inheritance

However there are increasing examples where they are
Hard and soft inheritance

Epigenetics and imprinted genes

Bi-allelic (normal)

Mum  Dad

Child

Mono-allelic (Imprinted)

Mum  Dad

Child
Hard and soft inheritance

Epigenetics and imprinted genes

There are only 100 imprinted genes but they may be important for social behaviour
Identifying social genes

Prosocial genes account for 40% similarity in monozygotic twins
Rushton 2005

Genetic and environmental contributions to pro-social attitudes: a twin study of social responsibility

J. Philippe Rushton
Department of Psychology, University of Western Ontario, London, Ontario N6A 5C2, Canada (rushton@uwo.ca)

23% is due to shared environment
Identifying social genes

Gene screening experiments are underway
Effects of gene deletions and polymorphisms

Cell signalling gene **DIF-1** in amoeba is linked to cooperative behaviour

*Foster et al* 2004
Effects of gene deletions and polymorphisms

In fire ants **Gp-9** gene polymorphism controls worker social behaviour

Krieger and Ross 2002
Effects of gene deletions and polymorphisms

In honey bees the **for** gene controls when workers change from hive maintenance to foraging

Ben-Shahar *et al* 2002
Social bonding genes

In mammals:
social monogamous vs. asocial promiscuous voles

Pine and Prairie voles are highly social, monogamous and show paternal care

Montane and Meadow voles are asocial, promiscuous and show no paternal care
Social bonding genes

Oxytocin and vasopressin and their respective receptors

Cys-Tyr-Ile-Gln-Asn-Cys-Pro-Leu-Gly-NH₂

Cys-Tyr-Phe-Gln-Asn-Cys-Pro-Arg-Gly-NH₂

Prairie OT Receptor

Montane

PL

NAcc
Social bonding genes

Oxytocin and vasopressin and their respective receptors
Both peptides promote social recognition memory

Ferguson et al 2000
Social bonding genes

Vasopressin v1ar receptor has a polymorphism that promotes its social distribution

Hammock and Young 2002 & 2005
Social bonding genes

A

Fold change in V1aR binding levels

long/short

Epi Gl 

unadjusted p value:

* p<0.05  
** p<0.01    
*** p<0.001 (Bonferroni cut-off)

B

Epi

D/VMP

PCing

short

C

dLS

D

Epi

BLA

long
Social bonding genes

A. Social odor investigation
   - Investigation latency
   - Number of approaches
   - Investigation duration

B. Non-social odor investigation
   - Investigation latency
   - Number of approaches
   - Investigation duration

C. Social approach and investigation
   - Investigation latency
   - Number of approaches
   - Investigation duration

D. Partner preference
   - Partner contact
   - Stranger contact

<table>
<thead>
<tr>
<th>Partner</th>
<th>PP</th>
<th>EP</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>long</td>
<td>18</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>short</td>
<td>14</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>
Social bonding genes

Same longer form of the gene is found in Humans and Bonobos but not Chimpanzees
Social bonding genes

Expressing the long form in the brain of an asocial vole makes it become social

Lim et al. 2004
Language genes

Foxp2 gene language and social communication.
Shu et al 2005
Gene variant on chromosome 11 linked to altruism
Bachner-Melman et al 2005

Dopaminergic polymorphisms associated with self-report measures of human altruism: a fresh phenotype for the dopamine D4 receptor

Has the opposite effect on the dopamine D4 receptor as risk-taking
Many human genetic disorders are associated with social behaviour dysfunction:

Autism and Aspergers
Disorders with social behaviour dysfunction

Positive link with the oxytocin receptor gene
Wu et al 2005

Table 5. Genetic Association between Haplotype and Autism

<table>
<thead>
<tr>
<th>Marker</th>
<th>Allele</th>
<th>S</th>
<th>E(S)</th>
<th>Specific Haplotype FBAT</th>
<th>Global Haplotype FBAT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Z</td>
<td>p</td>
</tr>
<tr>
<td>SNP1-SNP2</td>
<td>A-A</td>
<td>103.680</td>
<td>86.422</td>
<td>2.850</td>
<td>.0044</td>
</tr>
<tr>
<td>SNP1-SNP3</td>
<td>A-T</td>
<td>105.761</td>
<td>89.828</td>
<td>2.592</td>
<td>.0095</td>
</tr>
<tr>
<td>SNP1-SNP4</td>
<td>A-A</td>
<td>113.797</td>
<td>98.575</td>
<td>2.414</td>
<td>.0158</td>
</tr>
<tr>
<td>SNP2-SNP3</td>
<td>A-T</td>
<td>191.407</td>
<td>174.785</td>
<td>2.341</td>
<td>.0192</td>
</tr>
<tr>
<td>SNP2-SNP4</td>
<td>A-A</td>
<td>193.692</td>
<td>177.894</td>
<td>2.248</td>
<td>.0246</td>
</tr>
<tr>
<td>SNP3-SNP4</td>
<td>T-A</td>
<td>172.965</td>
<td>167.974</td>
<td>0.770</td>
<td>.4412</td>
</tr>
<tr>
<td>SNP1-SNP2-SNP3</td>
<td>A-A-T</td>
<td>96.669</td>
<td>81.261</td>
<td>3.102</td>
<td>.0019</td>
</tr>
<tr>
<td>SNP1-SNP2-SNP4</td>
<td>A-A-A</td>
<td>101.394</td>
<td>85.142</td>
<td>2.681</td>
<td>.0073</td>
</tr>
<tr>
<td>SNP1-SNP3-SNP4</td>
<td>A-T-A</td>
<td>106.423</td>
<td>90.551</td>
<td>2.565</td>
<td>.0103</td>
</tr>
<tr>
<td>SNP2-SNP3-SNP4</td>
<td>A-T-A</td>
<td>195.147</td>
<td>177.357</td>
<td>2.496</td>
<td>.0126</td>
</tr>
<tr>
<td>SNP1-SNP2-SNP3-SNP4</td>
<td>A-A-T-A</td>
<td>100.199</td>
<td>81.776</td>
<td>3.085</td>
<td>.0020</td>
</tr>
</tbody>
</table>

S, test statistics for the observed number of transmitted alleles; E(S), expected value of S under the null hypothesis (i.e., no linkage or association); SNP1, rs2254298; SNP2, rs53576; SNP3, rs2228485; SNP4, rs237911.

"Global haplotype represents the haplotype using all possible variants.

p, one-tailed.
Disorders with social behaviour dysfunction

Blood oxytocin levels are lower in autistic than control children

Modahl et al 1998
Intranasal infusions of oxytocin promote social trust

Kosfeld et al 2005
Disorders with social behaviour dysfunction

Increase resistance to psychosocial stress
Heinrichs et al 2003
Disorders with social behaviour dysfunction

Reduce repetitive antisocial behaviours in autistic individuals

Hollander et al 2003
Disorders with social behaviour dysfunction

The human vasopressin receptor gene \(\text{avpr1a}\) is also linked to autism

\textit{Kim et al} 2001

The link was strongest in autistic individuals without language impairment
Disorders with social behaviour dysfunction

William's syndrome

Mild to moderate mental retardation, cardiovascular abnormalities, growth retardation and a distinct facial appearance

Affects 1 in 7,500 individuals
Disorders with social behaviour dysfunction

Neurodevelopmental disorder with deletion of 28 genes on chromosome 7

Meyer-Lindenberg et al 2006
Disorders with social behaviour dysfunction

Neurodevelopmental disorder with deletion of 28 genes on chromosome 7

Reduced responsivity of the amygdala to threatening faces but not scenes

Meyer-Lindenberg et al 2006
Disorders with social behaviour dysfunction

Sufferers are distinctive - highly gregarious and social, with increased empathy and overfriendliness.

Although they always happy they are actually anxiety-prone in non-social contexts.
Disorders with social behaviour dysfunction

Angelman and Prader-Willi syndromes:

Complex genetic disorders causing mental retardation, growth and motor problems

Both result from abnormalities in a region of chromosome 15
Disorders with social behaviour dysfunction

They are associated with imprinted genes:

Prader-Willi involves loss of paternally expressed genes

Angelman involves loss of maternally expressed genes - notably UBE3A
Disorders with social behaviour dysfunction

Angelman syndrome is associated with excessively happy, smiling demeanour and inappropriate laughter.

Prader-Willi syndrome is associated with temper tantrums and obsessive compulsive mannerisms.
Disorders with social behaviour dysfunction

Sexual conflict theory?
Sexual conflict theory?

Mice lacking UBE3A gene have cognitive problems and abnormal brain EEG

Miura et al 2002
Epigenetic contributions to social behaviour

Effects of maternal nurturing behaviour

Meaney et al
Epigenetic contributions to social behaviour

Effects of maternal nurturing behaviour

Low nurturing experience causes higher stress response

Prevented by cross-fostering

Only affected during first week after birth

Dong Liu et al 1997
Epigenetic contributions to social behaviour

Mediated by altered epigenetic marks on the glucocorticoid receptor (GR) gene
Meaney and Szyf 2005
Epigenetic contributions to social behaviour

Mediated by altered epigenetic marks on the glucocorticoid receptor (GR) gene
Meaney and Szyf 2005

Methylation across the GR promoter region increased in low nurtured animals
Epigenetic contributions to social behaviour

Removing epigenetic marks with a histone deacetylase inhibitor, trichostatin A, reverses behavioural effects

Weaver et al 2004 and 2006
Epigenetic contributions to social behaviour

The critical component of maternal nurturing is simple tactile stimulation
Epigenetic contributions to social behaviour

The critical component of maternal nurturing is simple tactile stimulation

This is at the heart of all social interactions and stimulated by pro-bonding peptides
Epigenetic contributions to social behaviour

The critical component of maternal nurturing is simple tactile stimulation

This is at the heart of all social interactions and stimulated by pro-bonding peptides

In many modern cultures mutual tactile stimulation has decreased
Other epigenetic effects?

Many social, anxiety and aggression traits that are strongly influenced by parental care in animals.
Other epigenetic effects?

Many social, anxiety and aggression traits that are strongly influenced by parental care in animals.

So parents may alter the life-long social behaviour of their offspring through promoting epigenetic changes.

A sobering thought perhaps for both parents and children.
The future of human social behaviour?

Social behaviour is highly flexible and vulnerable to mutation and cultural change
The future of human social behaviour?

There are many genetic disorders that impact on aspects of sociability.
The future of human social behaviour?

Many species can switch between social and asocial phenotypes by changing a single gene.
The future of human social behaviour?

If we adopt a progressively asocial lifestyle it could quickly become an inherited trait.
The future of human social behaviour?

Anti-social behaviour patterns are on the increase and pro-social ones on the decrease.
The future of human social behaviour?

Are we moving towards individual rather than societal based cultures?
The future of human social behaviour?

Family, local, national and global boundaries are becoming blurred and resources easier to obtain.
The future of human social behaviour?

Co-operation is more about joining forces for resource acquisition than for reproductive support.
The future of human social behaviour?

Social altruism is an expensive form of co-operation!
Some final conclusions

Social behaviours improve reproductive fitness...

...and are under strong genetic control

Even co-operation and altruism have genetic components

Both genetic and epigenetic mechanisms are involved
Some final conclusions

Parental influences play a key role in epigenetic effects

Touch during early social interactions may be important

Single gene deletions and polymorphisms can have major effects
There are many human genetic disorders with altered social behaviour

Many other species can switch from being asocial to social
Some final conclusions

It would be relatively easy for humans to evolve into an asocial species...
Some final conclusions

It would be relatively easy for humans to evolve into an asocial species...

Evolution of man...

...or has it already happened?