The genetics of behavior

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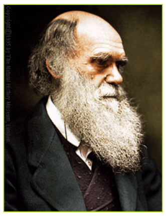
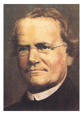
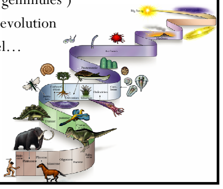
sneaky Who's Who



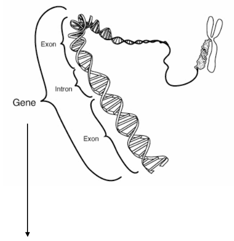
Charles Darwin

- Born February 12, 1809
- Dropped out of medical school at 18
- Graduated from the University of Cambridge at 22 (degree in theology)
- Voyage of the Beagle (1931-1936)
- *On the Origin of Species* (1859)
- Natural selection ('gemmules')
- Unifying theory of evolution
- Along came Mendel…

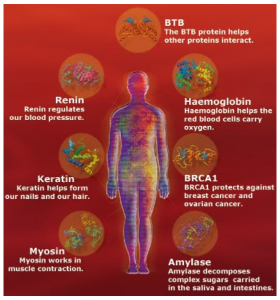




What are genes?



mRNA → proteins



BTB
The BTB protein helps other proteins interact.

Renin
Renin regulates our blood pressure.

Haemoglobin
Haemoglobin helps the red blood cells carry oxygen.

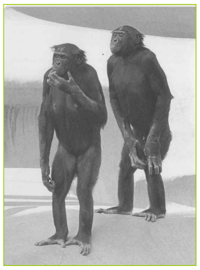
Keratin
Keratin helps form our nails and our hair.

BRCA1
BRCA1 protects against breast cancer and ovarian cancer.

Myosin
Myosin works in muscle contraction.

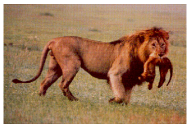
Amylase
Amylase decomposes complex sugars carried in the saliva and intestines.

Genetic basis for behavior



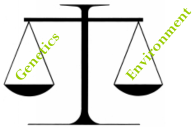
Bonobos (*Pan paniscus*)

1. Behavior is species specific
2. Behaviors often breed true
3. Behaviors change in response to alteration in DNA (i.e. genes)
4. Behavior shows phyletic relationships
5. In humans, some behaviors run in families



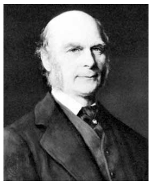
Nature and nurture

- (Most) behaviors have a genetic basis
- How much of behavior is influenced by genetics?
- By the environment?

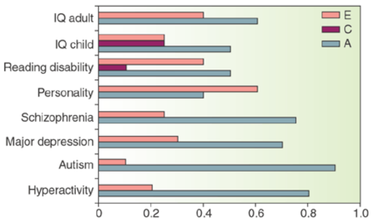


Behavioral genetics

- Sir Francis Galton: *Hereditary Genius* (1869)
- *"A man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical features of the whole organic world."*
- Searched for Darwin's gemmules
- Behaviors involve multiple genes (quantitative traits)
- Difficult to isolate individual genes
- Quantifying heritability



Heritability of human behavioral traits

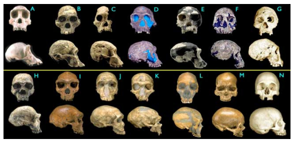


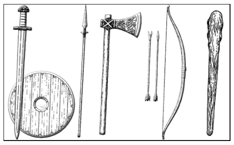
Identical twins end up similar even when reared apart.

P. McGuffin, B. Riley, R. Plomin, *Science*, **291**, 1232-1249 (2001)

The complexities of human behavior

- Non-Darwinian heritability
- Language
- Culture
- Memes

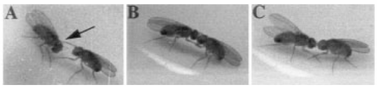




Genetics and animal behavior

- The evolution of adaptive behavior
- How do genes influence behavior?

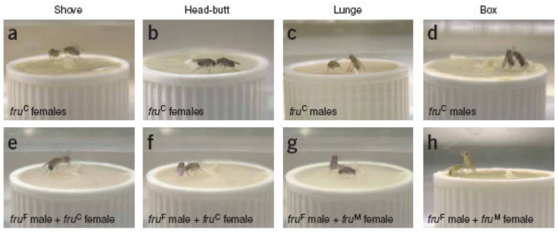
Method 1: Use of genetic mutants



fru (*fruitless*) mutant males show intense head-to-head interactions.

G. Lee, J.C. Hall, *Behavior Genetics*, **30**, 263-275 (2000)

More *fru* mutants…



The *fru* gene plays an important role in determining dominance relationships in drosophila.

E. Vrontou, S.P. Nilsen, E. Demir, E.A. Kravitz, B.J. Dickson, *Nature Neuroscience*, **9**, 1469-1471 (2006)

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fosB and nurturing behavior in mice

Wild-type female

fosB mutant female

The *fosB* gene plays an important role in nurturing behavior of female mice.

J.R. Brown, H. Ye, R.T. Bronson, P. Dikkes, M.E. Greenberg, *Cell*, **86**, 297-309 (1996)

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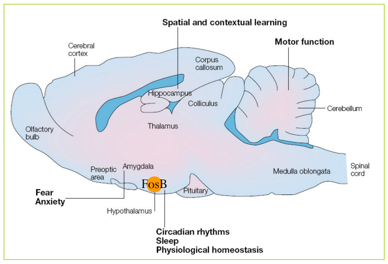
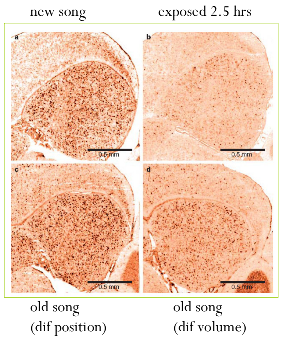
fosB on the brain

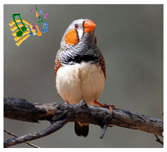


Nurturing behavior in mammals has a genetic component.

M. Bucan, T. Abel, *Nature Reviews*, 3, 114-123 (2002)

Zenk and song learning in finches





The expression of *zenk* influences song learning in zebra finches.

A.A. Kruse, R. Stripling, D.F. Clayton, *Neurobiol. Learn. Mem.* **82**, 91-108 (2004)

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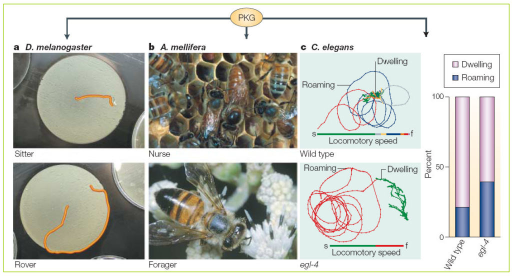
for, *amfor*, and *egl-4* orthologs

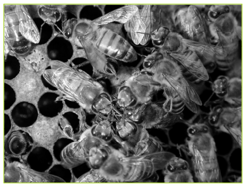


Some gene-to-behavior pathways are highly conserved.

G.E. Robinson, C.M. Grozinger, C.W. Whitfield, *Nature Reviews*, **6**, 257-270 (2005)

Genetics and insect sociality

- Haplodiploidy
- Haploid males, diploid females
- Females (r=0.75)
- Female and daughter (r=0.5)
- Br – C > 0
- Kin selection
- Worker sterility
- Eusociality



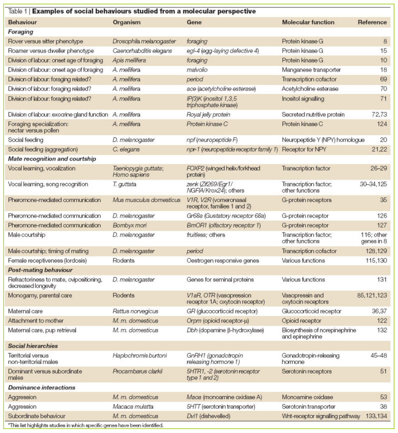
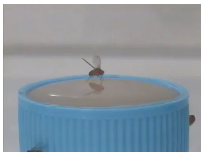


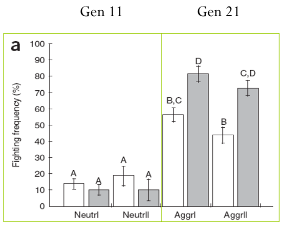
Table 1 | **Examples of social behaviours studied from a molecular perspective**

Behaviour	Organism	Gene	Molecular function	Reference
Foraging				
Rover versus sitter phenotype	*Drosophila melanogaster*	*foraging*	Protein kinase G	8
Roamer versus dweller phenotype	*Caenorhabditis elegans*	*egl-4* (*egg-laying defective 4*)	Protein kinase G	15
Division of labour: onset age of foraging	*Apis mellifera*	*foraging*	Protein kinase G	10
Division of labour: onset age of foraging	*A. mellifera*	*malvolio*	Manganese transporter	18
Division of labour: foraging related?	*A. mellifera*	*period*	Transcription cofactor	69
Division of labour: foraging related?	*A. mellifera*	*ace* (*acetylcholine esterase*)	Acetylcholine esterase	70
Division of labour: foraging related?	*A. mellifera*	*IP(3)K* (*inositol 1,3,5 triphosphate kinase*)	Inositol signalling	71
Division of labour: exocrine gland function	*A. mellifera*	*Royal jelly protein*	Secreted nutritive protein	72,73
Foraging specialization: nectar versus pollen	*A. mellifera*	*Protein kinase C*	Protein kinase C	124
Social feeding	*D. melanogaster*	*npf* (*neuropeptide F*)	Neuropeptide Y (NPY) homologue	20
Social feeding (aggregation)	*C. elegans*	*npr-1* (*neuropeptide receptor family 1*)	Receptor for NPY	21,22
Mate recognition and courtship				
Vocal learning, vocalization	*Taeniopygia guttata*; *Homo sapiens*	*FOXP2* (winged helix/forkhead protein)	Transcription factor	26–29
Vocal learning, song recognition	*T. guttata*	*zenk* (*Zif269/Egr1/ NGFIA/Krox24*); others	Transcription factor; other functions	30–34,125
Pheromone-mediated communication	*Mus musculus domesticus*	*V1R, V2R* (vomeronasal receptor, families 1 and 2)	G-protein receptors	35
Pheromone-mediated communication	*D. melanogaster*	*Gr68a* (*Gustatory receptor 68a*)	G-protein receptor	126
Pheromone-mediated communication	*Bombyx mori*	*BmOR1* (*olfactory receptor 1*)	G-protein receptor	127
Male courtship	*D. melanogaster*	*fruitless;* others	Transcription factor; other functions	116; other genes in 8
Male courtship; timing of mating	*D. melanogaster*	*period*	Transcription cofactor	128,129
Female receptiveness (lordosis)	Rodents	Oestrogen responsive genes	Various functions	115,130
Post-mating behaviour				
Refractoriness to mate, ovipositioning, decreased longevity	*D. melanogaster*	Genes for seminal proteins	Various functions	131
Monogamy, parental care	Rodents	*V1aR, OTR* (vasopression receptor 1A; oxytocin receptor)	Vasopressin and oxytocin receptors	85,121,123
Maternal care	*Rattus norvegicus*	*GR* (glucocorticoid receptor)	Glucocorticoid receptor	36,37
Attachment to mother	*M. m. domesticus*	*Orpm* (opioid receptor-μ)	Opioid receptor	122
Maternal care, pup retrieval	*M. m. domesticus*	*Dbh* (dopamine β-hydroxylase)	Biosynthesis of norepinephrine and epinephrine	132
Social hierarchies				
Territorial versus non-territorial males	*Haplochromis burtoni*	*GnRH1* (*gonadotropin releasing hormone 1*)	Gonadotropin-releasing hormone	45–48
Dominant versus subordinate males	*Procambarus clarkii*	*5HTR1, -2* (*serotonin receptor type 1 and 2*)	Serotonin receptors	51
Dominance interactions				
Aggression	*M. m. domesticus*	*Maoa* (monoamine oxidase A)	Monoamine oxidase	53
Aggression	*Macaca mulatta*	*5HTT* (serotonin transporter)	Serotonin transporter	38
Subordinate behaviour	*M. m. domesticus*	*Dvl1* (dishevelled)	Wnt-receptor signalling pathway	133,134

*This list highlights studies in which specific genes have been identified.

Method 2: Artificial selection experiments



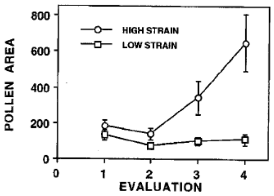


Aggressive behavior can be selected for in drosophila.

H.A. Dierick, R.J. Greenspan, *Nature Genetics*, **6**, 1023-1031 (2006)

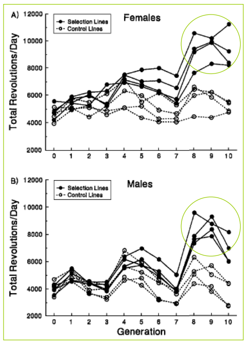
Selection for pollen hoarding in honey bees

http://pdphoto.org/PictureDetail.php?pg=8042



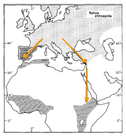
R.E. Page, M.K. Fondrk, *Behav Ecol* Sociobiol, **36**, 135-144, (1995)

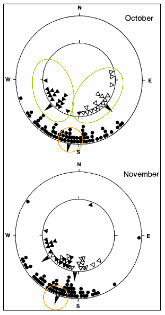
Selection for increased wheel-running behavior



J.G. Swallow, P.A. Carter, T. Garland, *Behavior Genetics*, **28**, 227-237 (1998)

Method 3: Studying populations with genetic differences

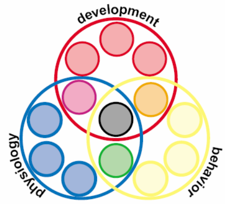




Provided direct evidence for a genetic basis of migratory directions in birds.

A.J. Helbig, *Behav Ecol* Sociobiol, 28, 9-12 (1991)

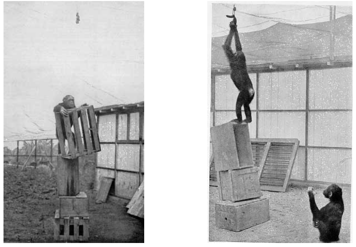
Genes —— ? ——→ Behavior



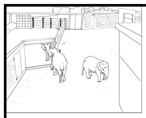
How to behave. Inclusive model of the genetic contribution to behavioral phenotype

J.S. de Belle, *Nature Genetics*, **31**, 1-2, (2002)

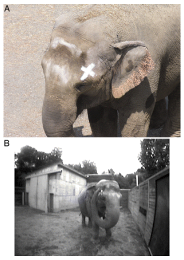
How about these behaviors?

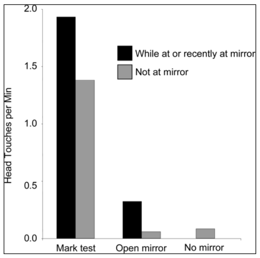


Kohler's experiments on chimpanzees

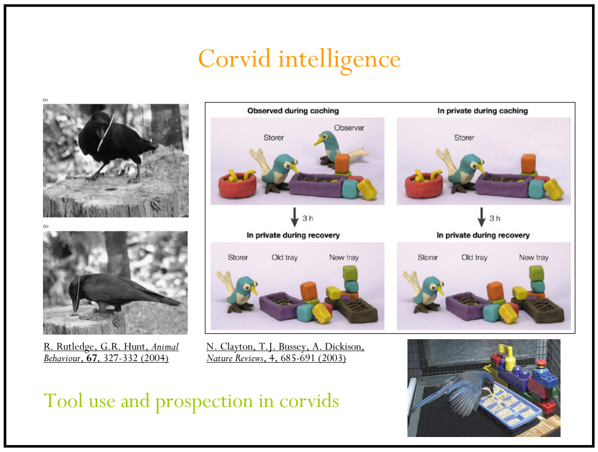


Self-awareness in elephants





J.M. Plotnik, F.B.M. de Waal, D. Reiss, *PNAS*, 103, 17053-17057 (2006)

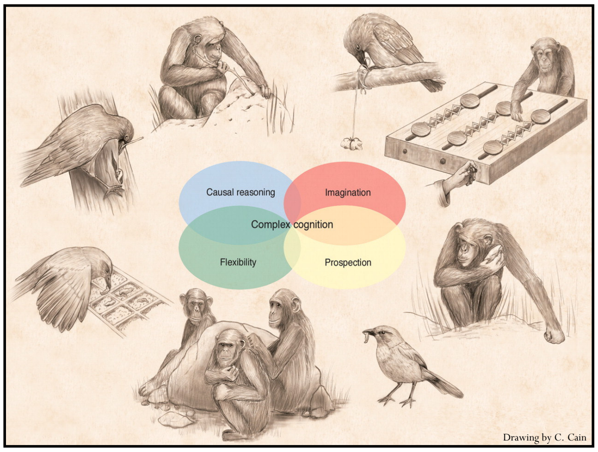


Corvid intelligence

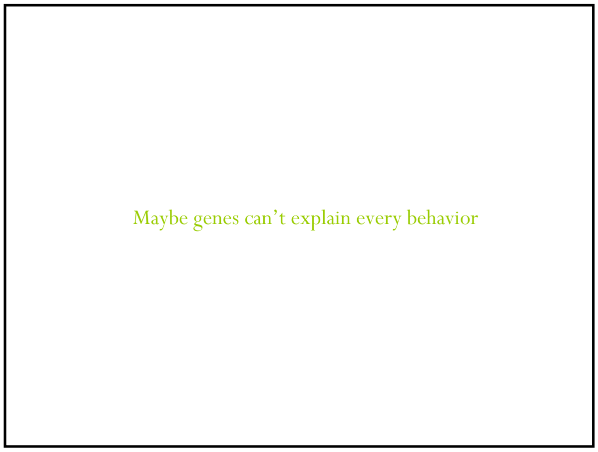
R. Rutledge, G.R. Hunt, *Animal Behaviour*, **67**, 327-332 (2004)

N. Clayton, T.J. Bussey, A. Dickison, *Nature Reviews*, 4, 685-691 (2003)

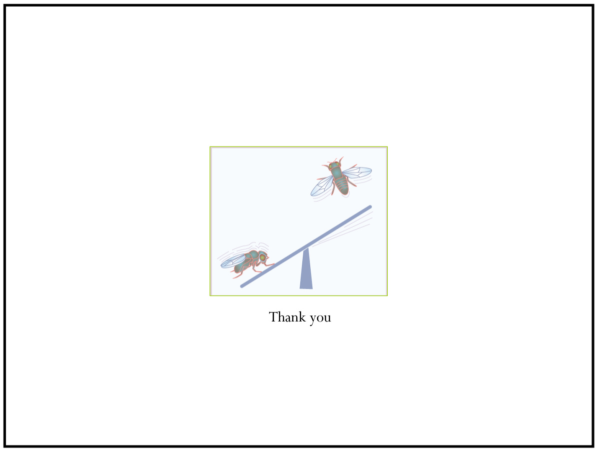
Tool use and prospection in corvids



Drawing by C. Cain



Maybe genes can’t explain every behavior



Thank you