LENScience CONNECT
Bringing Schools and Scientists Together

NATIONAL RESEARCH CENTRE FOR GROWTH AND DEVELOPMENT

LENScience Senior Biology Seminar Series 2011

The Evolving Brain: social interaction and complexity

Peter Gluckman, Alan Beedle, Tatjana Buklijas and Jacquie Bay

2 June 2011

LIGGINS INSTITUTE
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

kordia
people & technology as one

THE UNIVERSITY OF AUCKLAND
INFORMATION TECHNOLOGY SERVICES

The Evolving Brain

Communication
Intelligence
Technologies
Social Complexity
Cultural Complexity

NCEA Level 3 Achievement Standards

3.1 – Ecological Niche

3.2 –Contemporary Biological Issue

3.3 – DNA and Gene Expression

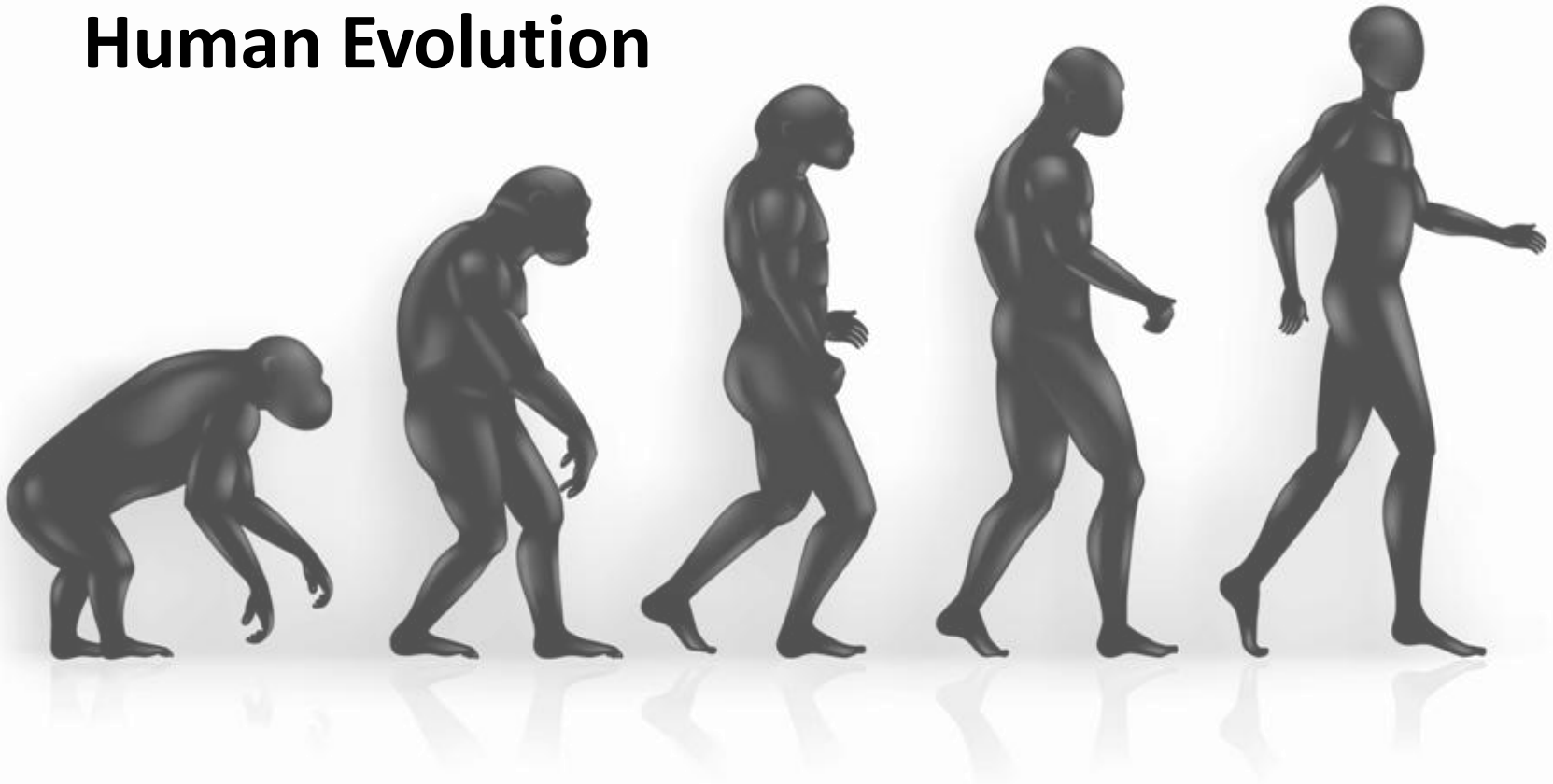
3.4 – Animal Behaviour & Plant Responses

3.5 – Processes & Patterns of Evolution

3.6 – Applications of biotechnological techniques

3.7 – Trends in Human Evolution

Human Evolution



The Evolving Brain

Biological, social and cultural

environments influence evolution

What is culture?

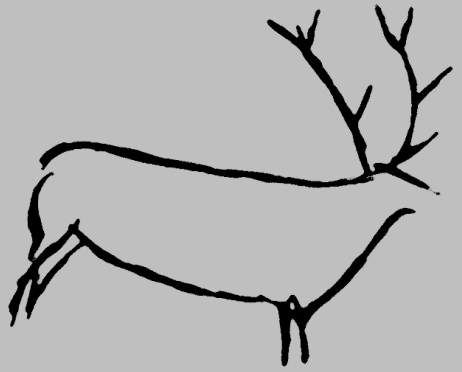
'Information capable of affecting individuals' behaviour that they acquire from other members of their species through teaching, imitation, and other forms of social transmission'

(Boyd & Richerson, *Not by genes alone*, 2005)

What is culture?

- *Skills*
- *Knowledge*
- *Beliefs*
- *Attitudes*
- *Values*

Cultural Evolution



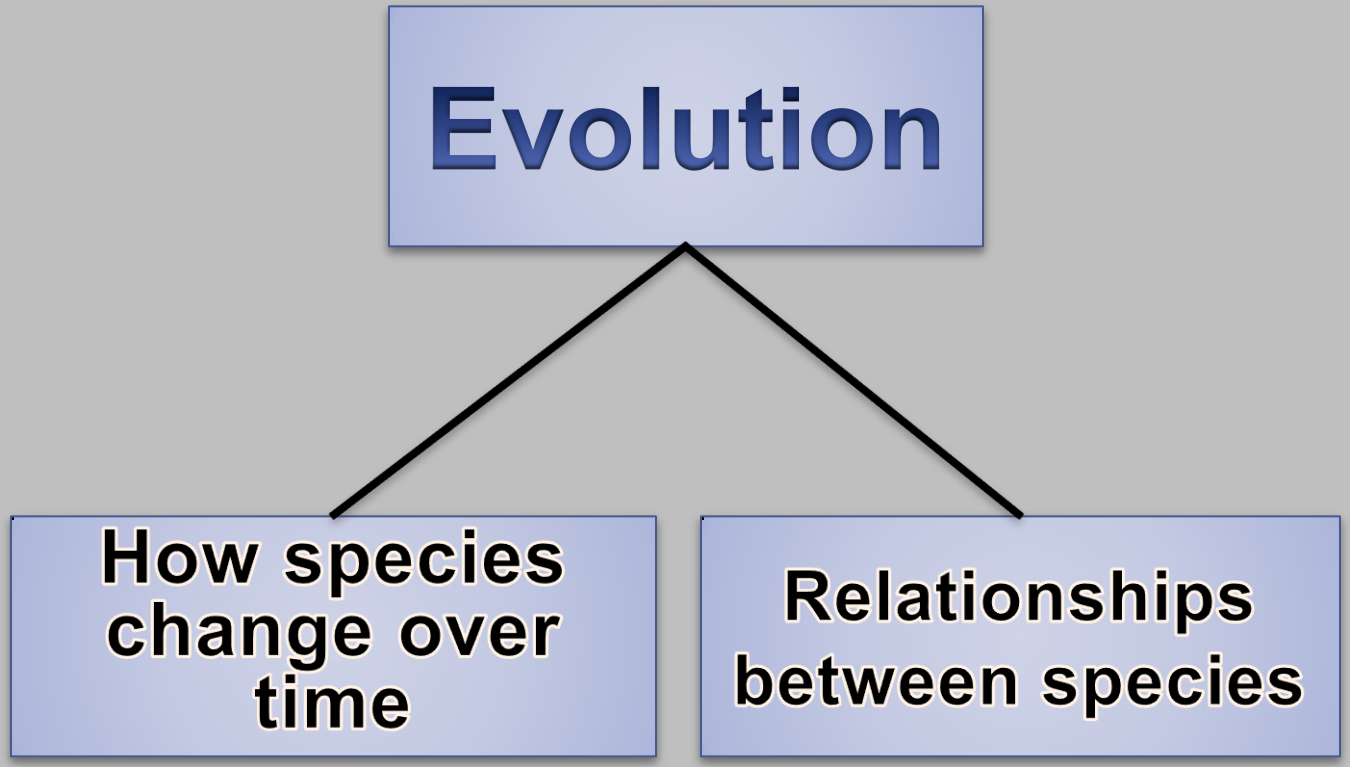
Biological versus Cultural Evolution

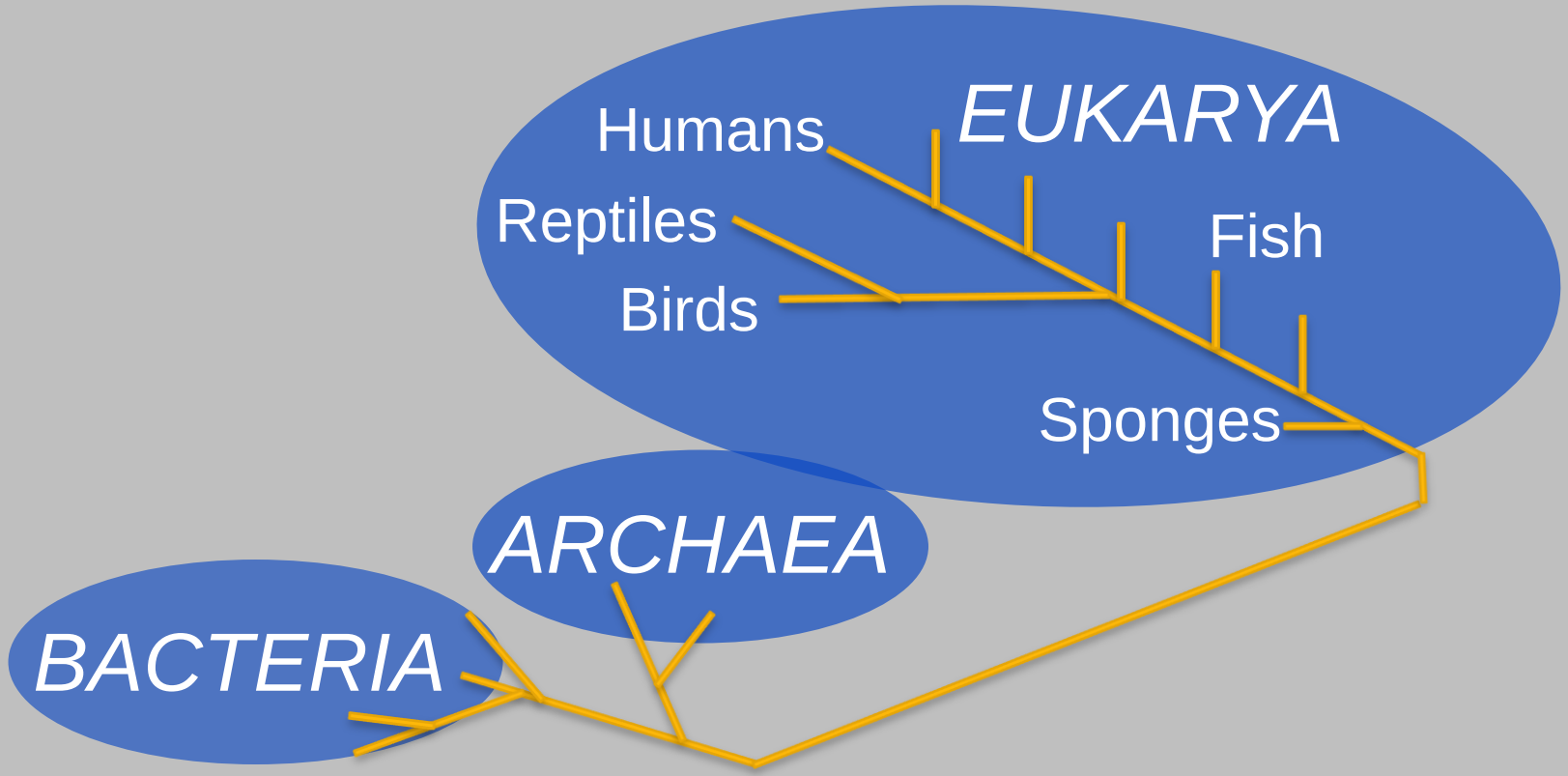
Biological

- Transmitted as genes
- Natural or sexual selection
- Fitness measure is reproductive success

Cultural

- Transmitted by stories, books, films, music
- Societal preference selects
- Fitness measure is utility or aesthetics


Evolution
How species change over time
Relationships between species


EUKARYA
Humans
Reptiles
Birds
Fish
Sponges
ARCHAEA
BACTERIA

How does evolution work?

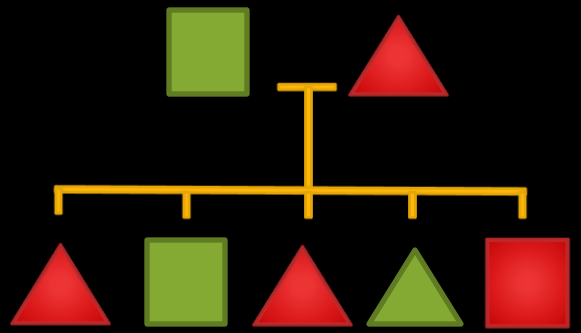
- Species tend to produce more offspring than the resources available can support

How does evolution work?

- Offspring
- Individual variation affects survival

How does evolution work?

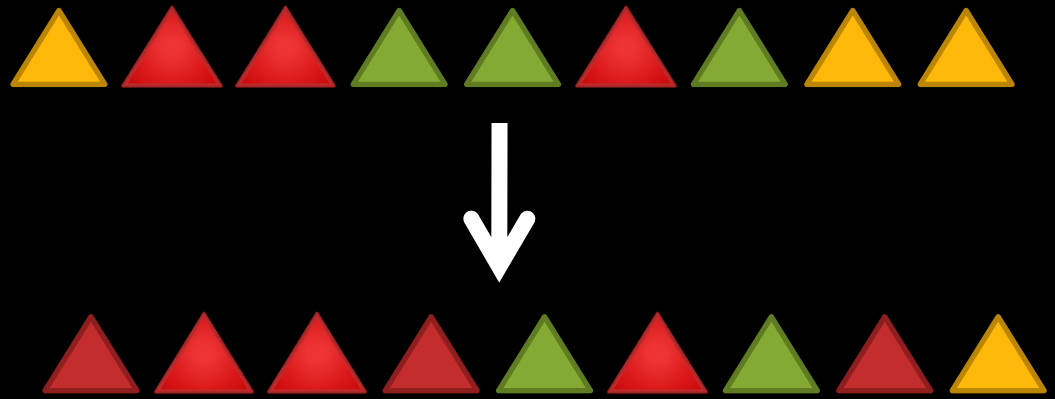
- Offspring
- Variation
- Inheritance



Some variation is heritable

How does evolution work?

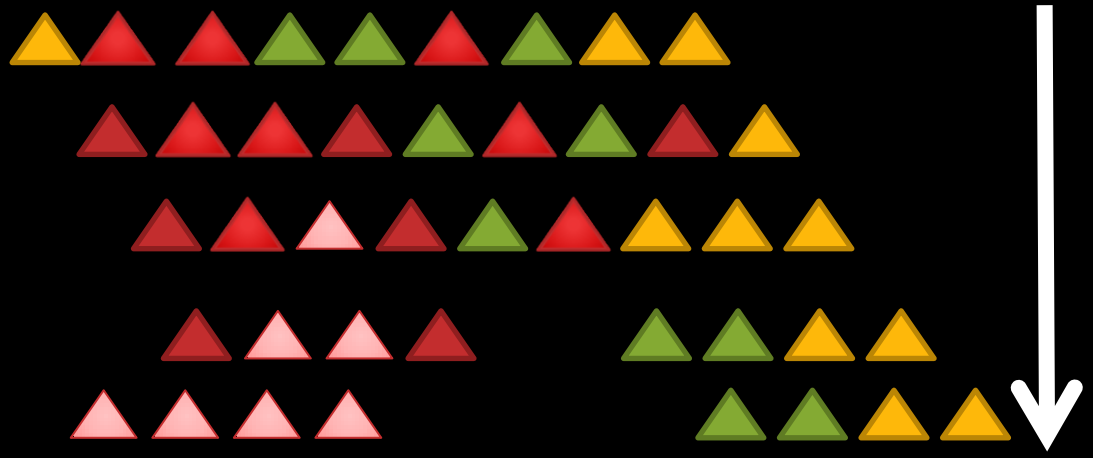
- Offspring
- Variation
- Inheritance
- Selection



Differential survival & reproduction

How does evolution work?

- Offspring
- Variation
- Inheritance
- Selection
- Evolution



Selection over generations leads to genetic change

How does evolution work?

- A **trait** is a particular characteristic of the phenotype

How does evolution work?

- **Fitness** is the ability of an organism to survive and reproduce in its current environment
- Fitness is defined as number of reproducing offspring

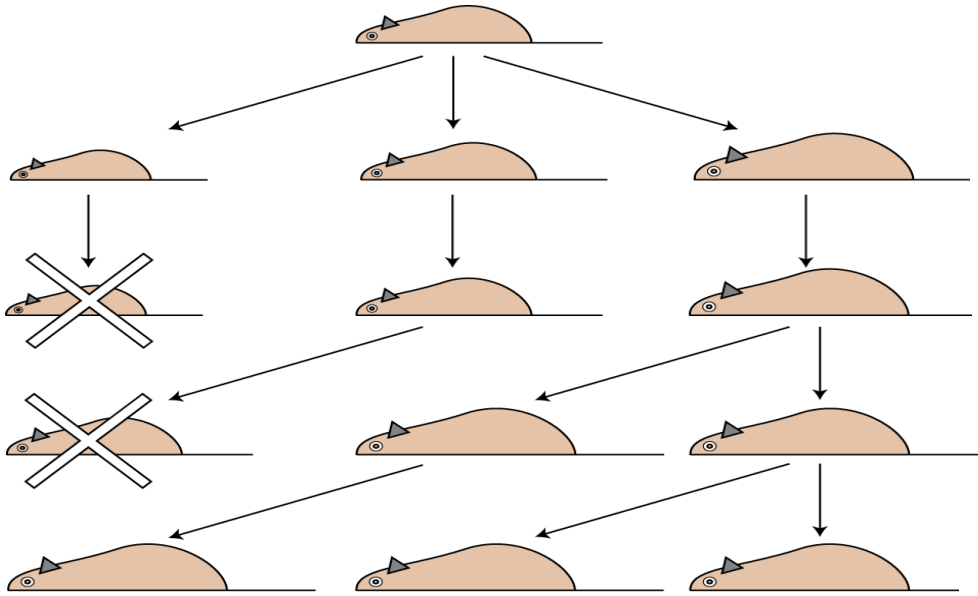
How does evolution work?

Evolved traits that contribute to fitness are called **adaptations**

Types of selection

- Natural selection
- Sexual selection
- Artificial selection

Natural Selection



Mutation causes variation in body size

Smaller body size selected against

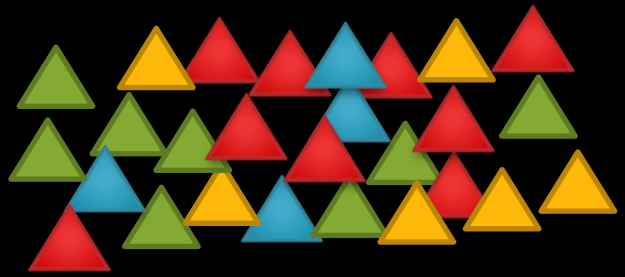
Population evolved to larger body size

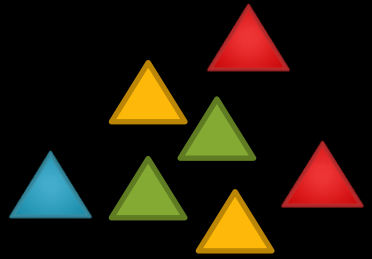
Sexual Selection

Artificial Selection

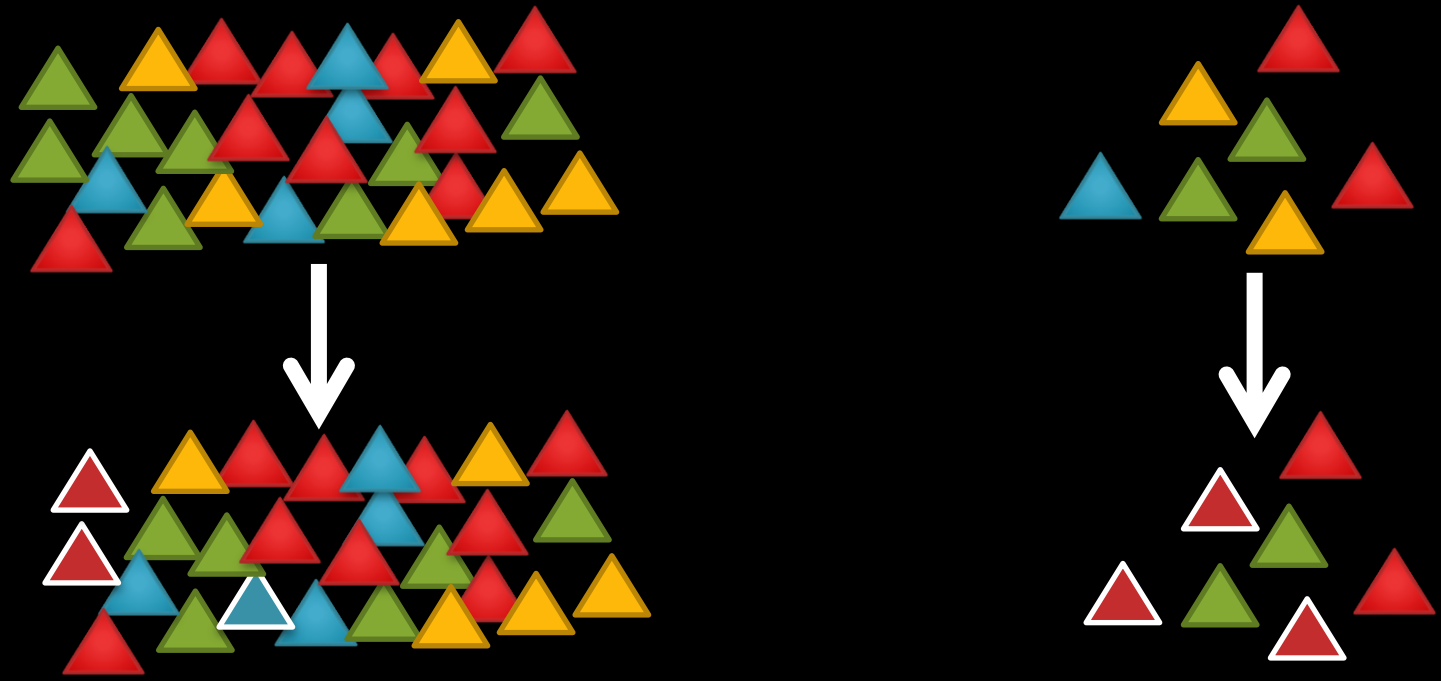
Is selection the only mechanism of evolution?

Genetic drift – random change

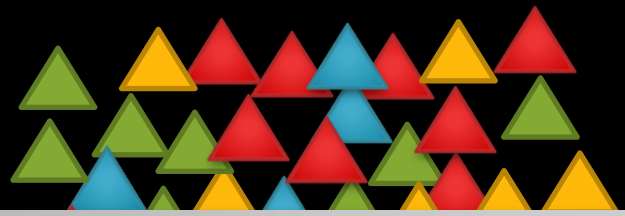




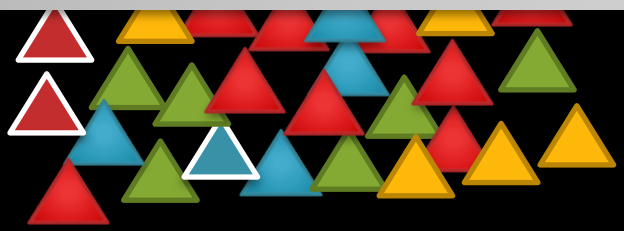
Genetic drift – random change



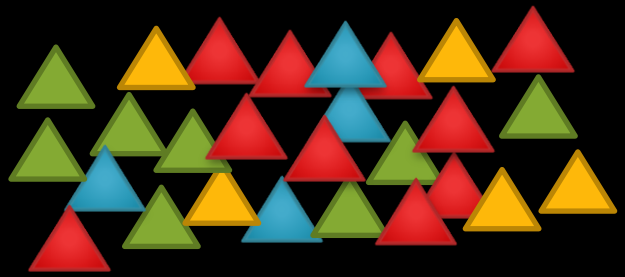
Genetic drift – random change



Effect of random change is more significant in small populations



Population Bottleneck



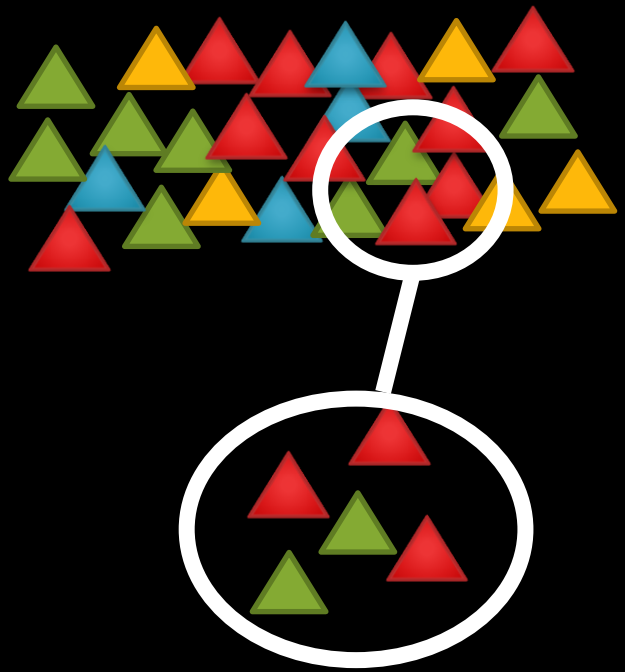
Original Population

Population Bottleneck

Disaster – disease / famine

Small surviving population

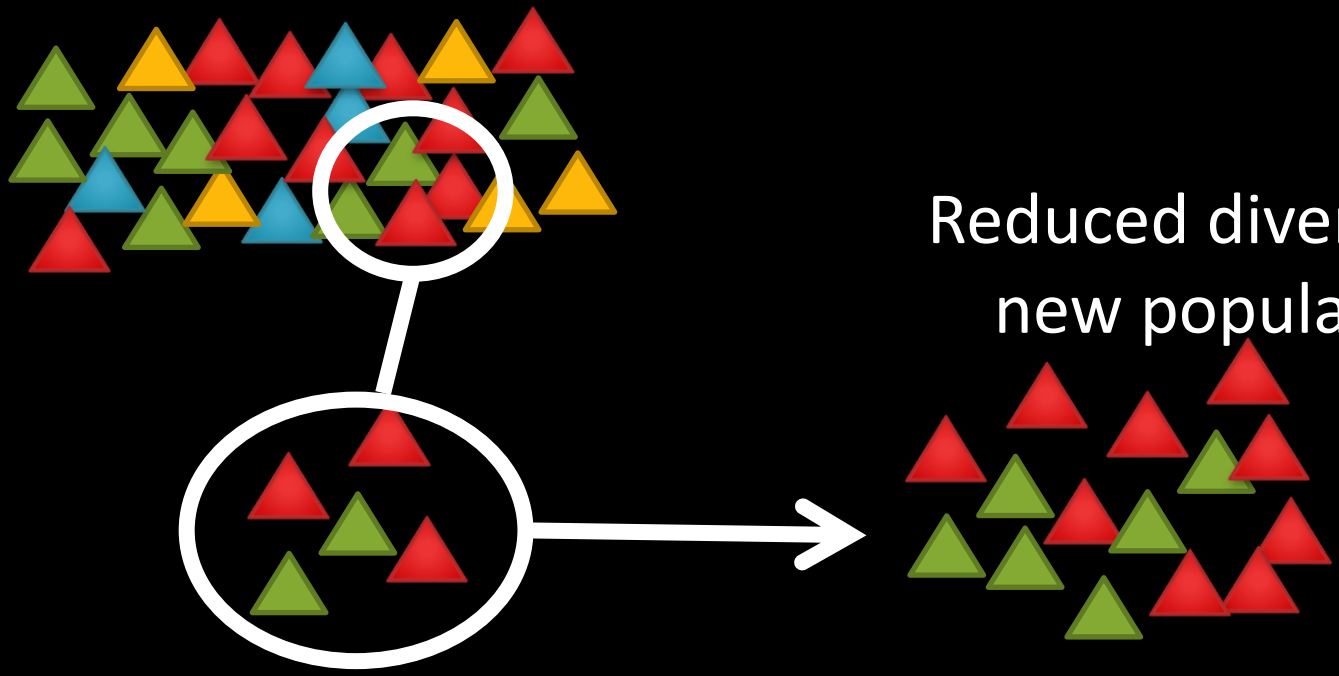
Population Bottleneck



Disaster – disease / famine

Small surviving population

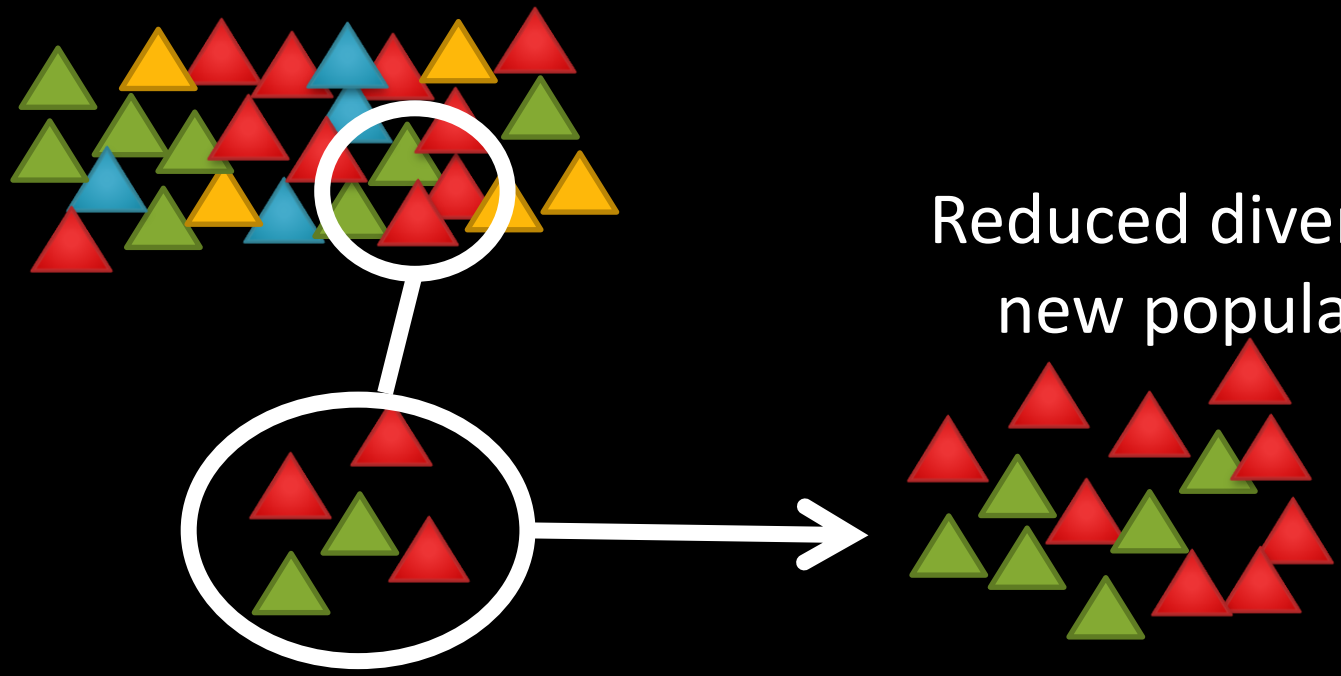
Population Bottleneck



Reduced diversity in new population

Attribution: Frances Scmechel Wikicommons

Founder Effect



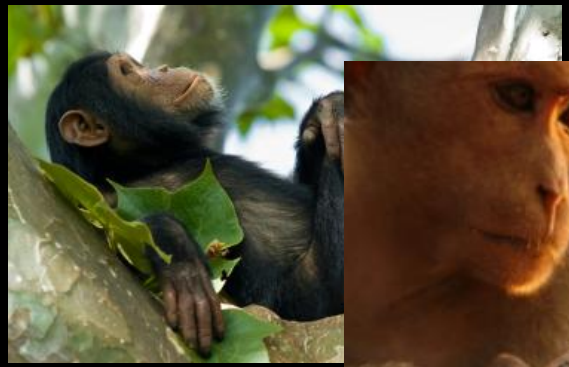
Reduced diversity in new population

The Hominoid Group

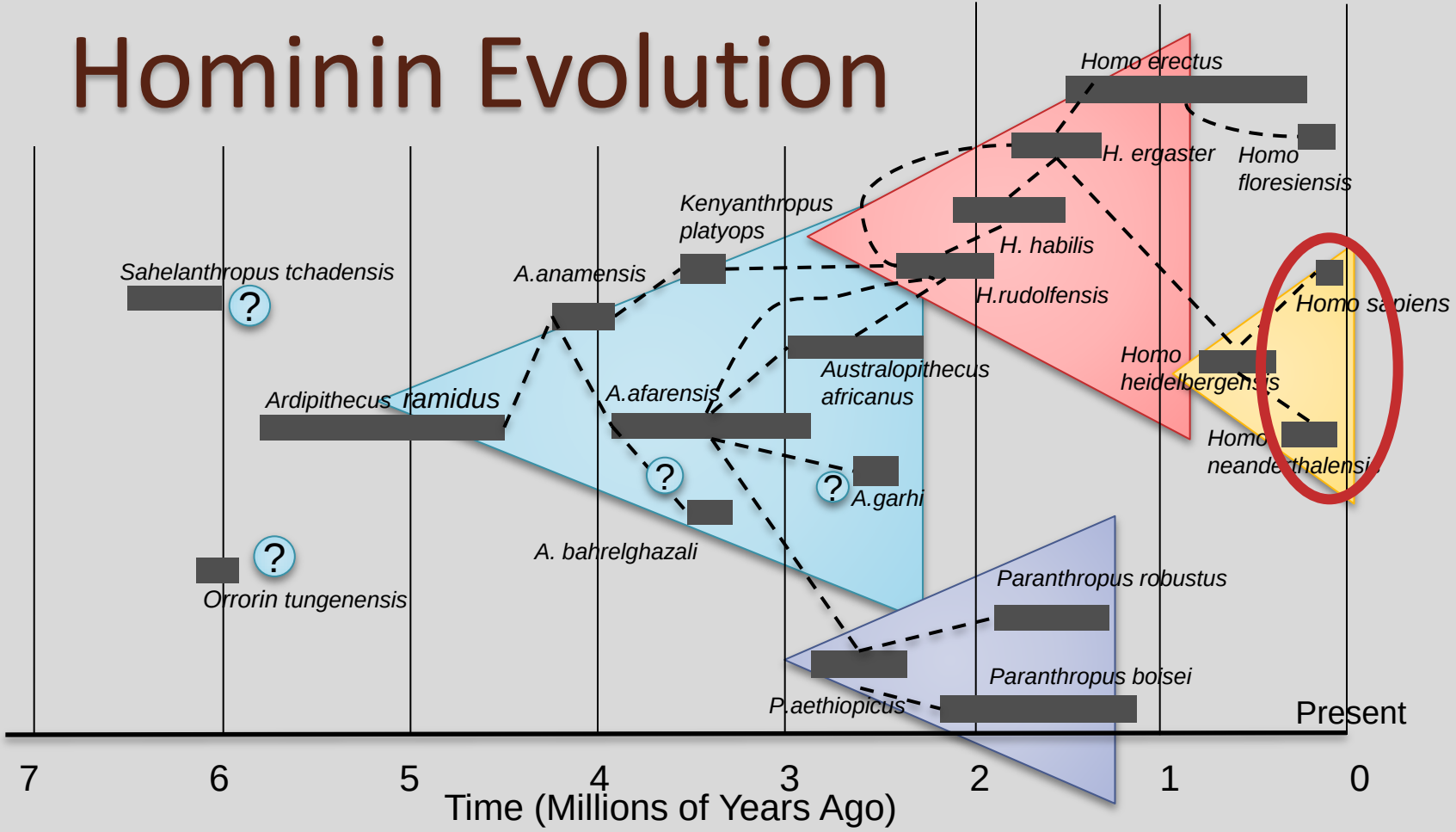
Hominoids

Great Apes

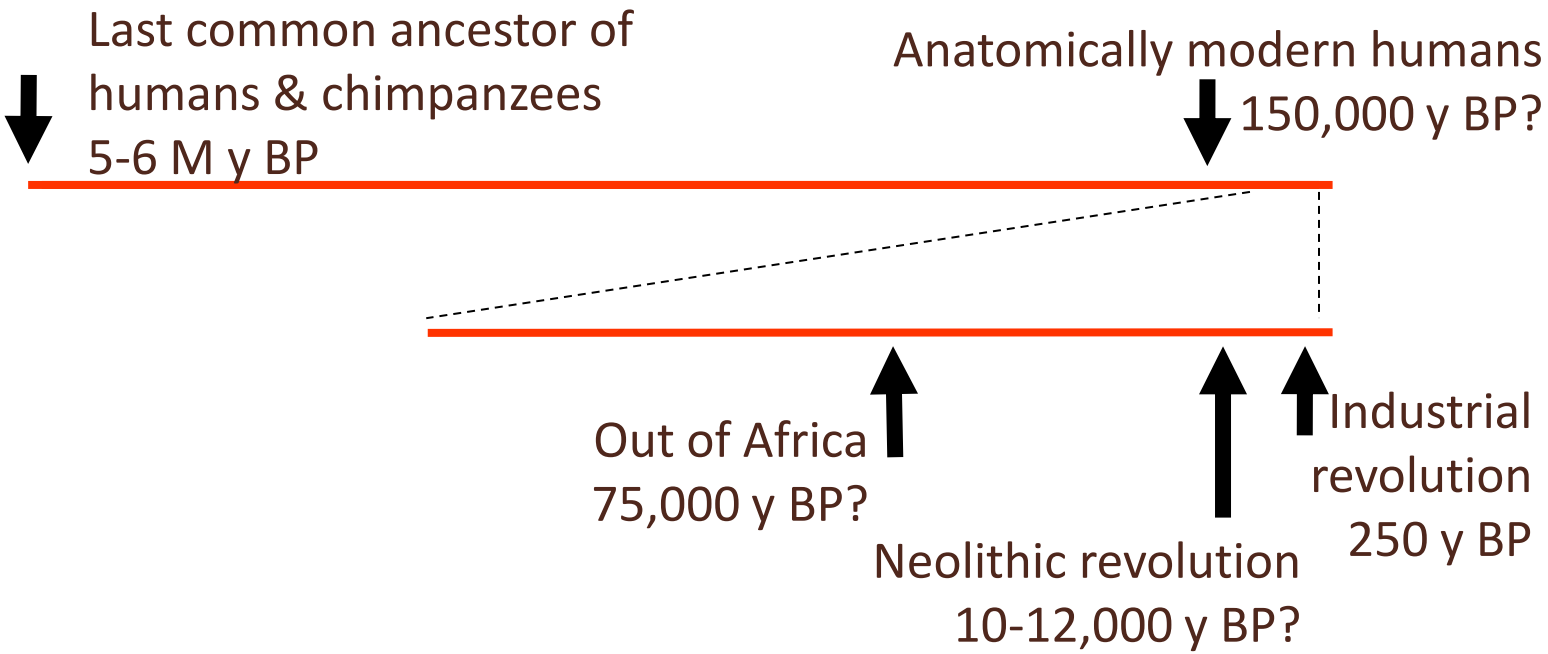
Hominins



Hominin Evolution

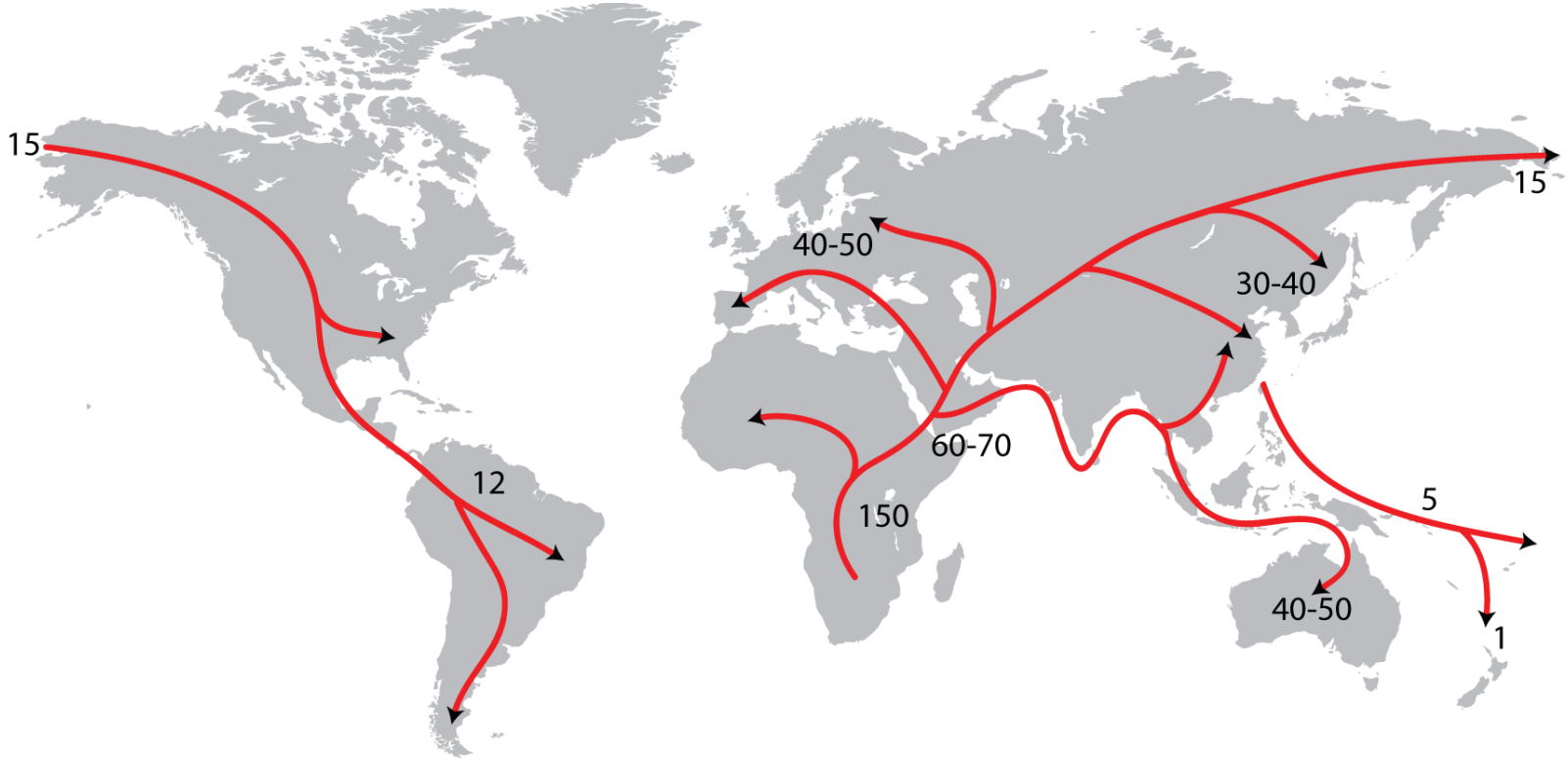


Timeline of human evolution



Routes of human migration

Numbers are thousands of years ago



EVOLUTION

of the

BRAIN

Advantages Arising from Brain Development

Social Structure

Communication of Abstract Thought

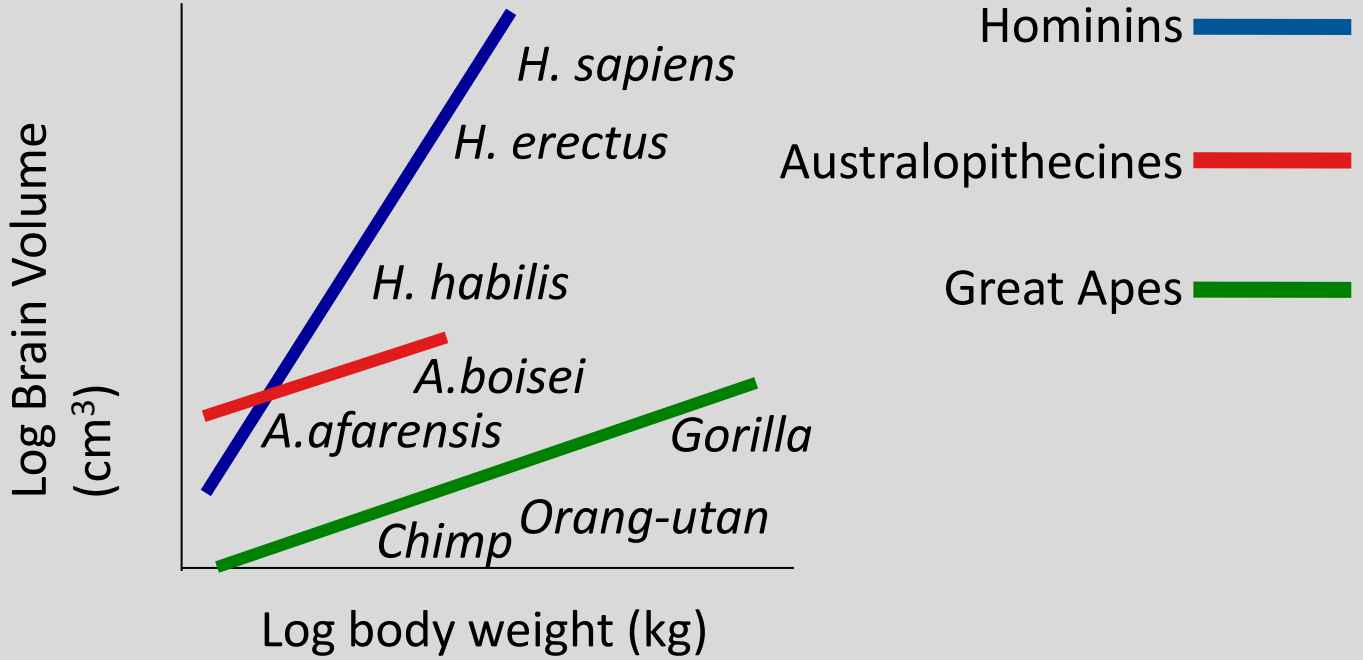
Communication / Language

Technology

Culture / Learning

Art / Religion / Music / Science

Brain volume change through hominin evolution



Redrawn from Bonner J.T., Why Size Matters. Princeton University Press 2006

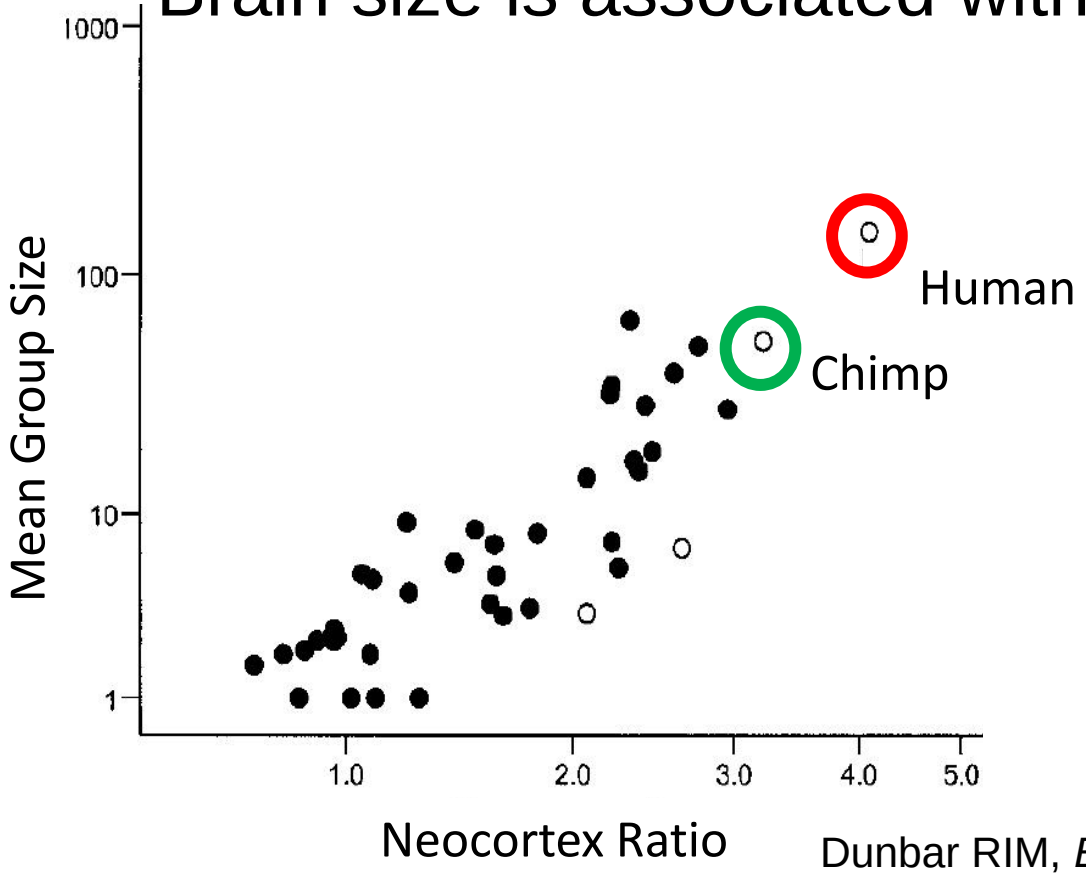
What drove the increase in brain size?

1. Individual solutions to ecological problems (tools, hunting)
2. Adaptive advantage of social communication

What drove the increase in brain size?

1. Individual solutions to ecological problems (tools, hunting)
2. **Adaptive advantage of social communication**

Brain size is associated with group size



Dunbar RIM, *Br Acad Rev* 2008;11:15-17.

The role of the Neocortex

Higher order functions

- sensory perception
- generation of motor commands
- spatial reasoning
- conscious thought
- language (humans only)

Human social groups	Size
Neolithic villages 7500 – 6500 BP	150-200
Roman army (military unit) 2000 BP	120-130
Hunter-gatherer societies	165
Church congregations	200
Social network	134
Christmas card distribution list	154

Advantages and challenges of living in large groups

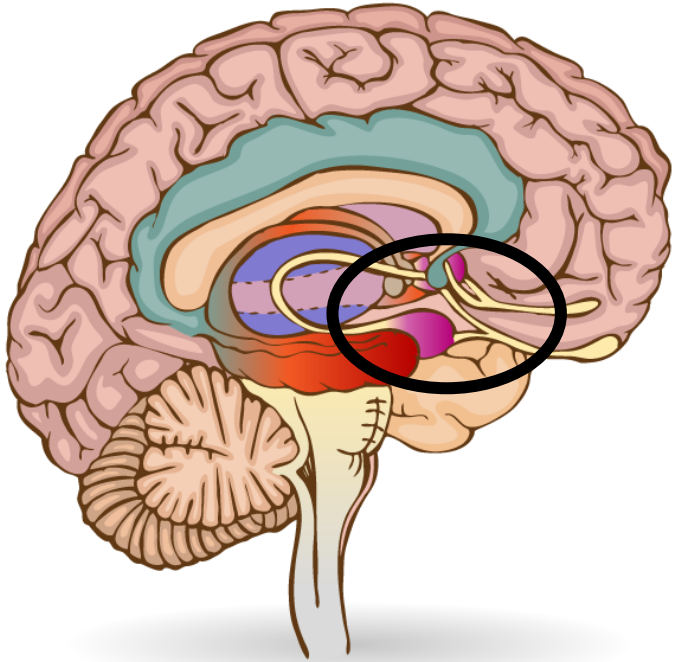
Advantages

- defence against predators
- food supply
- large pool of mating partners

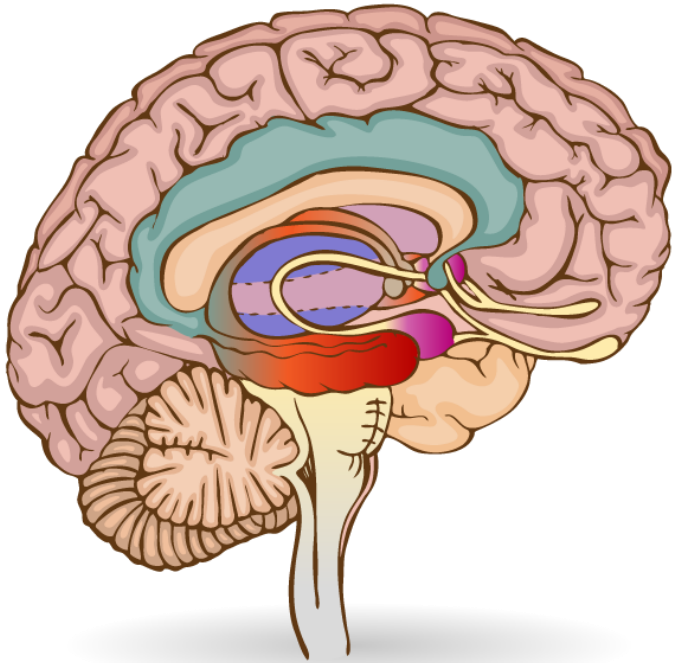
Demands

- complex dynamic among the individuals

Amygdala and the social brain



Amygdala and the social brain



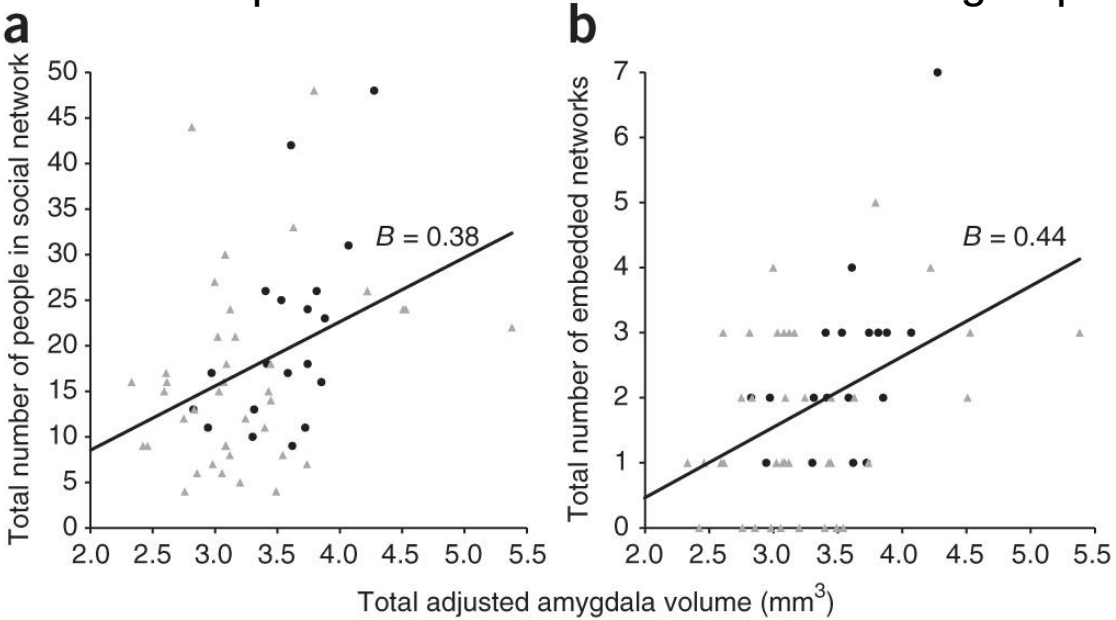
Increased amygdala size:

- Increased size of social networks
- Increase in social behaviour / play

Social group size, number of groups & amygdala volume

Group Size

Number of groups



Bickart KC, Amygdala volume and social network size in humans, *Nature Neuroscience* 2010, doi:10.1038/nn.2724

The social brain: why has living in large groups driven the brain size upwards?

- Developing effective and efficient forms of communication

The social brain: why has living in large groups driven the brain size upwards?

Social cognition:

- appreciation that another individual has a mind controlling its behaviour

The social brain: why has living in large groups driven the brain size upwards?

Social Cognition:

- alliances and friendships
- deception

Communication: evolution of the language

Grooming:

- Primates 20% of time
- Humans (groups size) 50% of time

Communication: evolution of the language

Vocalization

- wordless singing - *Homo erectus*

- origins of music

Attribution: José-Manuel Benito Álvarez wikicommons

Communication: evolution of the language

- Early social language (0.5 MYA)
- Grammatical speech (200 KY)


Why has living in large groups driven the brain size upwards?

Social cognition

Appreciation that another individual has a mind controlling their behaviour.

Theory of Mind

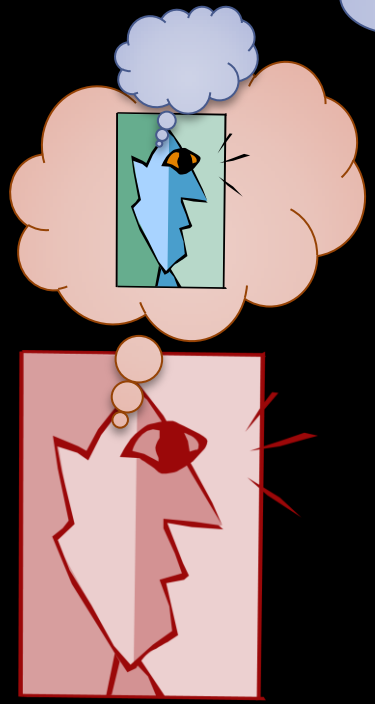
1. I know what I am thinking

2. And I think I know what you are thinking

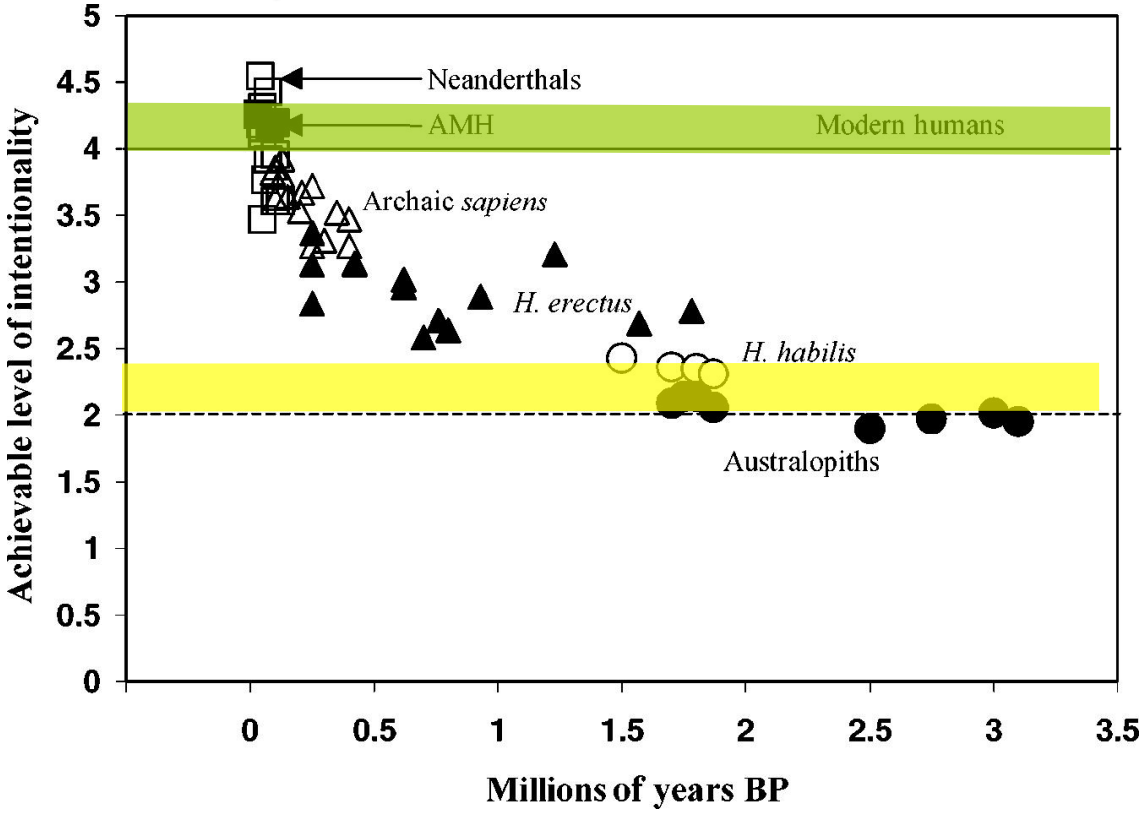
3. I think I know about what you are thinking about me

4. I think I know about what you are thinking about what I am thinking

5. I think I know what will happen if you don't respond in the way I want you to respond……



Intentionality Predictions for Ancestral Hominins



Evolution of social structure

Thinking about thinking increases the complexity of social structure

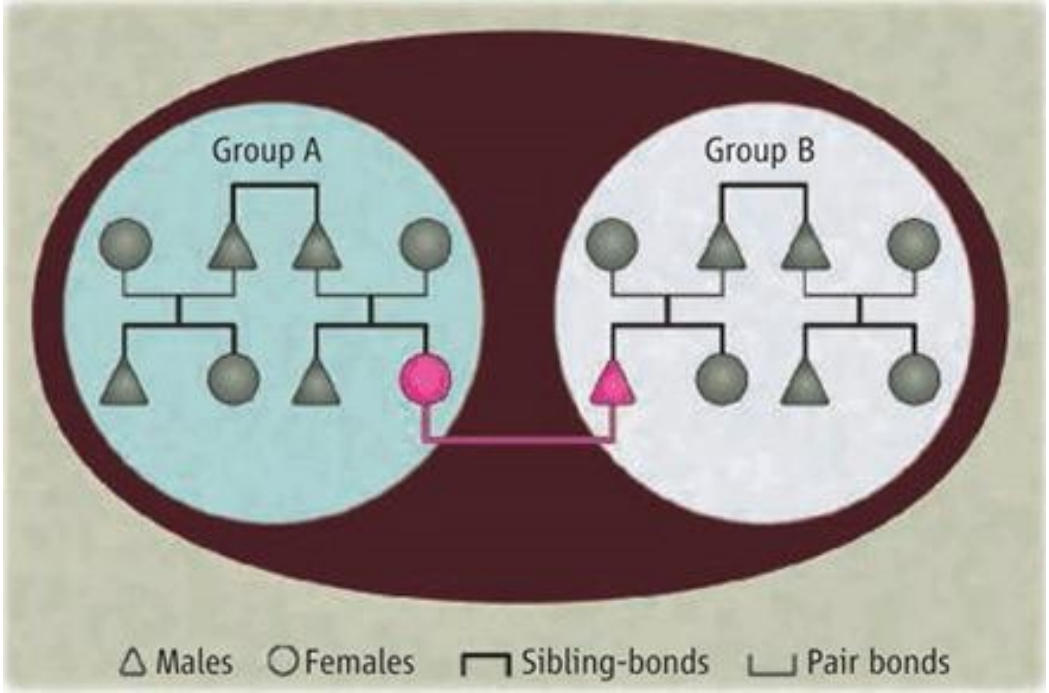
Evolution of human social structure

- Pair-bonding
- Either sex may disperse or remain in the original group
- Recognition of paternal as well as maternal line
- Co-residing adult siblings of opposite sexes

Evolution of human social structure

Human groups exist within multilevel, nested structures of alliances

Creating Human Societies



Science
AAAS

B Chapais Science 2011;331:1276-1277

Evolution of social behaviour

Social environment is a key element of our selective environment; selection favours traits that promotes fitness in the social environment of our evolution.

Evolution of social behaviour

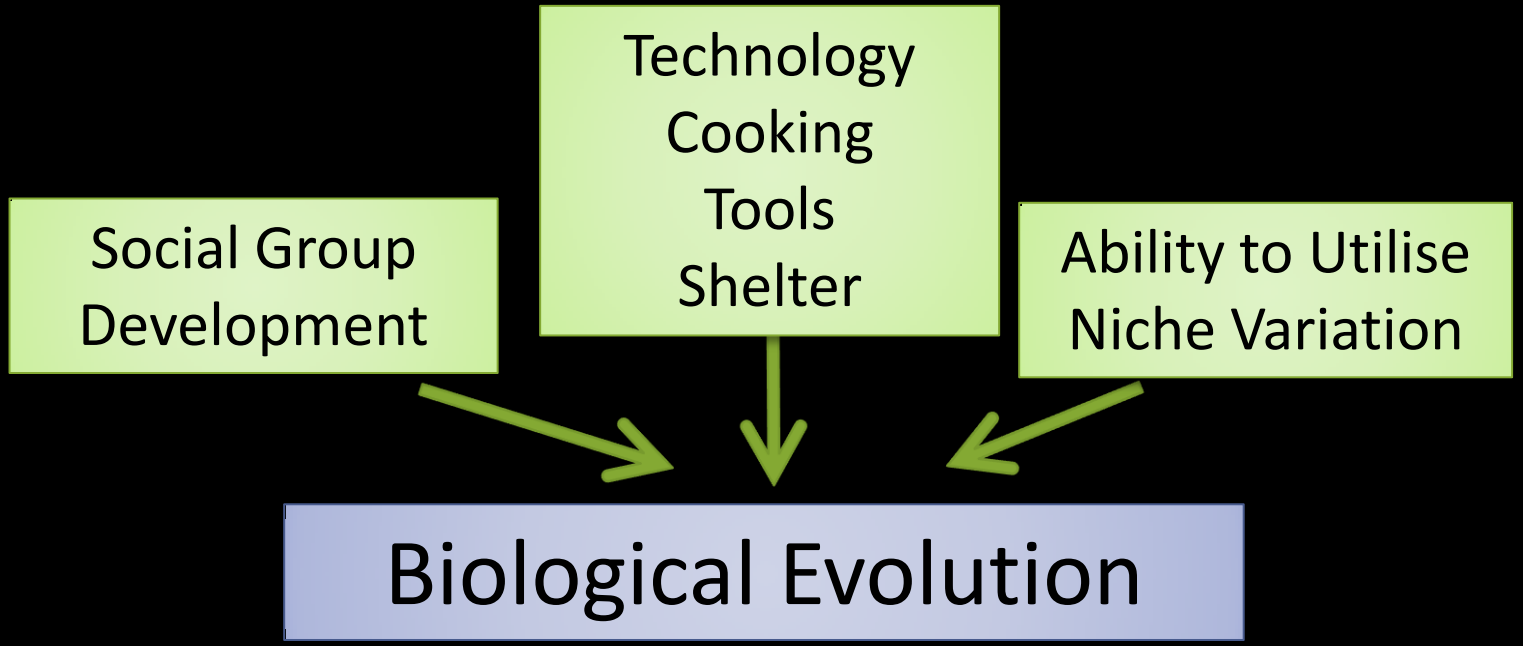
Human culture and biology have co-evolved.


If evolution operates on the individual, why do humans engage in socially beneficial behaviour?
Blood Donations
TODAY

Social Behaviour

- Kinship selection
- Reciprocal altruism
- Dealing with cheats and ‘free-loaders’
- Altruism
- Sexual selection

Interplay between cultural evolution and biological evolution



Cultural environment, social behaviour and social structure

The cultural environment may change much more rapidly than the biological environment and become maladaptive.

Modelling “devolution” to understand cultural evolution: the impact of social isolation

Modelling “devolution” to understand cultural evolution: the impact of social isolation

- Tasmania
- Human settlement 34,000 years ago
- Cut off from Australia 10-12,000 years ago

The impact of social isolation

Technological evolution stopped:

- lost the ability to manufacture and use bone tools (8000 – 3000 years ago)
- could not sew warm clothing
- lost the ability to catch bony and cartilaginous fish (5000 – 3800 years ago)

Can DEVOLUTION help us understand RAPIC CULTURAL EVOLUTION?

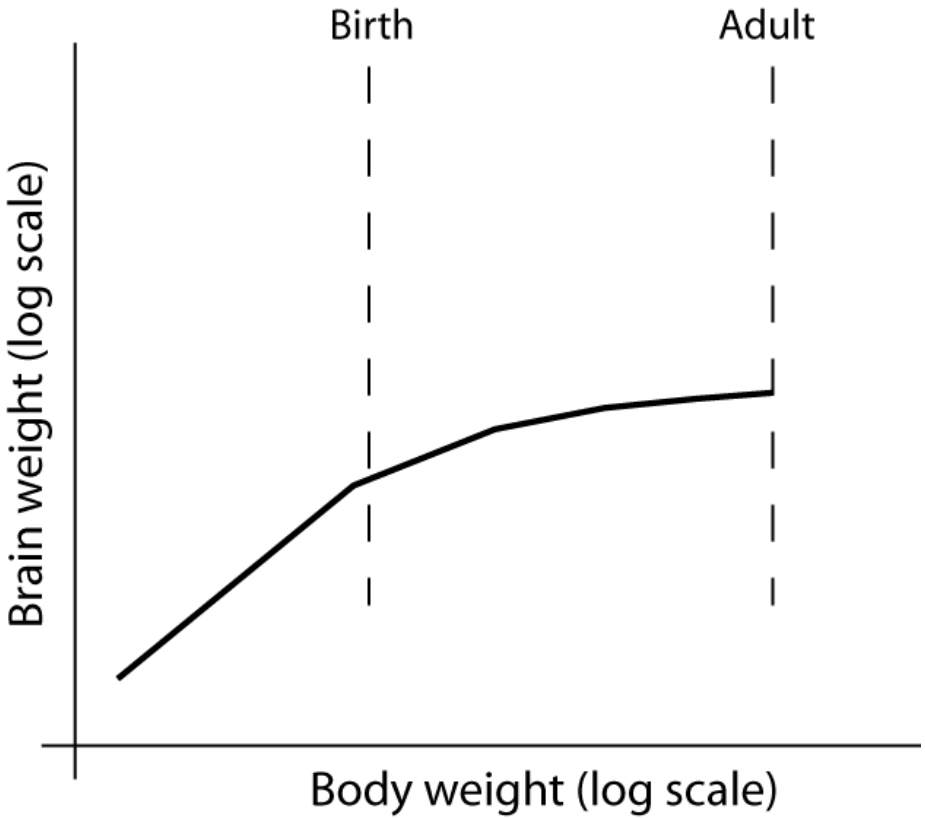
The cost of a large brain

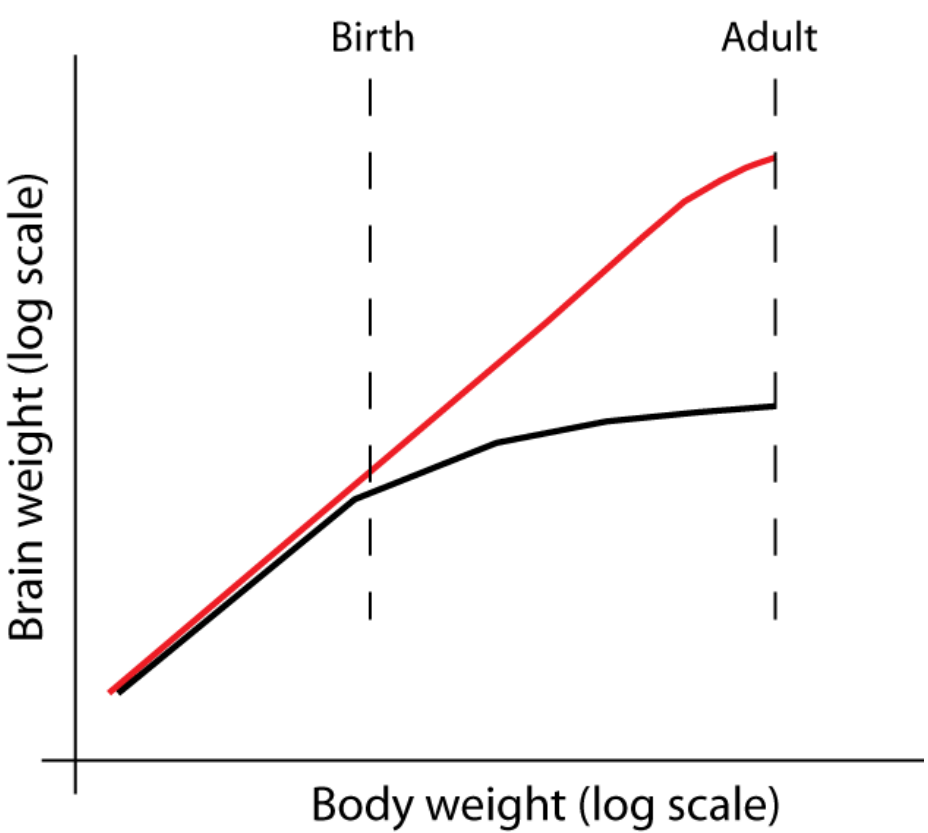
Human adult brain size 1350 cm^3

Human newborn 400 cm^3

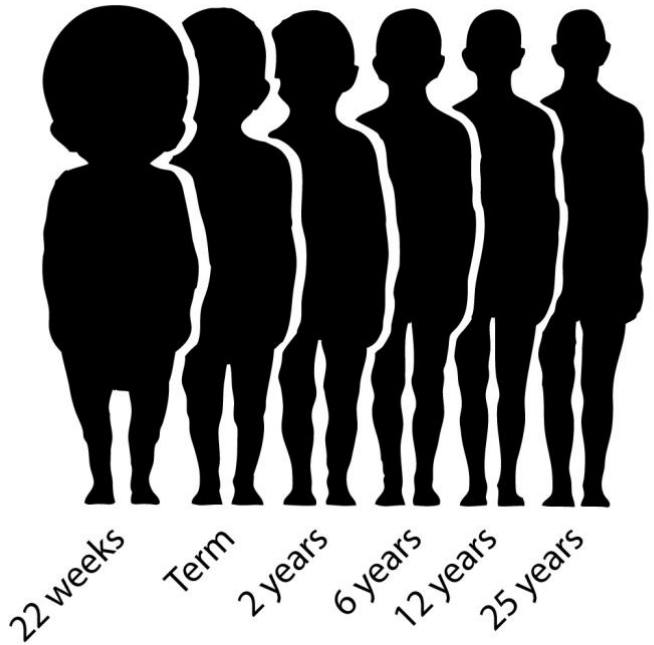
Chimpanzee adult 400 cm^3

Chimpanzee newborn 160 cm^3

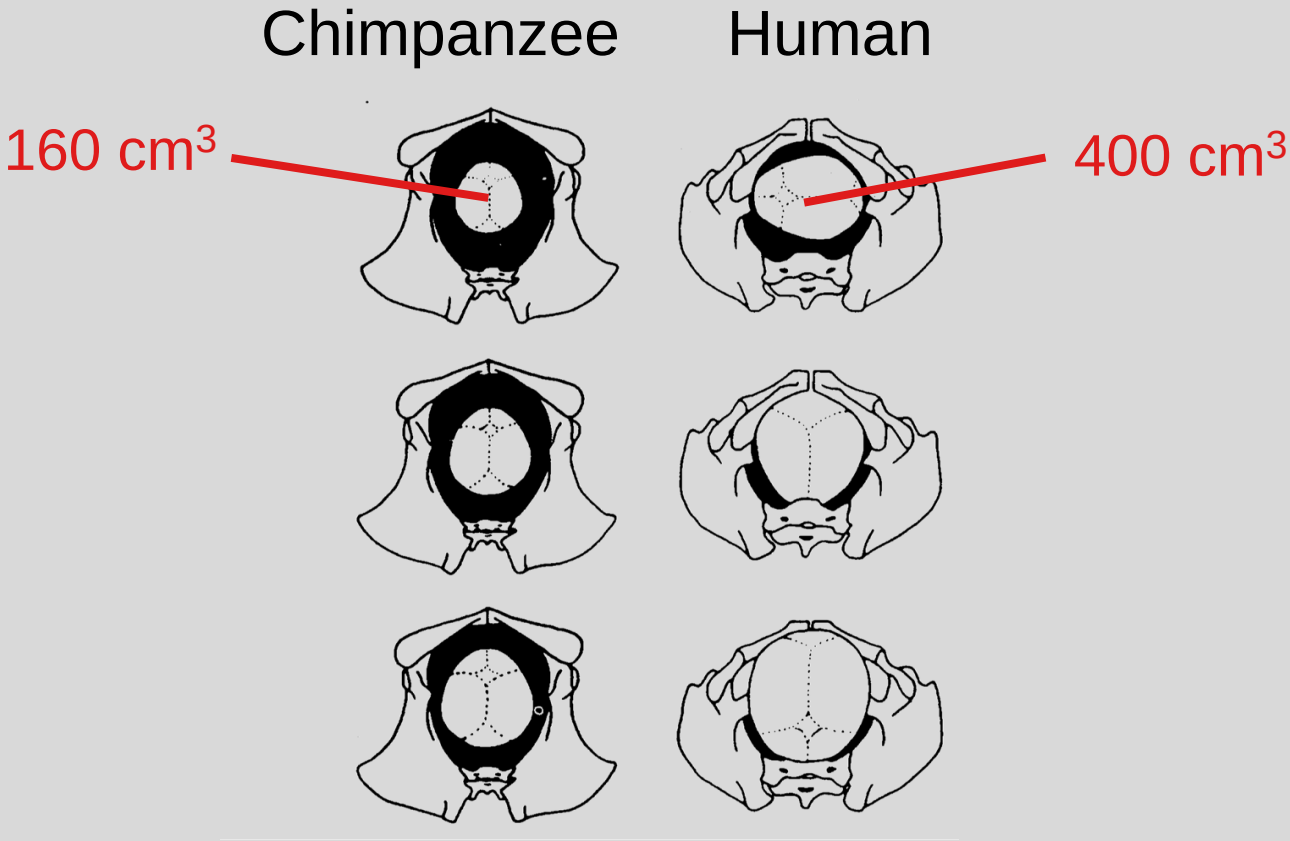

Birth
Adult
Brain weight (log scale)
Body weight (log scale)

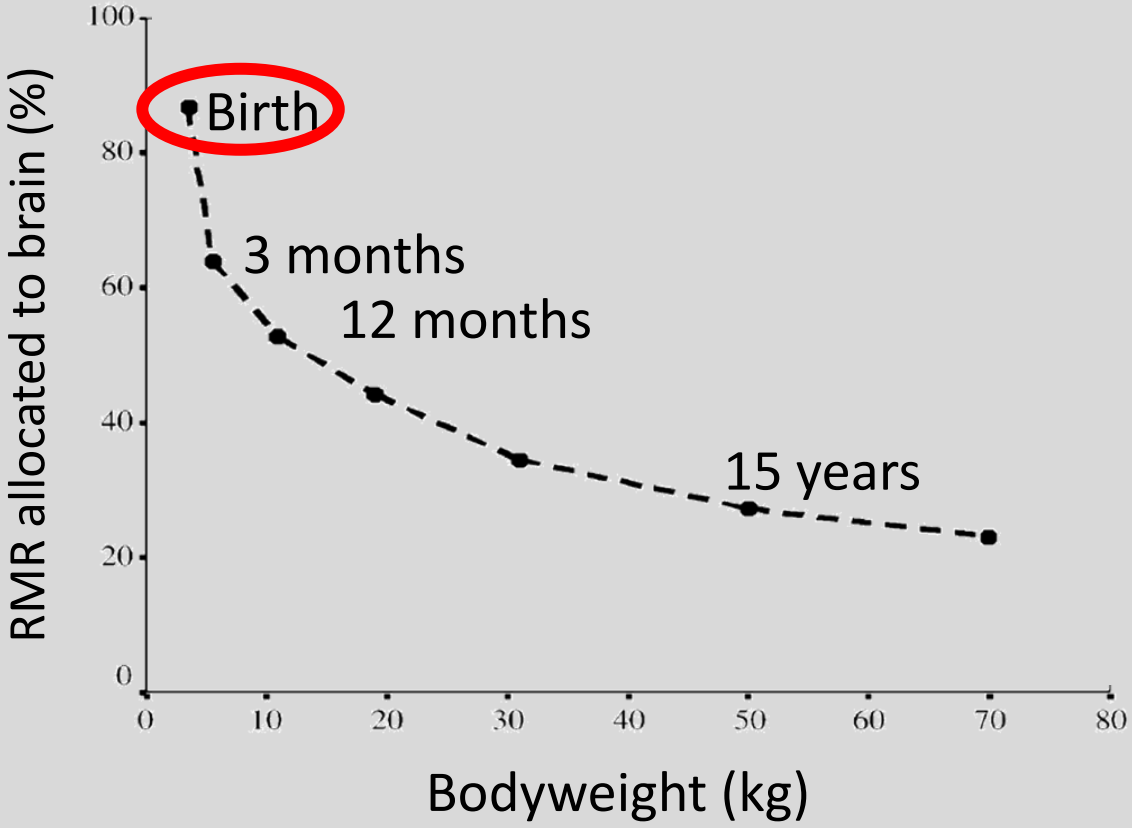

Birth
Adult
Brain weight (log scale)
Body weight (log scale)

Proportional Brain Size and Development



- Brain growth (in terms of weight) finishes by about 7-8 years old
- Brain maturity isn’t complete until about 25 years old!

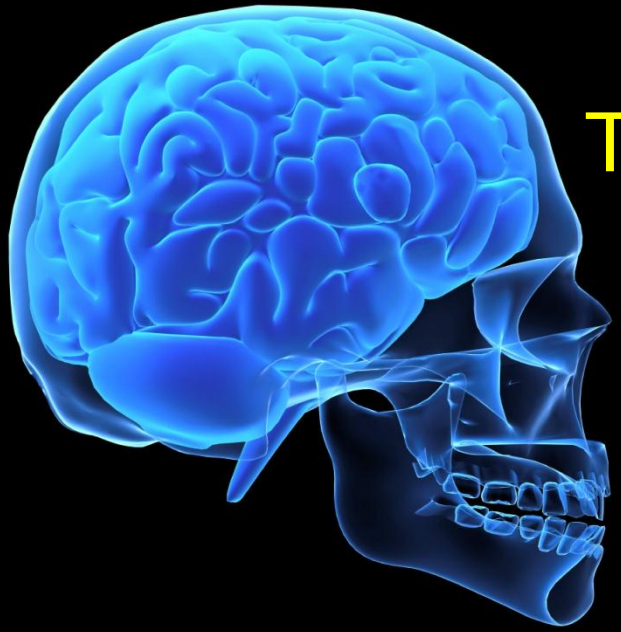

Chimpanzee
Human
160 cm3
400 cm3


RMR allocated to brain (%)
100
80
60
40
20
0
Birth
3 months
12 months
15 years
0
10
20
30
40
50
60
70
80
Bodyweight (kg)

Cost of a large brain

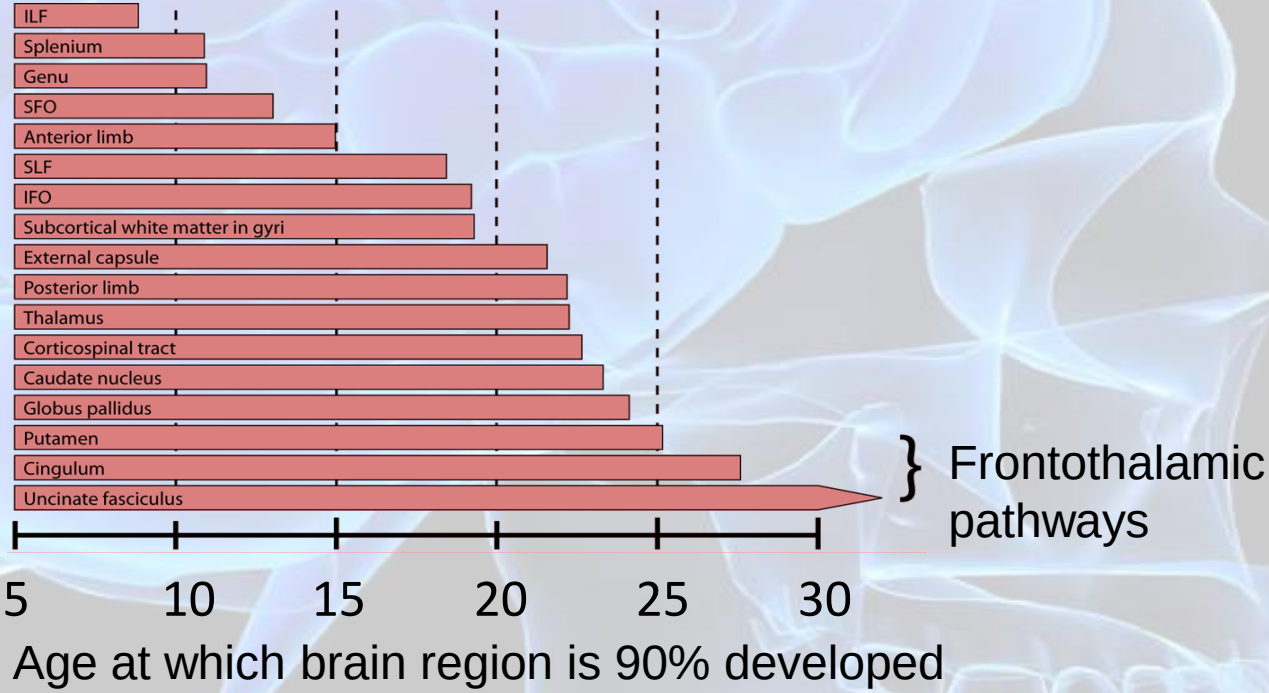
Long childhood dependency

Consequence:
late maturation of human brain

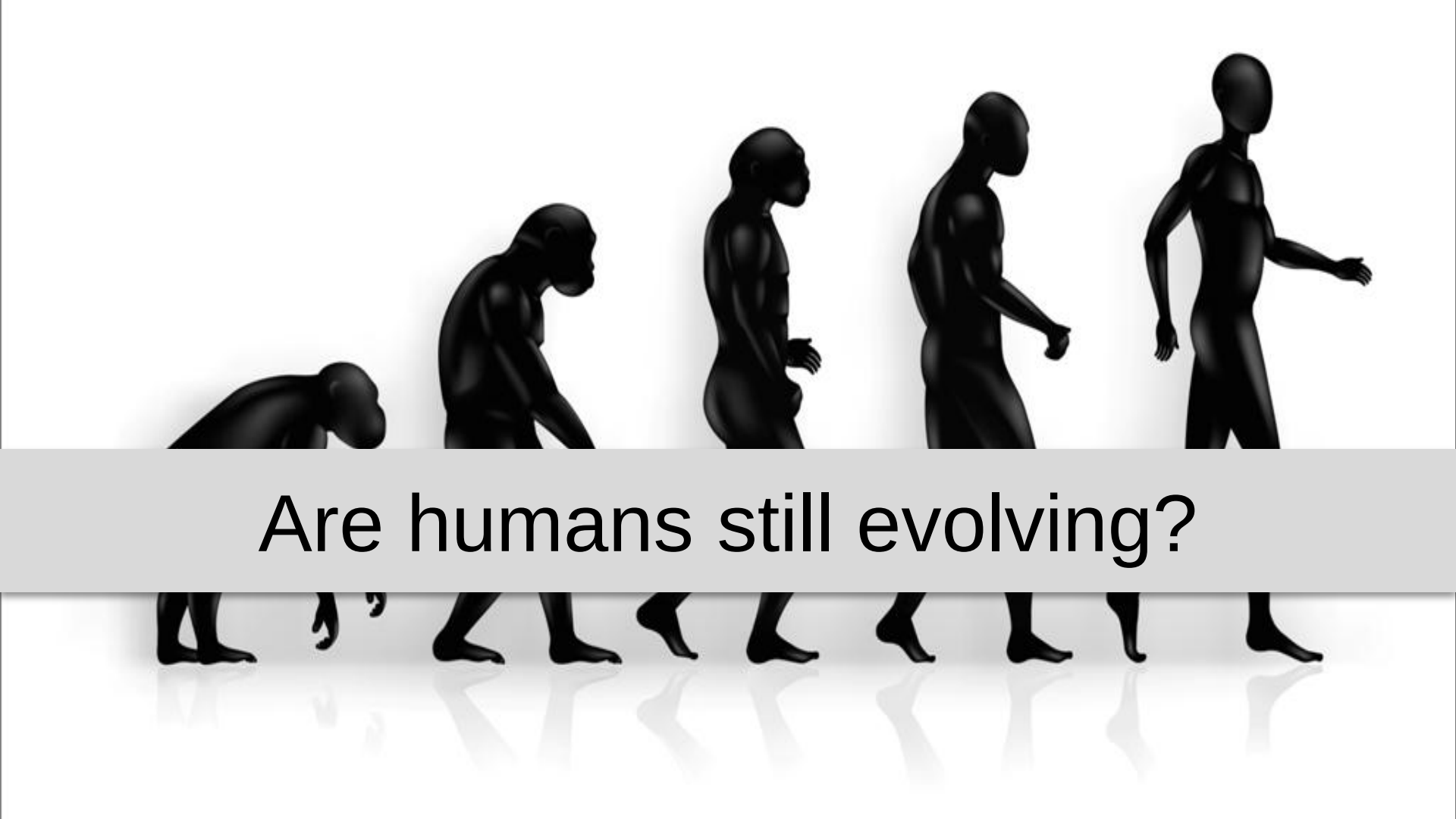


The human brain takes 25 years to develop fully

Consequence: late maturation of human brain



From PD Gluckman, AS Beedle, MA Hanson, *Principles of evolutionary medicine*, OUP, 2009,
Modified from C Lebel et al, *Neuroimage* 40(2008), 1044-1055.



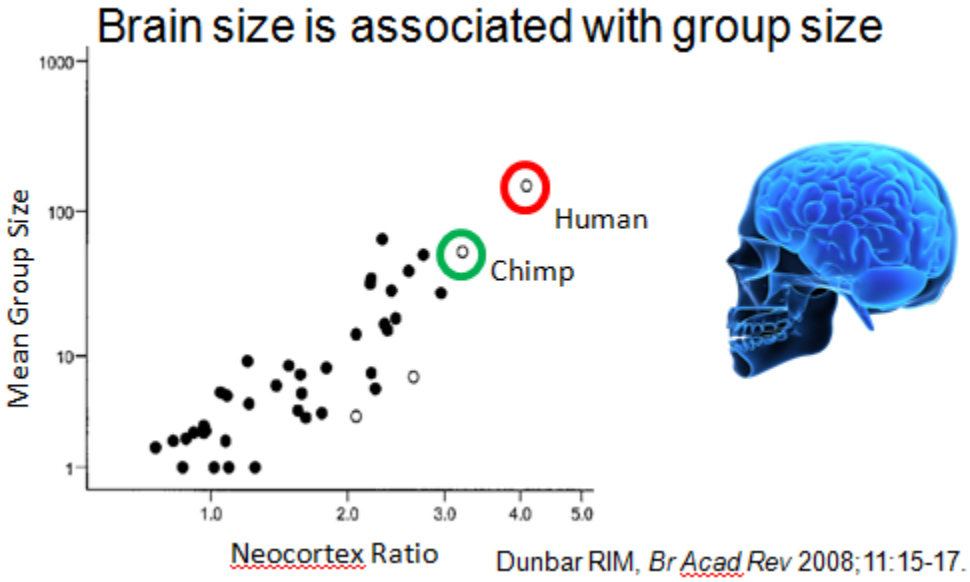
Are humans still evolving?

Challenge 1 Cultural and Biological Evolution

Compare and contrast biological and cultural evolution in terms of transmittance of information between generations, selection, and fitness.

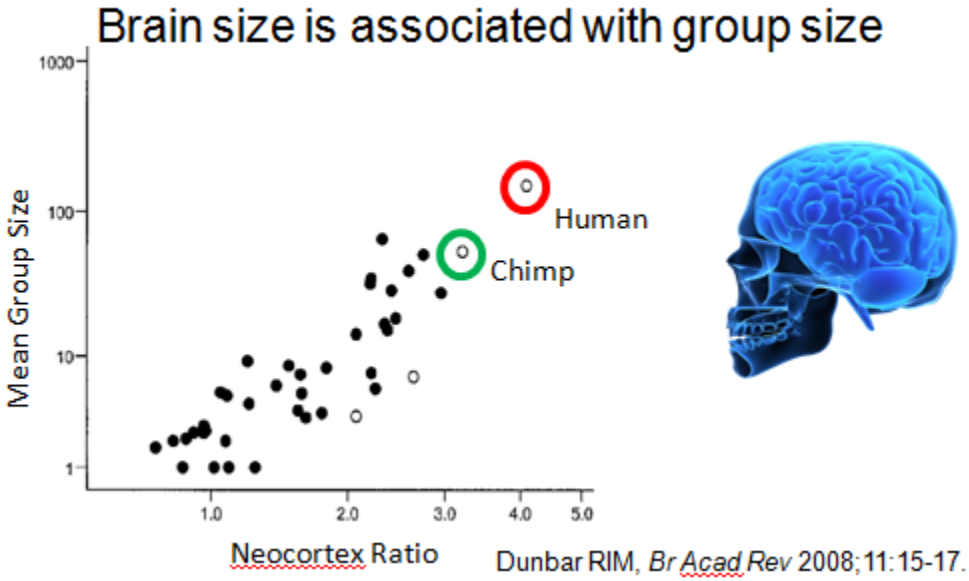
Challenge 2 Brain Expansion & Social Interactions

Discuss the role of living in groups in the evolution of humans and our ancestors.



Challenge 2 Brain Expansion & Social Interactions

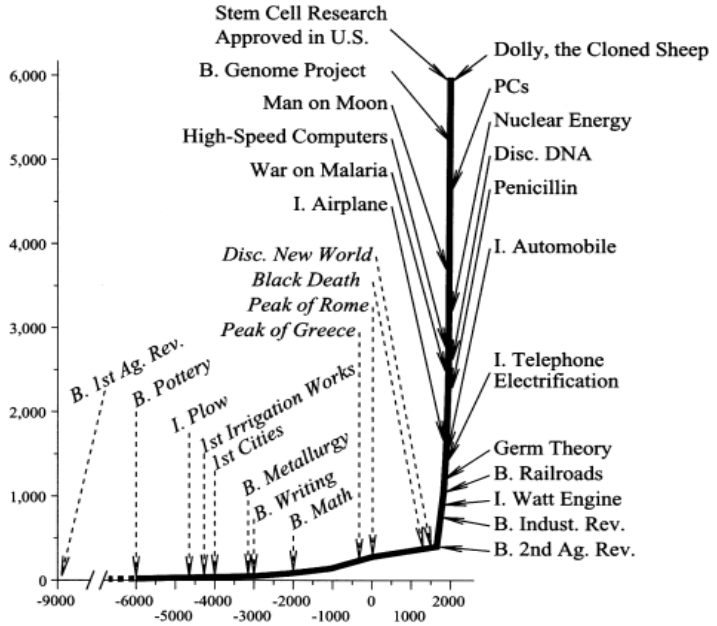
Discuss the potential challenges that are offered to modern humans by the technological advances in communication and travel and consider the potential effect of these on the success of human populations.



Challenge 3 Human Population Growth

Robert Fogel suggests that there is a link between human population growth rates and cultural evolution.

Discuss the potential challenges that are offered to modern humans by the technological advances in communication and travel and consider the potential effect of these on the success of human populations.



Wiki challenge.....

LENScience CONNECT

Wiki challenge.....

Stacey Caldwell

WAIKATO DIOCESAN
School for Girls

Producer / Director
Dave Hedge
Multicast
Robert Hamilton
Technical Manager
Nick Haines
Production Assistant
James Turnbull
Camera
Paul Richards, Ben Firman, Oliver Cross
Sound
Andrew Lovrin
Livechat
Helen Mora; Shawn Cooper
Writers / Presenters
Peter Gluckman, Alan Beedle, Tatjana Buklijas Jacquie Bay

LENScience Connect is Funded by the National Research Centre for Growth and Development