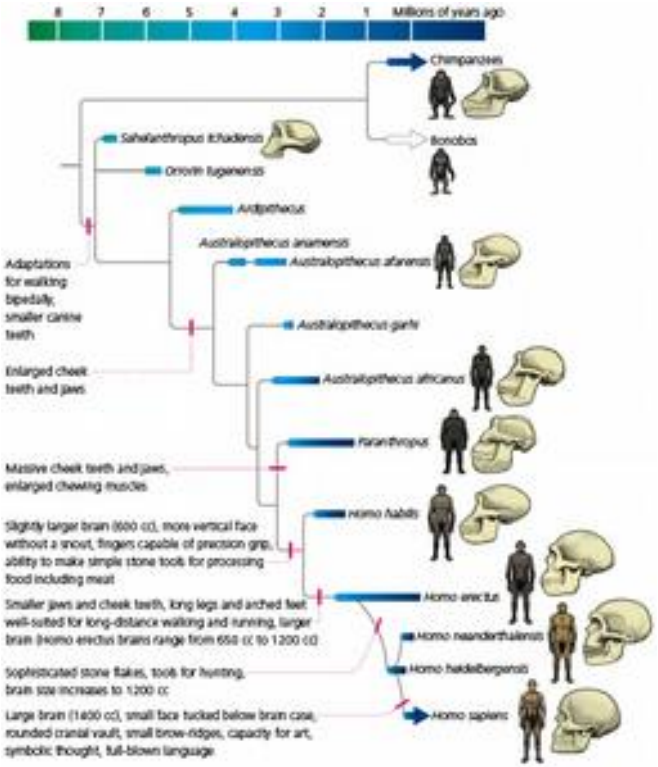
Genes and culture in language evolution



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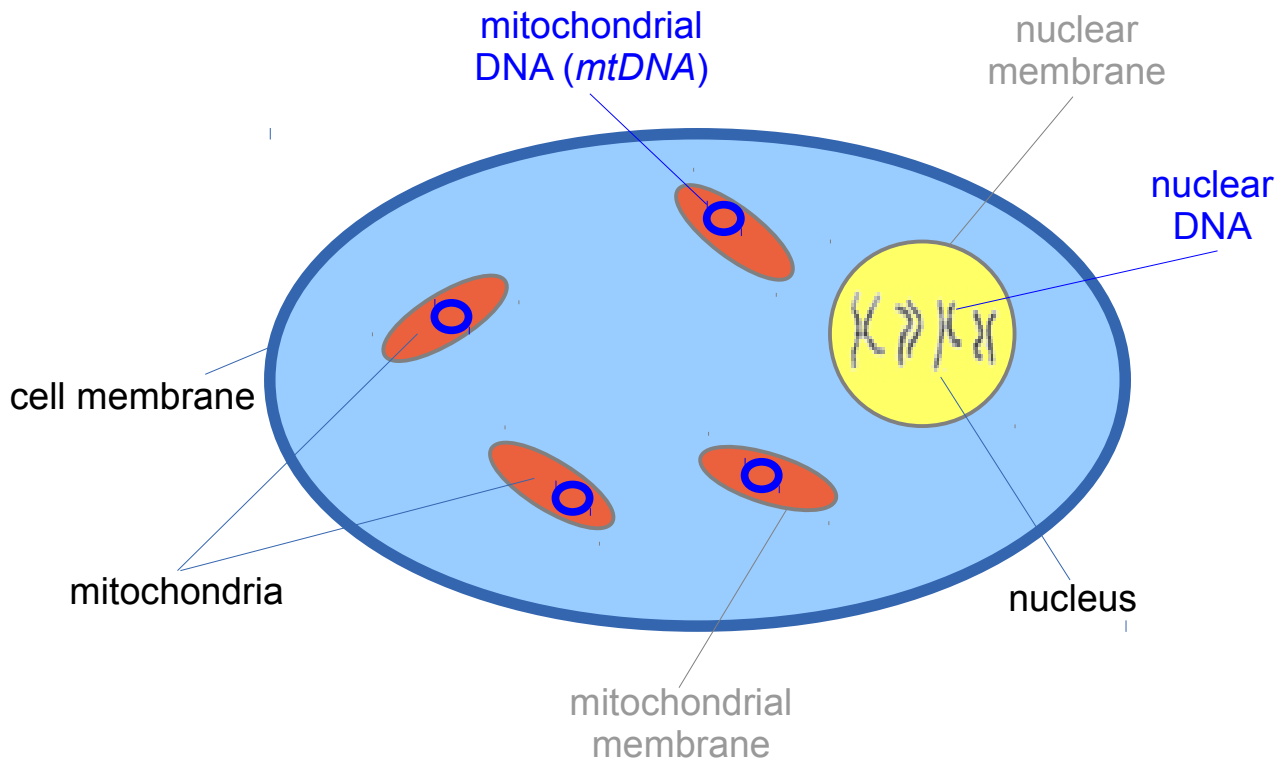
Language and Genetics
Max Planck Institute for Psycholinguistics
Nijmegen
The Netherlands

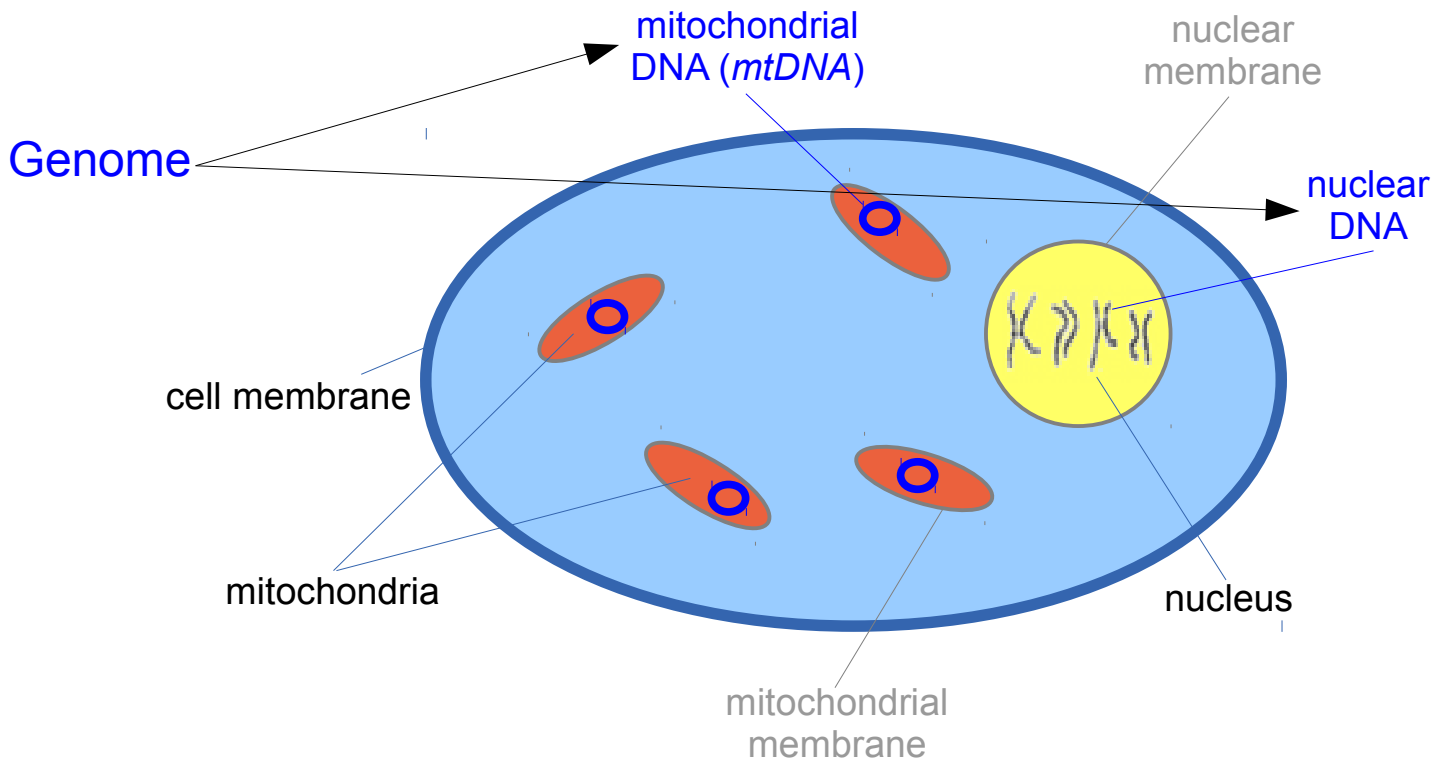
LSA2013
Universality and Variability:
New Insights from Genetics
29th of June, 2013

Overview

- Population and evolutionary genetics
- Human evolution
- Human genetic and linguistic diversity
- Genetic biasing, gene-culture co-evolution, niche construction


mitochondrial
DNA (*mtDNA*)
nuclear
membrane
nuclear
DNA
cell membrane
mitochondria
nucleus
mitochondrial
membrane

Population and evolutionary genetics



Population and evolutionary genetics

- Some genes (energy production)
- Own genetic code
- “D-loop” → *hypervariable regions* (HVR-I & HVR-II)

Population and evolutionary genetics

- Some genes (energy production)
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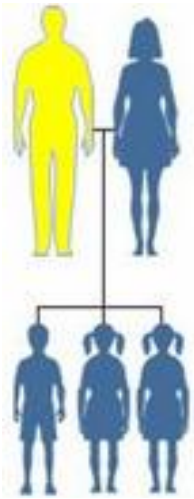
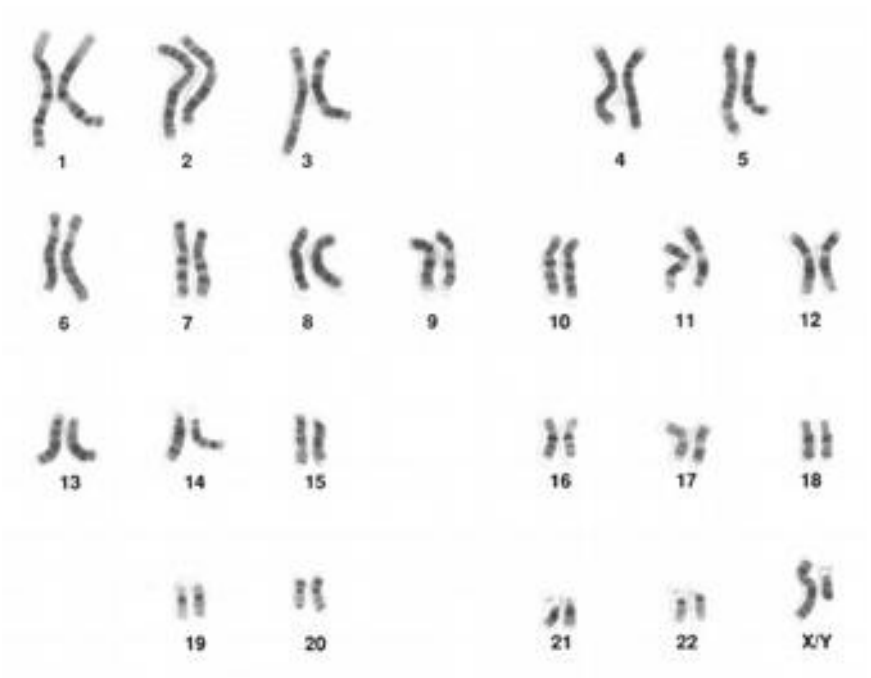
Maternal inheritance



Population and evolutionary genetics

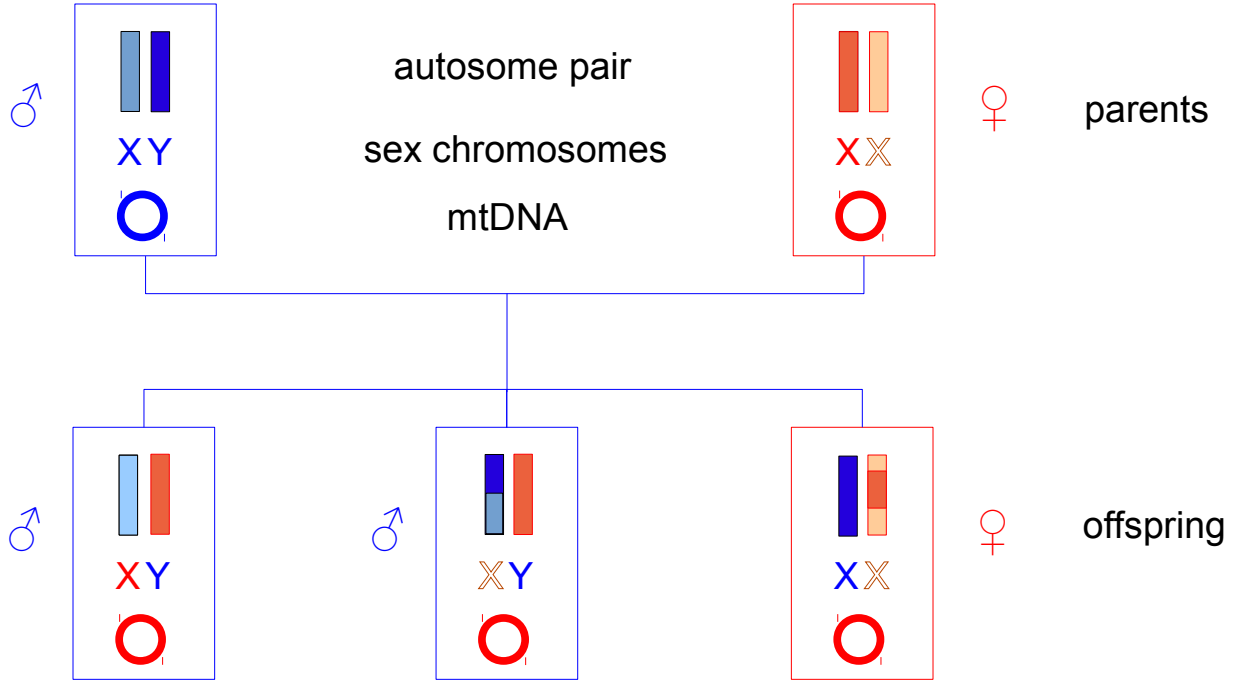
- **Chromosomes**: single linear molecules of DNA
- **Karyotype** = all chromosomes in the nucleus
- Humans: **23 pairs** of chromosomes (diploid)

- 22 pairs **autosomes**
- 1 pair **sex chromosomes**
  - **XX**=♀ **XY**=♂
- **Inheritance**:
  - X & autosomes: both parents
  - Y: paternal inheritance



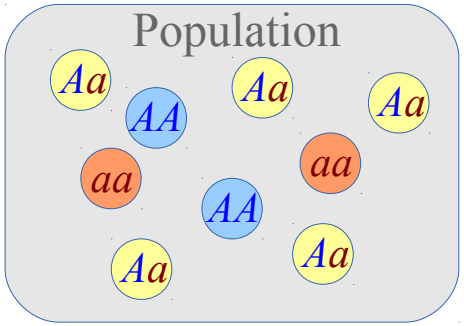
Population and evolutionary genetics

- the **inheritance** of the nuclear genome
- **recombination**, **independent assortment**



Population and evolutionary genetics

- Bi-allelic autosomal locus → A & a



Population and evolutionary genetics

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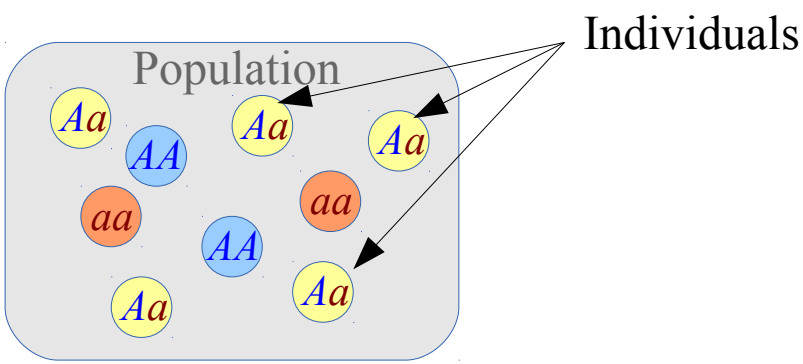

Population and evolutionary genetics

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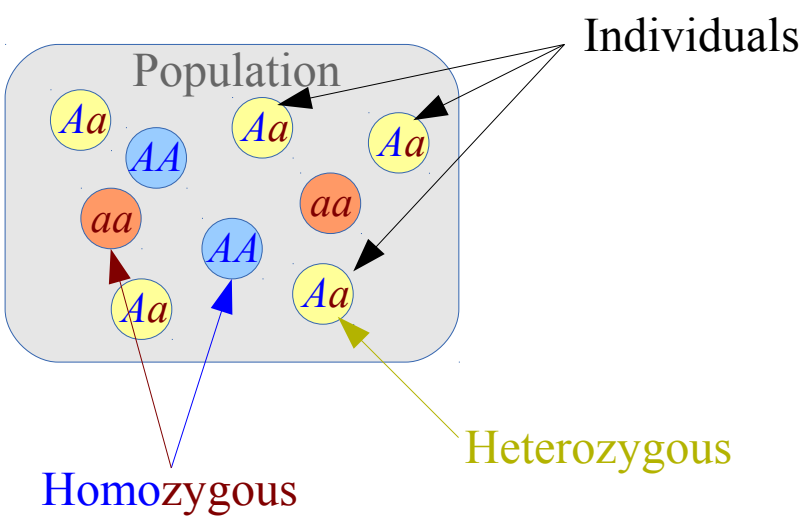
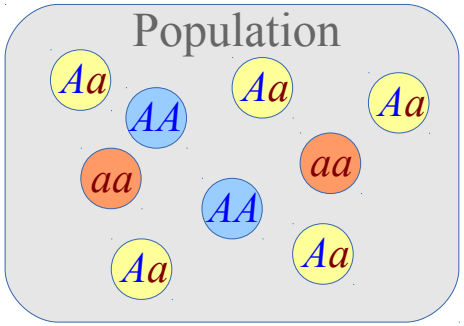


Population and evolutionary genetics

- Bi-allelic autosomal locus → A & a
- Allele frequencies p_A & p_a
- Genotype frequencies p_{AA}, p_{Aa} & p_{aa}



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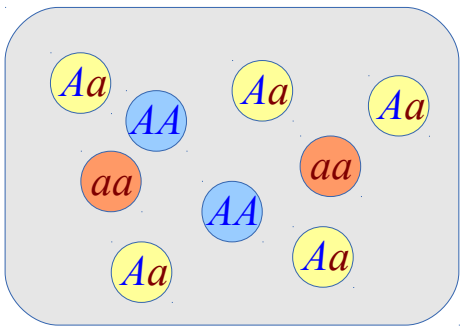

t

$p_A, p_a; p_{AA}, p_{Aa}$ & p_{aa}

Time

Population and evolutionary genetics

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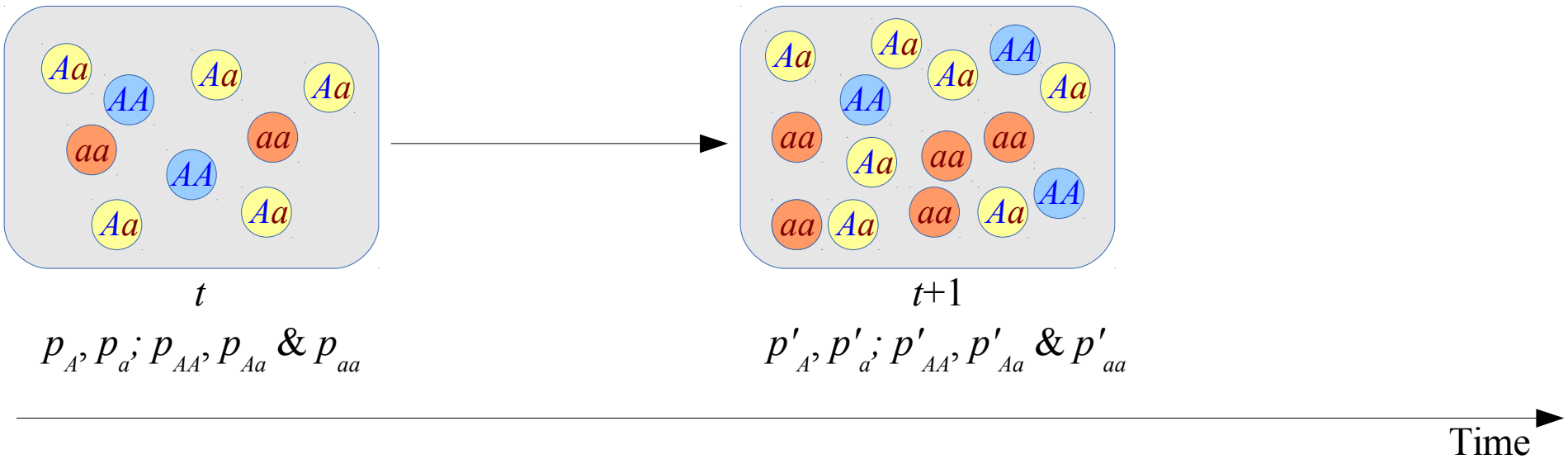

Population and evolutionary genetics

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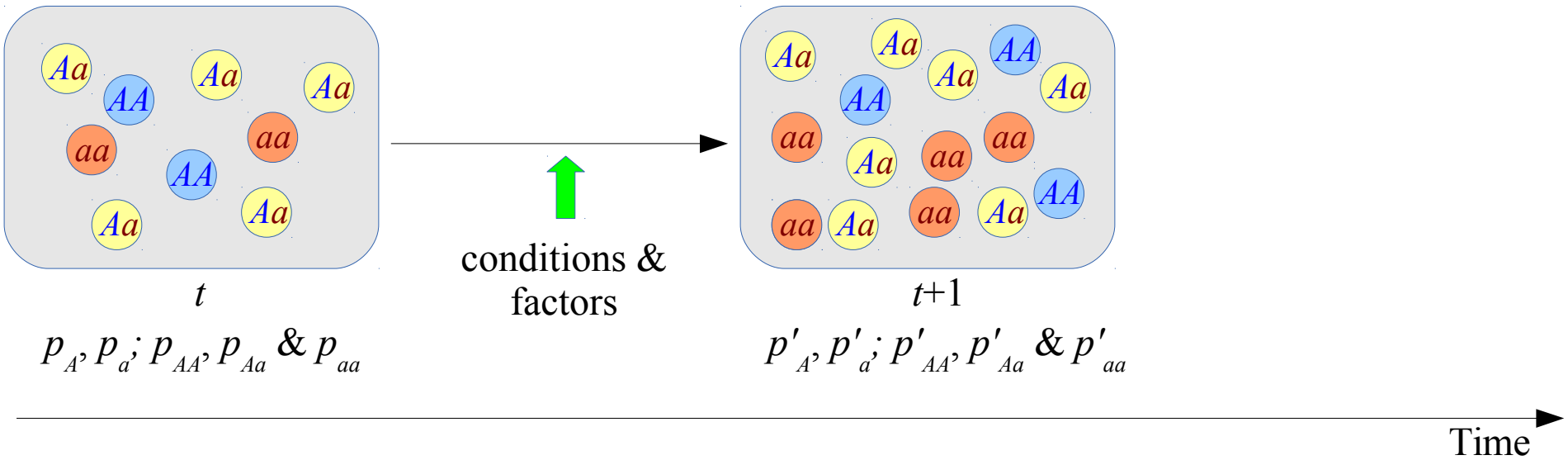

Population and evolutionary genetics

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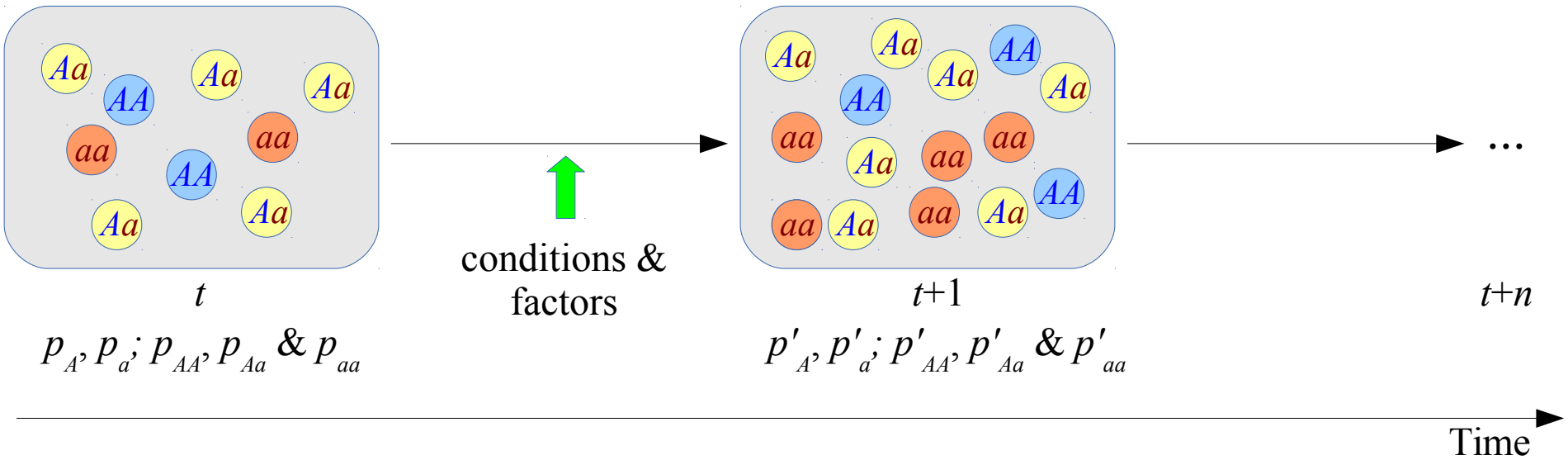
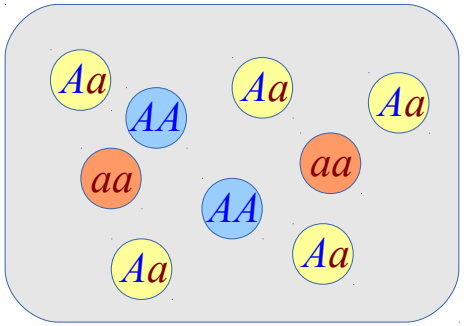


Population and evolutionary genetics

- Hardy-Weinberg Equilibrium (HWE):

  if nothing interesting happens → no change



t

$p_A, p_a; p_{AA}, p_{Aa}$ & p_{aa}

Time

Population and evolutionary genetics

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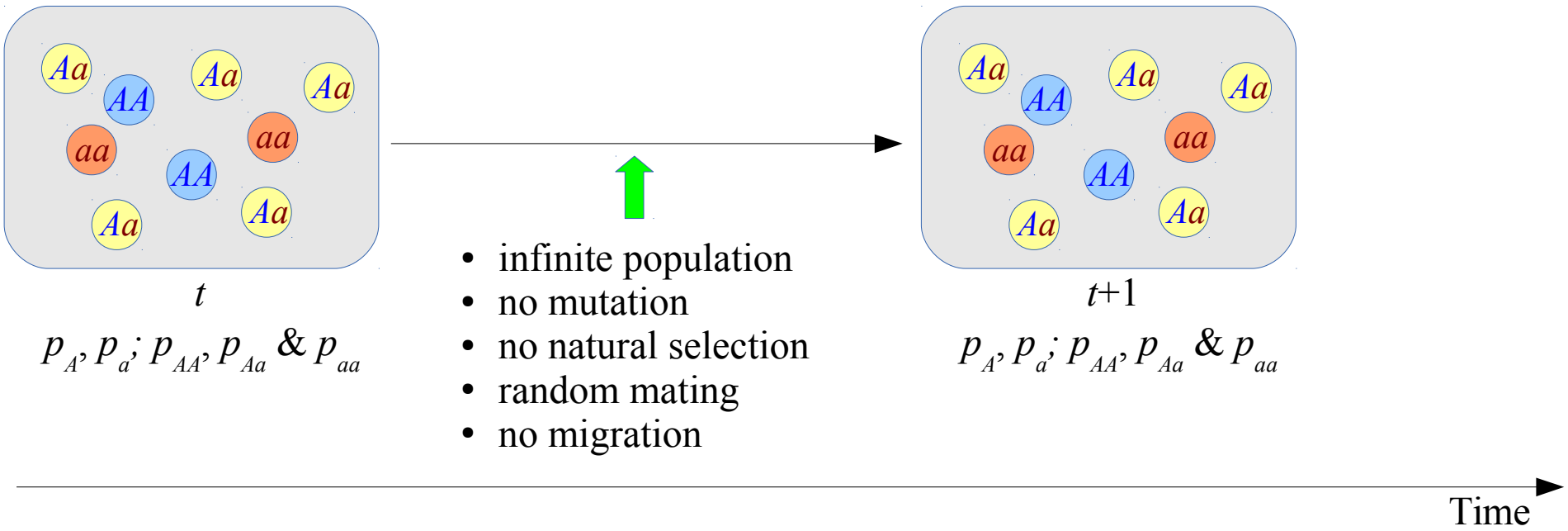

Population and evolutionary genetics

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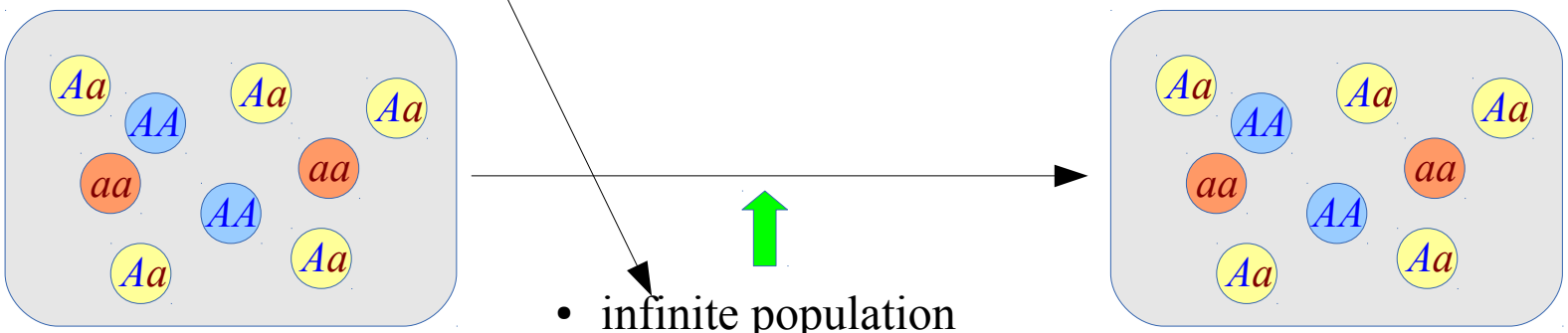


t

$p_A, p_a; p_{AA}, p_{Aa}$ & p_{aa}

- infinite population
- no mutation
- no natural selection
- random mating
- no migration

t+1

$p_A, p_a; p_{AA}, p_{Aa}$ & p_{aa}

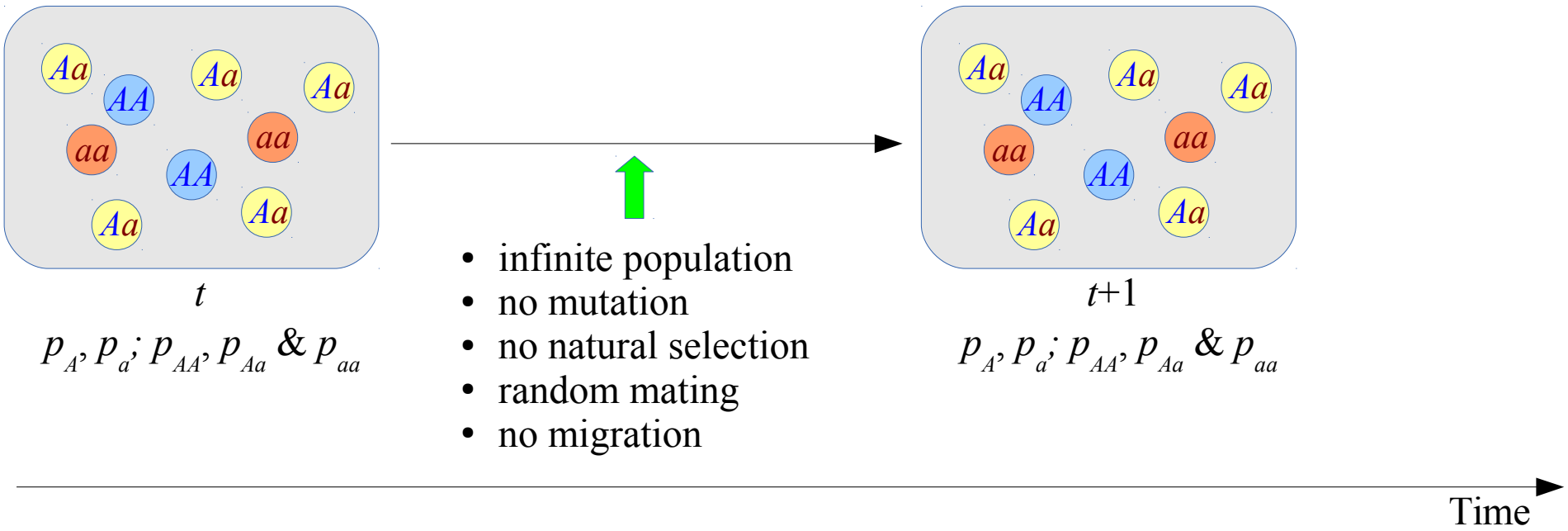
Time

Population and evolutionary genetics

- Hardy-Weinberg Equilibrium (HWE):

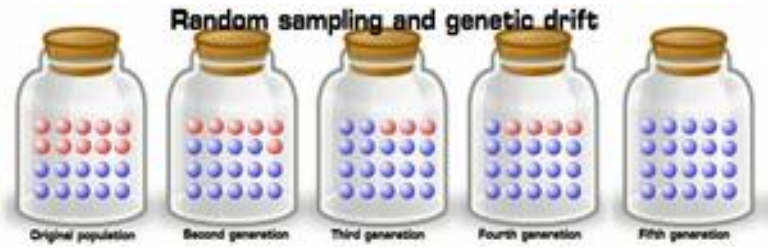
  if nothing interesting happens → no change

  → simple null hypothesis



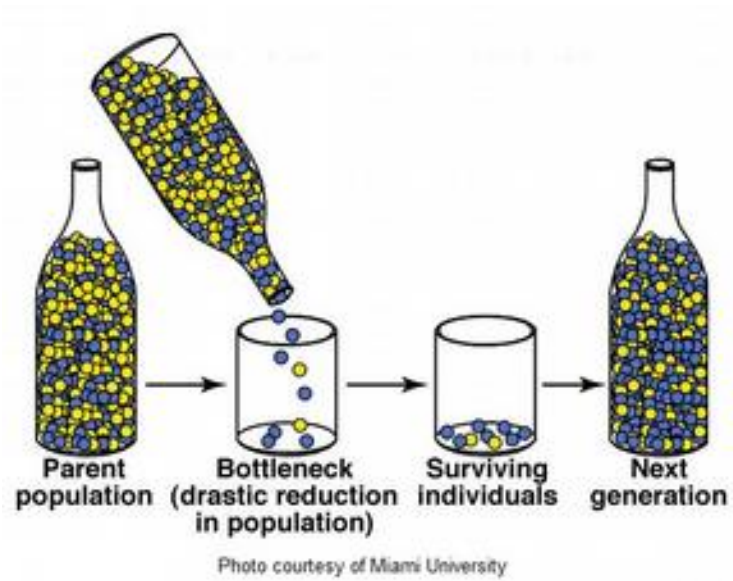
Population and evolutionary genetics

- Finite populations → reproduction = random sampling



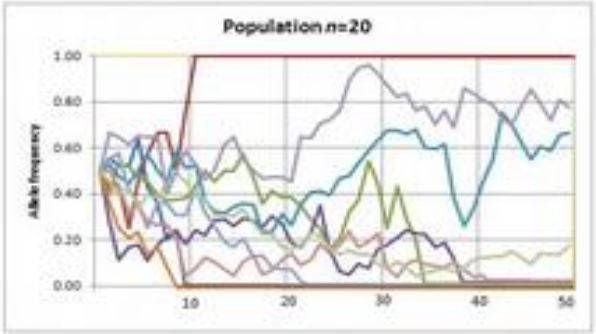
Population and evolutionary genetics

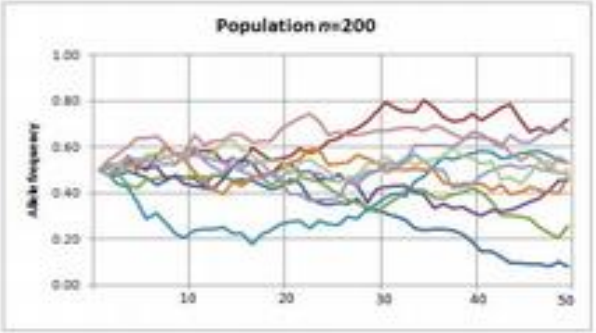
- Finite populations → reproduction = random sampling
- Bottlenecks → "founder effect" (e.g., SLI on Robinson Crusoe Island)

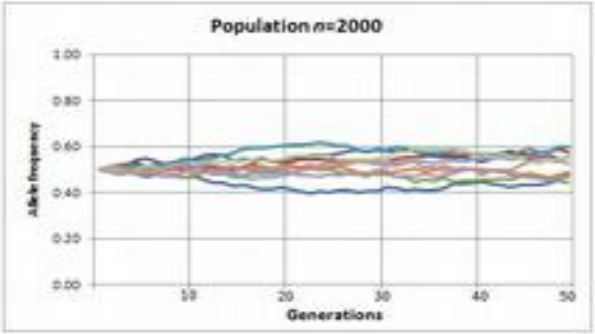


Population and evolutionary genetics

- Finite populations → reproduction = random sampling
- Bottlenecks → "founder effect"
- (Effective) population size, N_e







Population and evolutionary genetics

- Finite populations → reproduction = random sampling
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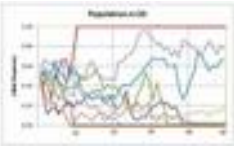
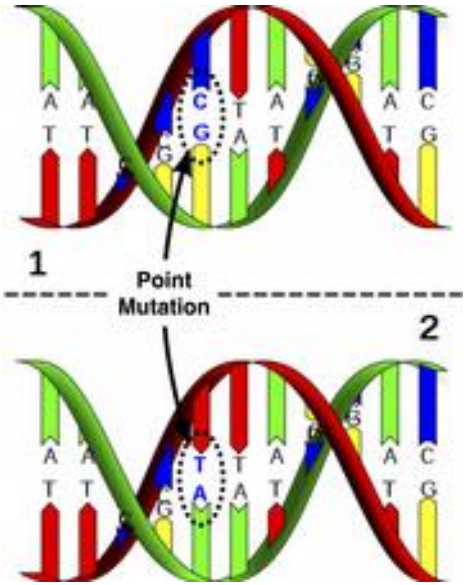
- (Effective) population size, N_e

→ reduces genetic diversity



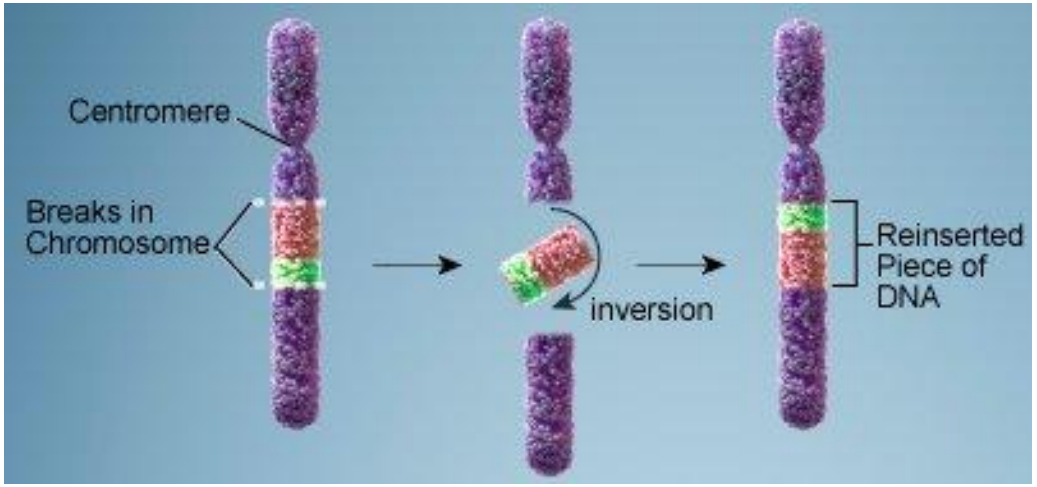
Population and evolutionary genetics

- Mutation → changes the genetic information (e.g., $A \rightarrow a$)
- Many types: point mutation



Population and evolutionary genetics

- Mutation → changes the genetic information (e.g., $A \rightarrow a$)
- Many types: point mutation, chromosomal rearrangements



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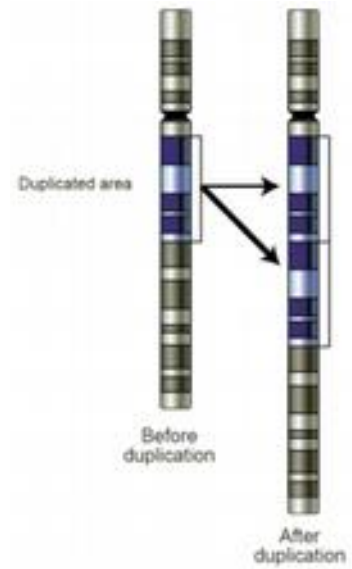

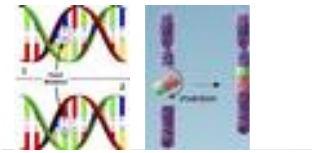

Population and evolutionary genetics

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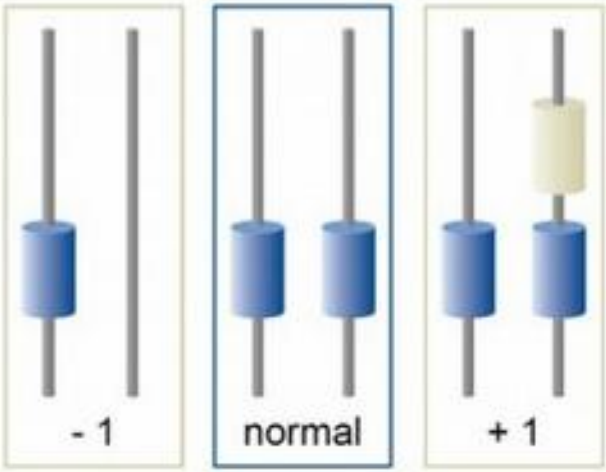

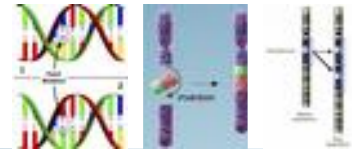

Population and evolutionary genetics

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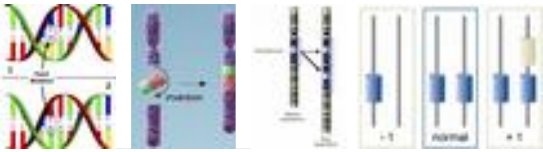
- Many types: point mutation, chromosomal rearrangements, gene duplications, CNVs...

→ increases genetic diversity



Population and evolutionary genetics

- Selection → differential survival and reproduction

Population and evolutionary genetics

- Selection → differential survival and reproduction
- Types:

natural

Population and evolutionary genetics

- Selection → differential survival and reproduction
- Types:

natural vs sexual

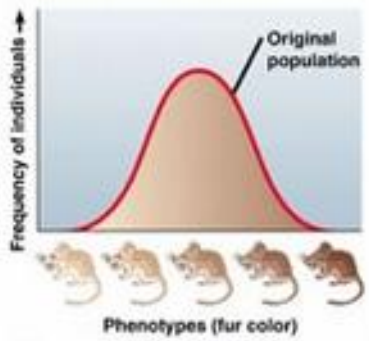
Population and evolutionary genetics

- Selection → differential survival and reproduction
- Types:

natural vs sexual vs artificial

Population and evolutionary genetics

- Selection → differential survival and reproduction
- Types:




vs

vs


Population and evolutionary genetics

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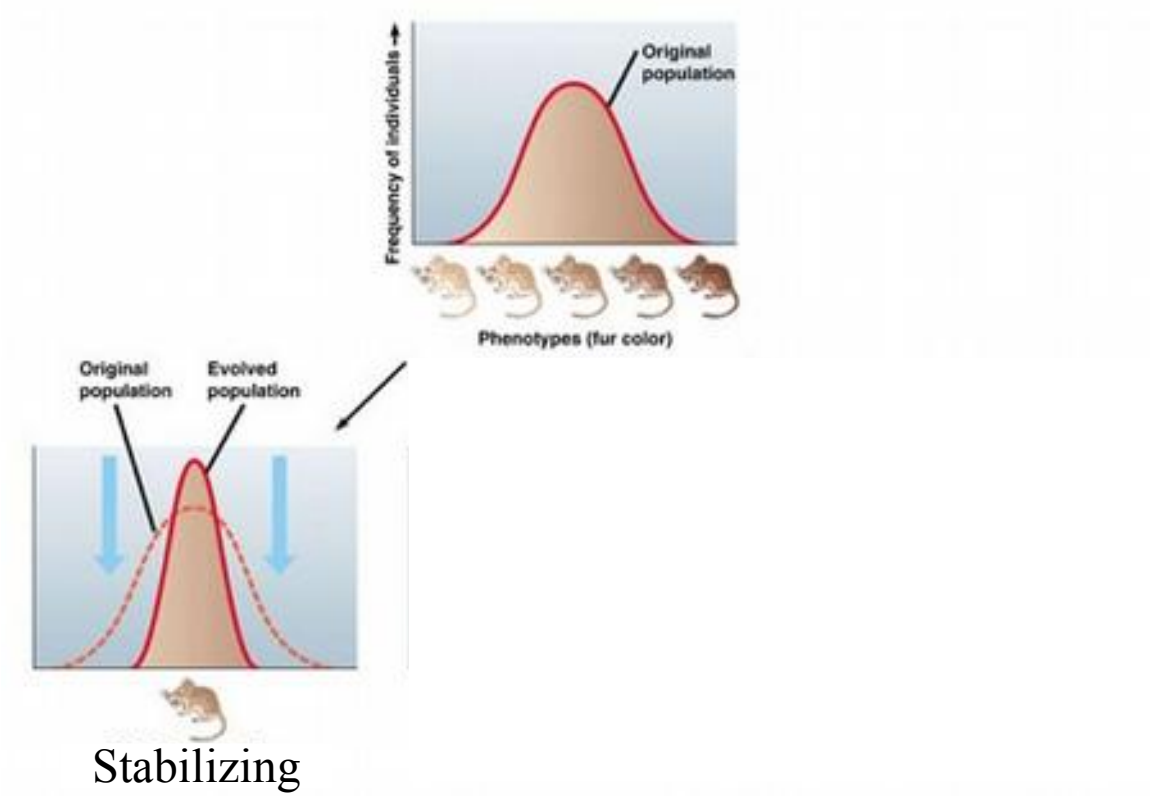


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Population and evolutionary genetics

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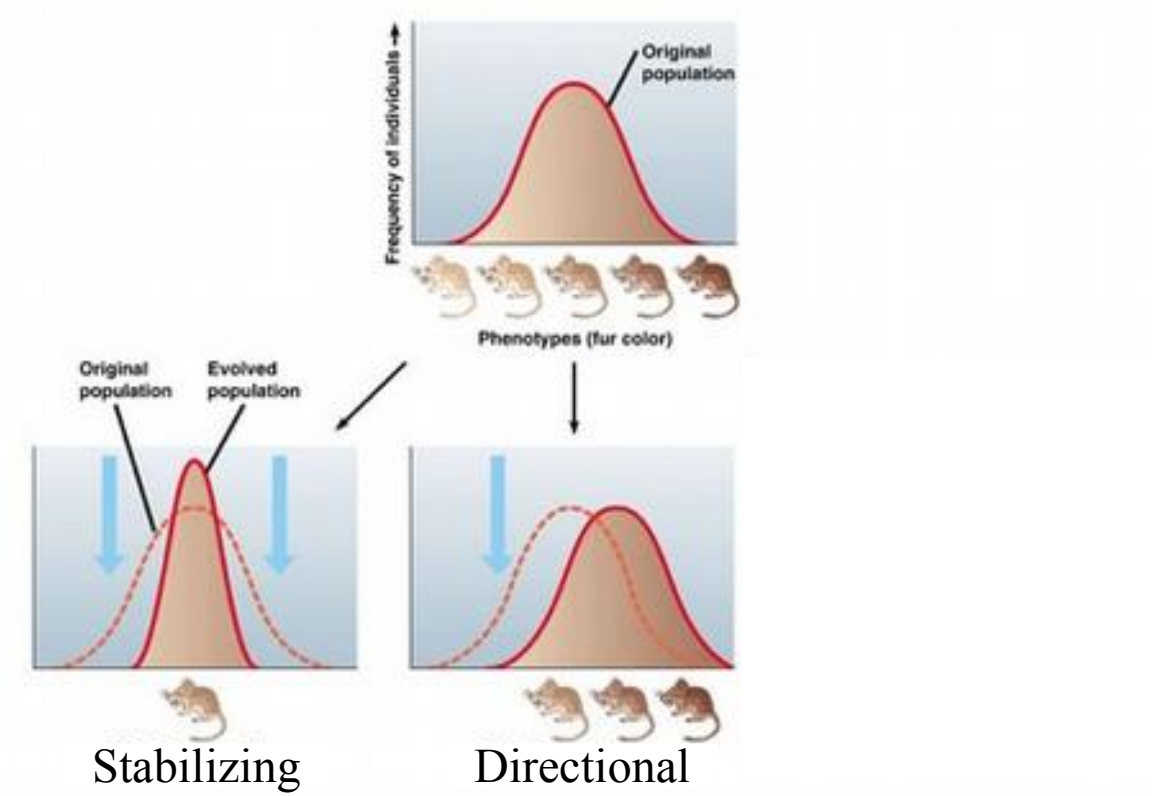


vs

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Population and evolutionary genetics

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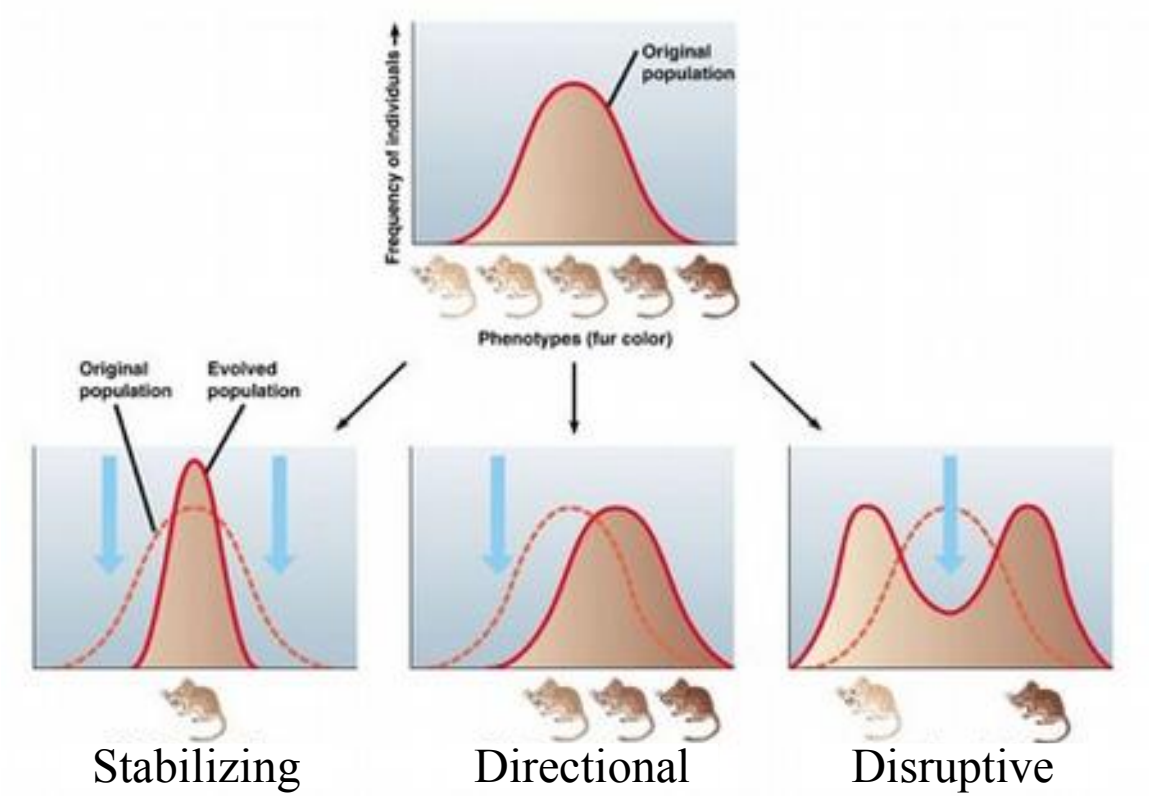


vs

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Population and evolutionary genetics

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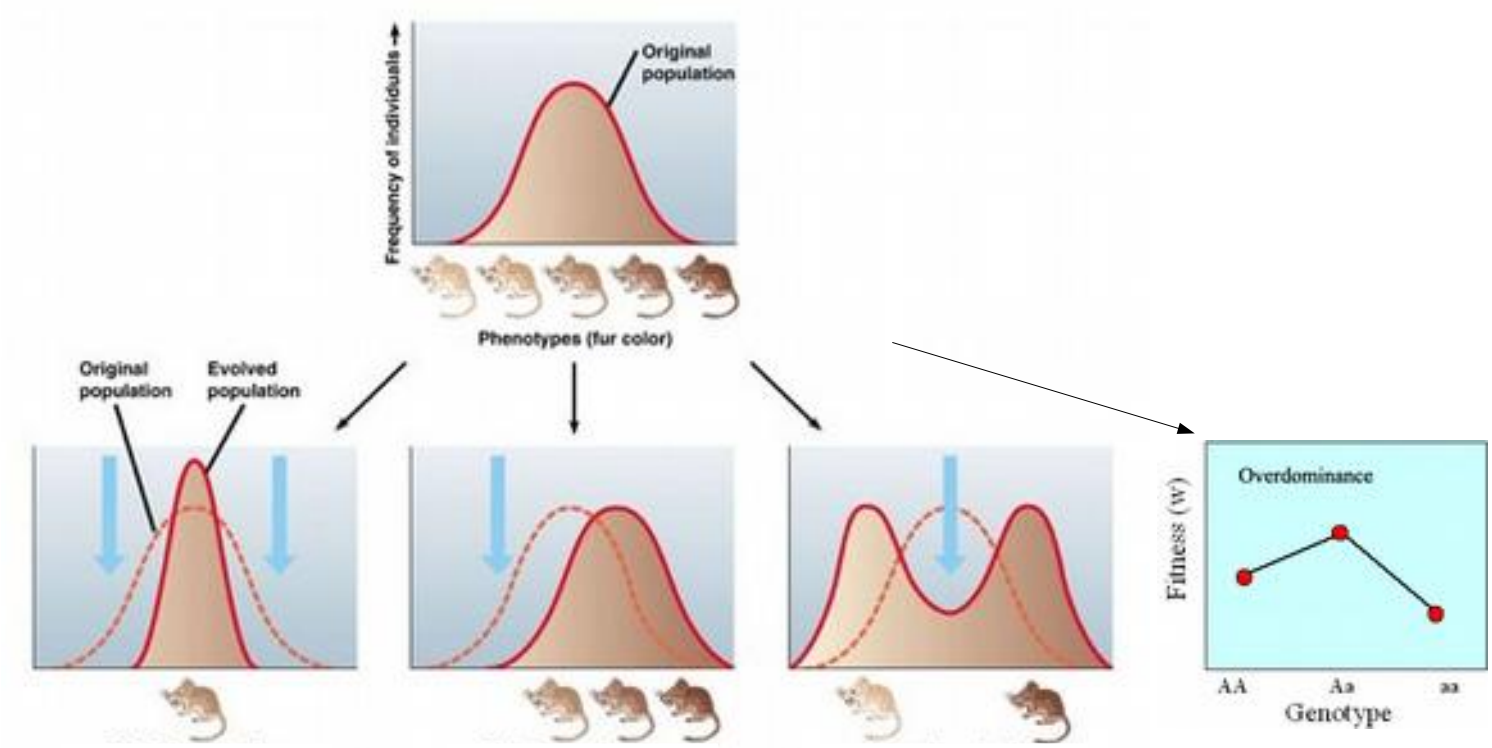


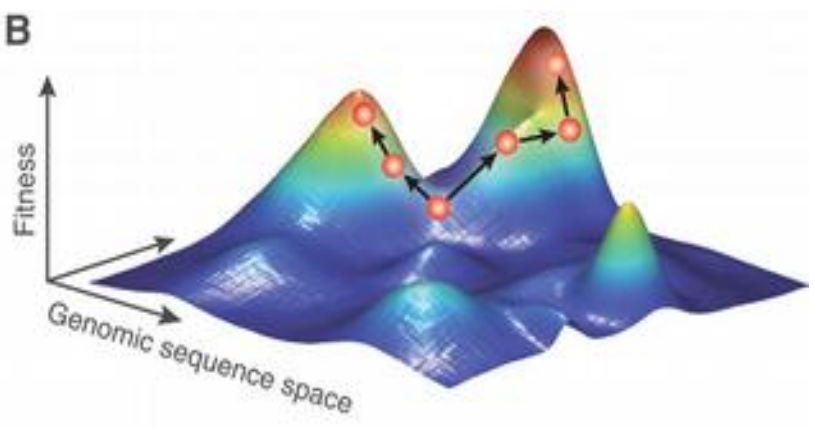
Stabilizing Directional Disruptive Heterozygote advantage


vs

vs


Population and evolutionary genetics

- Selection → differential survival and reproduction
- Walking the fitness landscape



Population and evolutionary genetics

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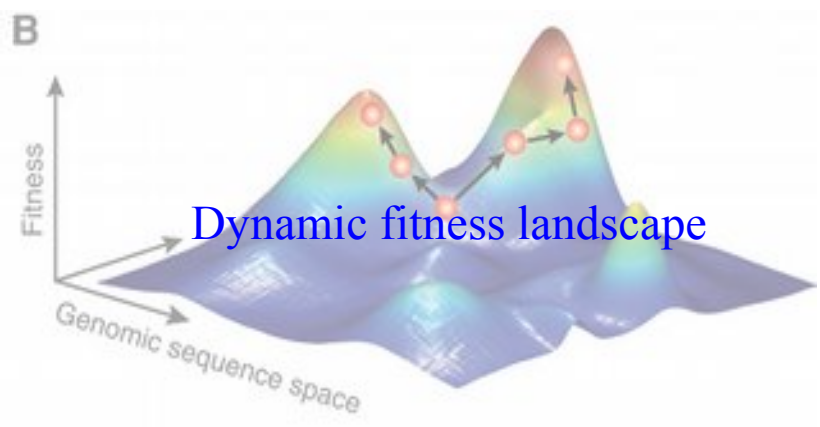
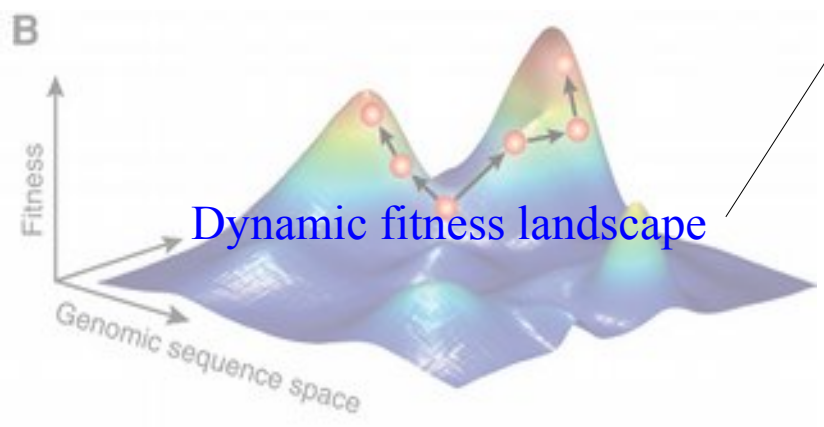


Dynamic fitness landscape

Population and evolutionary genetics

- Selection → differential survival and reproduction
- Walking the fitness landscape

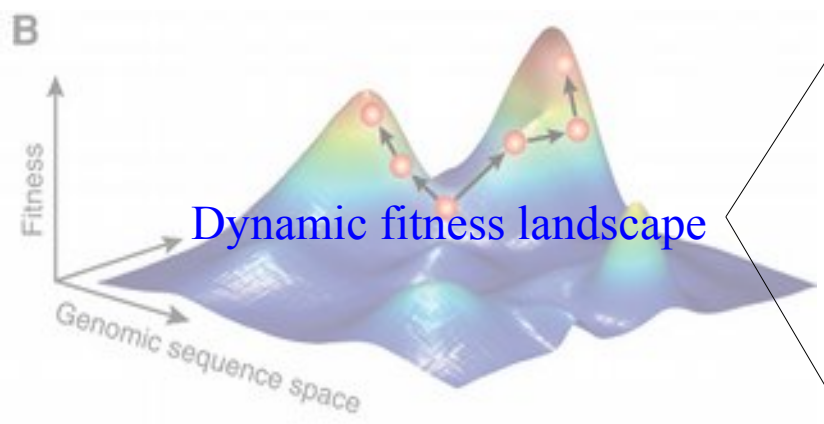


Dynamic fitness landscape

Co-evolution & arms races

Population and evolutionary genetics

- Selection → differential survival and reproduction
- Walking the fitness landscape



Dynamic fitness landscape

Co-evolution & arms races

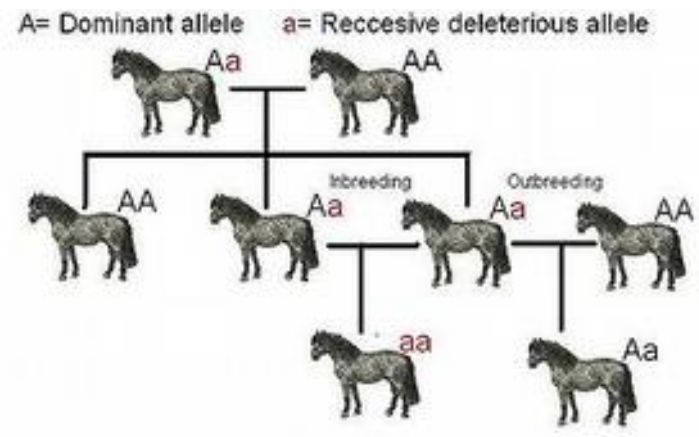
Niche construction

Population and evolutionary genetics

- Non-random mating

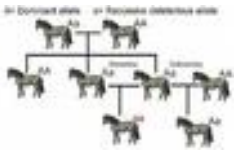
Population and evolutionary genetics

- Non-random mating
  - inbreeding



Population and evolutionary genetics

- Non-random mating
  - inbreeding
  - assortative mating



Population and evolutionary genetics

- Non-random mating
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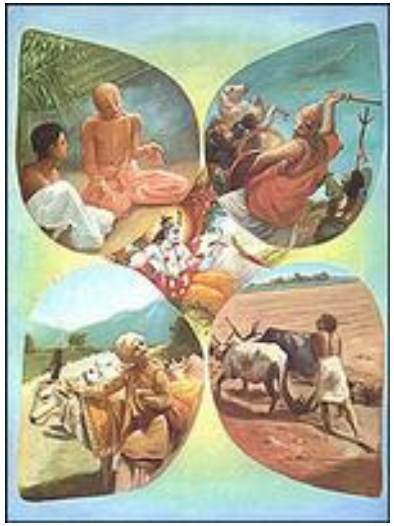
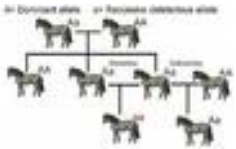
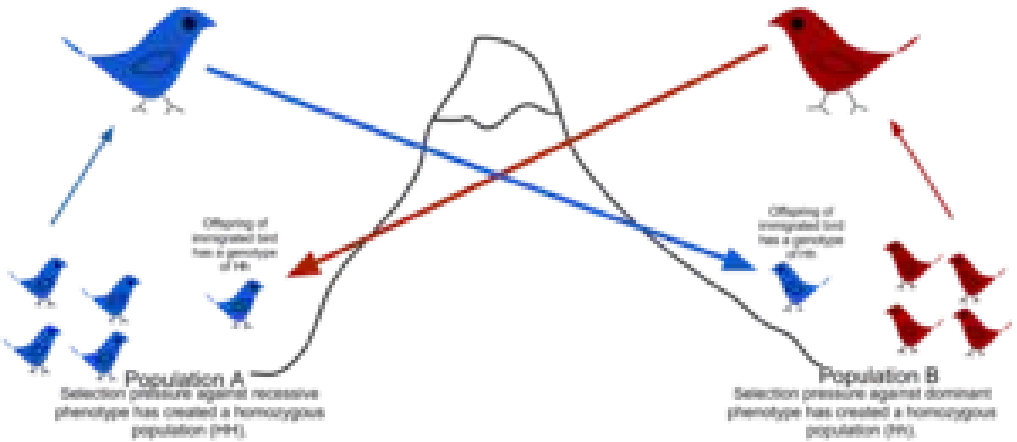
  - assortative mating
  - population subdivision

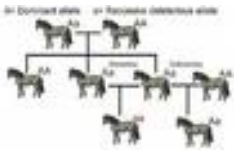




Population and evolutionary genetics

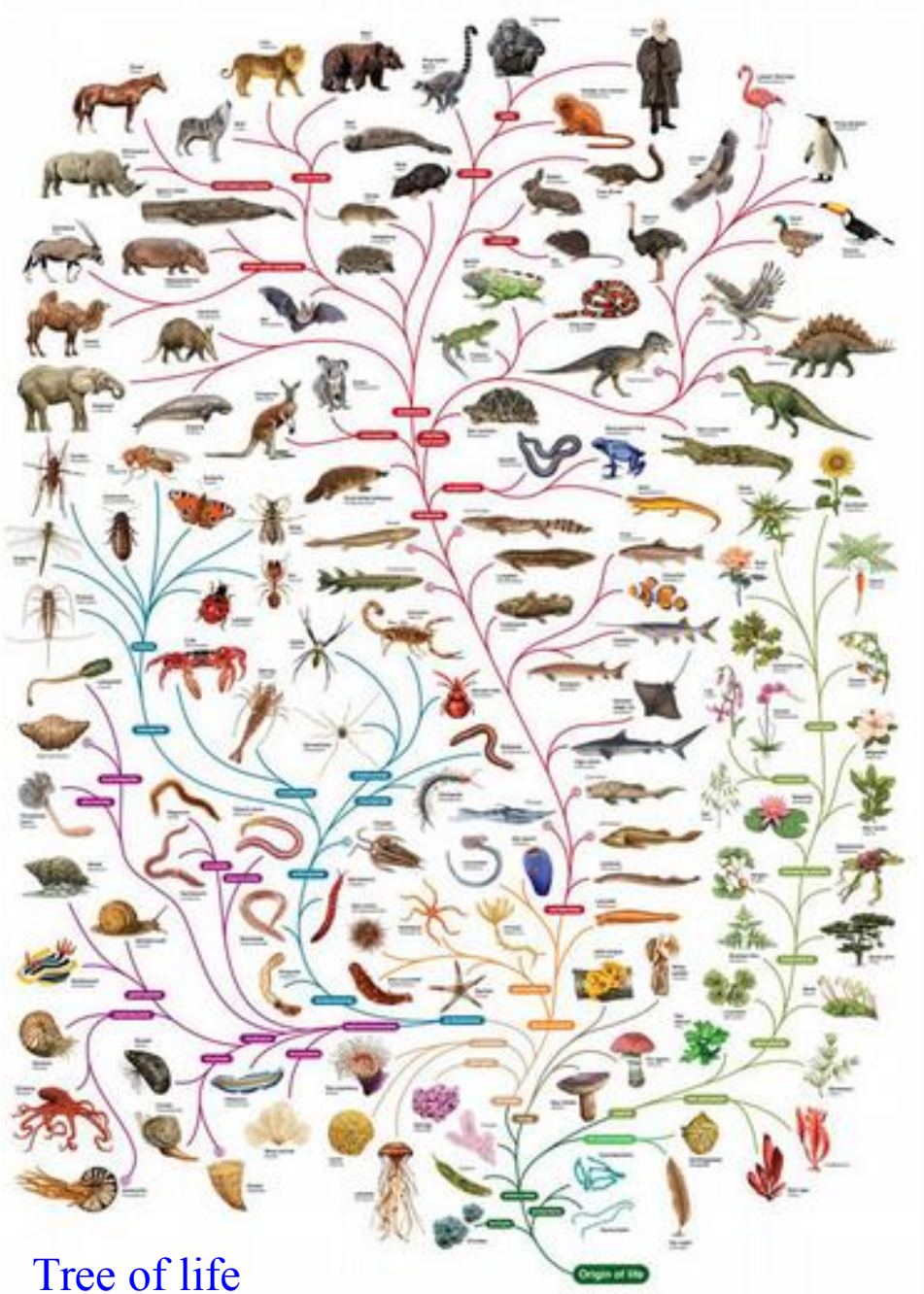
- Non-random mating
  - inbreeding
  - assortative mating
  - population subdivision
    → gene flow/admixture





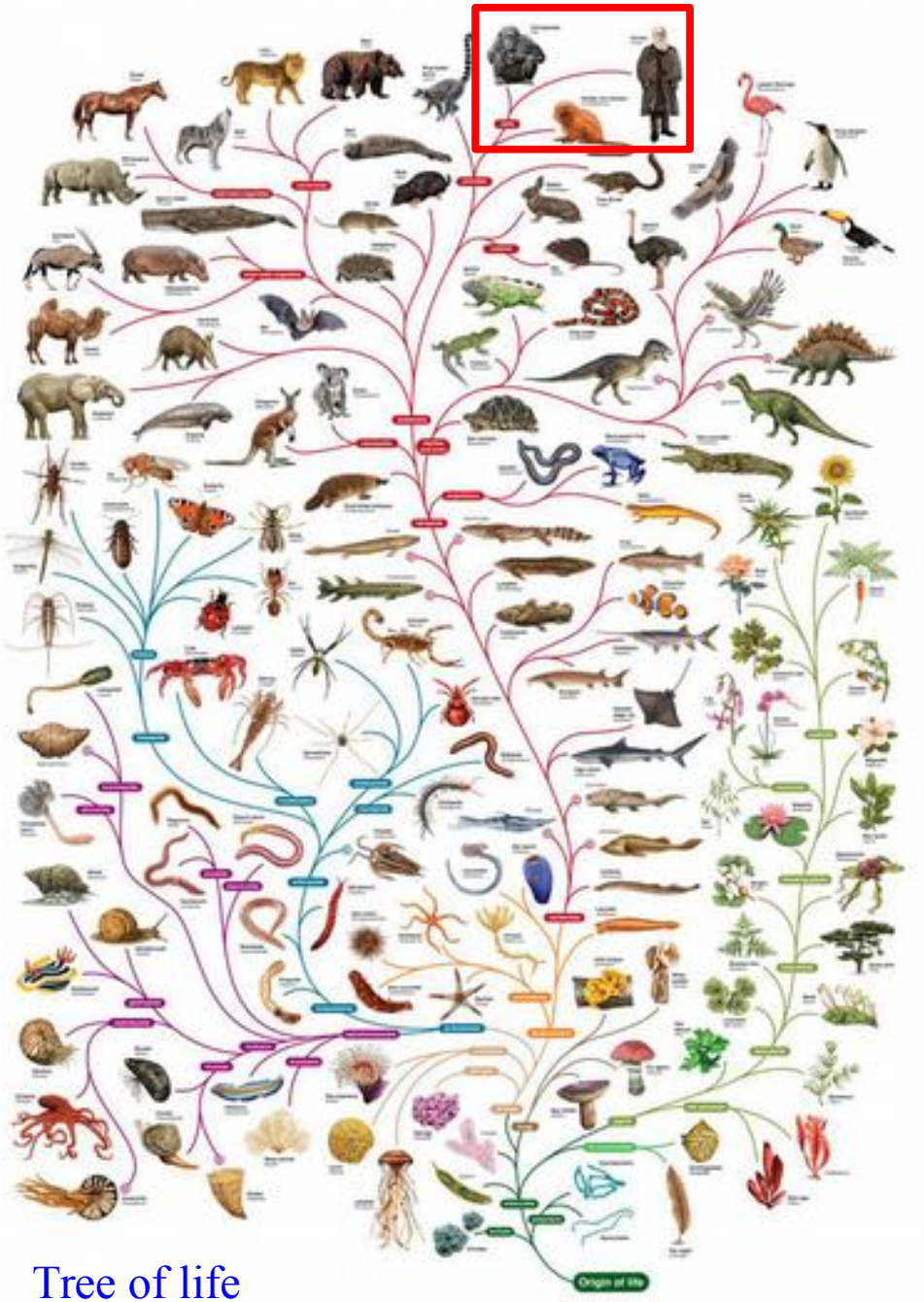
Human evolution

Human evolution



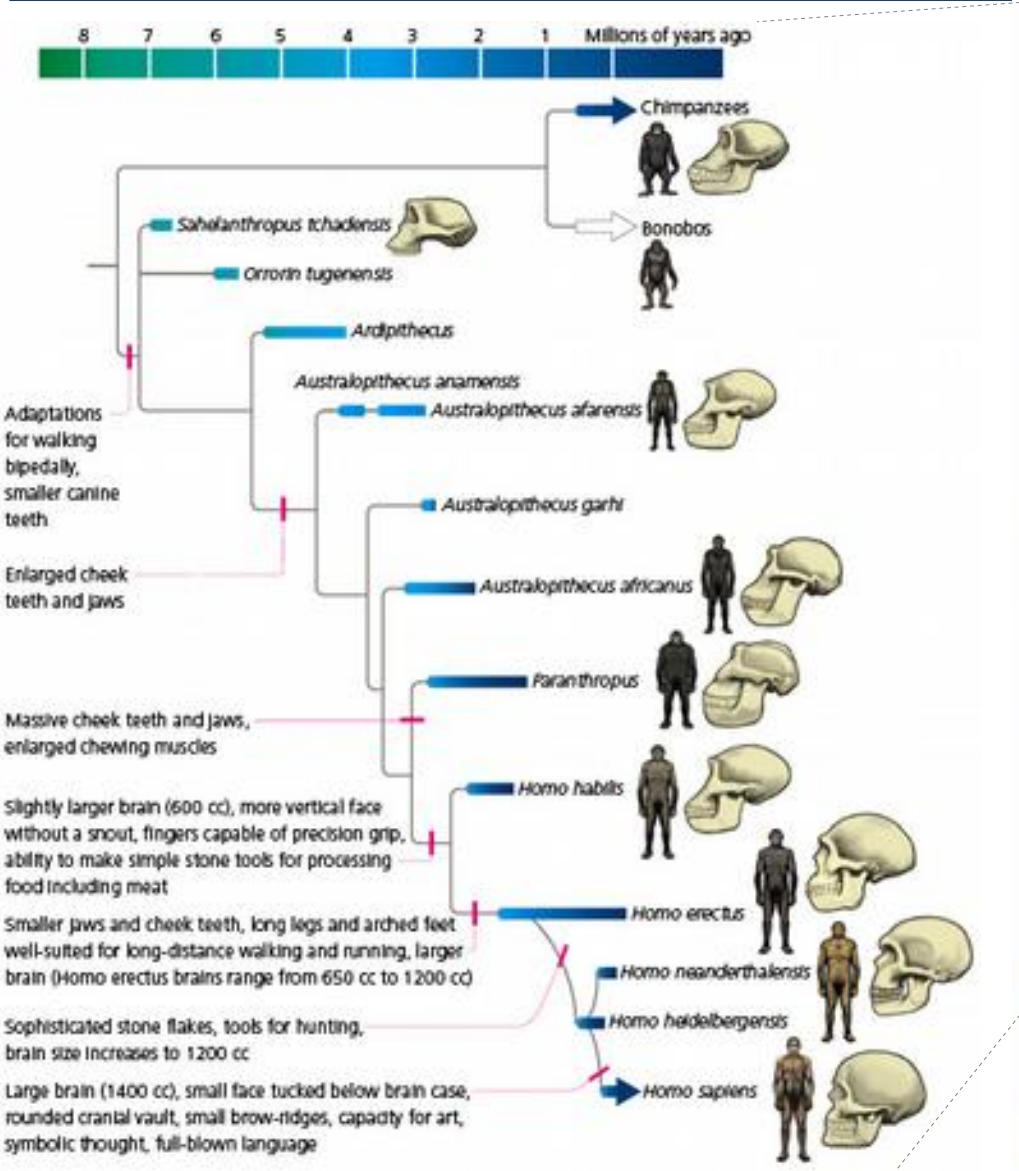
Tree of life

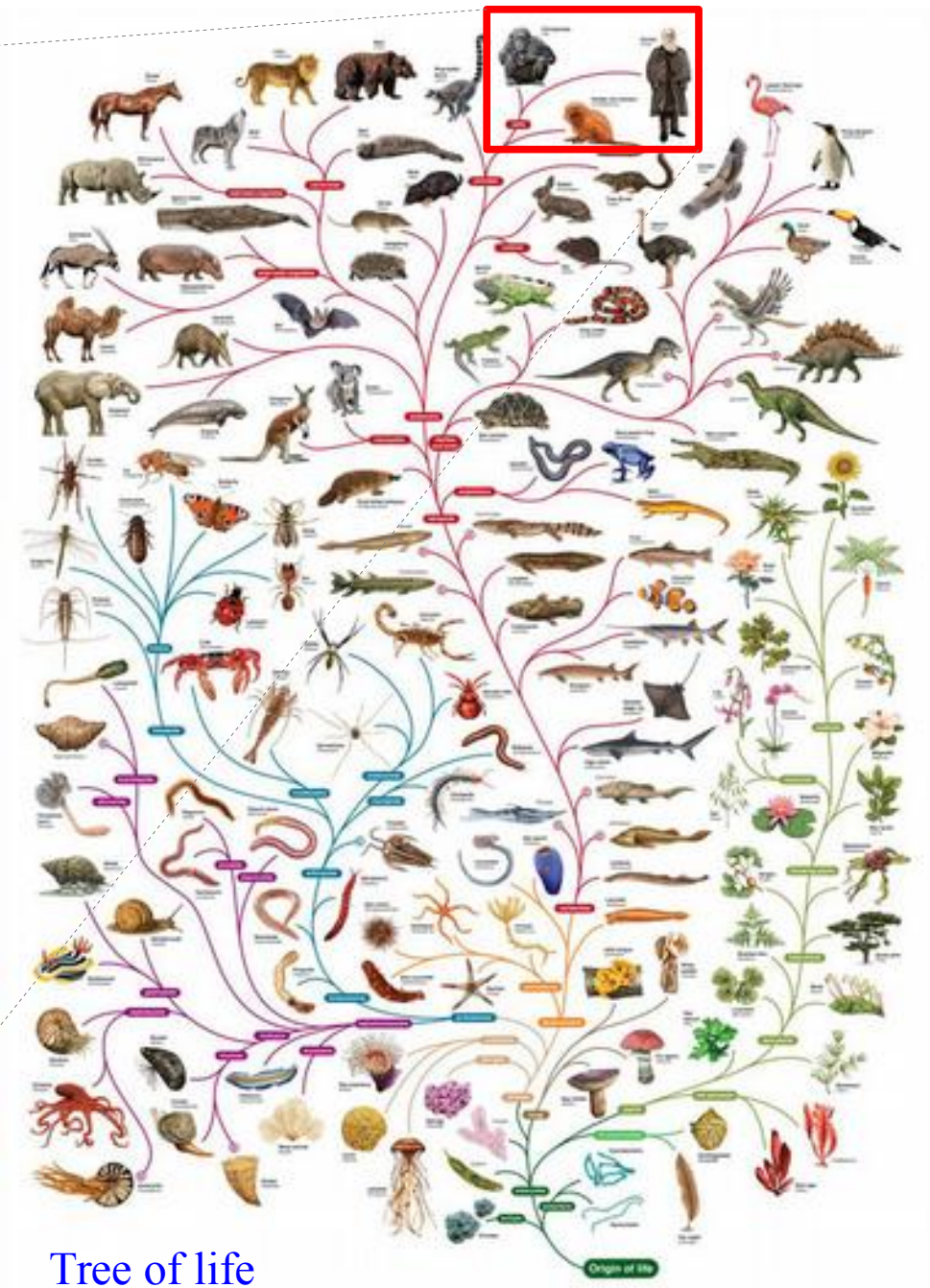
Human evolution



Tree of life

Human evolution

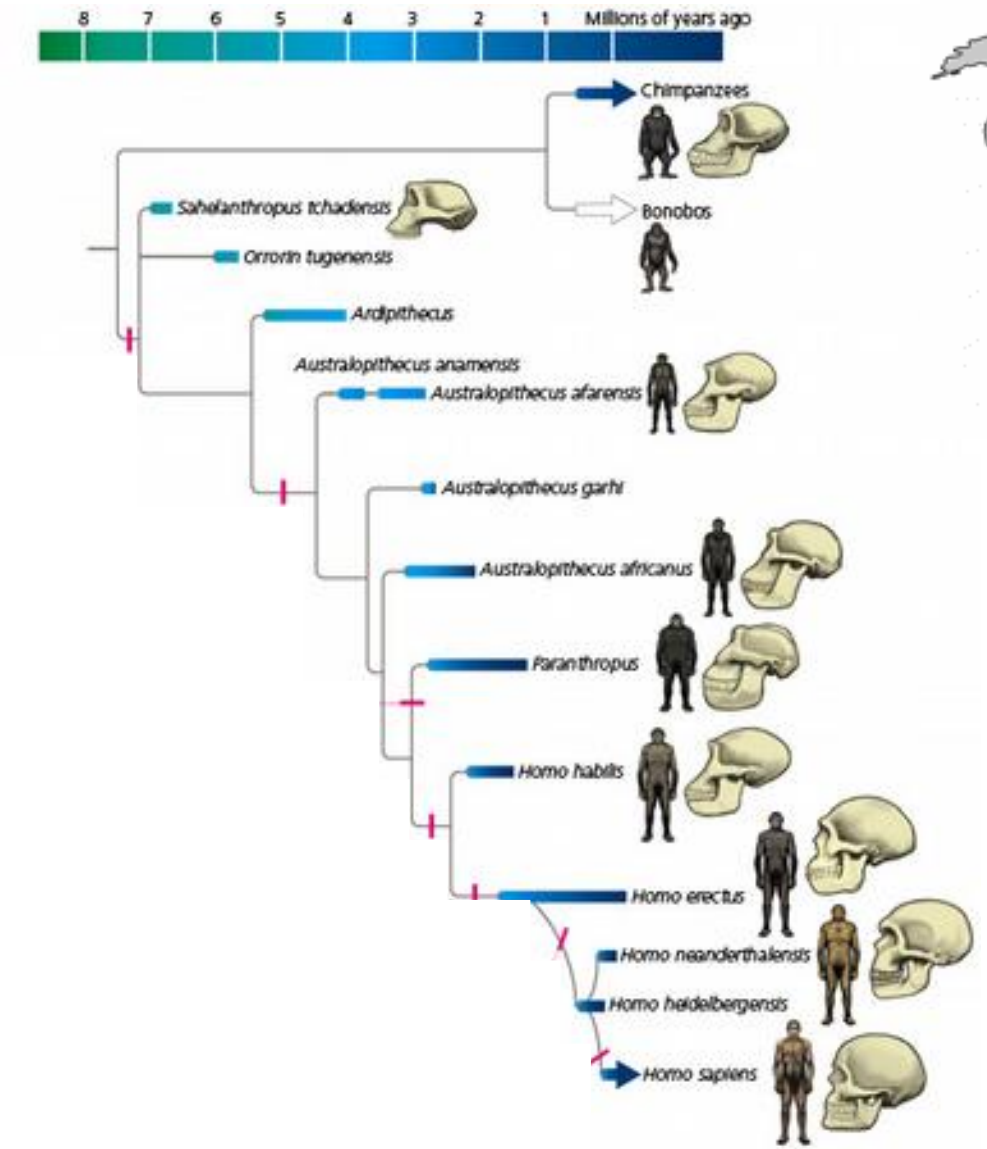




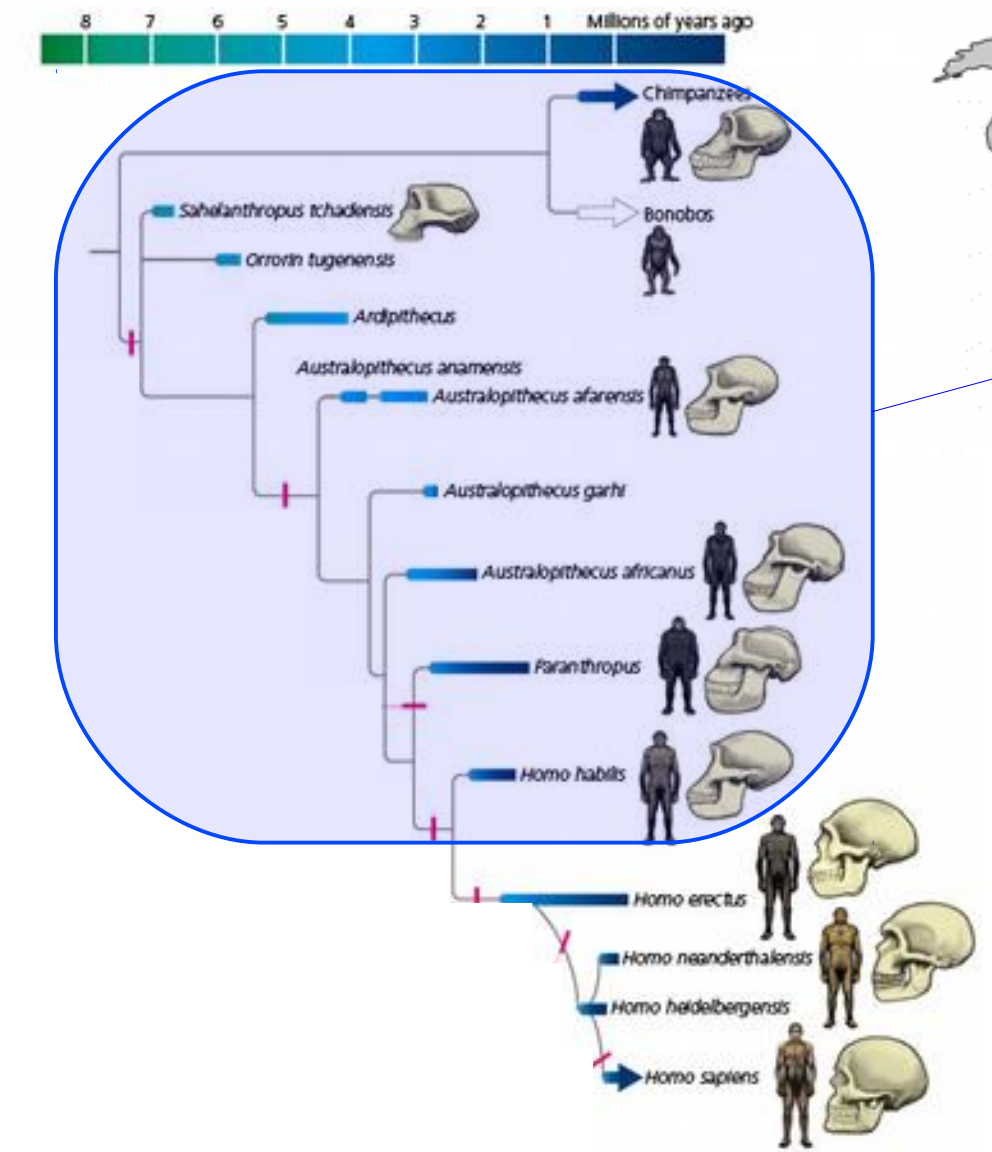
Human evolution

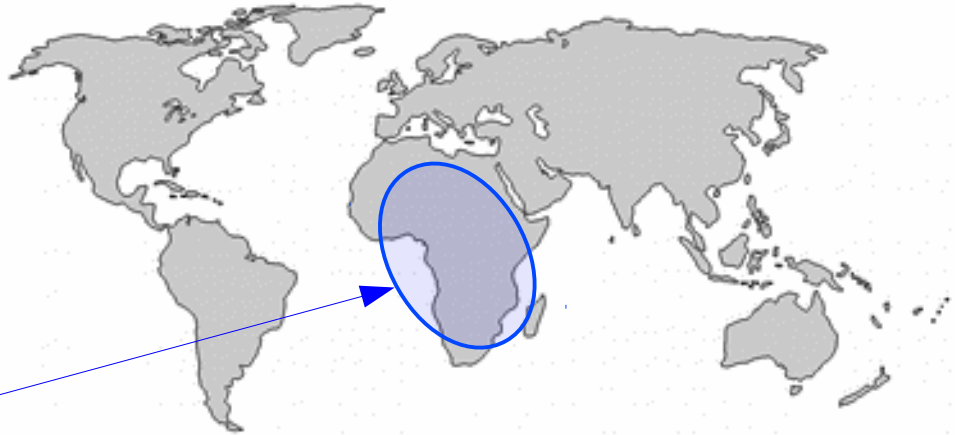
Tree of life

Human evolution

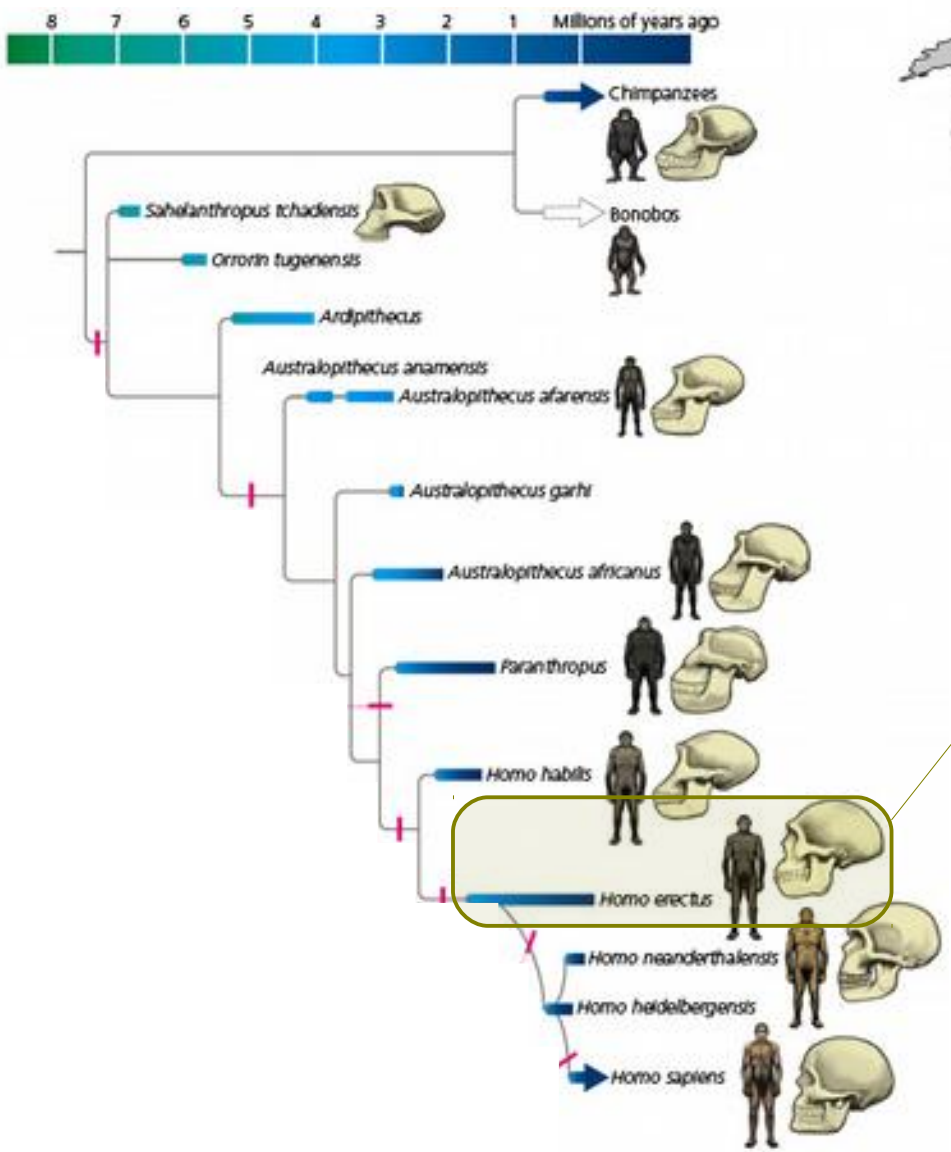


Human evolution





Human evolution



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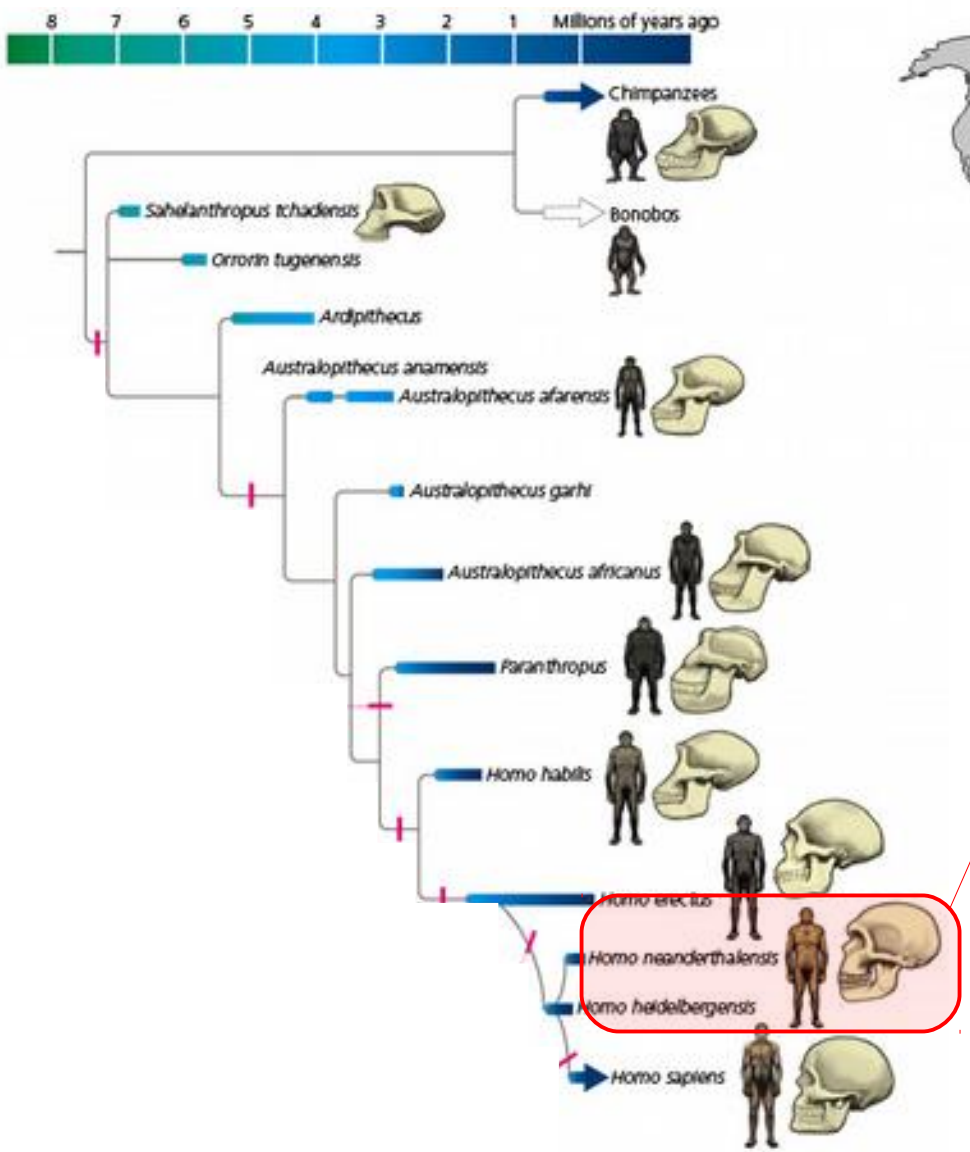

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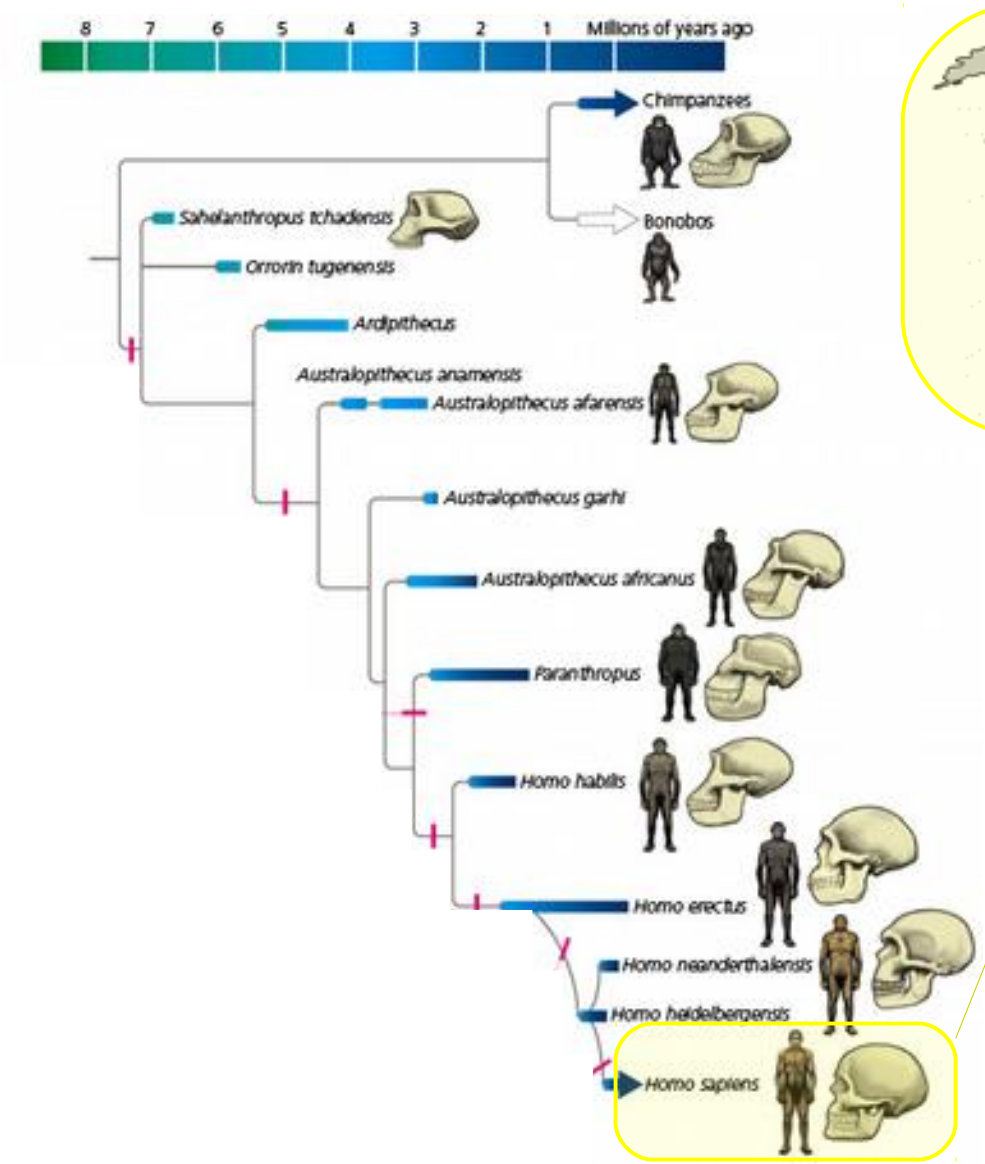
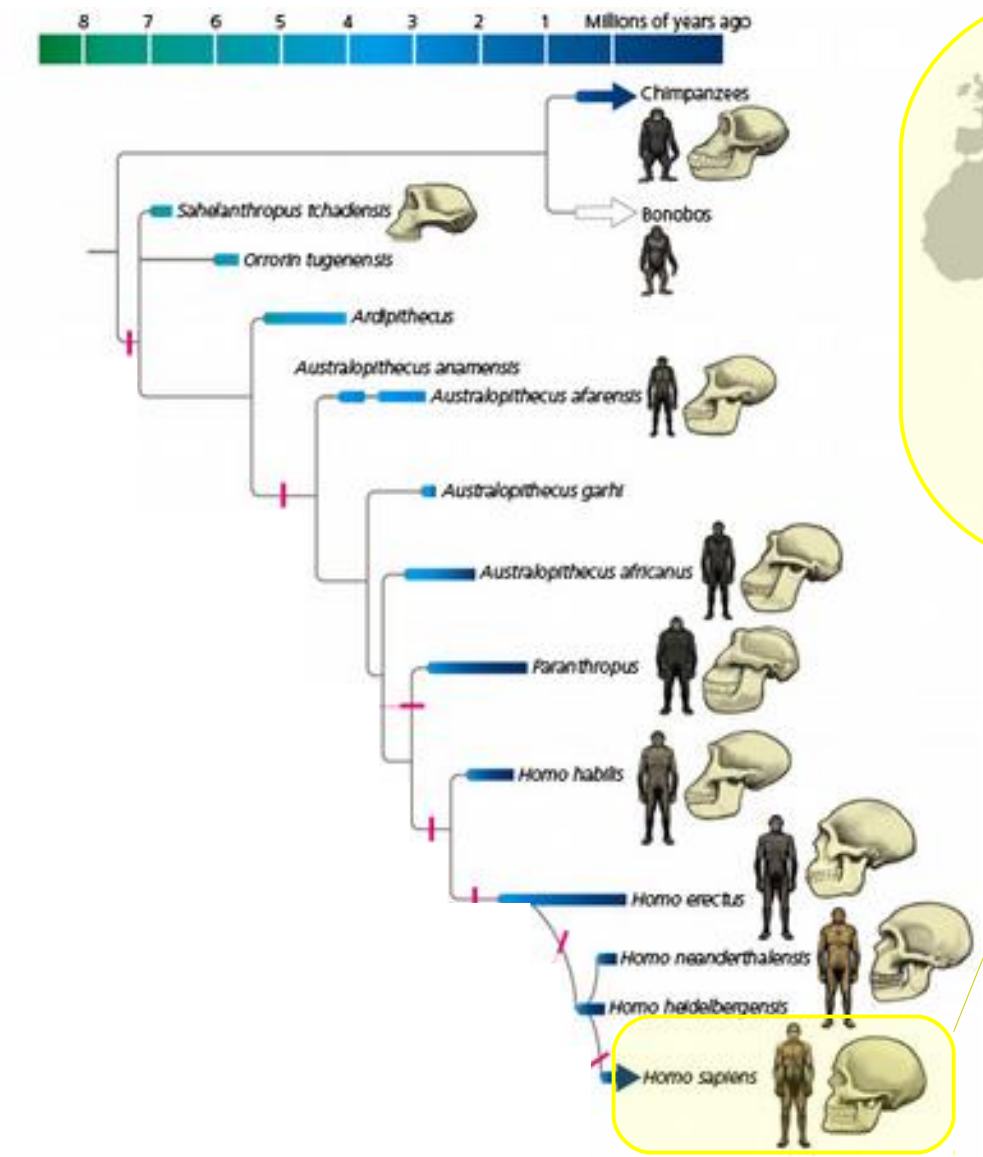
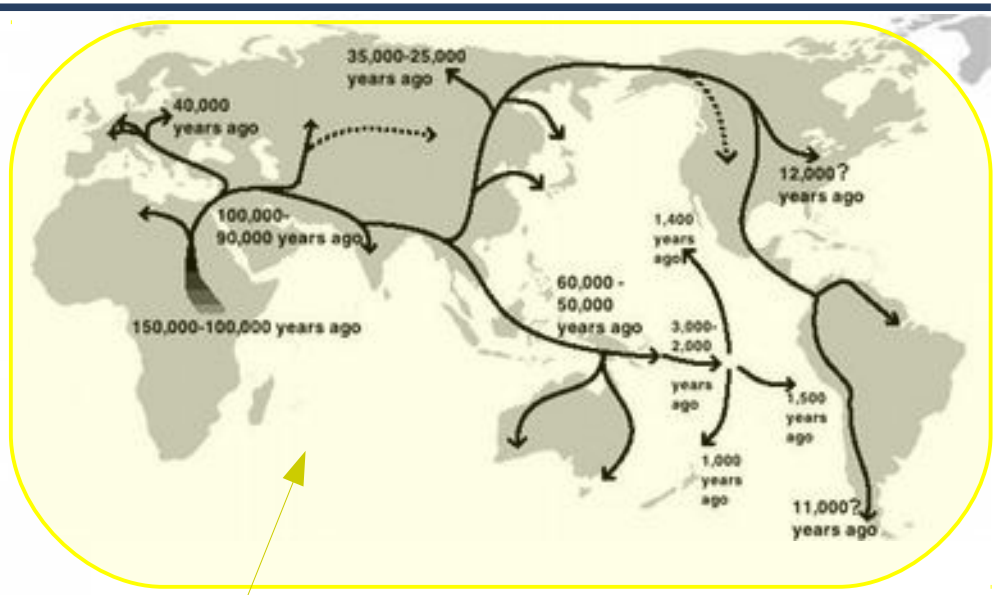


Human evolution





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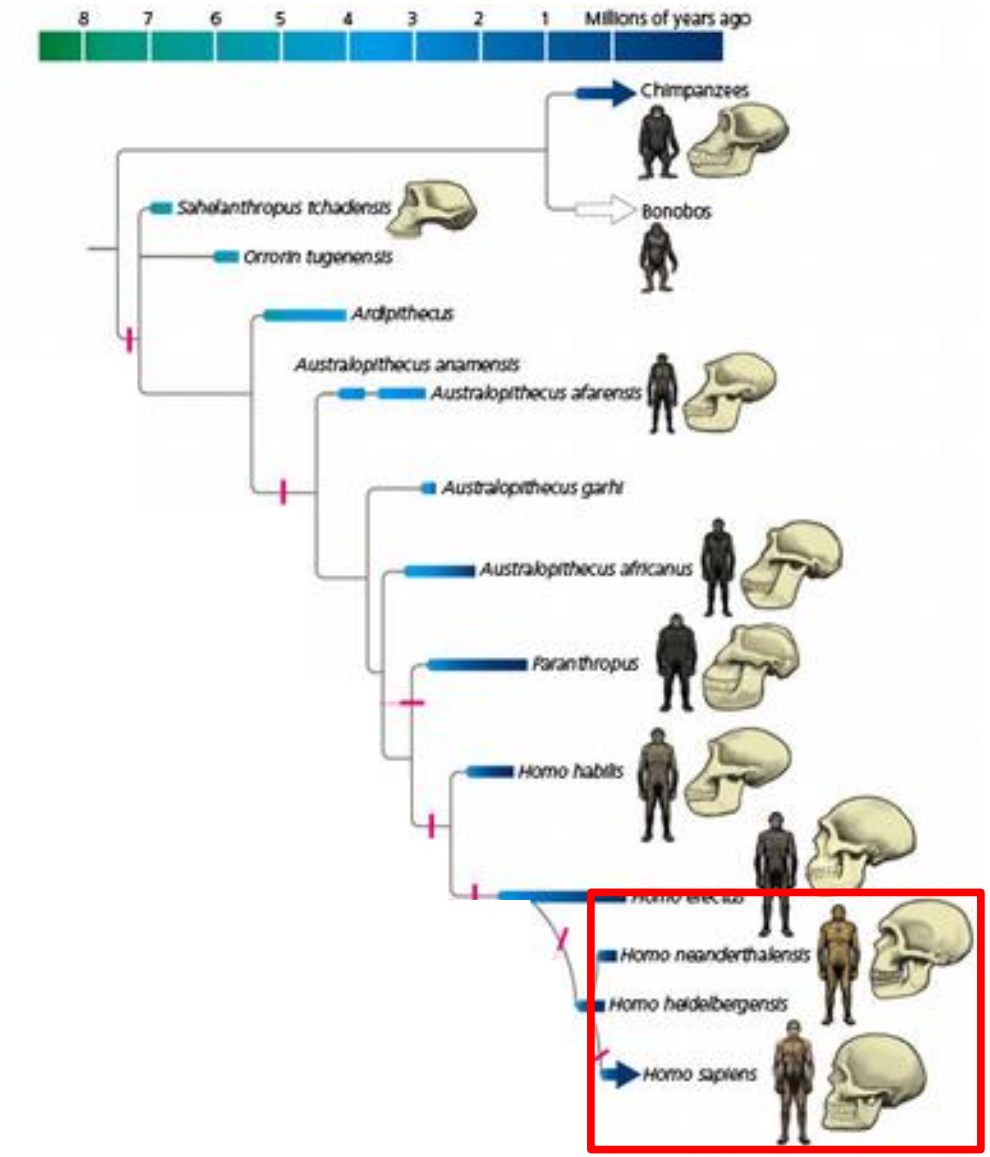
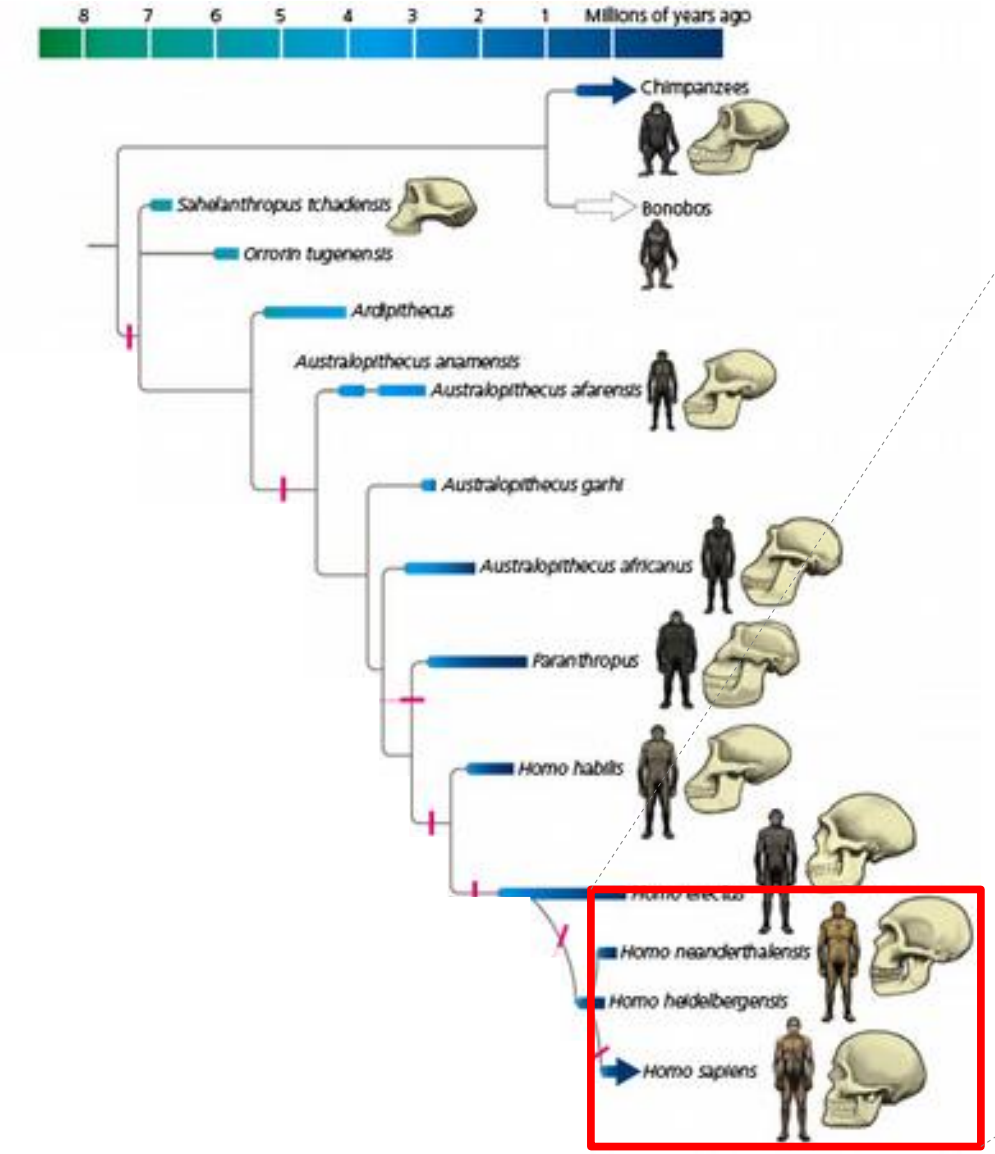
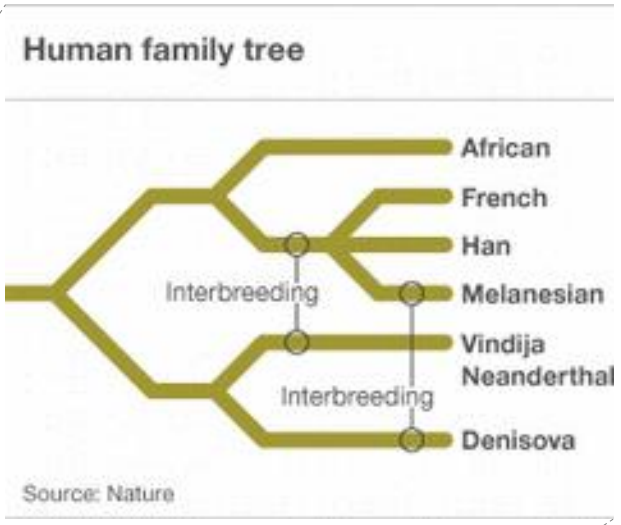
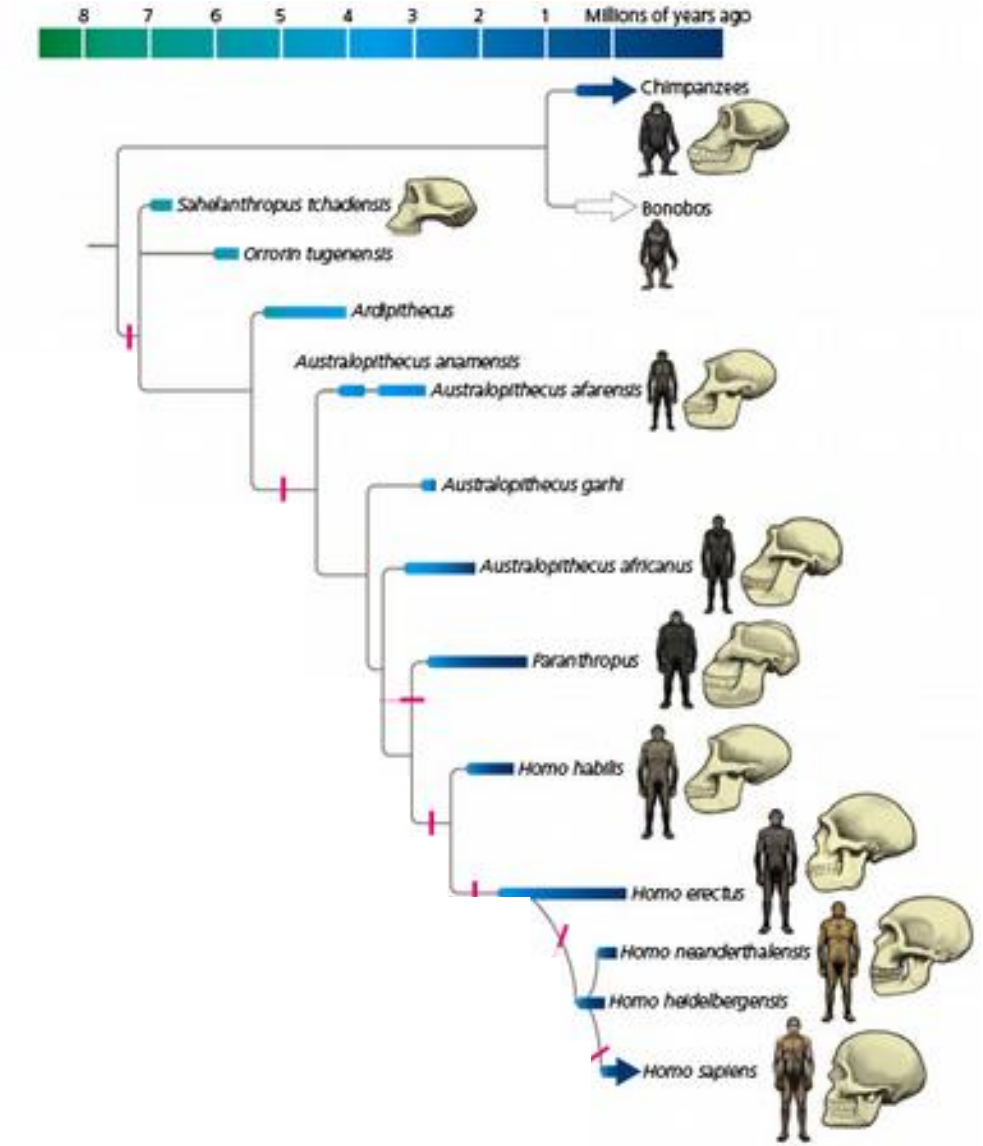


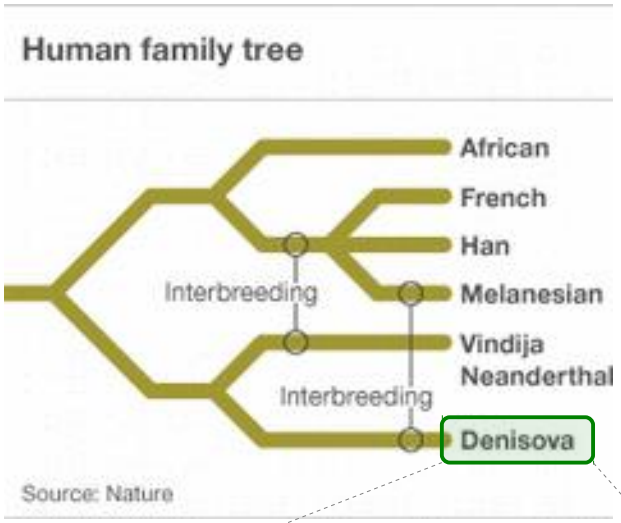
Human evolution

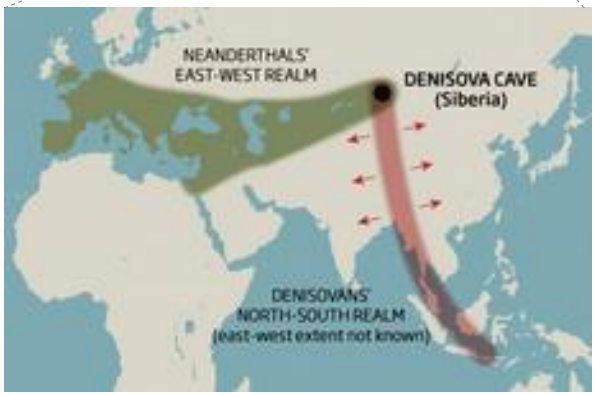




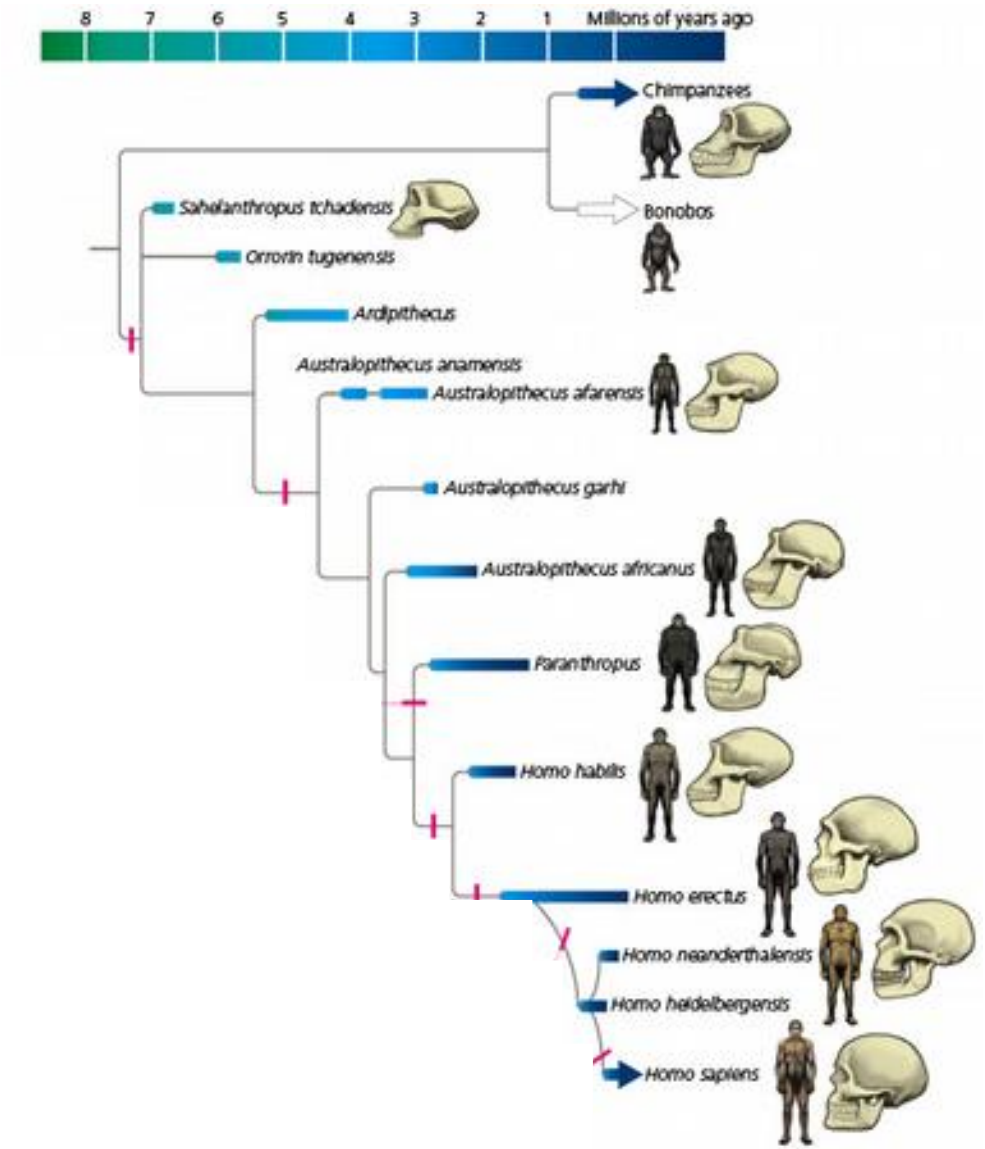
Human evolution

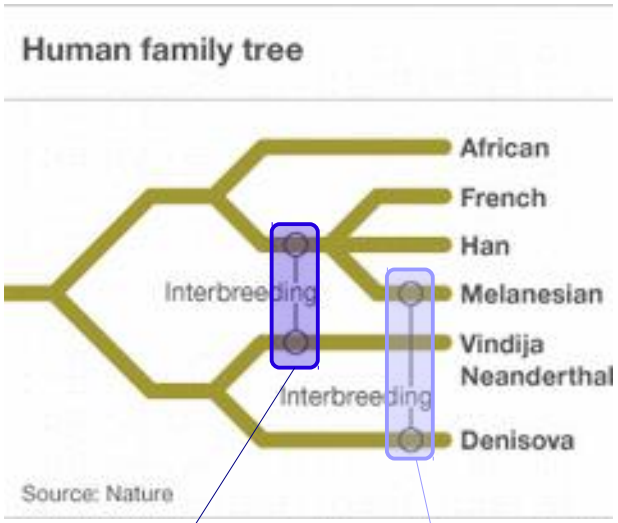






Human evolution





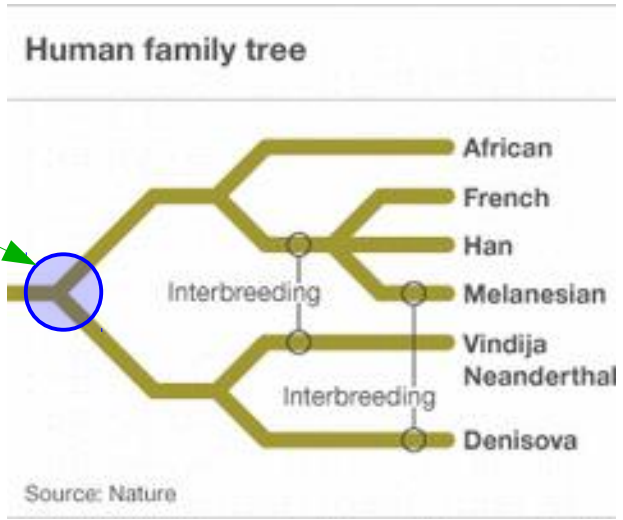
~4% Melanesians

1-4% (2.5%) non-Africans

Human evolution

- "Modern" exon *FOXP2*
- Hyoid bone
- Audiograms
- Tools
- Symbolic culture (?)

=



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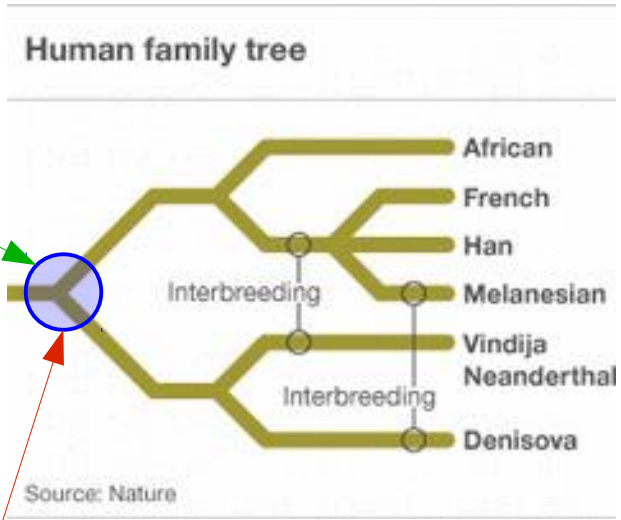

≠

- Intron 8 *FOXP2*/*POU3F2*

- *CNTNAP2*
- *MCPH1*, *ASPM*, *DRD5*, *MEF2A*

- Survival

- Symbolic culture, tools...

Human evolution

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- Audiograms

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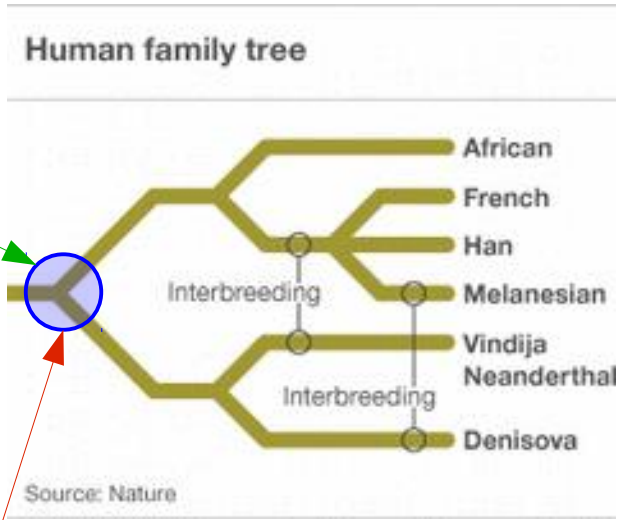

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- *CNTNAP2*
- *MCPH1*, *ASPM*, *DRD5*, *MEF2A*

- Survival

- Symbolic culture, tools...

≠

Did “they” have language?
If so, what kind?

Human genetic and linguistic diversity

- Genetically quite similar to other animals:
  - 98% to chimps

Human genetic and linguistic diversity

- Genetically quite similar to other animals:
  - 98% to chimps
  - 85% to mice

Human genetic and linguistic diversity

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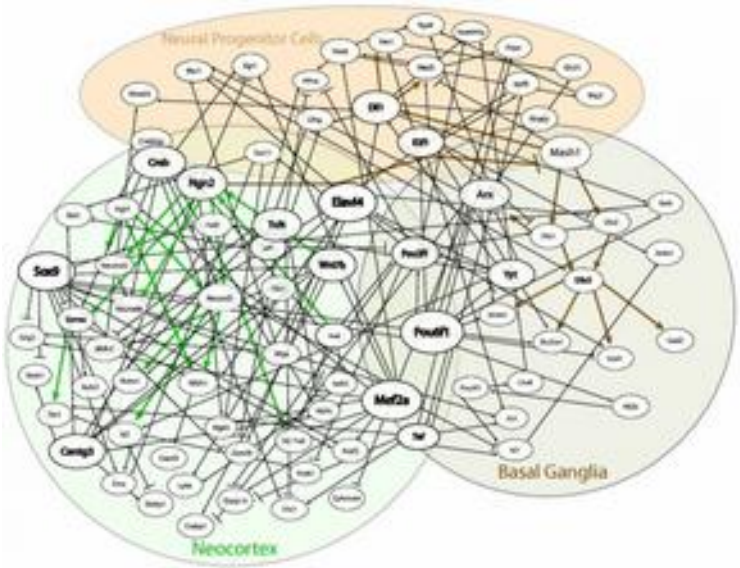
  - 50% to fruit flies

Human genetic and linguistic diversity

- Genetically quite similar to other animals:
  - 98% to chimps
  - 85% to mice
  - 50% to fruit flies
- Most differences in regulatory networks and dynamics



Human genetic and linguistic diversity

- Relatively genetically uniform species ← evolutionary history

Human genetic and linguistic diversity

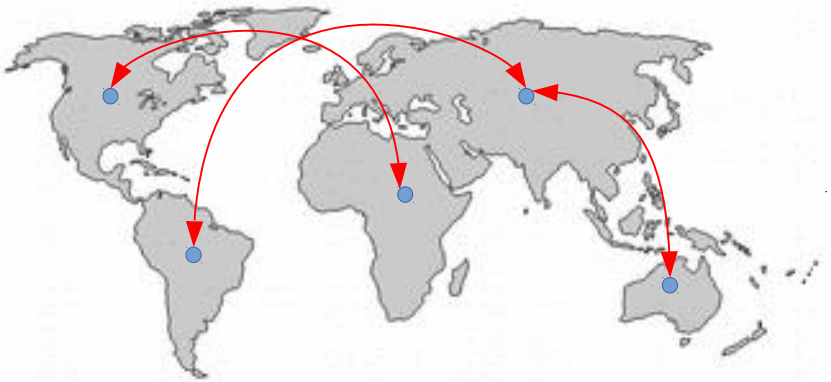
- Relatively genetically uniform species ← evolutionary history
- But we are no clones!

  ~ <0.5% nucleotide diversity b/w individuals (15 million bases)

Human genetic and linguistic diversity

- Relatively genetically uniform species ← evolutionary history
- But we are no clones!
- Distribution of diversity

  ~ 8% between : 7% within continents : 85% within local groups



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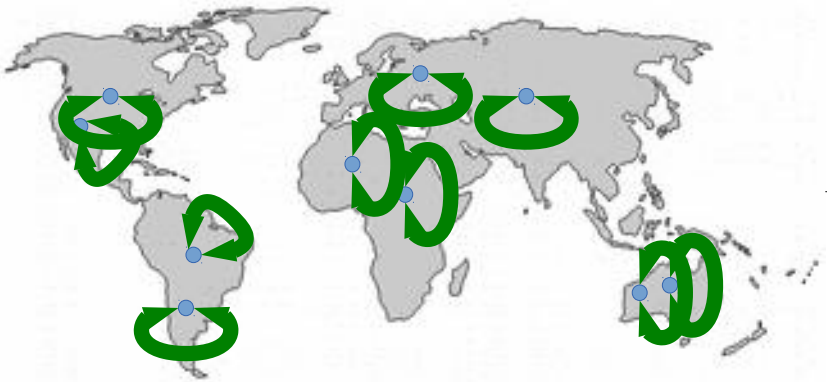

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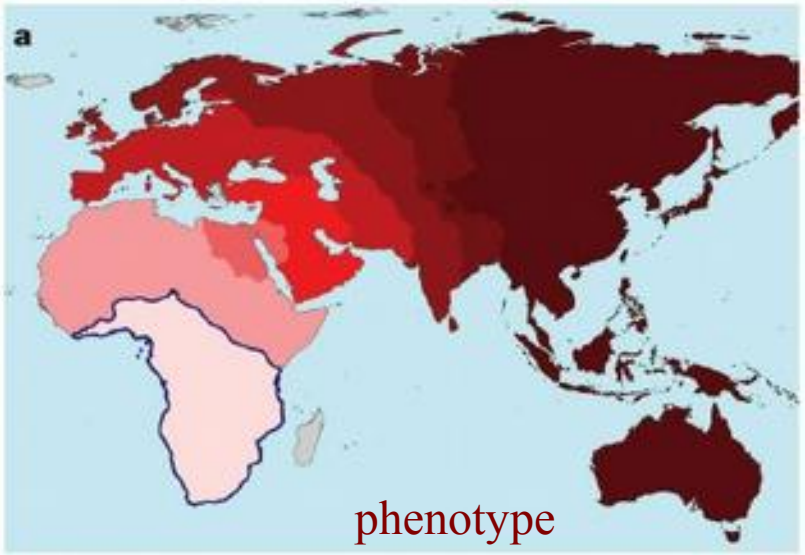

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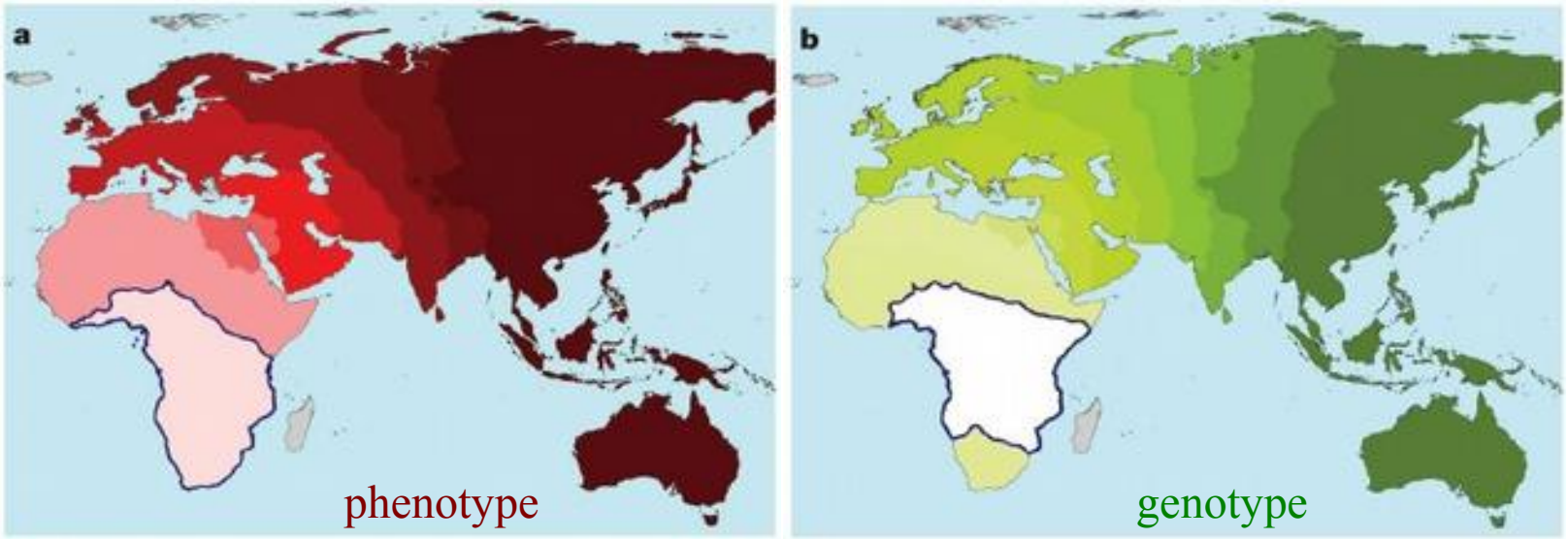

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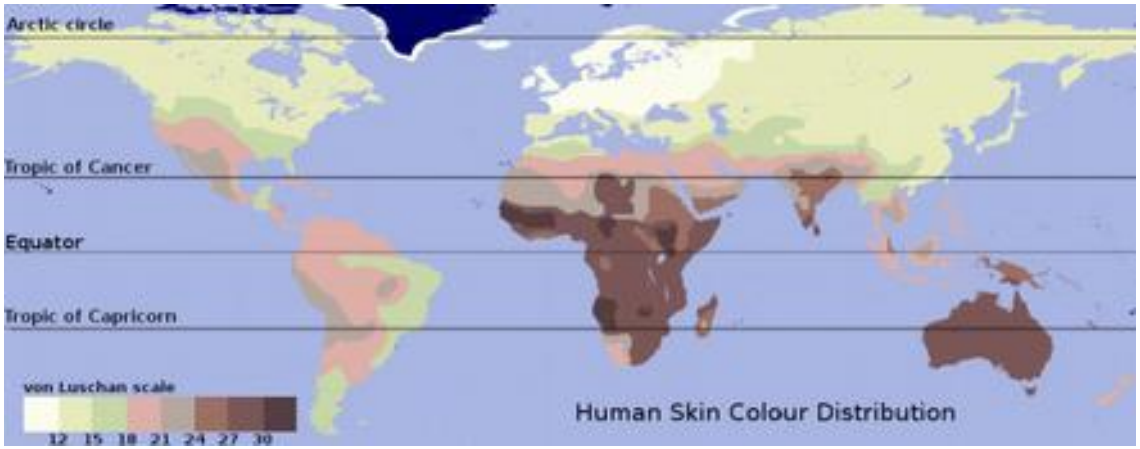

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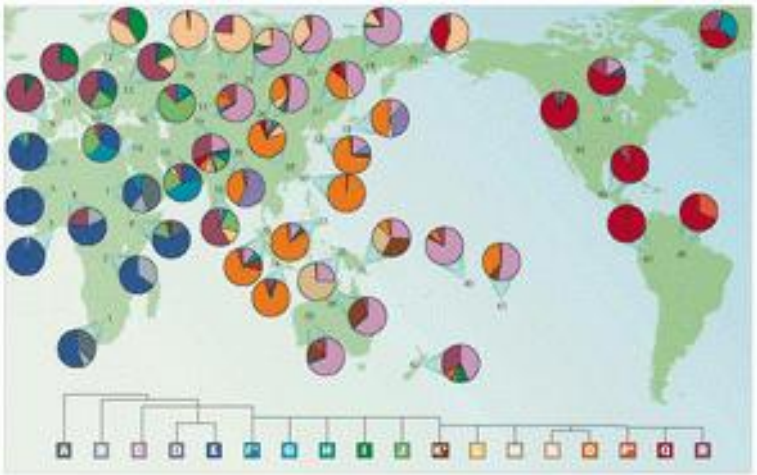
  gradual clines as opposed to discontinuous boundaries

  due to ubiquitous allele frequencies, less to private alleles:

Human genetic and linguistic diversity

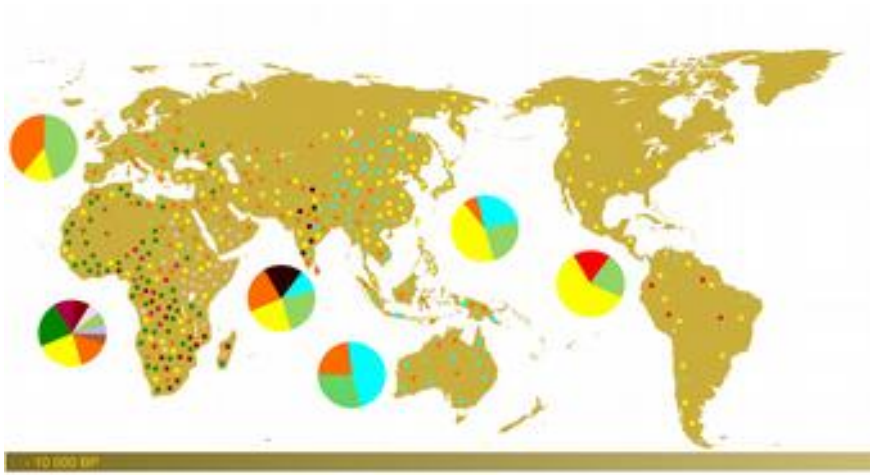
- continuous



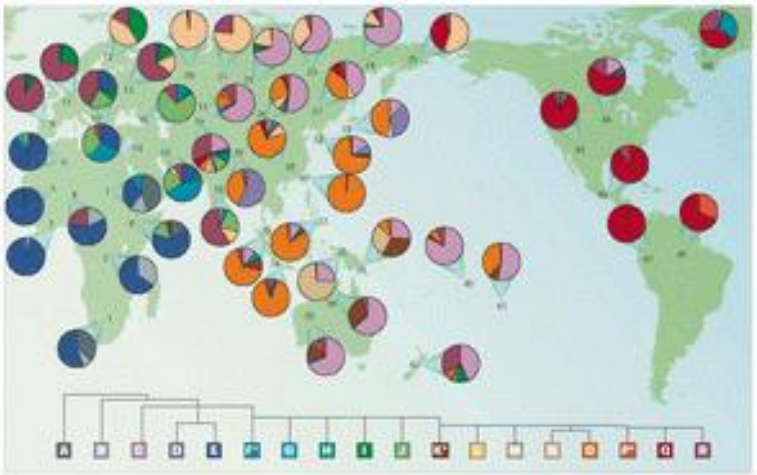
Distribution of Y haplogroups
(Jobling & Tyler-Smith 2003)

Human genetic and linguistic diversity

- continuous
- multiple loci



Human genetic diversity
(Barbujani & Colonna, 2010)



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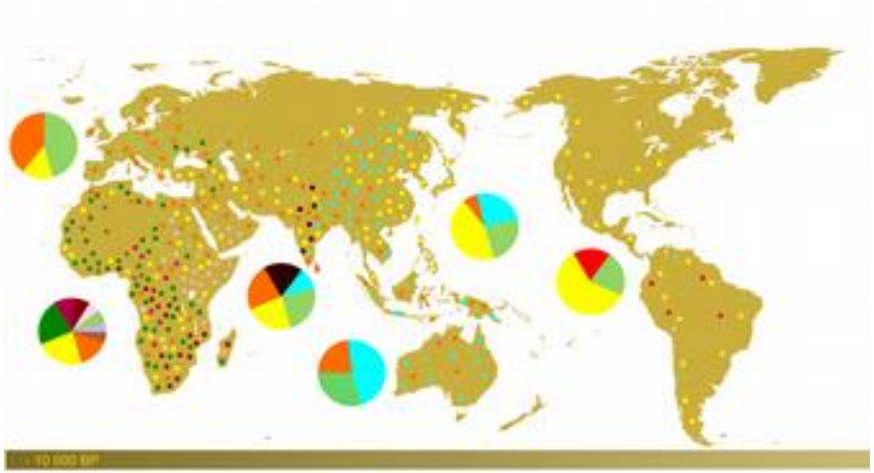
Human genetic and linguistic diversity

- continuous
- multiple loci
- geography



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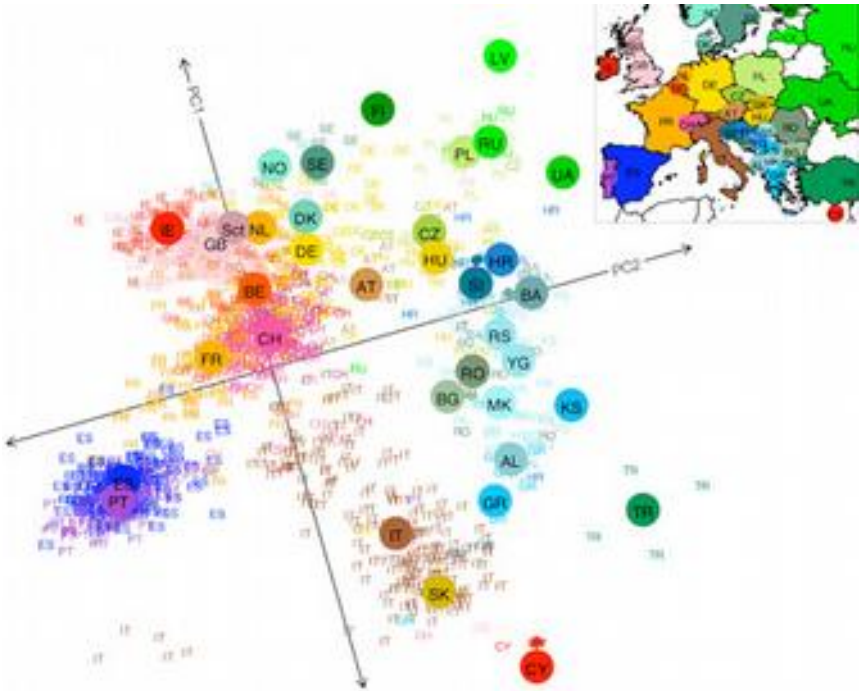
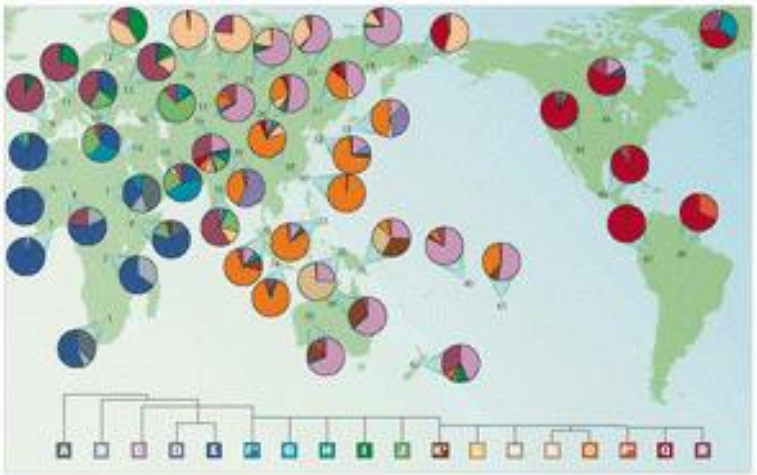


Genetic diversity Europe (500,000 SNPs)



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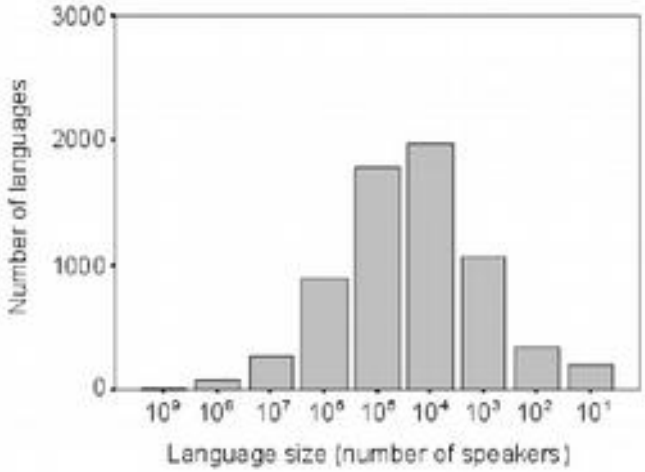
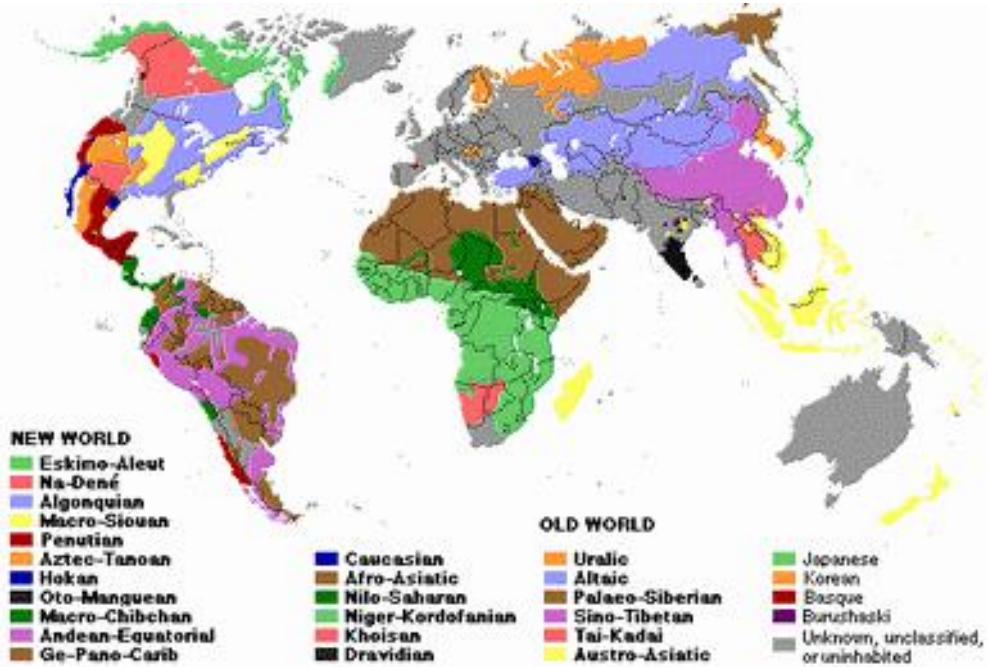
Human genetic and linguistic diversity

- ~ **7000** languages
- > **100** language families
  - ~ **150** incl. language isolates

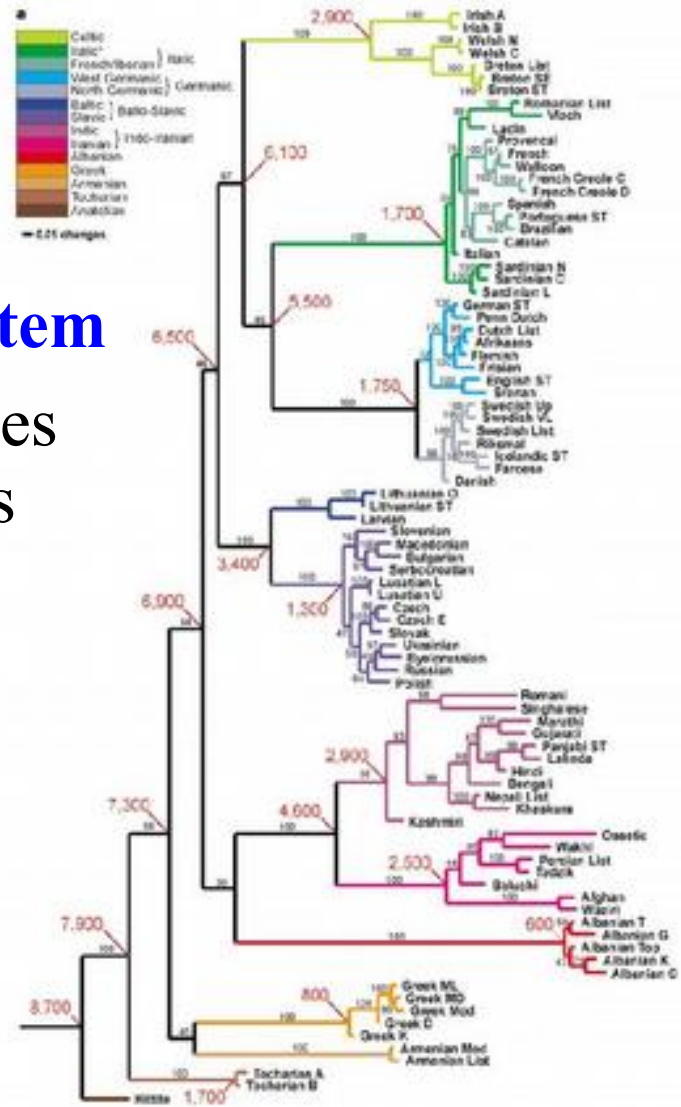




Human genetic and linguistic diversity

- ~ **7000** languages
- > **100** language families
  - ~ **150** incl. language isolates
- Language = **cultural evolutionary system**
- **vertical** inheritance → language families
- **horizontal** processes → language areas

Indian sprachbund


IE tree with ages, Gray & Atkinson (2003)

Human genetic and linguistic diversity

- Humans carry genes & languages
  → **historical processes** should create or break correlations
- Migrations

Viking longboat

Human genetic and linguistic diversity

- Humans carry genes & languages
  → **historical processes** should create or break correlations
- Migrations
- Conquest

Roman legion

Human genetic and linguistic diversity

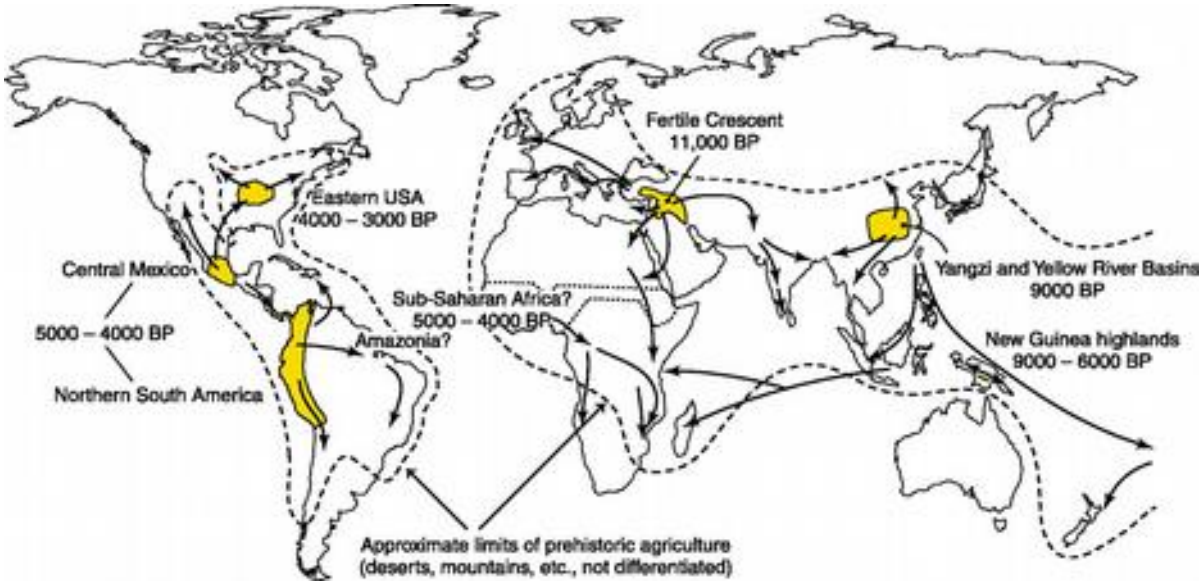
- Humans carry genes & languages
  → **historical processes** should create or break correlations

- Migrations
- Conquest
- Religion

Sultan Ahmed Mosque, Istambul

Human genetic and linguistic diversity

- Farming/language co-dispersal



Proposed farming expansions Diamond & Bellwood (2003)



Human genetic and linguistic diversity

→ accidental correlations




Human genetic and linguistic diversity

→ accidental correlations
→ non-accidental correlations:




Human genetic and linguistic diversity

→ accidental correlations
→ non-accidental correlations:
- village sign languages

Kata Kolok

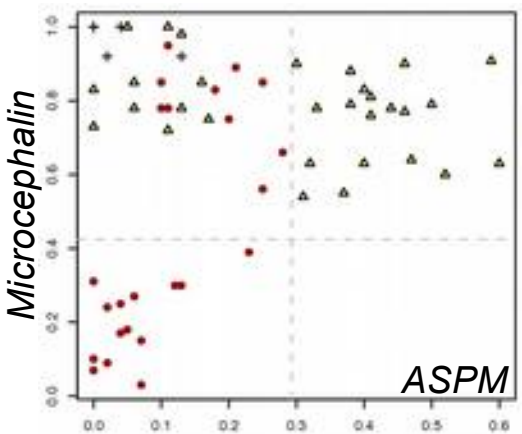
ABSL




Human genetic and linguistic diversity

→ accidental correlations
→ non-accidental correlations:

- village sign languages
- tone, *ASPM*, *Microcephalin*







Human genetic and linguistic diversity

→ accidental correlations

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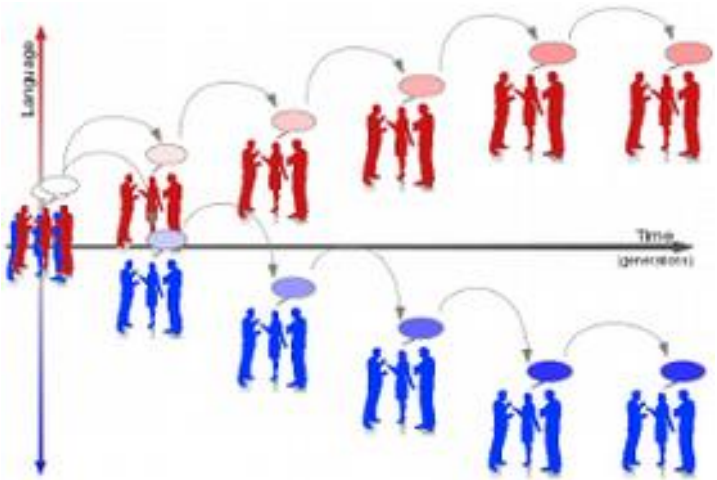
} → genetic biasing

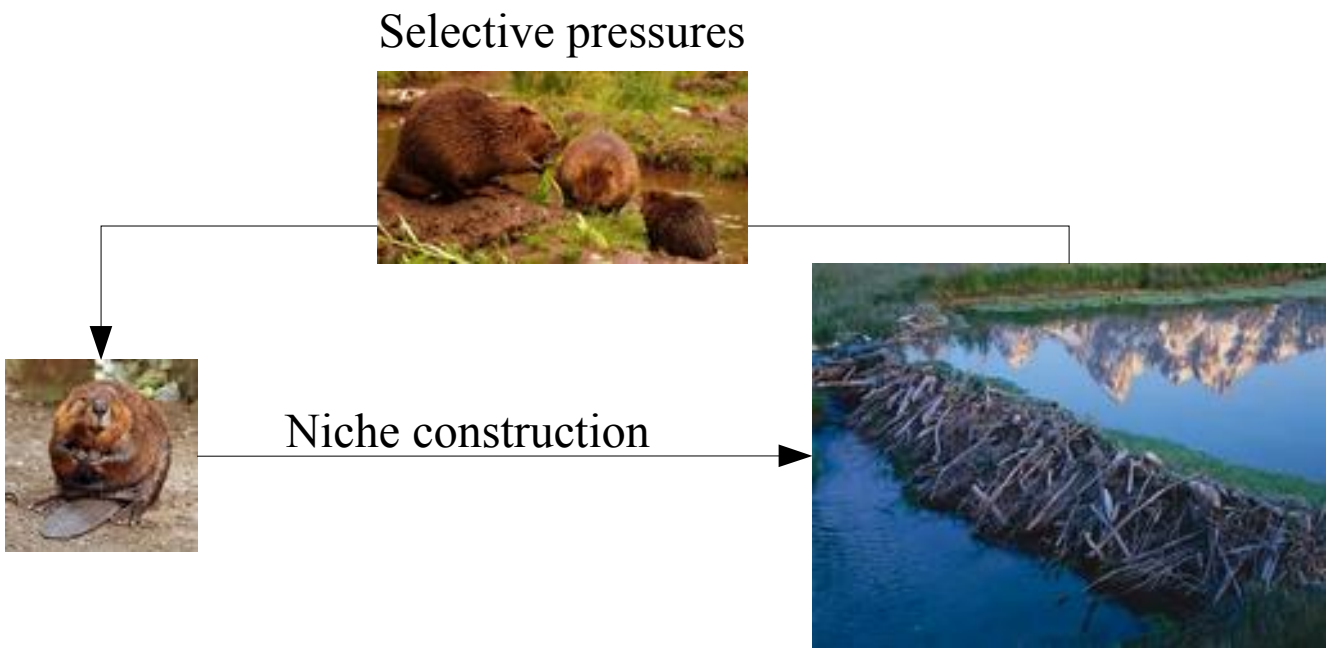







Niche construction & Gene-culture co-evolution

- Organisms construct their niches



Niche construction & Gene-culture co-evolution

- Organisms construct their niches
- Culture shapes selective pressures:
  - farming

Niche construction & Gene-culture co-evolution

- Organisms construct their niches
- Culture shapes selective pressures:
  - farming → immune system

Niche construction & Gene-culture co-evolution

- Organisms construct their niches
- Culture shapes selective pressures:
  - farming → immune system, amylase gene

Niche construction & Gene-culture co-evolution

- Organisms construct their niches
- Culture shapes selective pressures:
  - farming → immune system, amylase gene, lactose tolerance...

Niche construction & Gene-culture co-evolution

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  - tool use → hand

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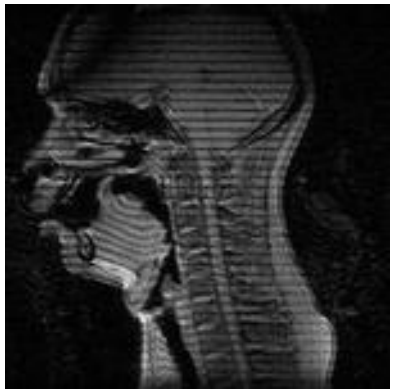

Niche construction & Gene-culture co-evolution

- Organisms construct their niches
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  - farming → immune system, amylase gene, lactose tolerance...
  - tool use → hand
  - speech → vocal tract
  - language → whole world

Conclusions

- Human evolution was really complicated → no simple story

- Complex relationships between genes and language
  → co-evolution and niche construction

- Ongoing evolution of the genetic architecture for language?

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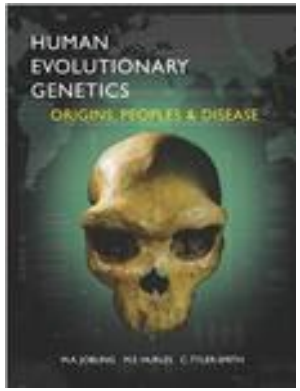
Thanks to: Alejandrina Cristia, Sarah Graham, Steve Levinson

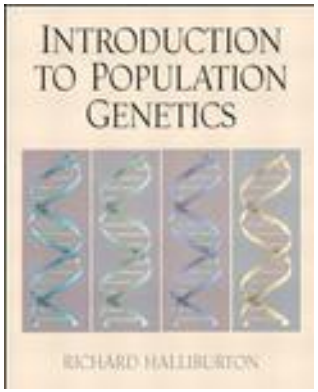
Funding: Netherlands Organisation for Scientific Research (NWO) Vidi grant 276-70-022

Suggested reading

- Books:



Jobling, M. A., Hurles, M., & Tyler-Smith, C. (2004). *Human Evolutionary Genetics: Origins, Peoples and Disease*. Garland Science: NY.



Halliburton, R. (2004). *Introduction to population genetics*. Pearson Eduction Inc.: Upper Saddle River.

- Population and evolutionary genetics:

Hurst, L. D. (2009). Fundamental concepts in genetics: genetics and the understanding of selection. *Nat Rev Genet* **10**:83–93. doi:10.1038/nrg2506

Charlesworth, B. (2009). Fundamental concepts in genetics: effective population size and patterns of molecular evolution and variation. *Nat Rev Genet* **10**:195–205. doi:10.1038/nrg2526

Jablonka, E., & Raz, G. (2009). Transgenerational epigenetic inheritance: prevalence, mechanisms, and implications for the study of heredity and evolution. *The Quarterly Review of Biology* **84**:131–176.

Koonin, E. V. (2009). Darwinian evolution in the light of genomics. *Nucleic Acids Res* **37**:1011–1034. doi:10.1093/nar/gkp089

Suggested reading

- Human evolution:

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