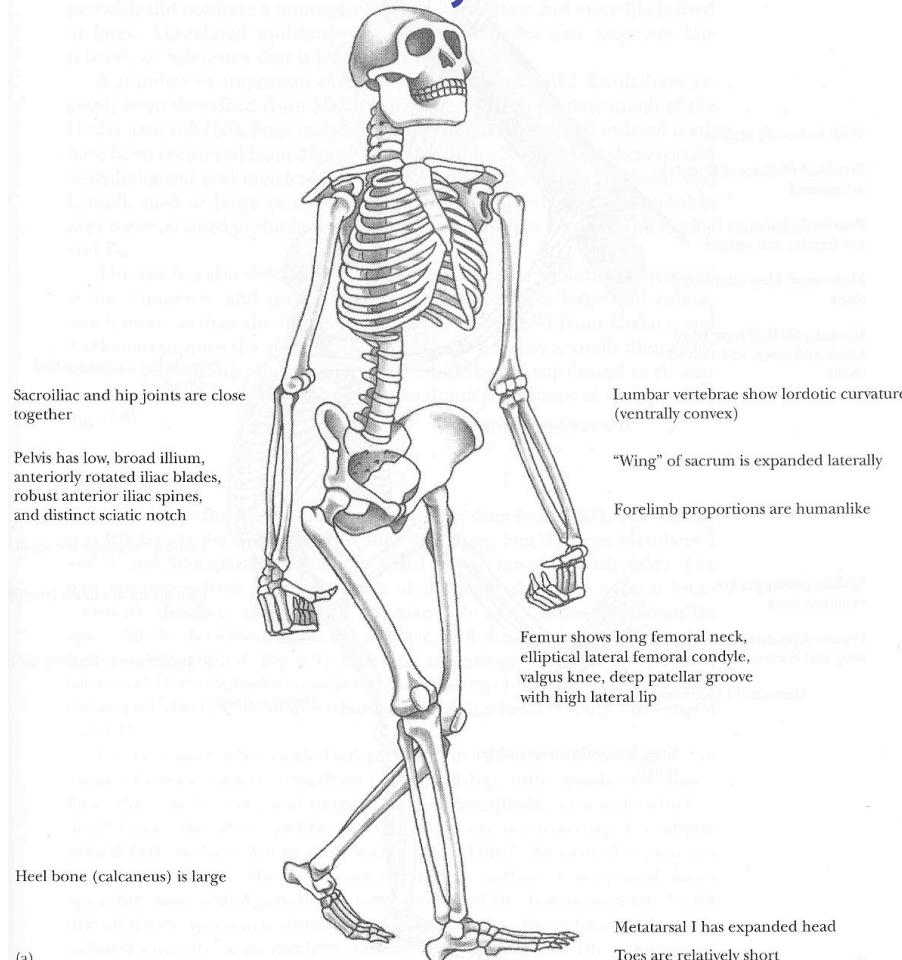
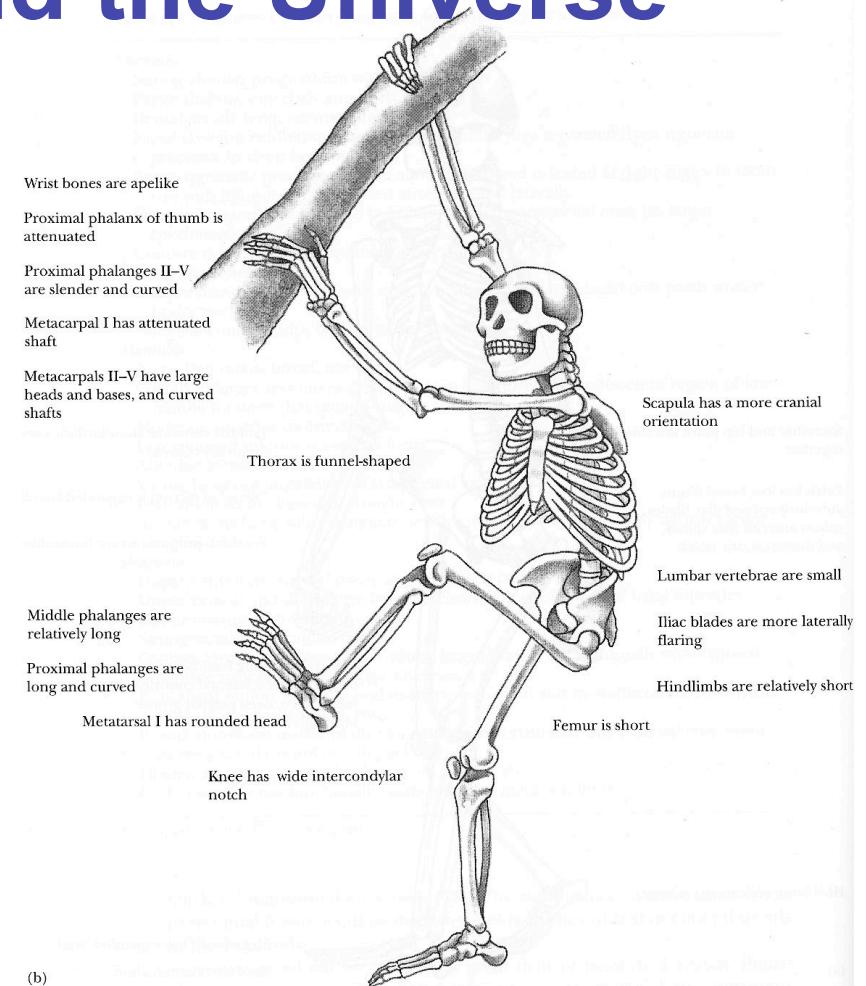


The Age of Things: Sticks, Stones and the Universe



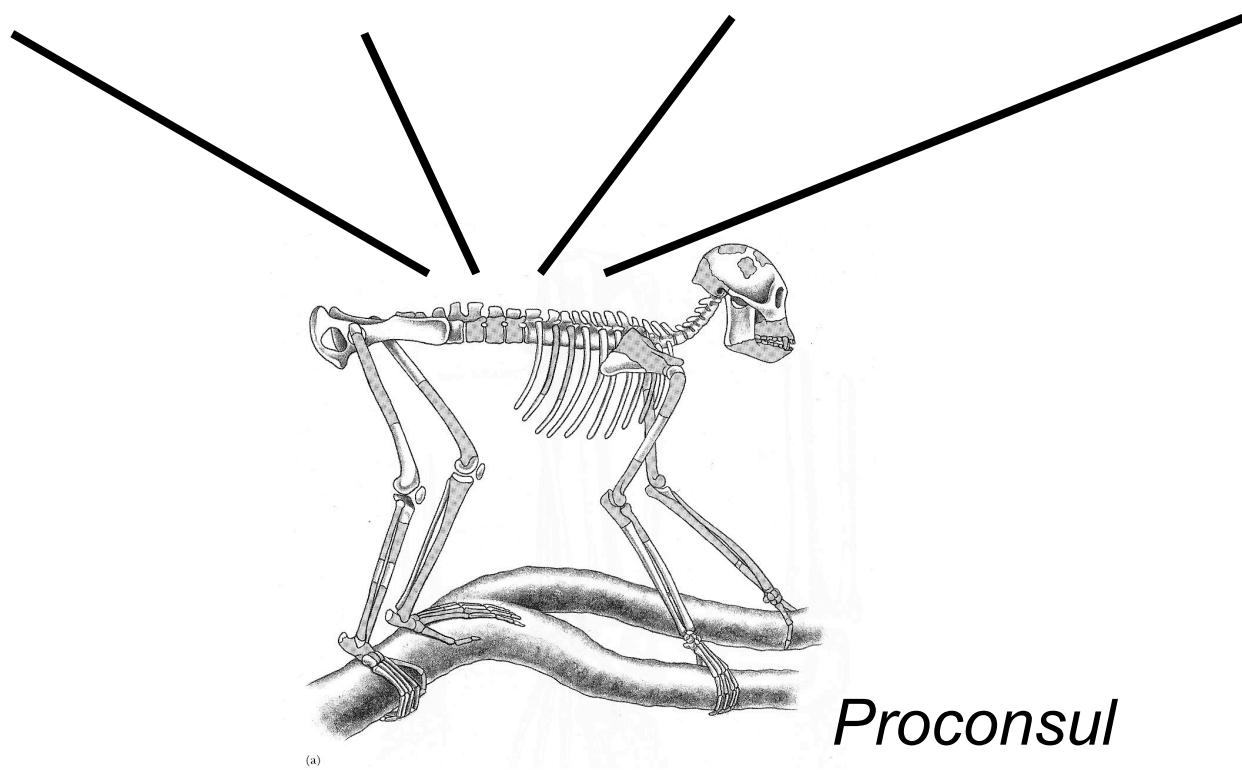
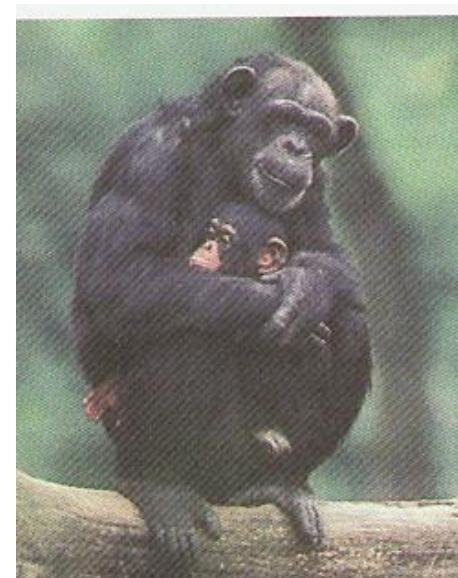
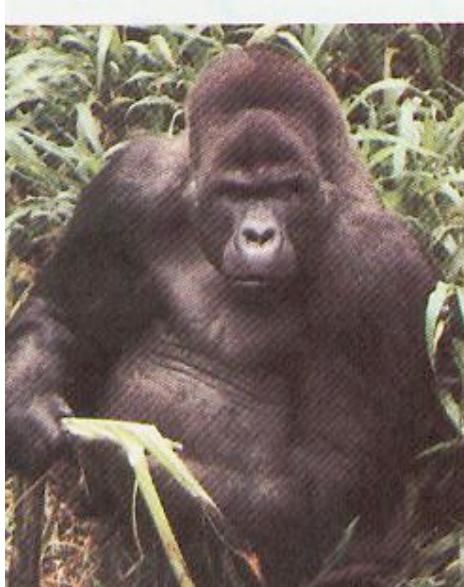
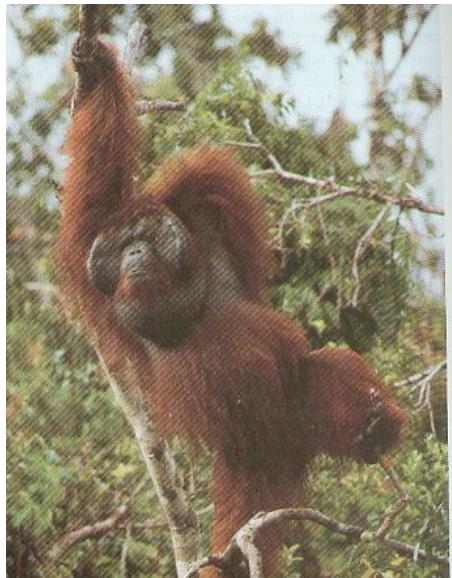
(a)



(b)

Potassium, Argon, DNA and Walking Upright

<http://cfcp.uchicago.edu/~mmhedman/compton1.html>

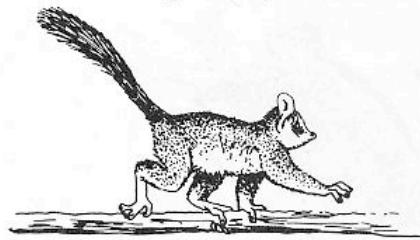


Proconsul

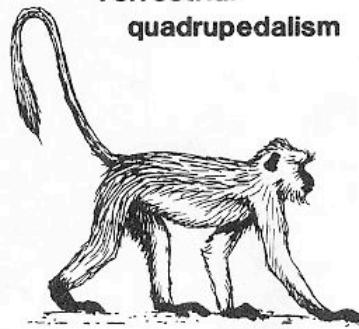
(a)

LOCOMOTION

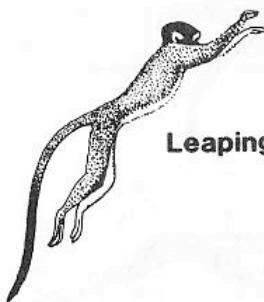
Arboreal quadrupedalism



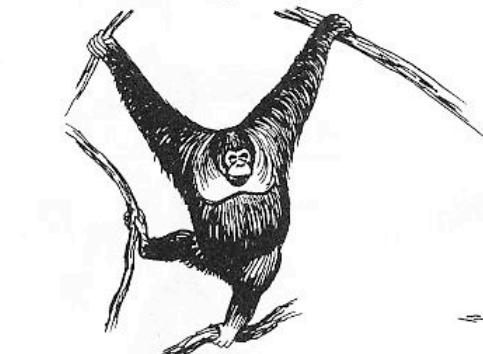
Terrestrial quadrupedalism



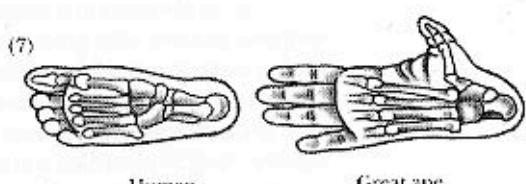
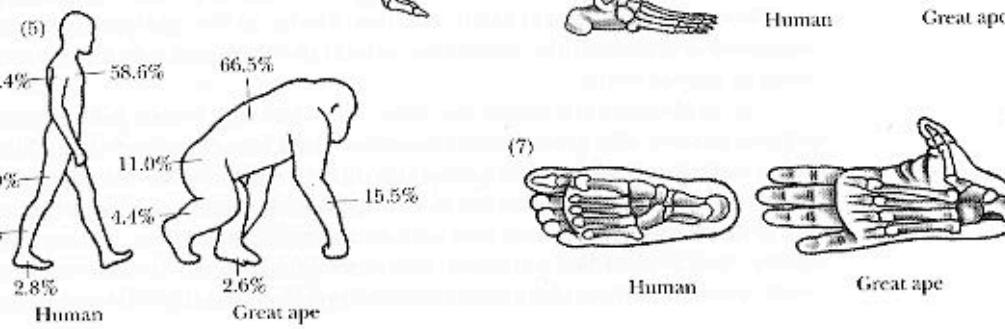
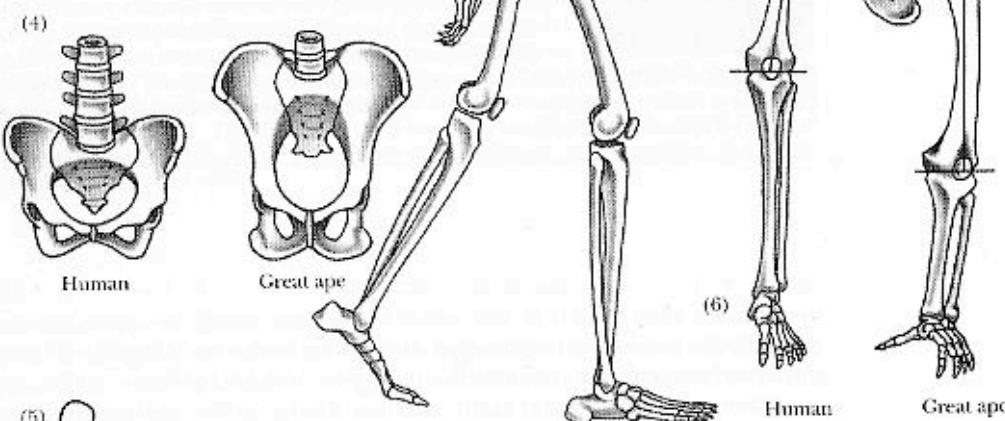
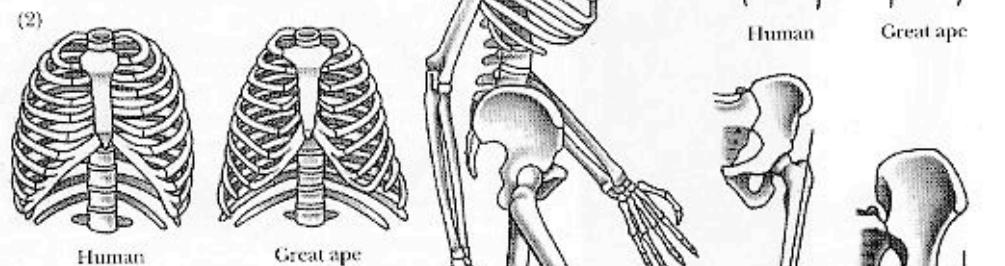
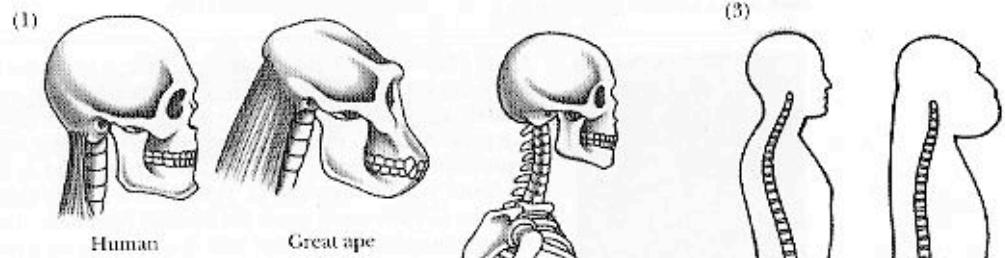
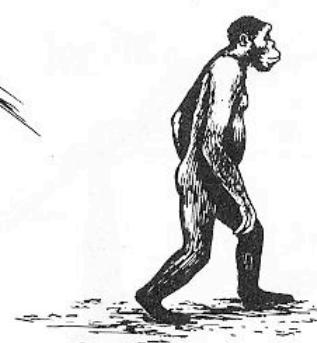
Knuckle-walking quadrupedalism

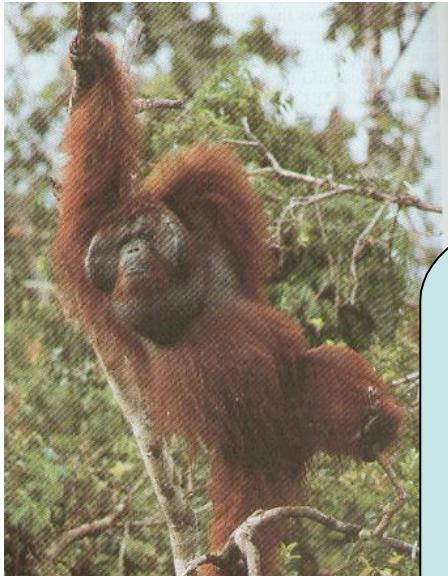


Suspensory climbing



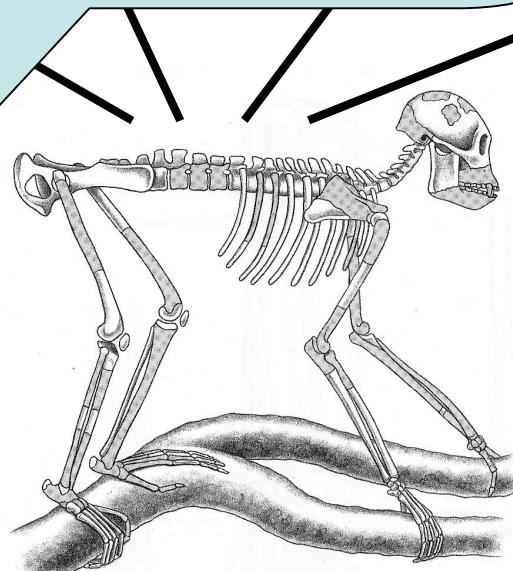
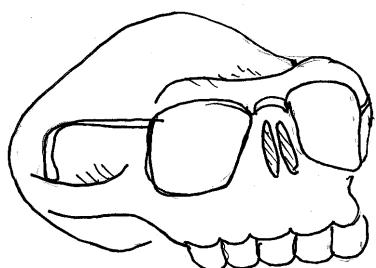
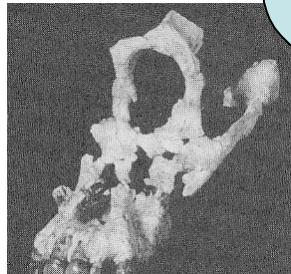
Bipedalism





WARNING!

Astrophysicist talking
about Paleoanthropology

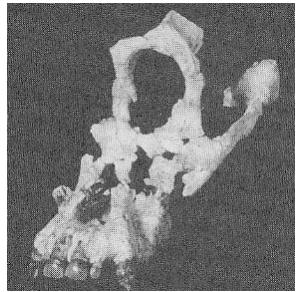
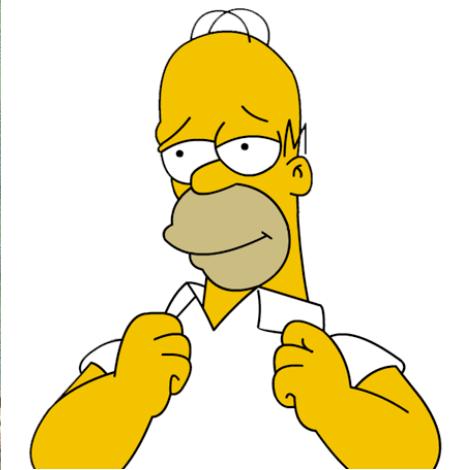
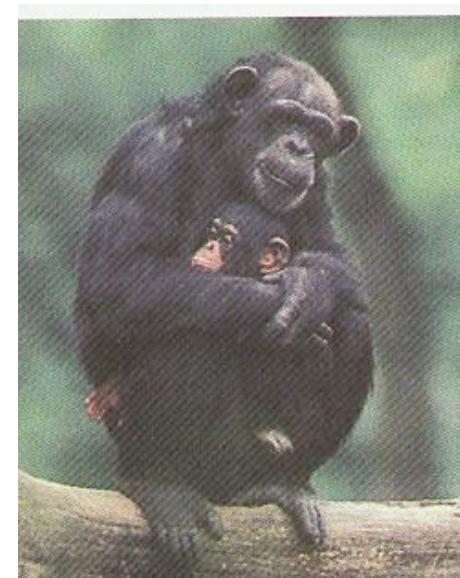
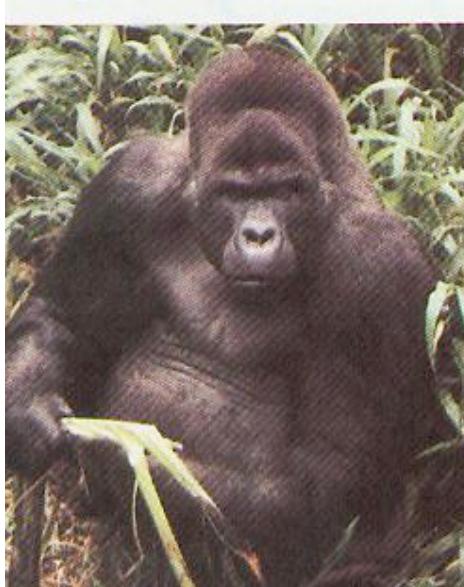
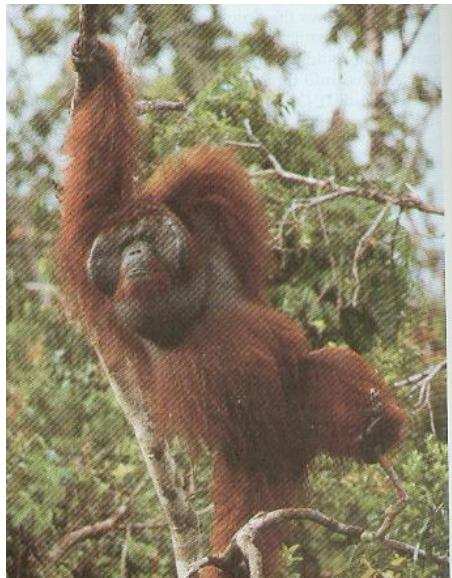


(a)

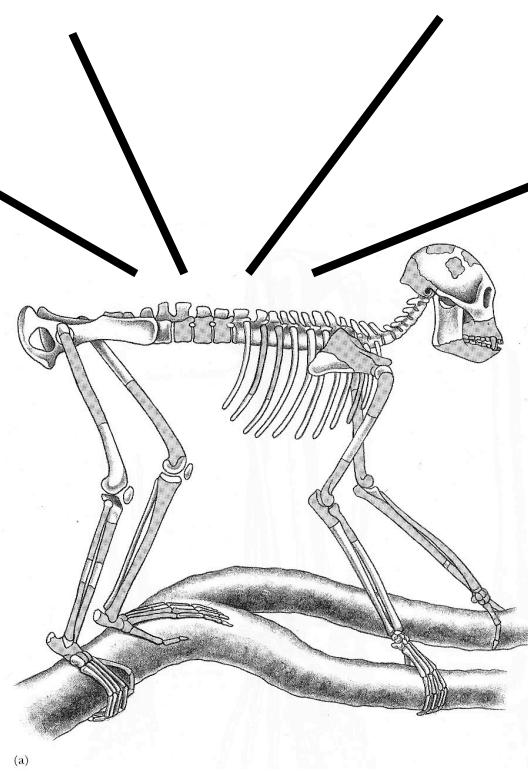
Proconsul



Australopithecus



Sivapithecus

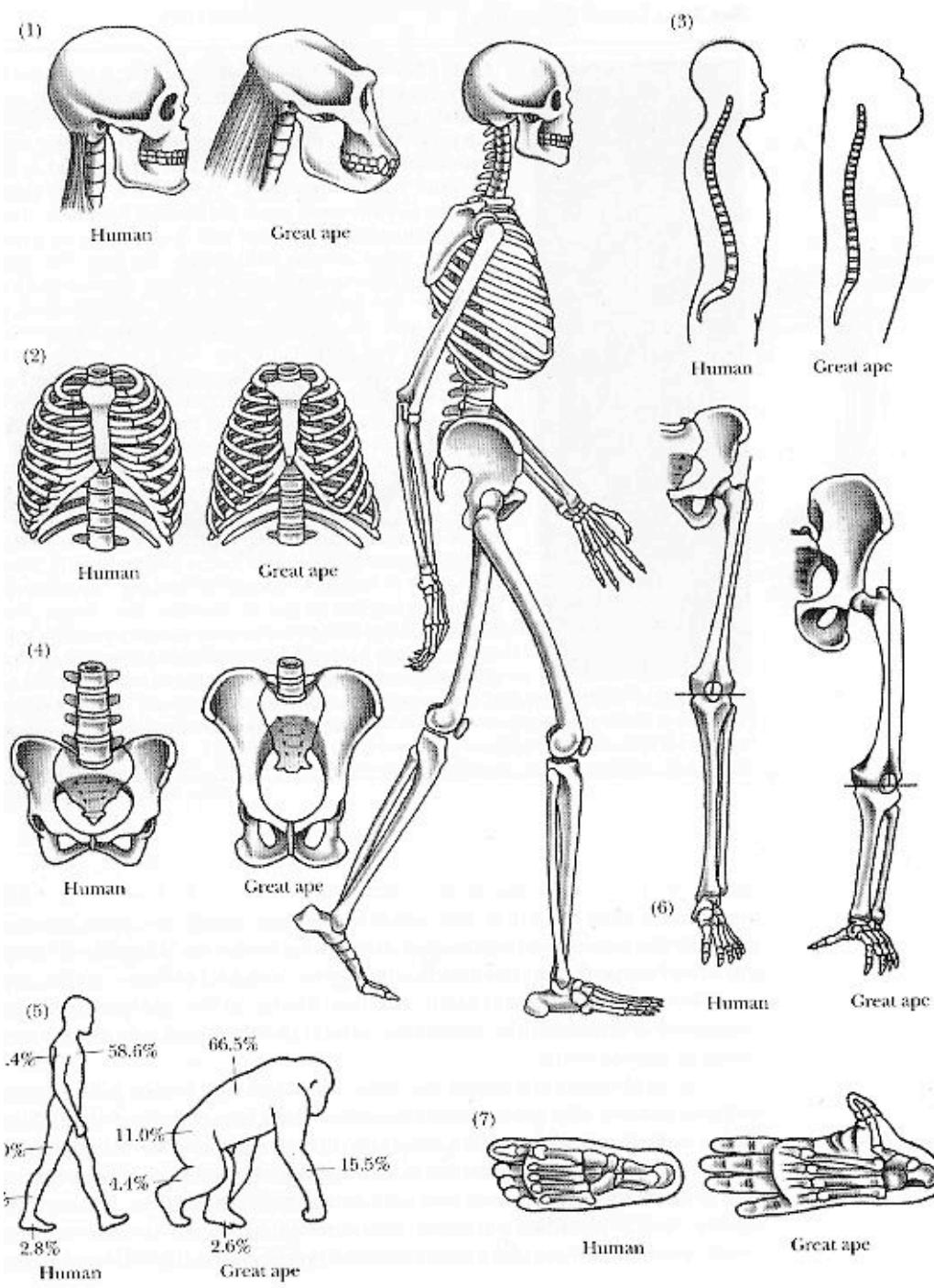


(a)



Australopithecus

Proconsul



1 Carrying



(a) Weapons and tools



(b) Food



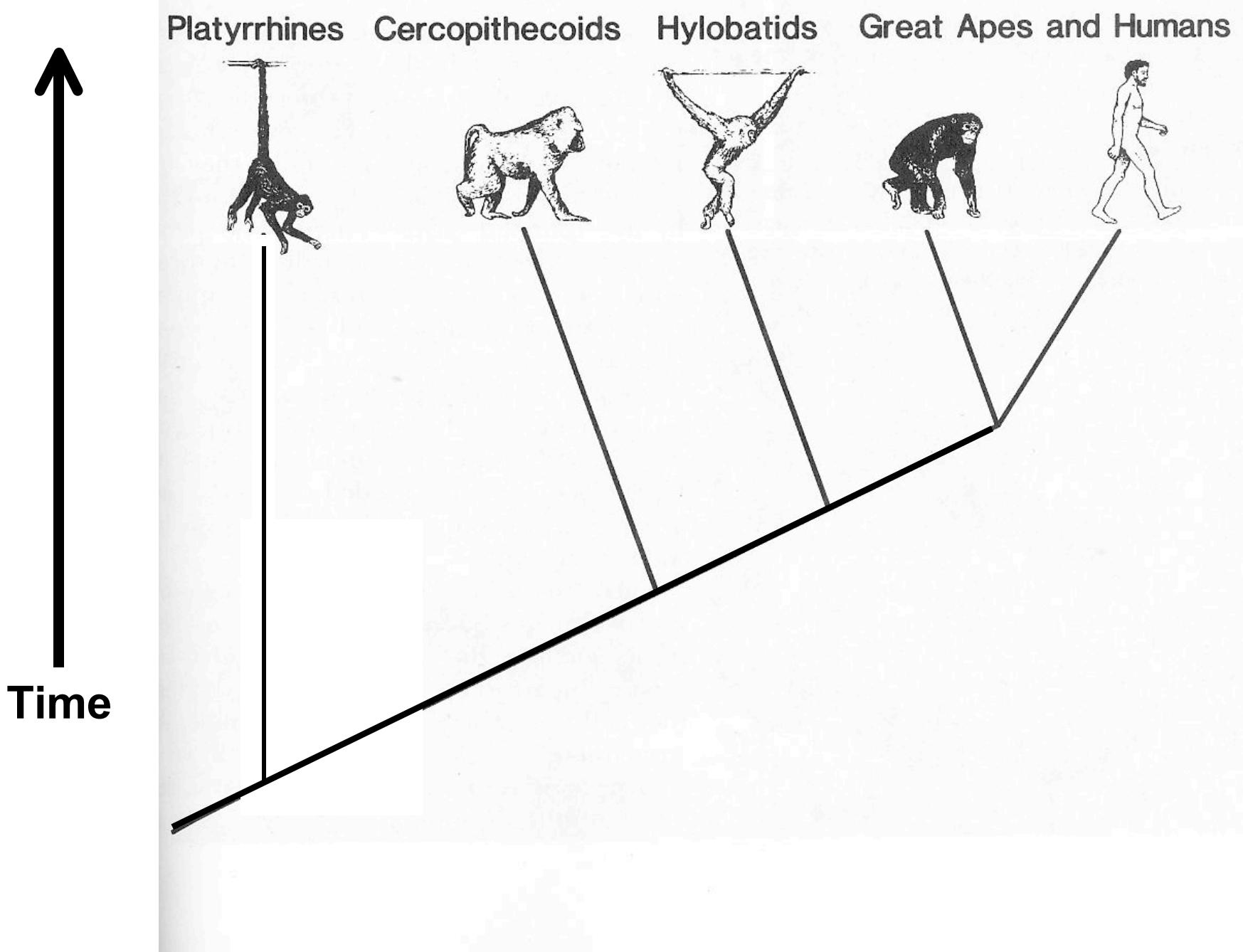
(c) Provisioning in and between trees

2 Hunting

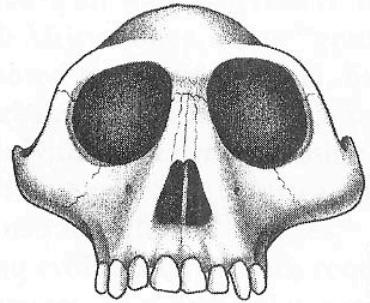


5 Feeding from bushes

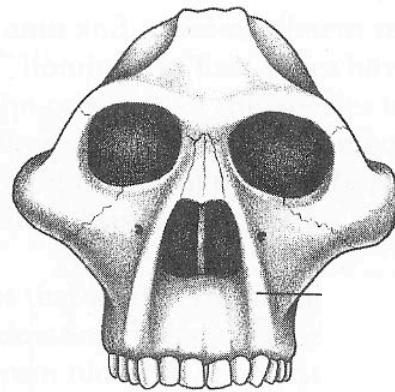




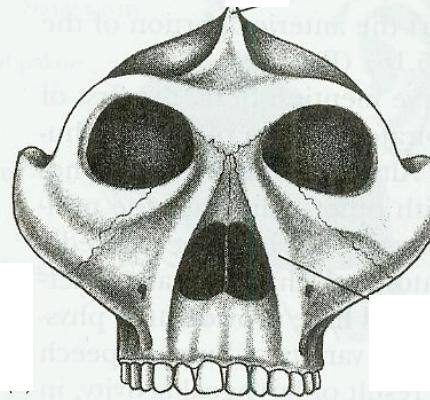
Different Types of Hominids



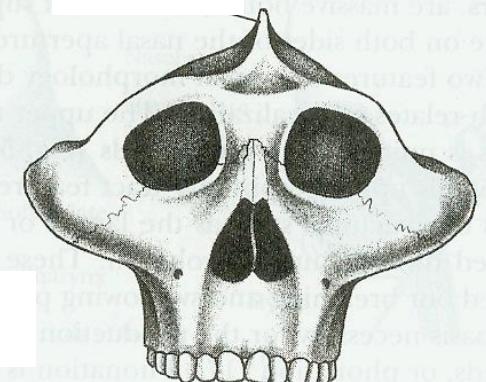
*Australopithecus
afarensis*



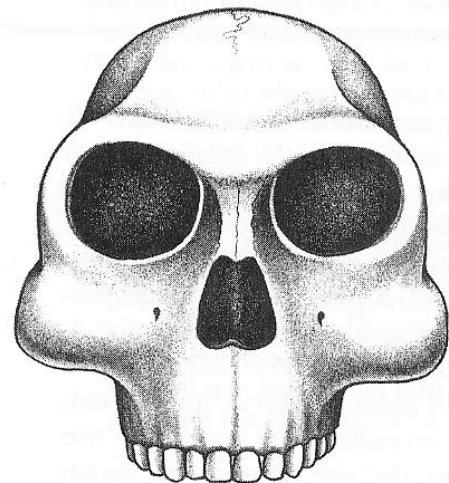
*Australopithecus
africanus*



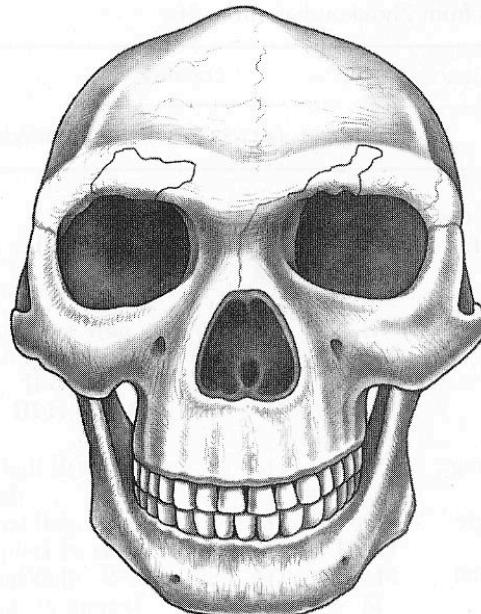
*Paranthropus
robustus*



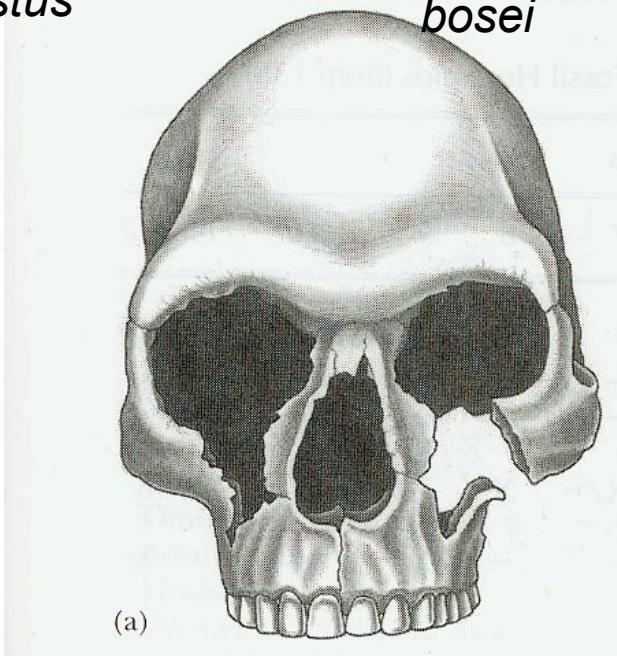
*Paranthropus
bosei*



Homo habilis



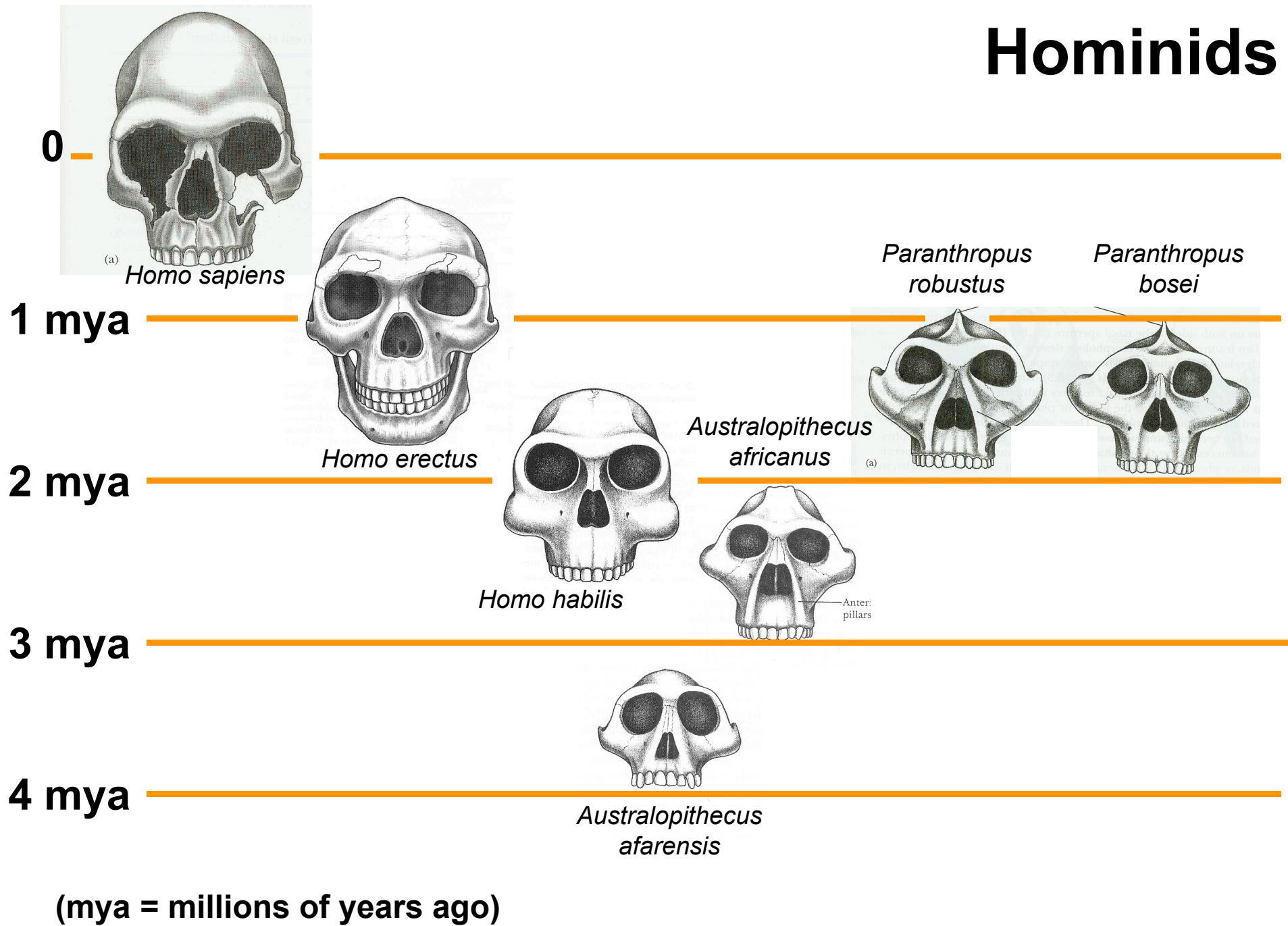
Homo erectus



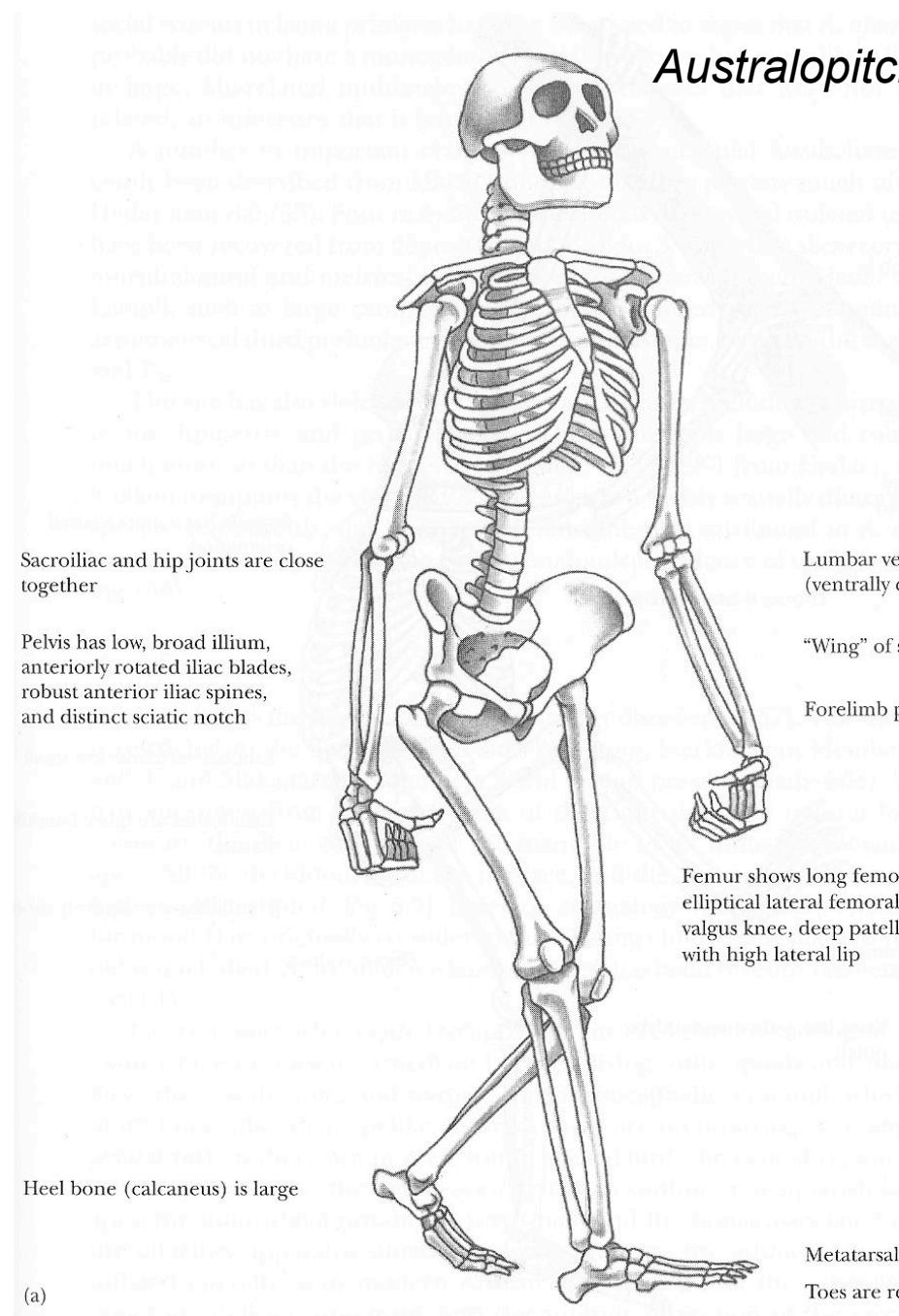
(a)

Homo sapiens

Hominids



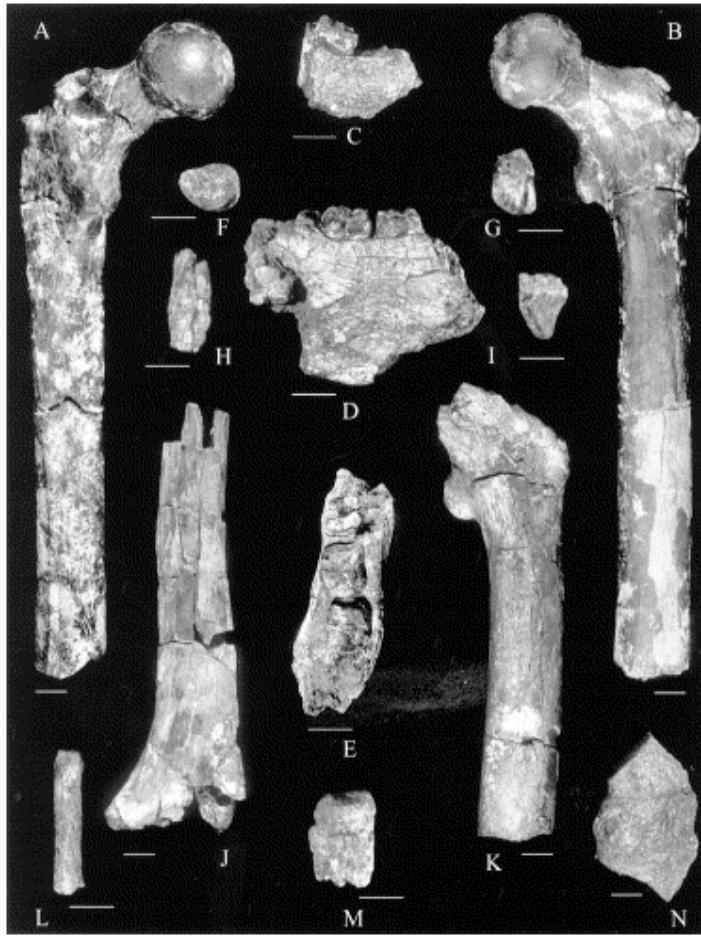
All these hominids could walk on two legs



Australopithecus afarensis



Recent hominid finds



Orrorin tugenensis



*Sahelanthropus
tchadensis*

Age of the fossils



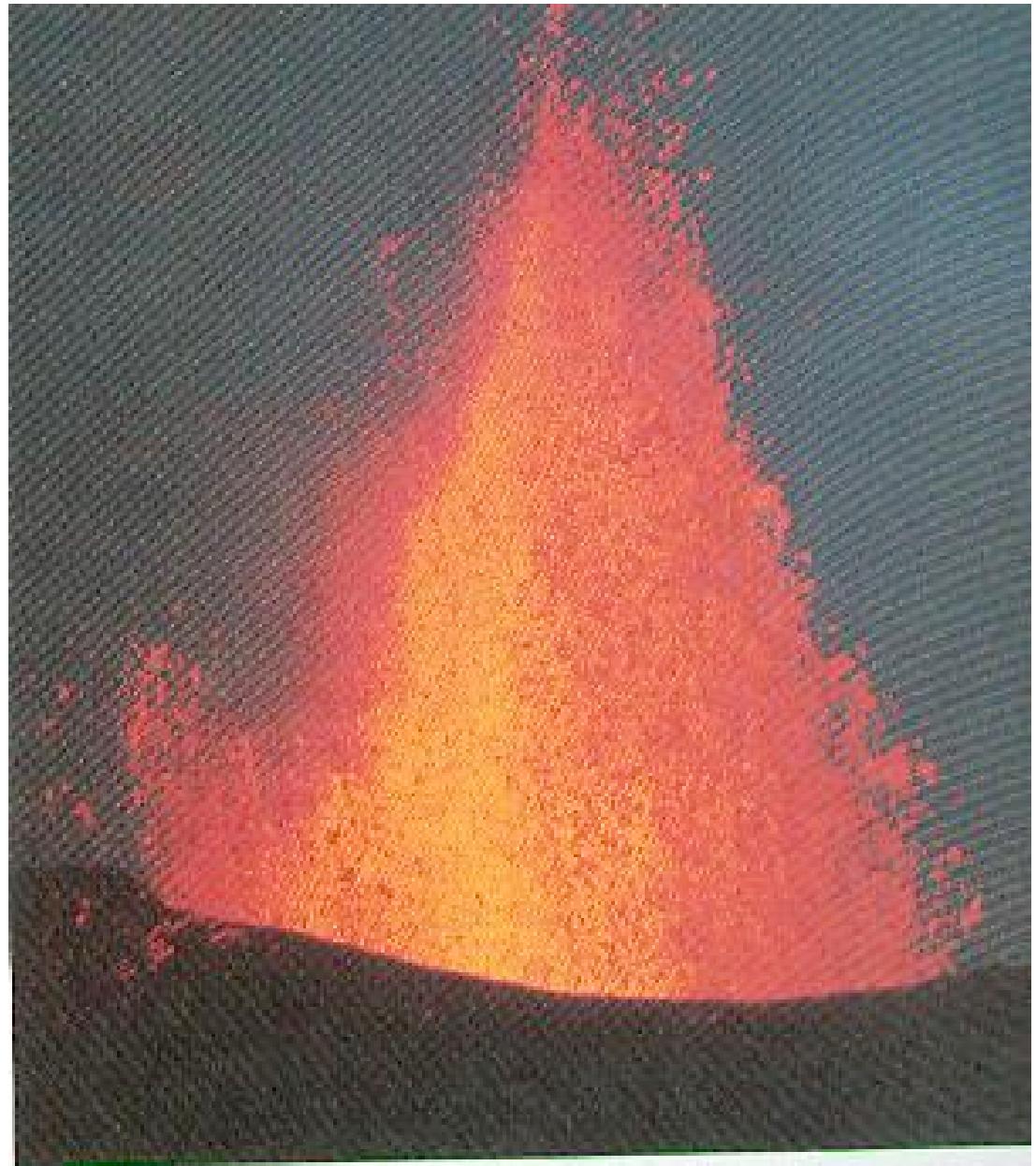
Based on Geological Data

Time when hominids first became bipedal



Based on Molecular Data

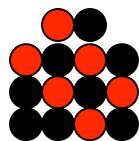
Dating the Fossils with the Potassium-Argon method



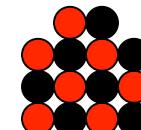
Potassium-Argon Dating

● Proton ● Neutron

Carbon 14



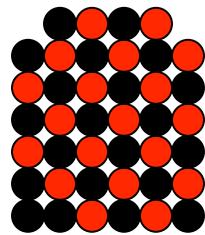
Nitrogen 14



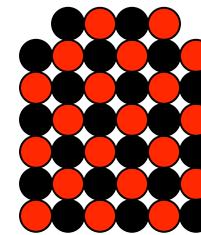
electron

neutrino

Potassium 40



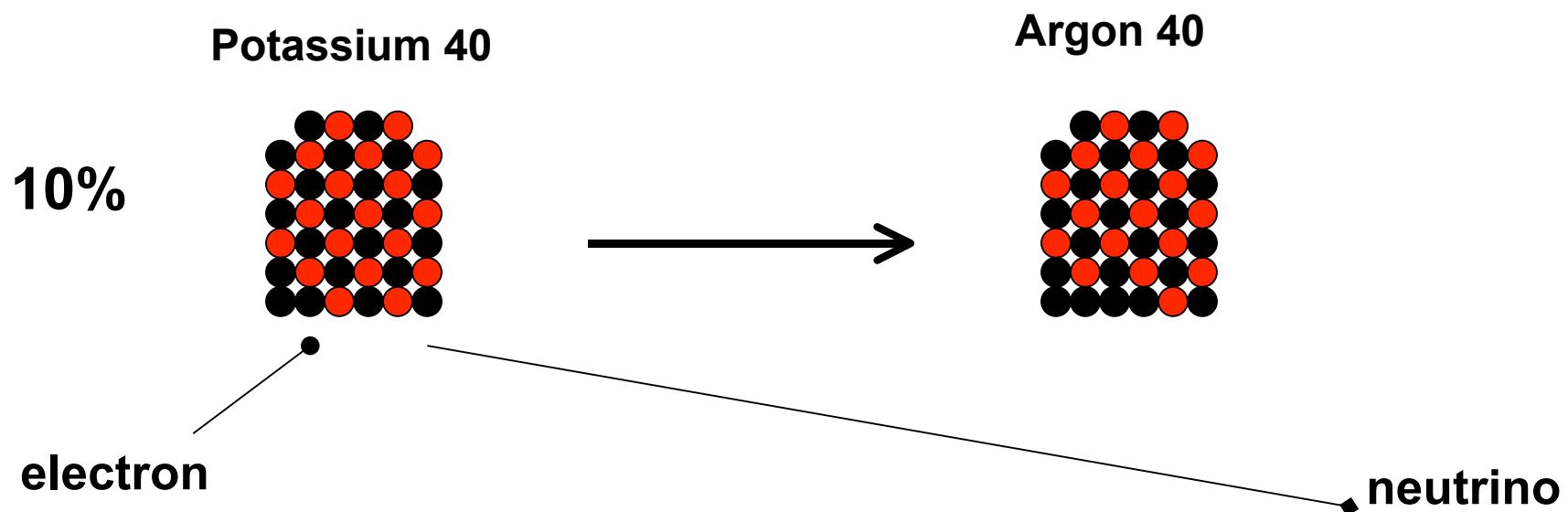
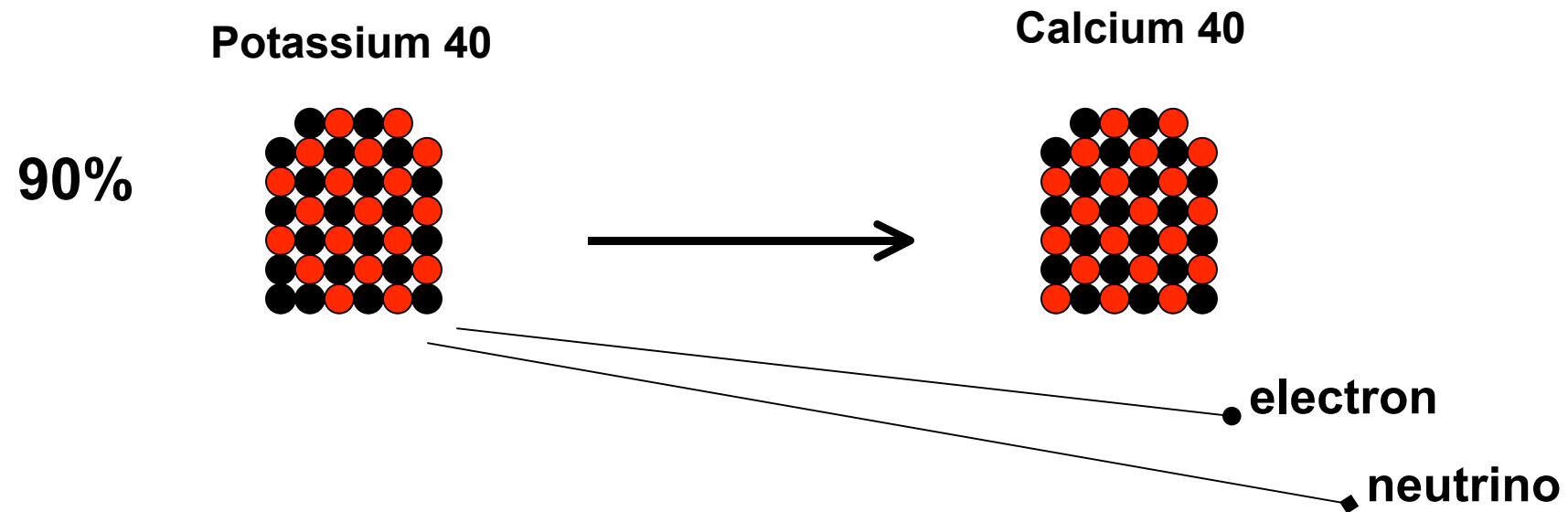
Calcium 40



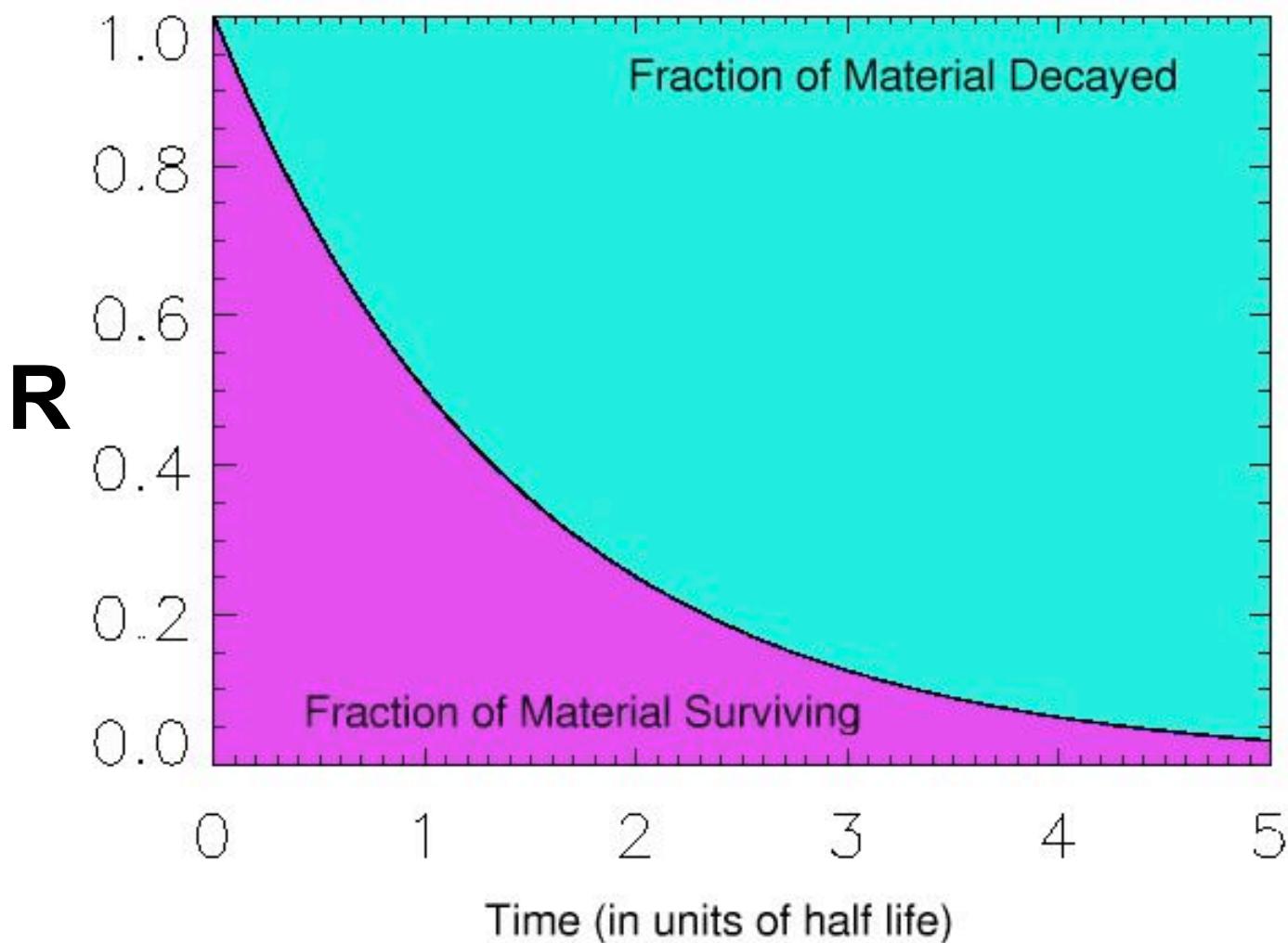
electron

neutrino

Potassium-40 has two ways it can decay

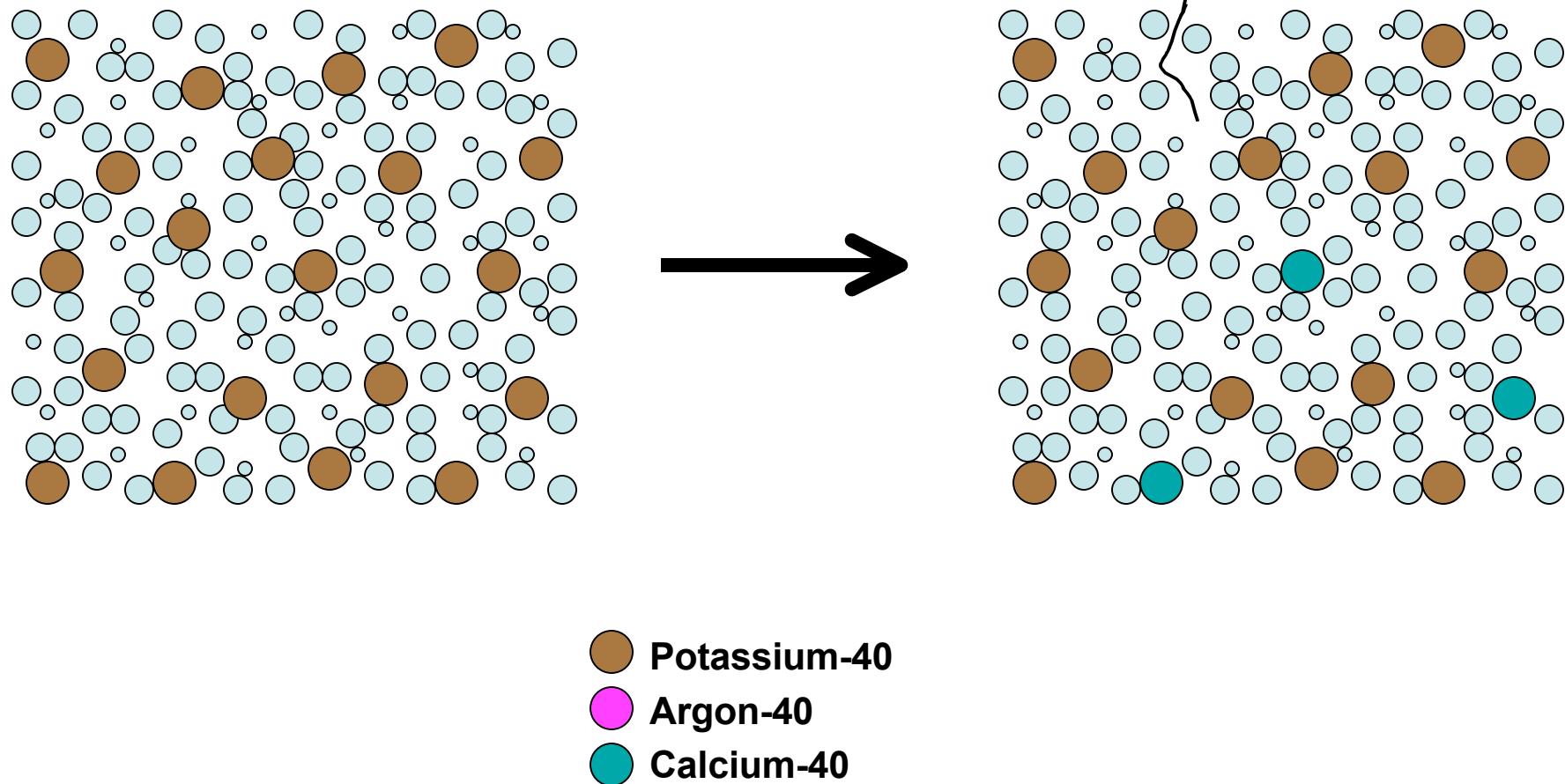


$$R = \frac{\text{Current amount of Potassium-40}}{\text{Original amount of Potassium-40}}$$

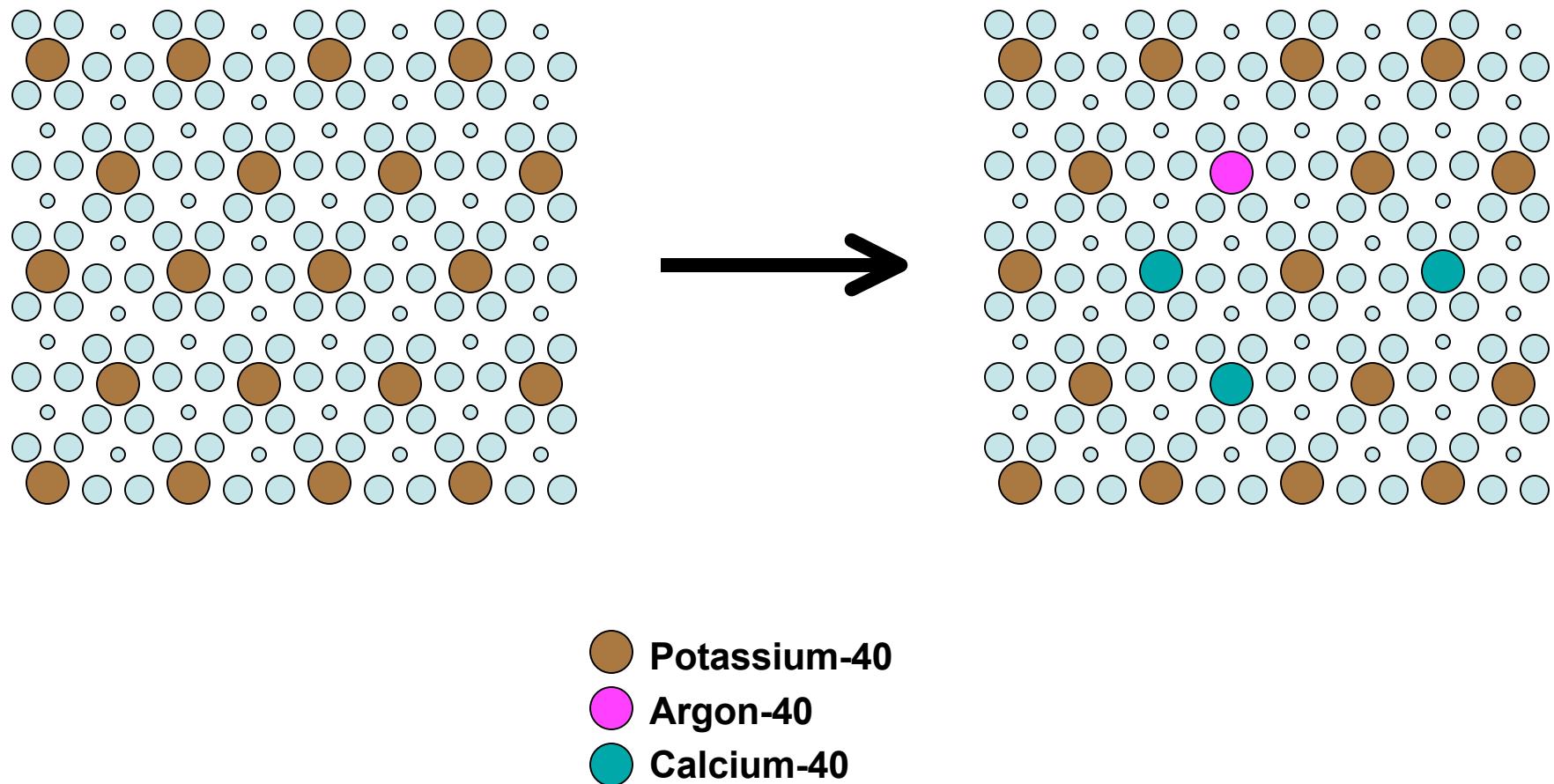


Half-Life of Potassium-40 is 1.25 billion years

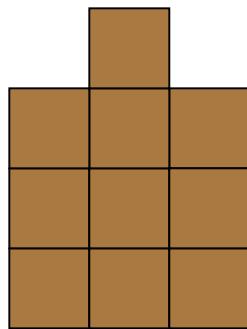
Potassium-40 decay in molten rock



Potassium-40 decay in solid rock



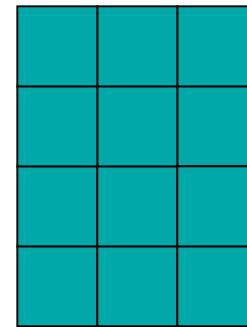
The Rock Today



Potassium-40

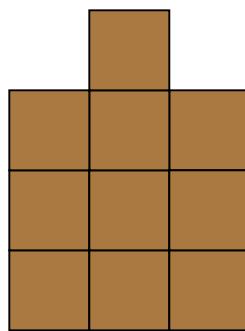


Argon-40



Calcium-40

The Rock Today



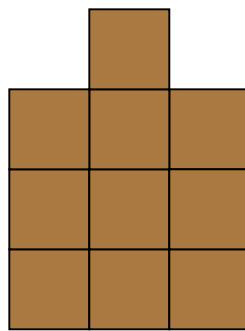
Potassium-40



Calcium-40



Argon-40



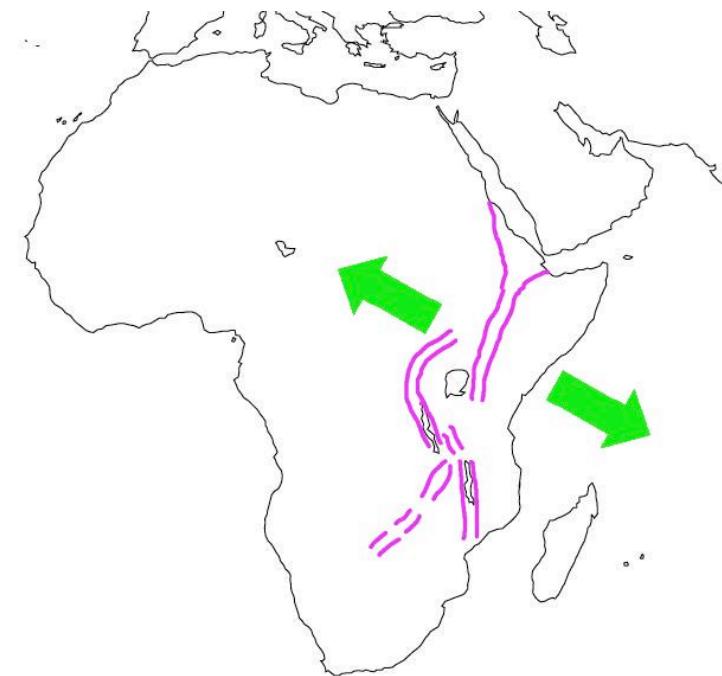
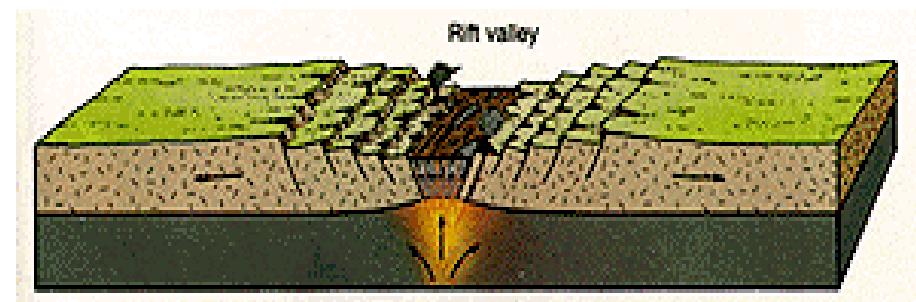
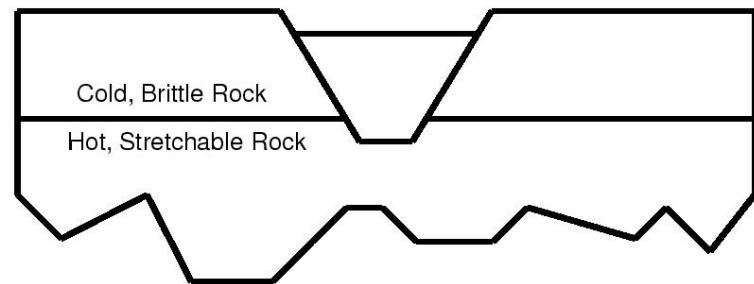
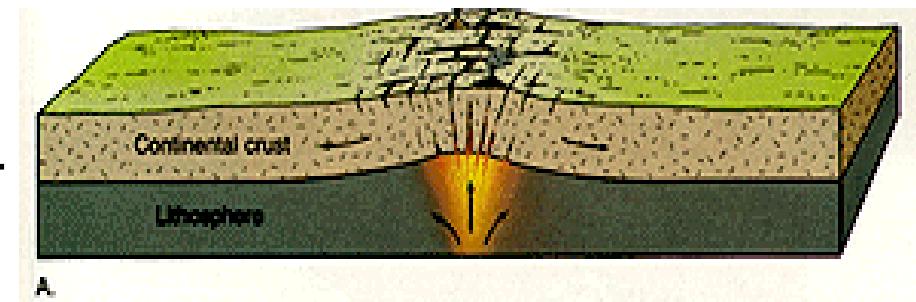
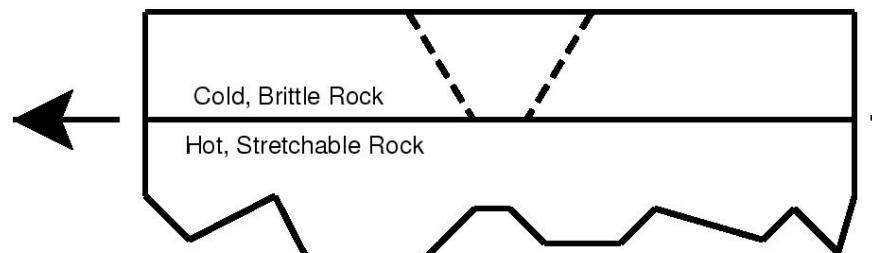
Potassium 40

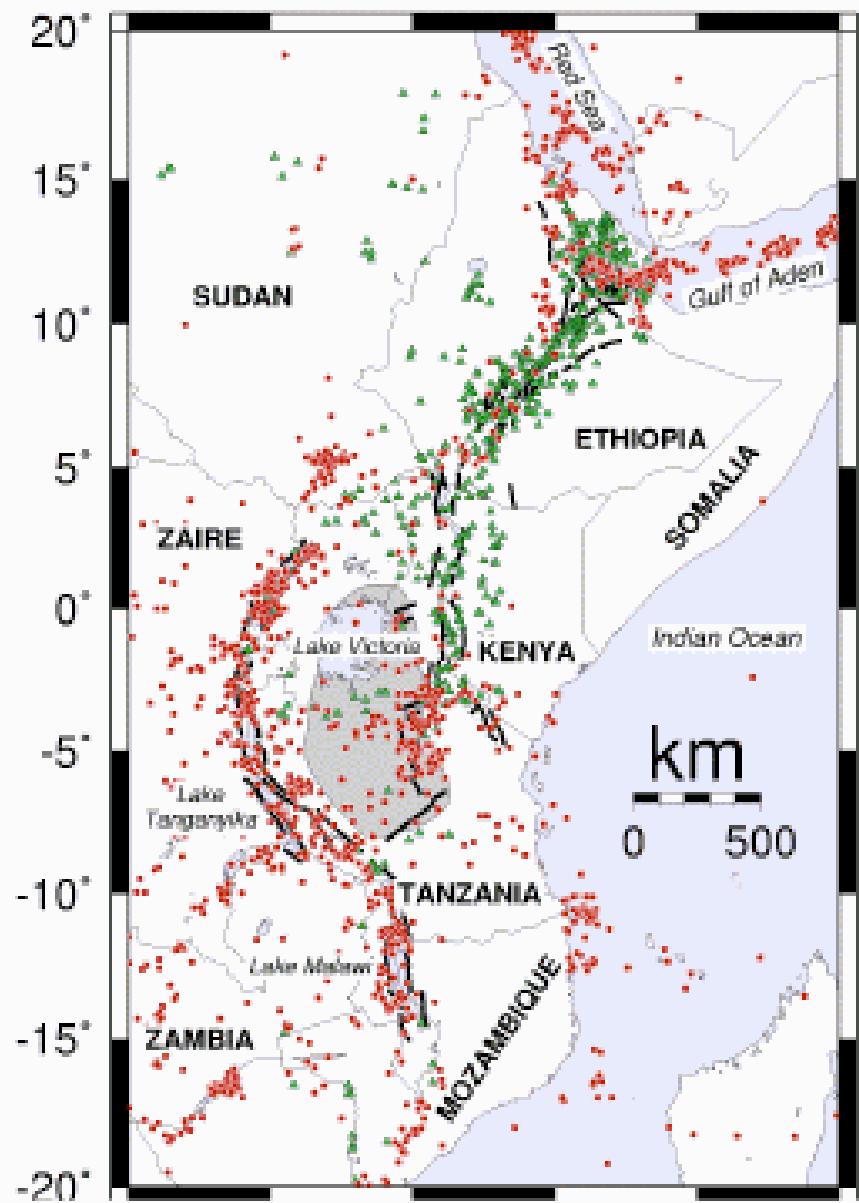
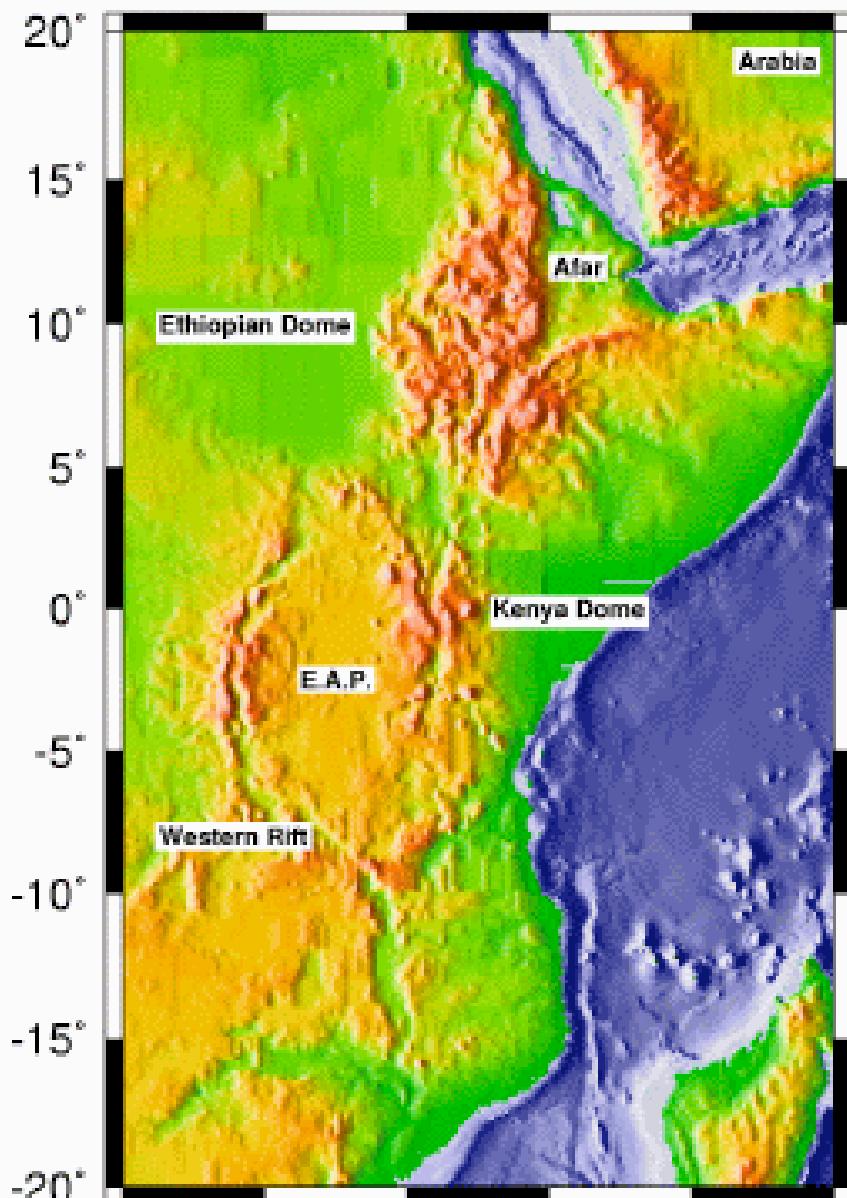


Calcium-40

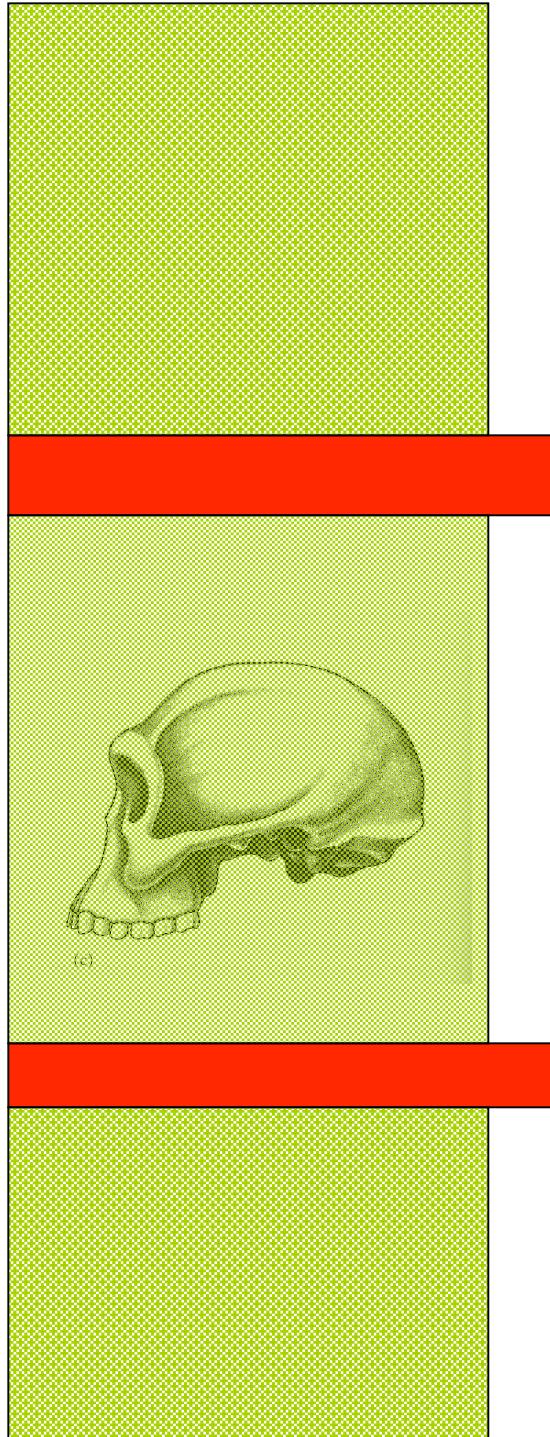
The Original Rock

The East African Rift System





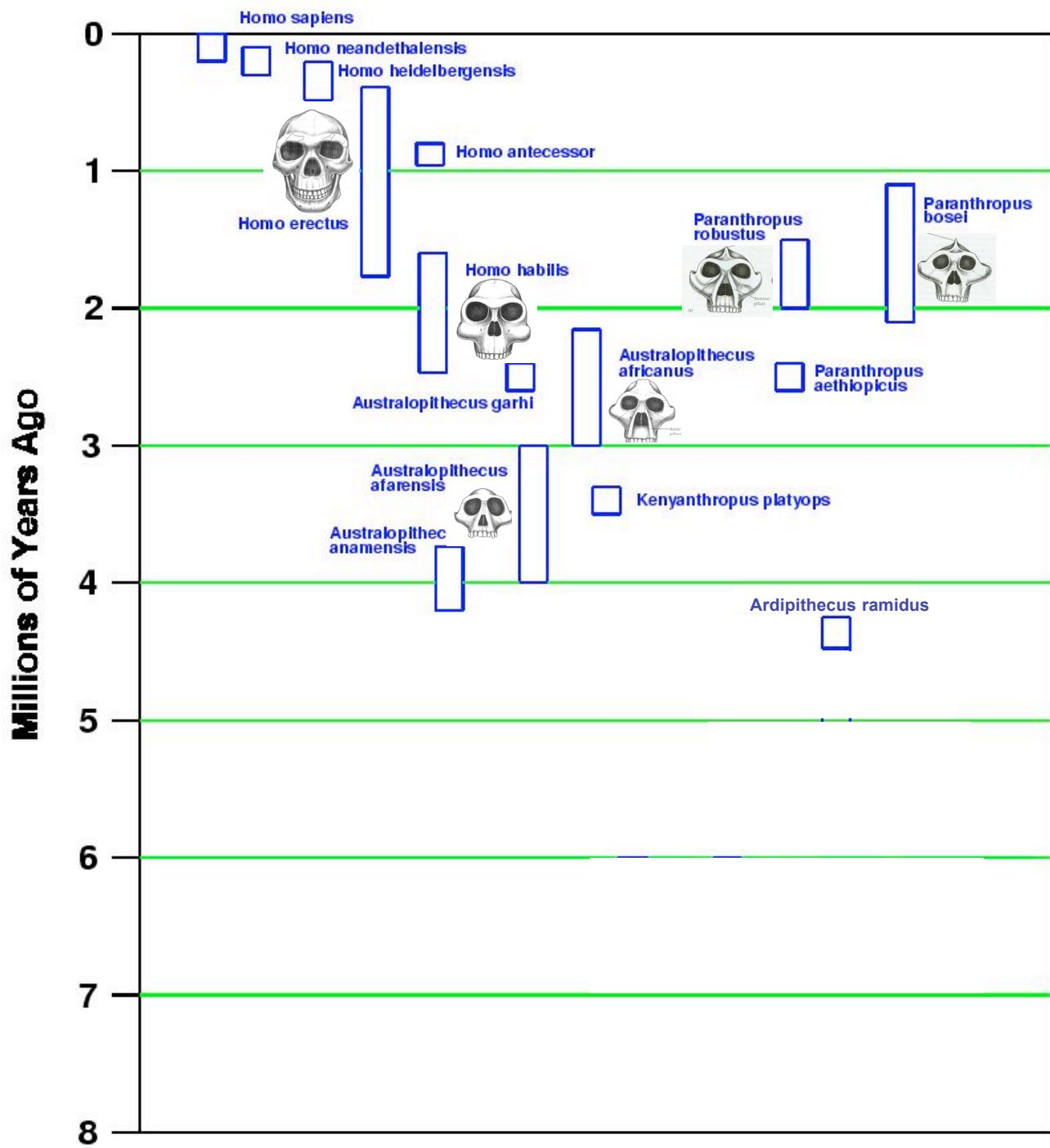
Red Circles=Earthquakes
Green triangles=Volcanoes

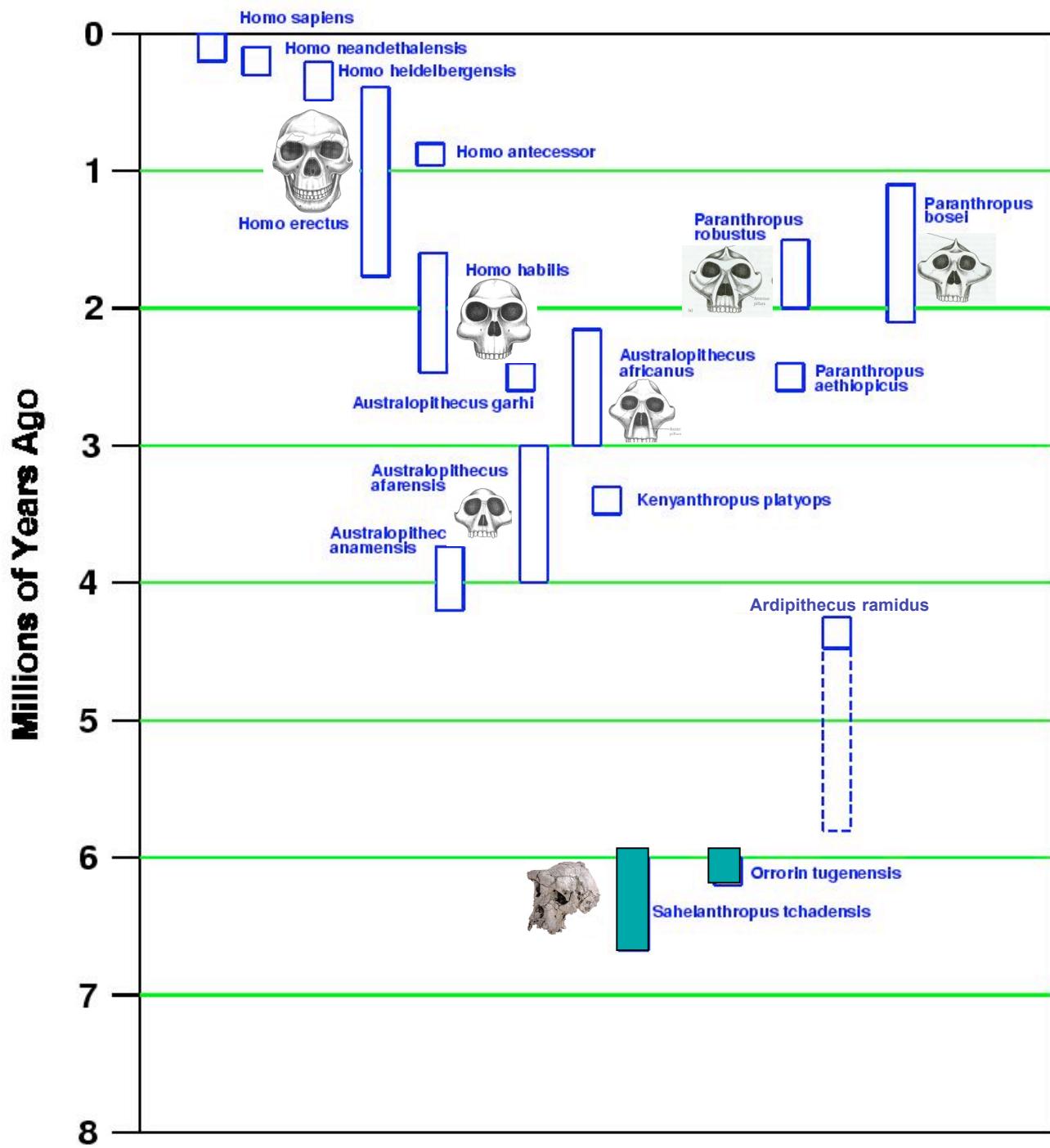


2.5 Million Years Ago

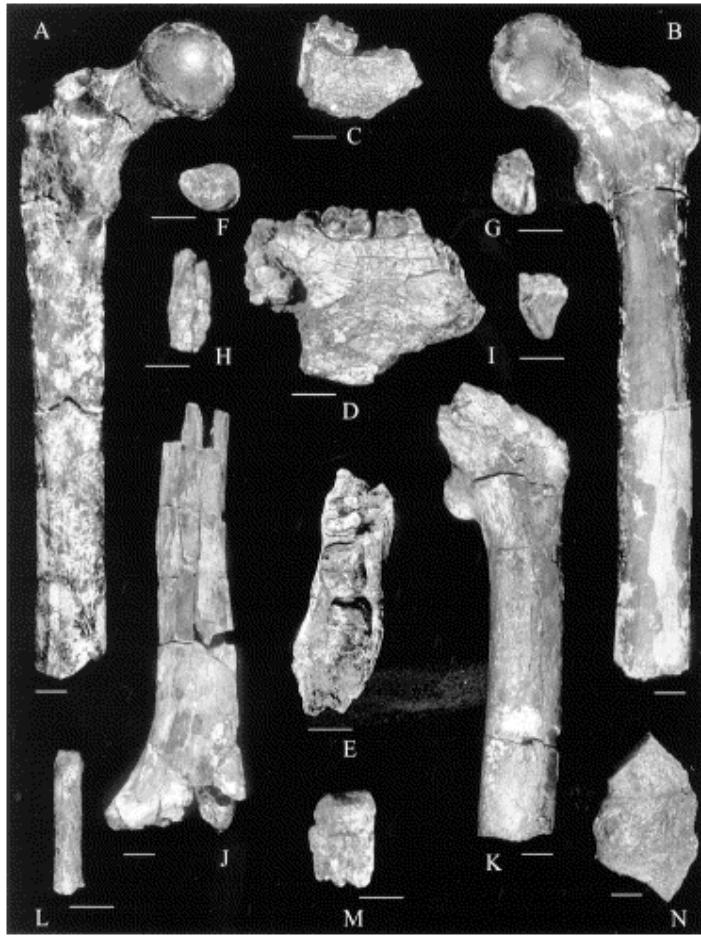
3 Million Years Ago

Age MYA	Meters	Tuff
	750	
1.39	700	L (= Chari)
	650	K
1.64	650	J4 (= Okote)
	600	J
1.82	600	H4 (= Malbe)
1.88	600	H2 (= KBS)
	550	H
	500	
	450	
	400	
2.33	350	G
2.35	350	F (= Kalochoro)
	300	E (= Kokiselei)
2.52	250	D (= Lokalalei)
	200	
2.6	180	C4 (= Burgi)
	150	C (= Hasuma)
2.95	150	B10
	100	
3.35	80	B (= Tulu Bor)
	50	A (= Lokochot)
	0	





Recent hominid finds



Orrorin tugenensis



*Sahelanthropus
tchadensis*

Age of the fossils

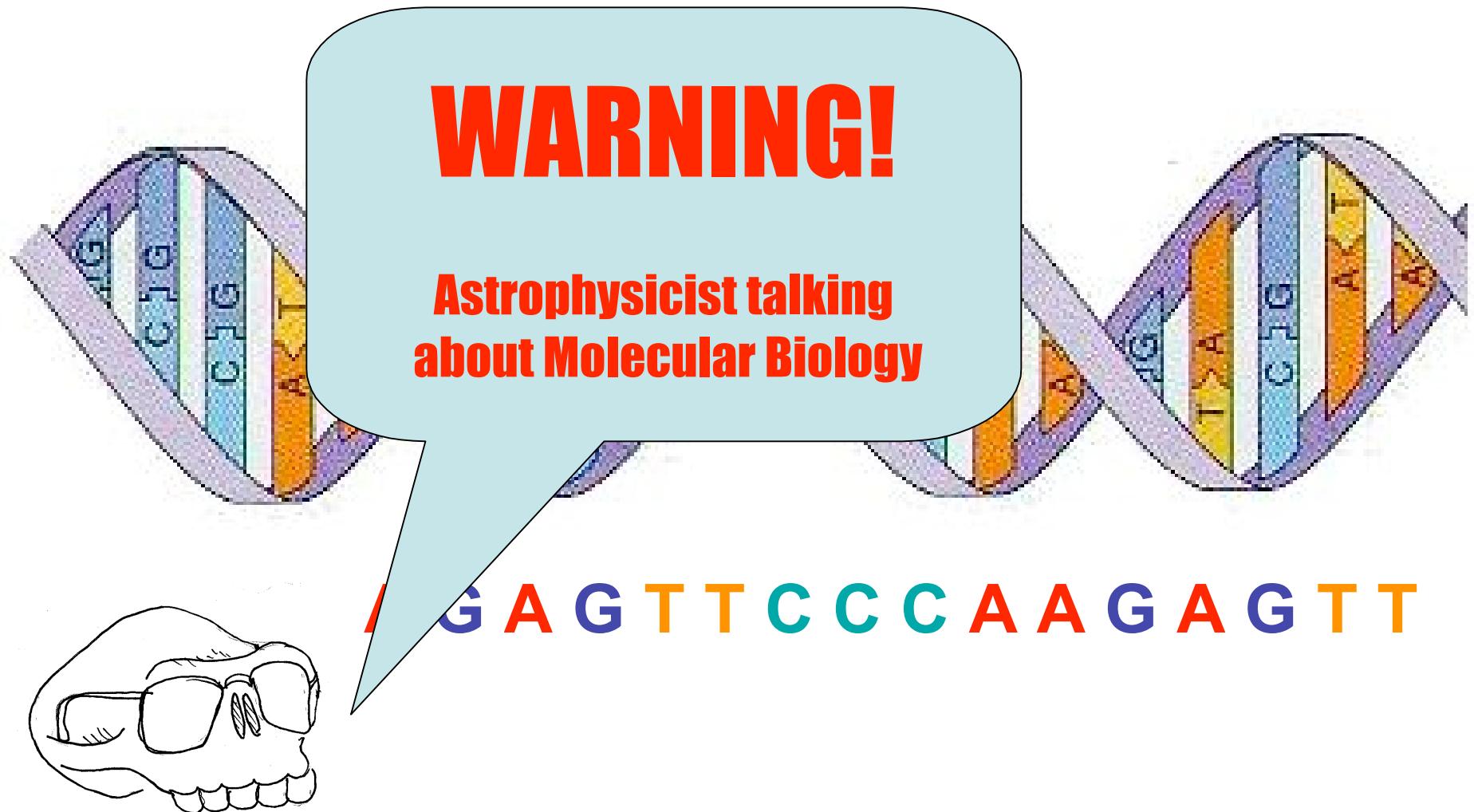


Time when hominids first became bipedal

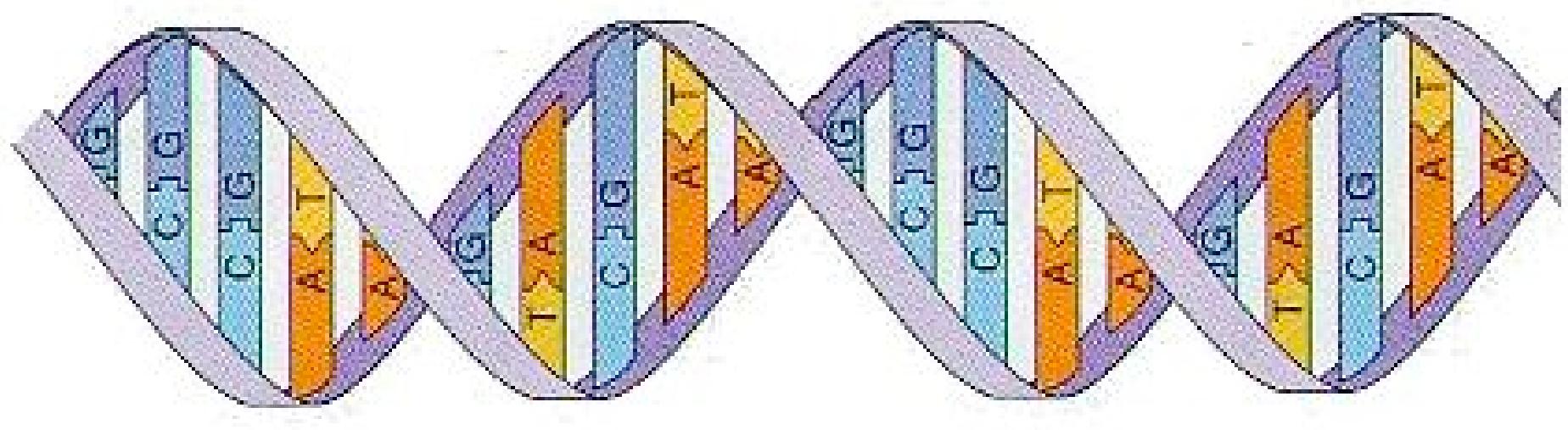
Based on Geological Data

Based on Molecular Data

Molecular Dating Methods



Molecular Dating Methods



CCCCAAAGAGTTCCCCAAAGAGTT

Mutations in DNA

Original

CCC**AAGAGTT**CCC**AAGAGTT**



Substitution

CCC**ATGAGTT**CCC**AAGAGTT**

GAGT

Deletion

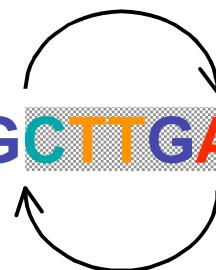
CCC**AAT**CCC**AAGAGTT**

Insertion

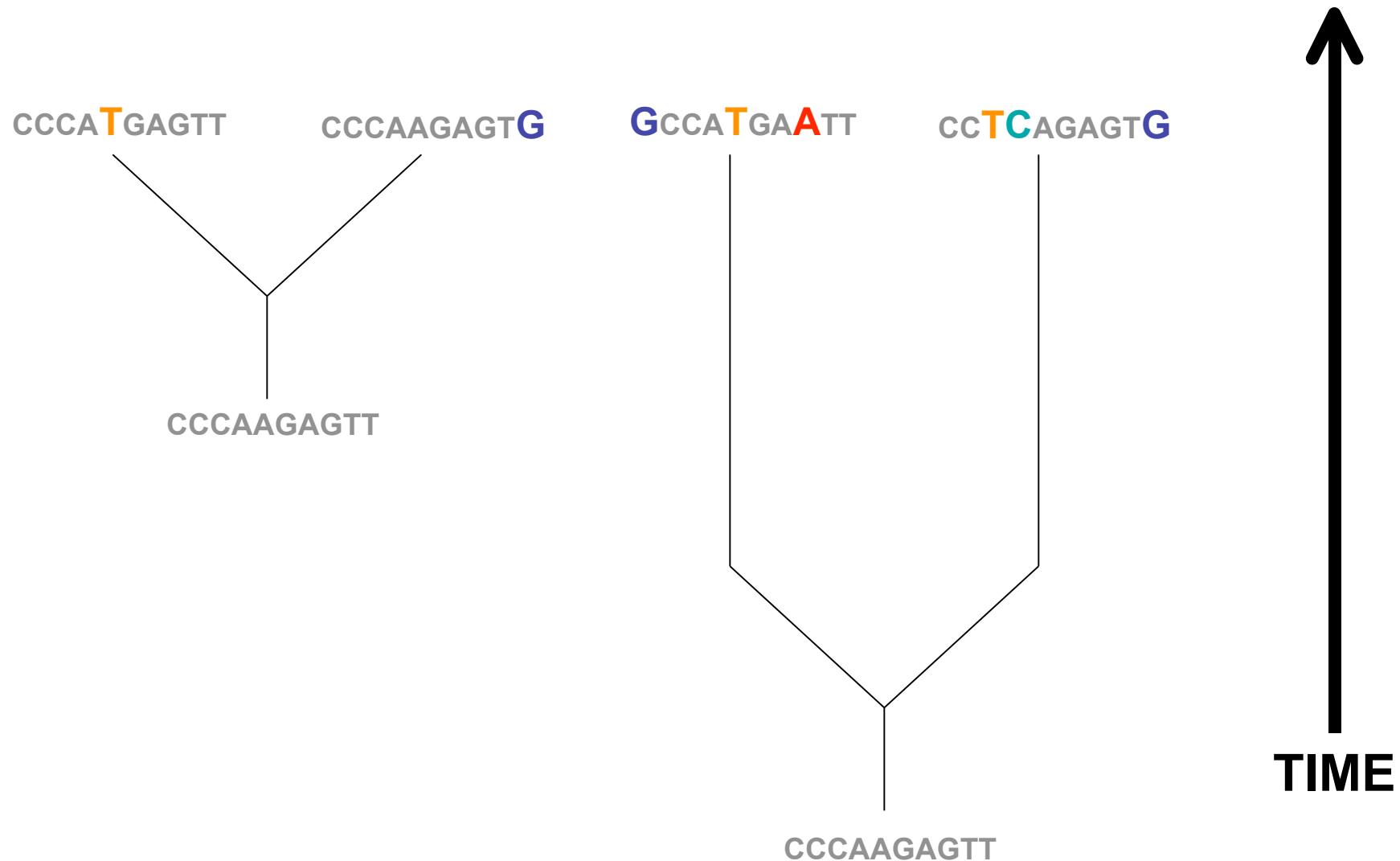
CCC**AAGAGTT**C**ACTT**CCC**AAGAGTT**

Inversion

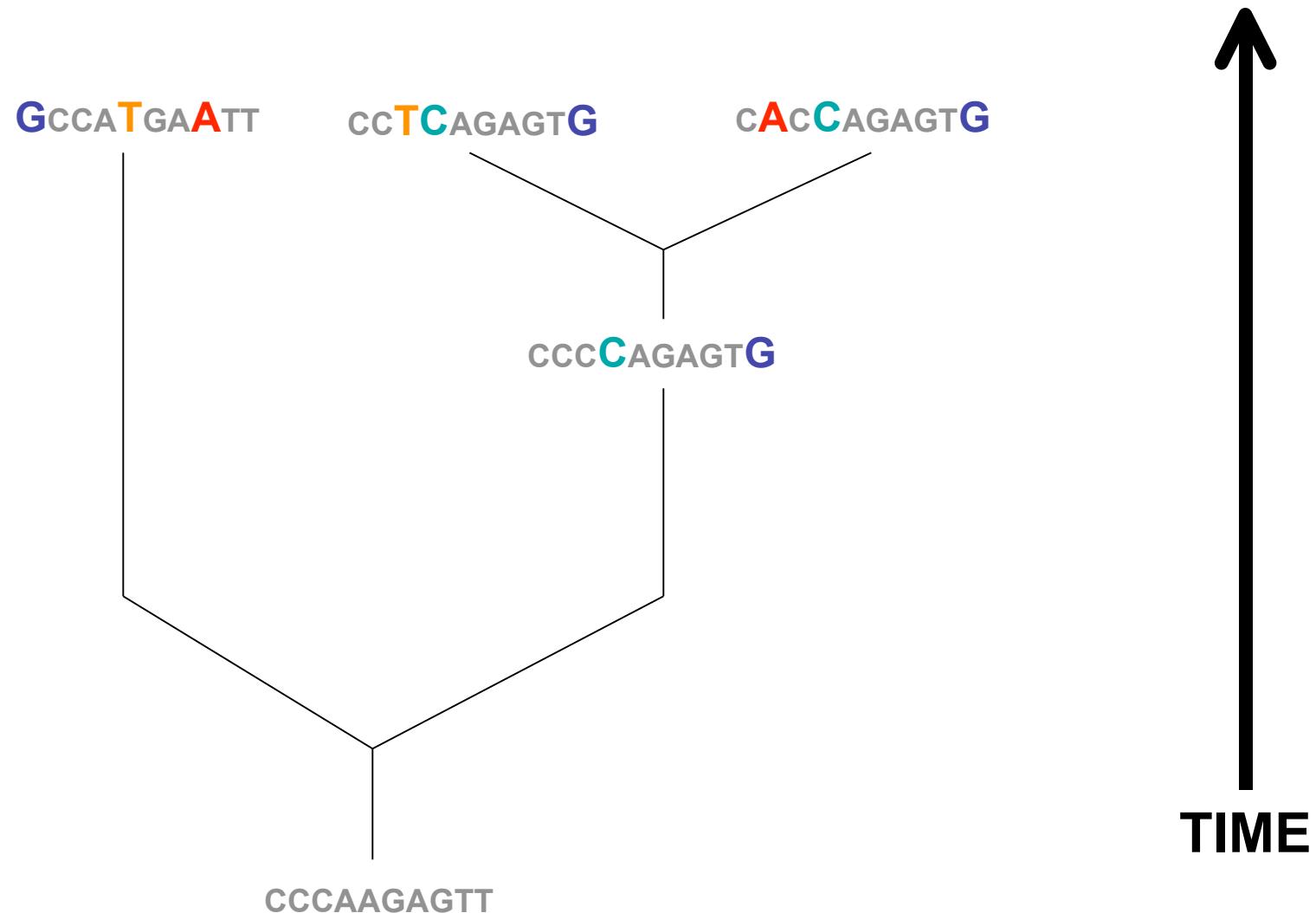
CCC**AAGCTTGACCAAGAGTT**



The accumulation of mutations over time



The accumulation of mutations over time



Could mutations accumulate at a constant rate ?

Two conditions must be met

1. Mutations occur at the same rate in all animals

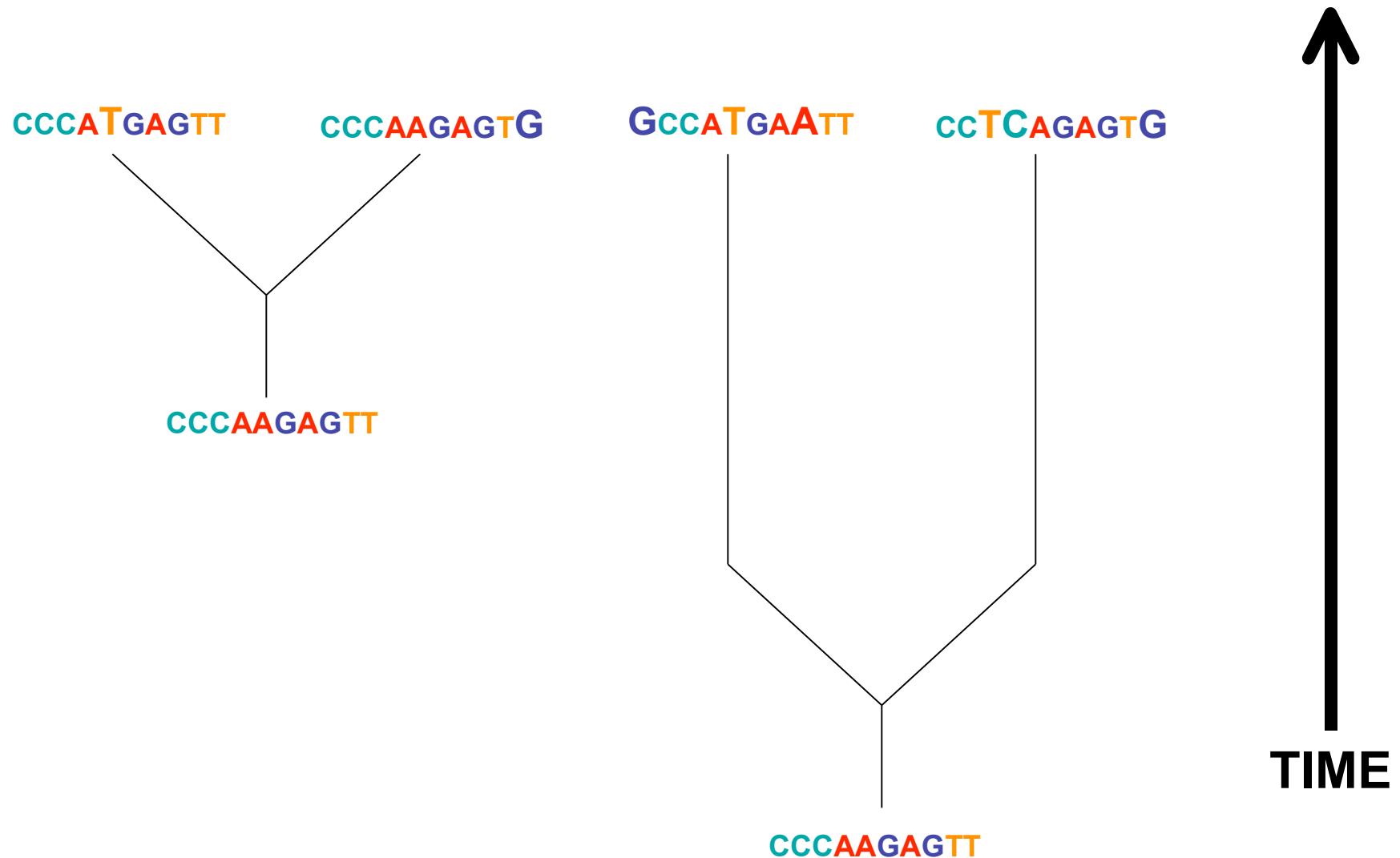
Possible, mutations are due to biochemical processes that are almost identical in different animals

2. Mutations are equally likely to be passed on in all animals

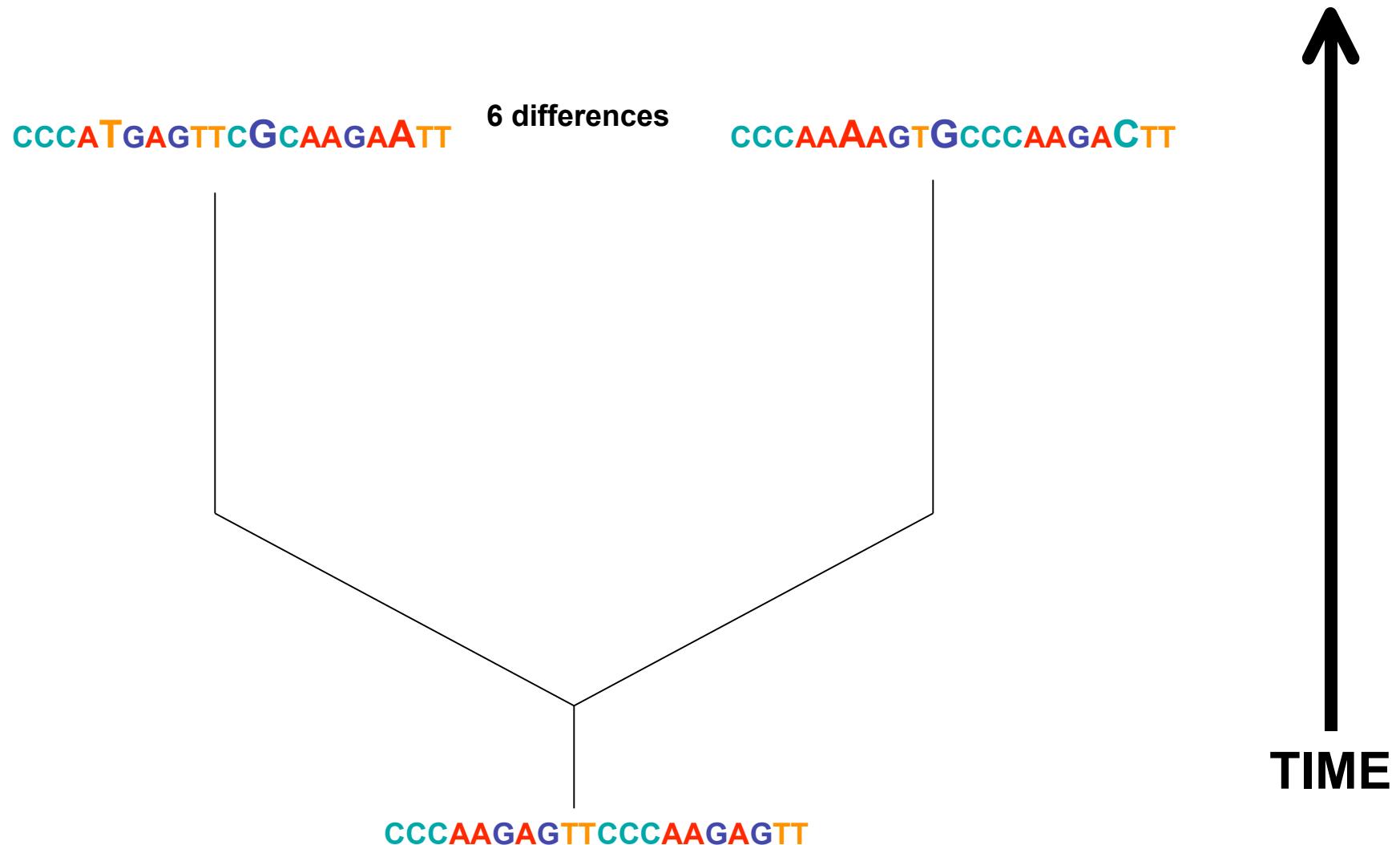
Unlikely, if mutations affect physical characteristics of animal
(Rate depends on environment, etc.)

True if mutations have no impact on the health or appearance of the animal
Neutral or “Silent” mutations

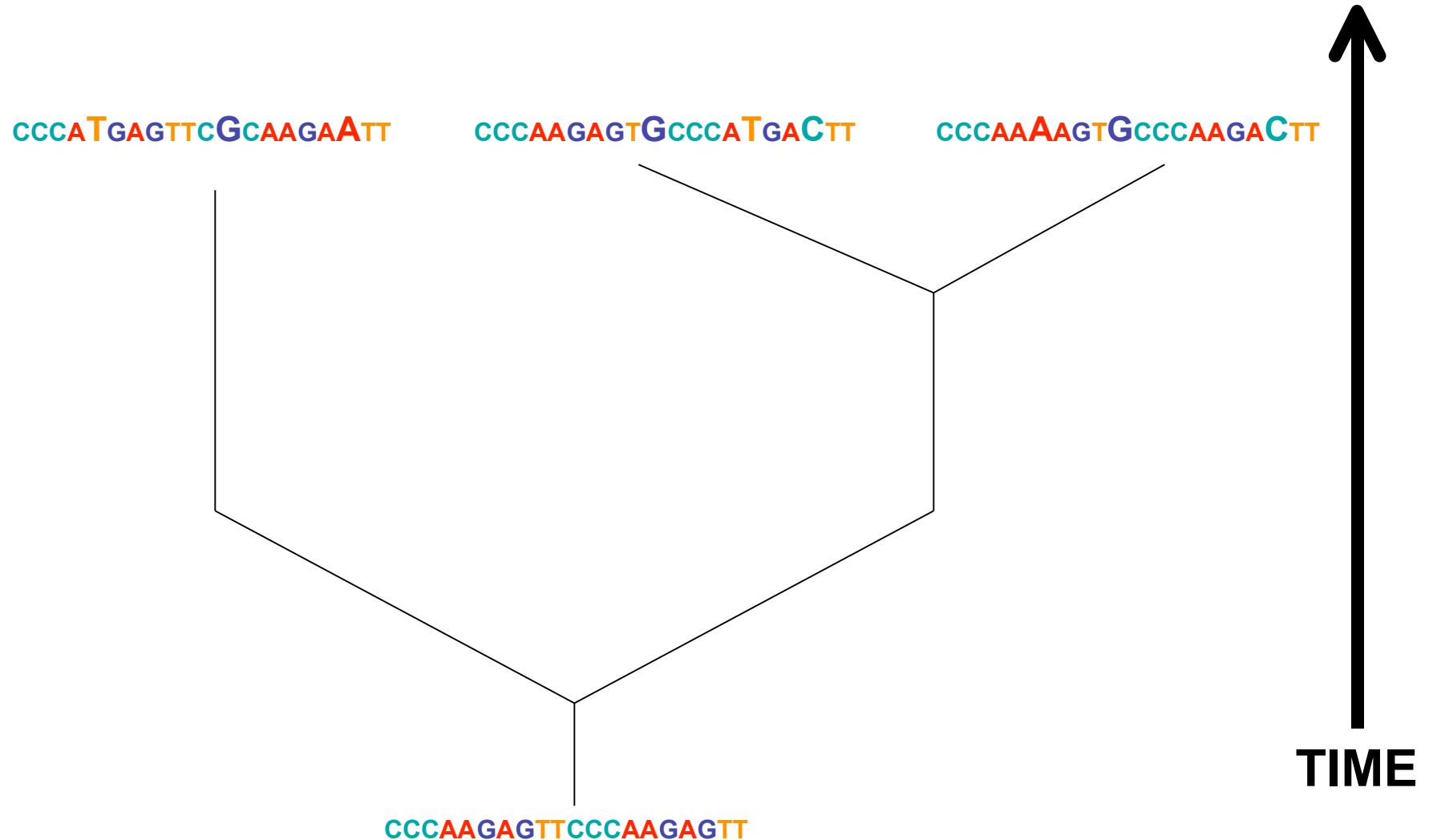
The accumulation of mutations over time

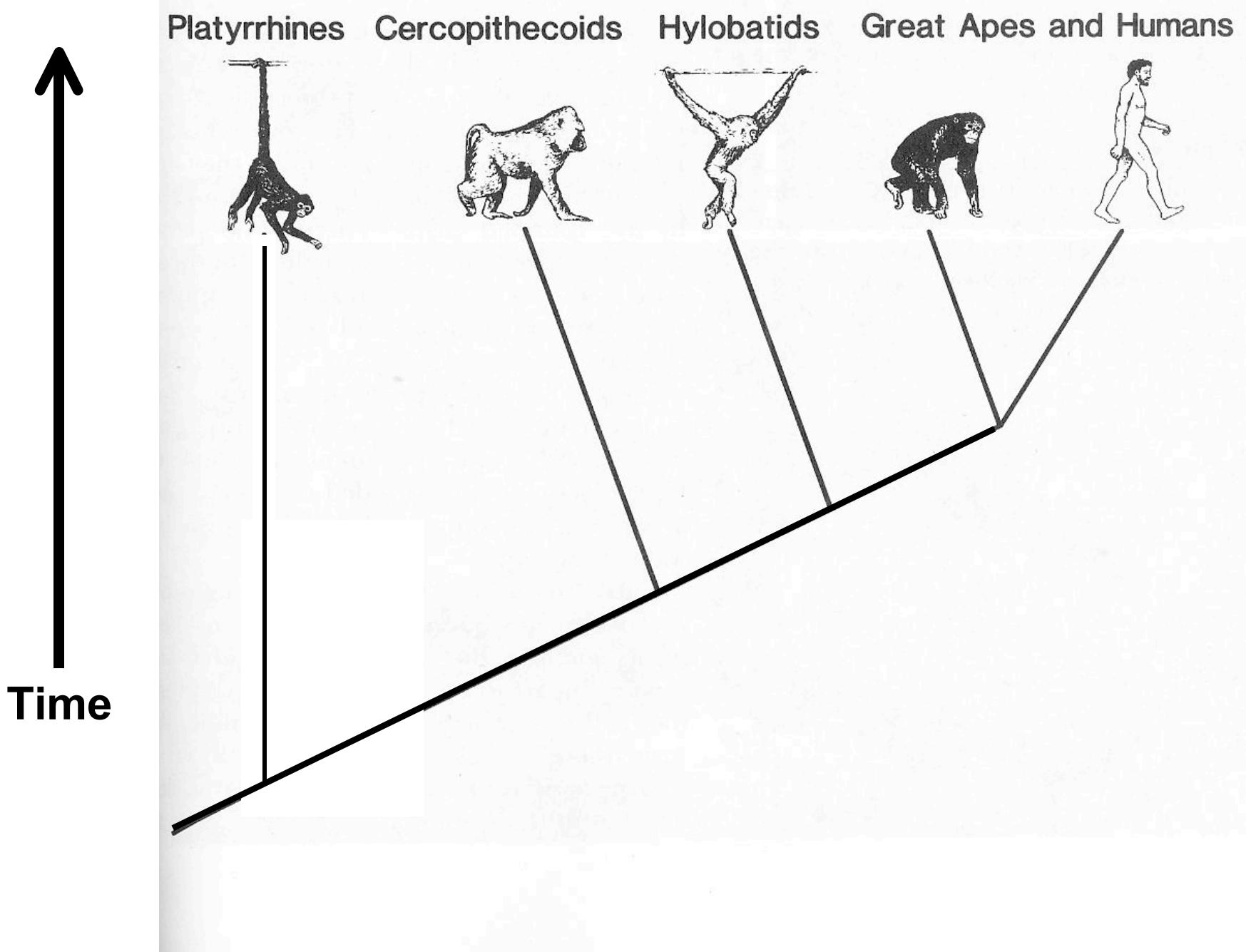


The accumulation of mutations over time

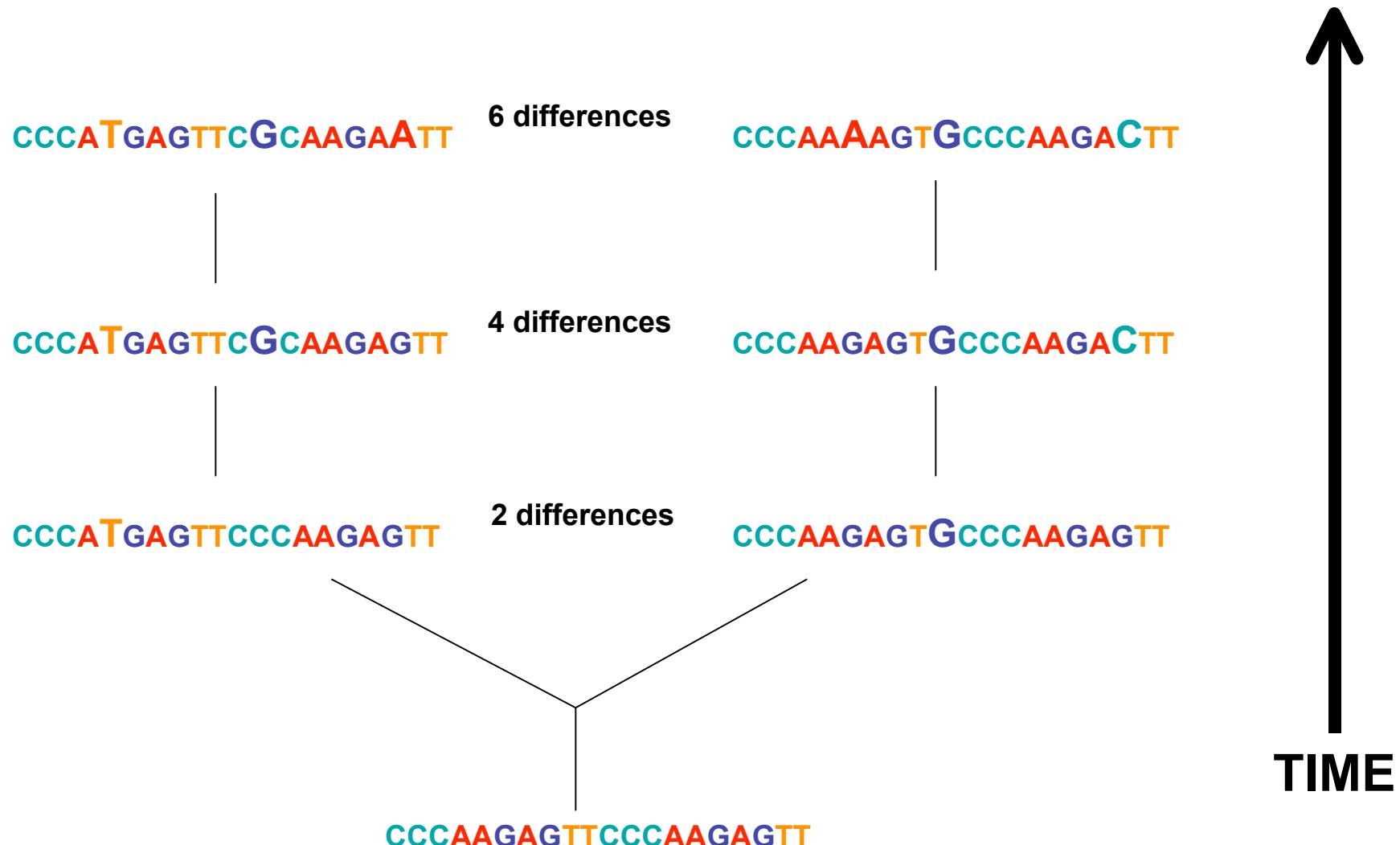


Using mutations to establish relationships

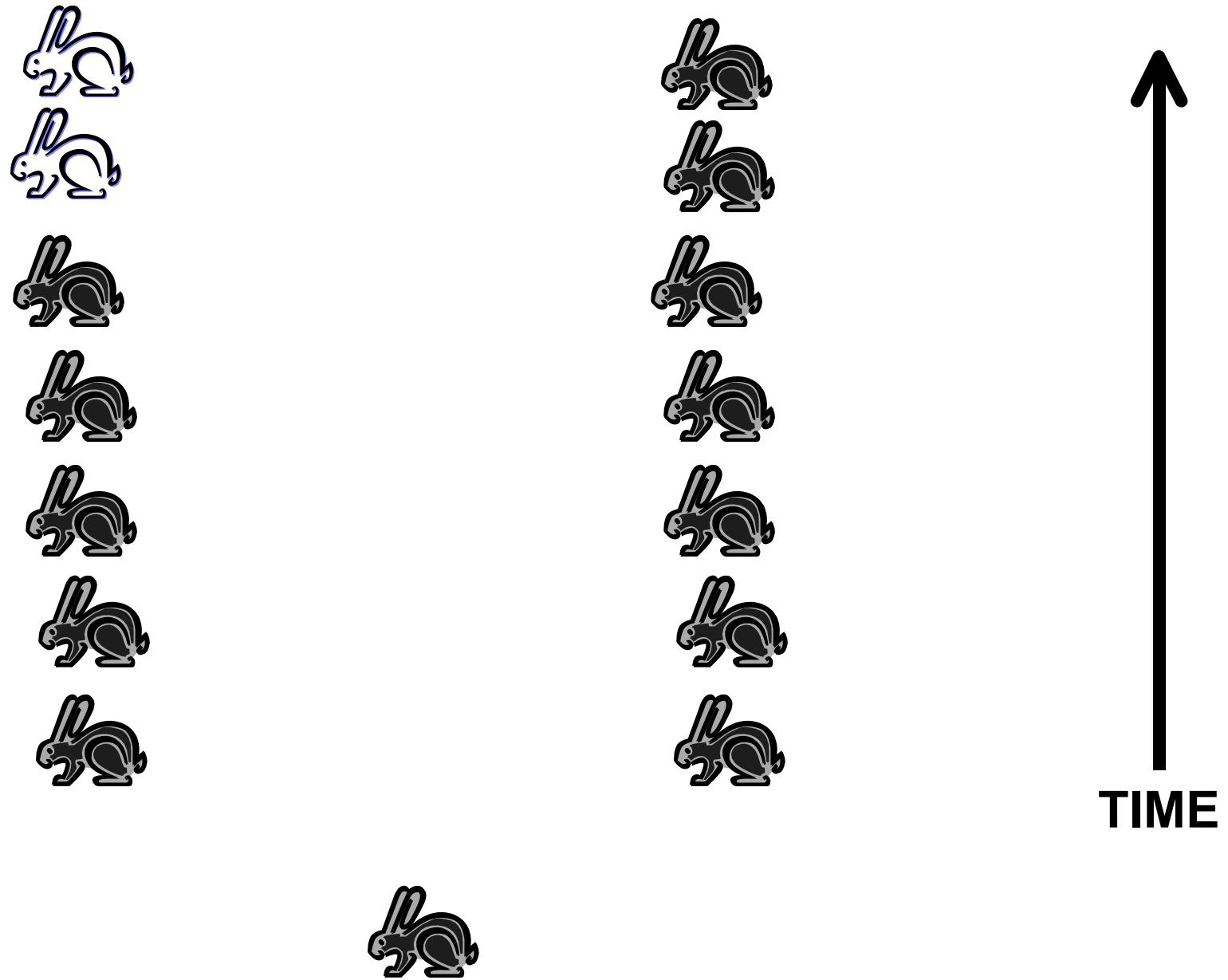




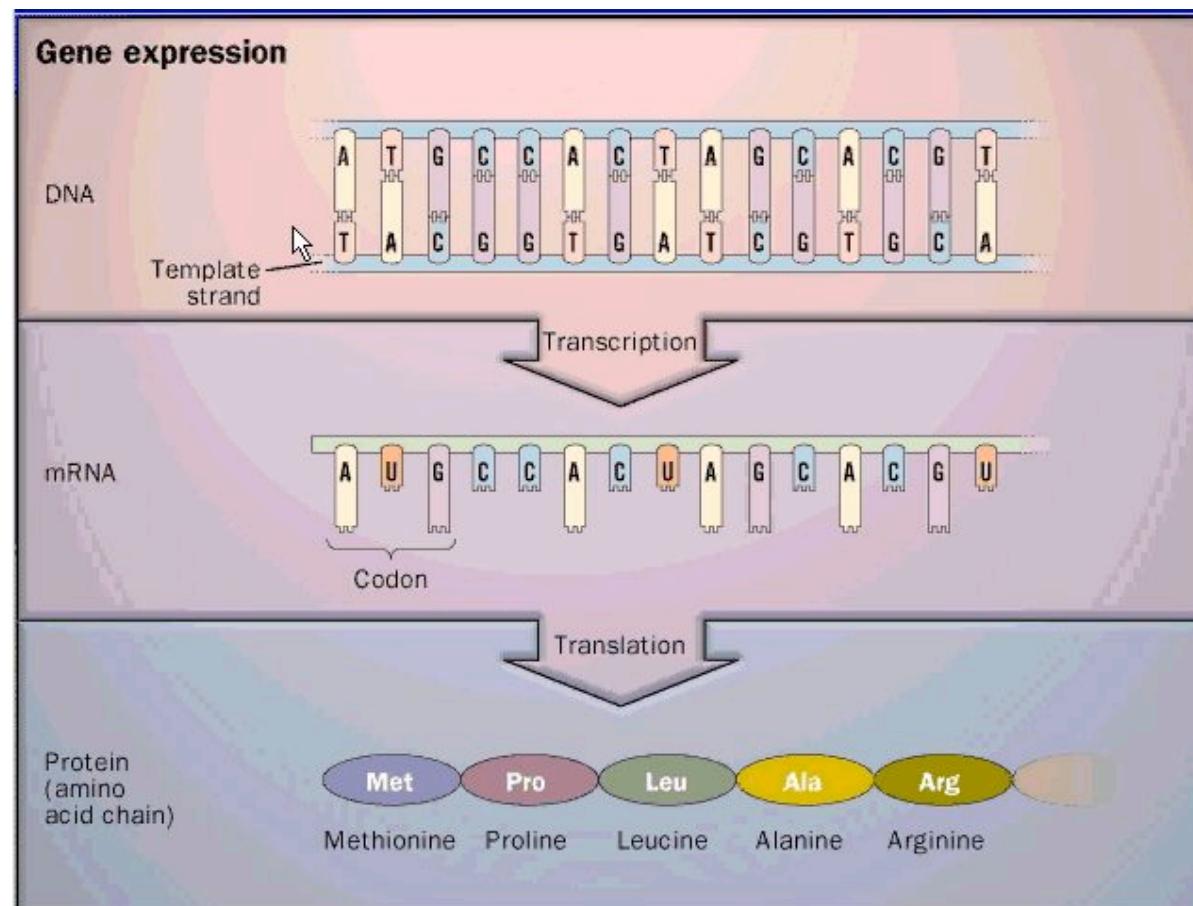
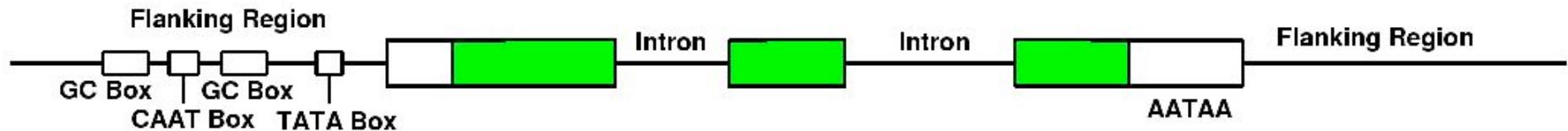
The accumulation of mutations over time

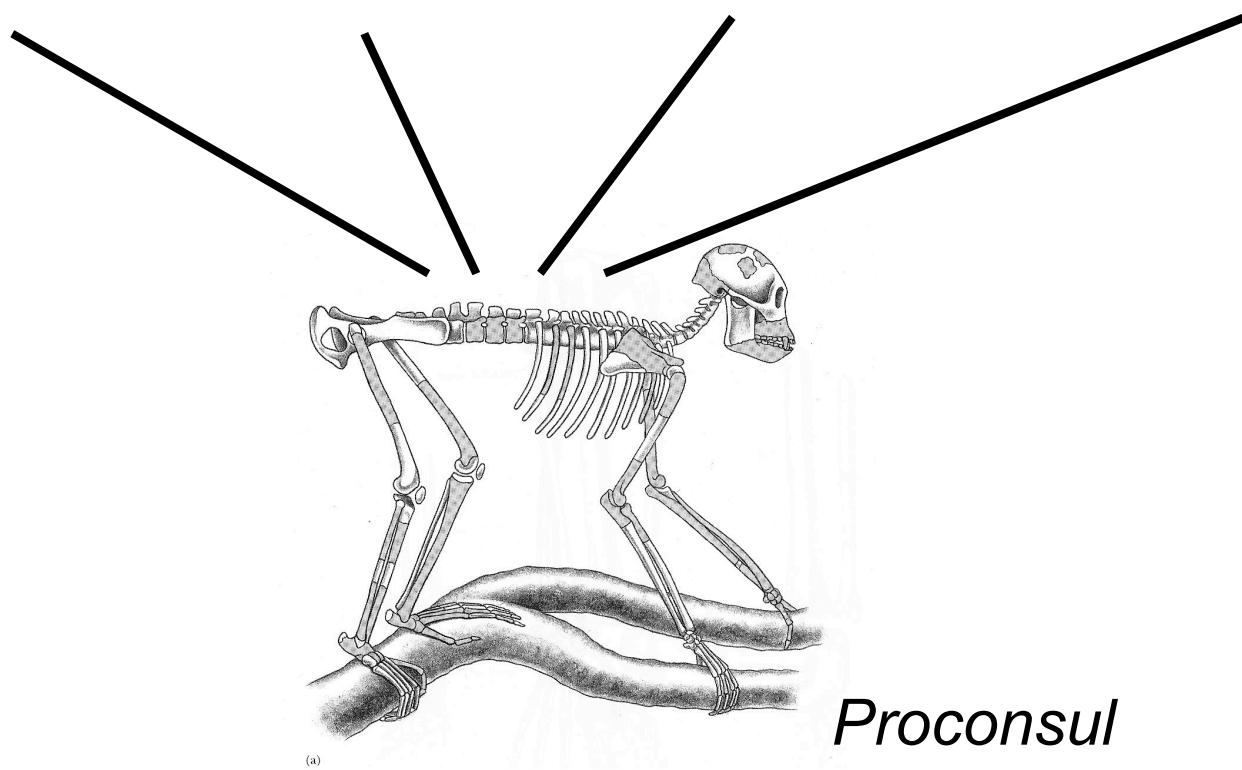
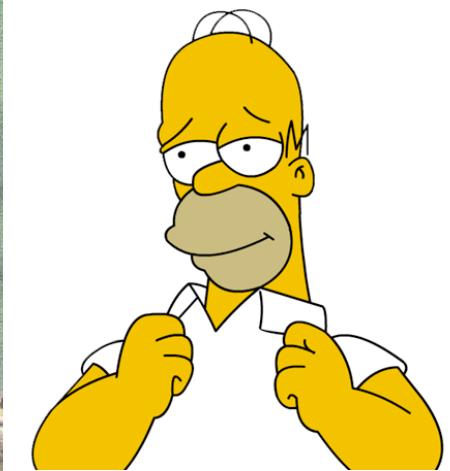
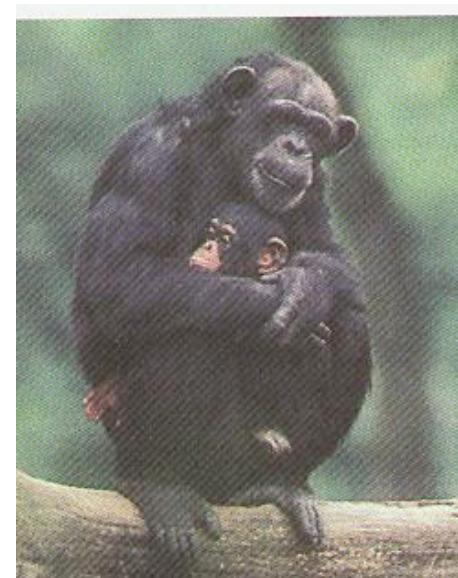
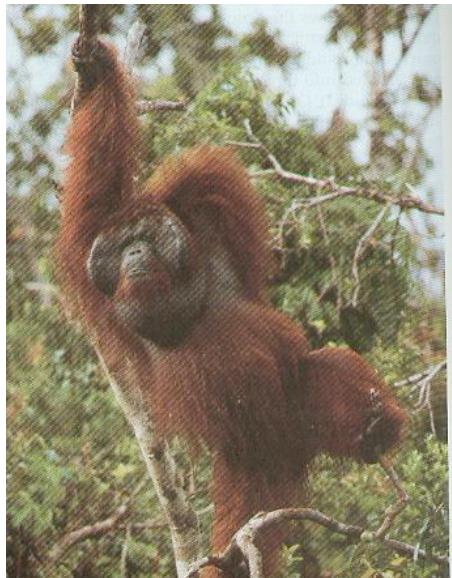


The environment constrains certain mutations



Identifying “useful” regions of DNA





Proconsul

(a)

Molecular Dating in Humans and Apes

Am. J. Hum. Genet. 68:444–456, 2001

Genomic Divergences between Humans and Other Hominoids and the Effective Population Size of the Common Ancestor of Humans and Chimpanzees

Feng-Chi Chen^{1,*} and Wen-Hsiung Li²

¹Department of Life Science, National Tsing Hua University, Taiwan, and ²Department of Ecology and Evolution, University of Chicago, Chicago

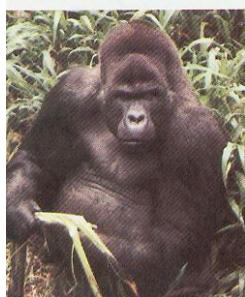
To study the genomic divergences among hominoids and to estimate the effective population size of the common ancestor of humans and chimpanzees, we selected 53 autosomal intergenic nonrepetitive DNA segments from the human genome and sequenced them in a human, a chimpanzee, a gorilla, and an orangutan. The average sequence divergence was only $1.24\% \pm 0.07\%$ for the human-chimpanzee pair, $1.62\% \pm 0.08\%$ for the human-gorilla pair, and $1.63\% \pm 0.08\%$ for the chimpanzee-gorilla pair. These estimates, which were confirmed by additional data from GenBank, are substantially lower than previous ones, which included repetitive sequences and might have been based on less-accurate sequence data. The average sequence divergences between orangutans and humans, chimpanzees, and gorillas were $3.08\% \pm 0.11\%$, $3.12\% \pm 0.11\%$, and $3.09\% \pm 0.11\%$, respectively, which also are substantially lower than previous estimates. The sequence divergences in other regions between hominoids were estimated from extensive data in GenBank and the literature, and *Alus* showed the highest divergence, followed in order by Y-linked noncoding regions, pseudogenes, autosomal intergenic regions, X-linked noncoding regions, synonymous sites, introns, and nonsynonymous sites. The neighbor-joining tree derived from the concatenated sequence of the 53 segments—24,234 bp in length—supports the *Homo-Pan* clade with a 100% bootstrap value. However, when each segment is analyzed separately, 22 of the 53 segments (~42%) give a tree that is incongruent with the species tree, suggesting a large effective population size (N_e) of the common ancestor of *Homo* and *Pan*. Indeed, a parsimony analysis of the 53 segments and 37 protein-coding genes leads to an estimate of $N_e = 52,000$ to 96,000. As this estimate is 5 to 9 times larger than the long-term effective population size of humans (~10,000) estimated from various genetic polymorphism data, the human lineage apparently had experienced a large reduction in effective population size after its separation from the chimpanzee lineage. Our analysis assumes a molecular clock, which is in fact supported by the sequence data used. Taking the orangutan speciation date as 12 to 16 million years ago, we obtain an estimate of 4.6 to 6.2 million years for the *Homo-Pan* divergence and an estimate of 6.2 to 8.4 million years for the gorilla speciation date, suggesting that the gorilla lineage branched off 1.6 to 2.2 million years earlier than did the human-chimpanzee divergence.



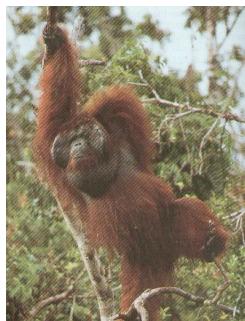
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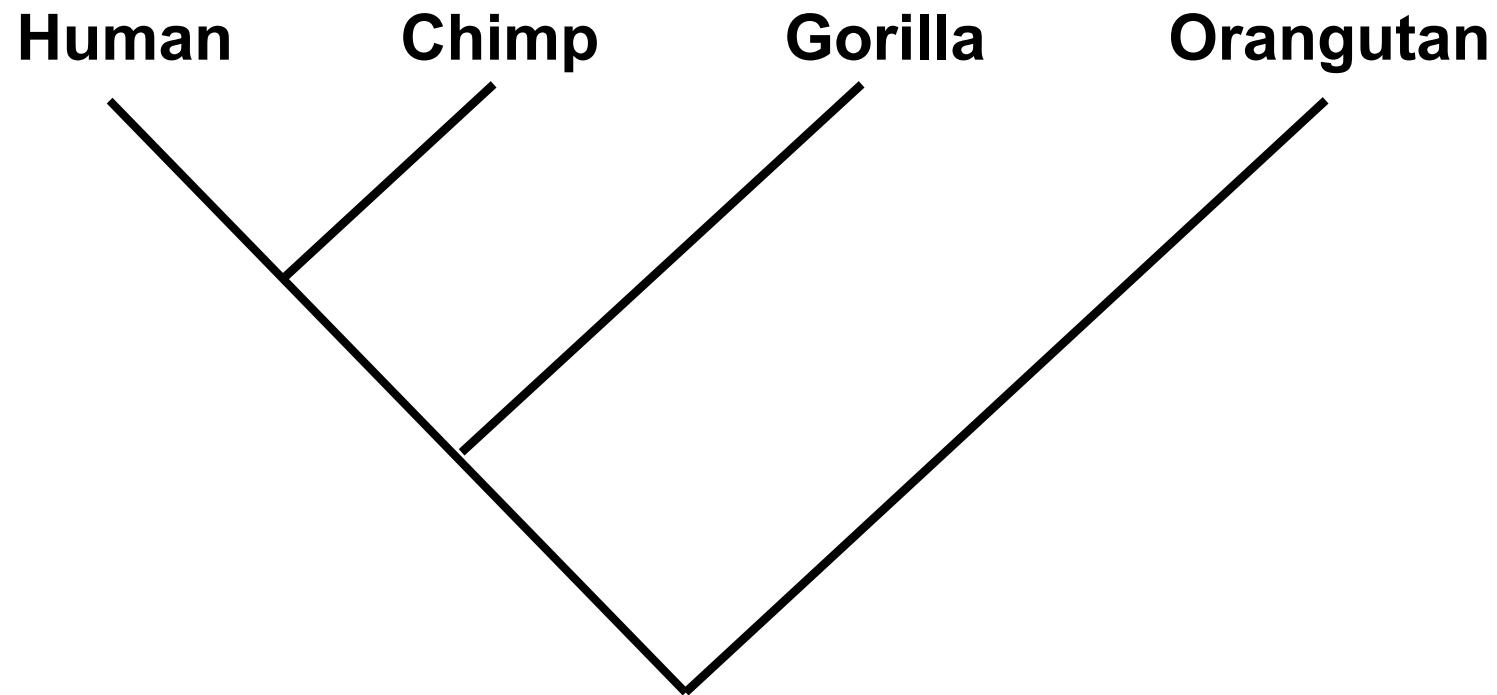


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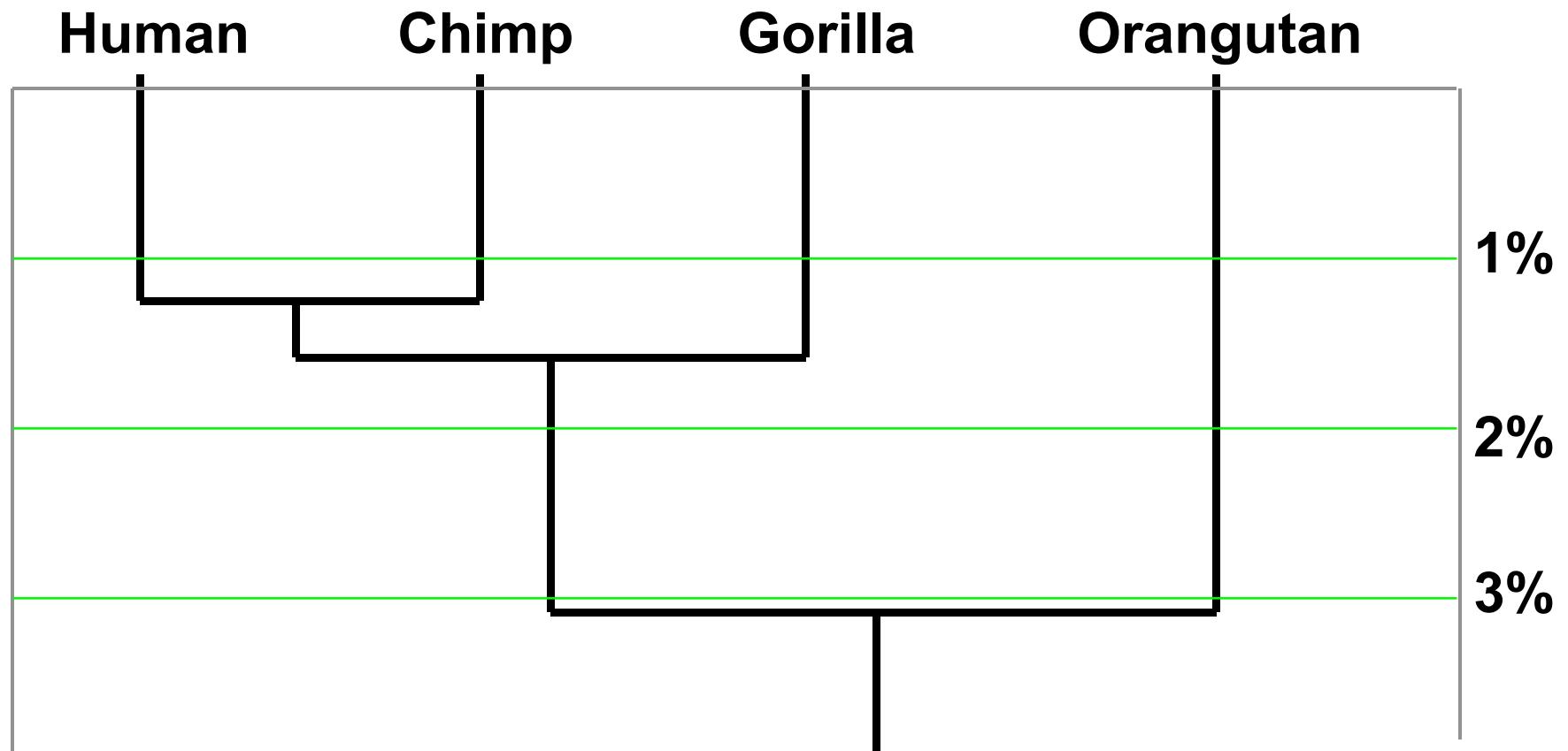


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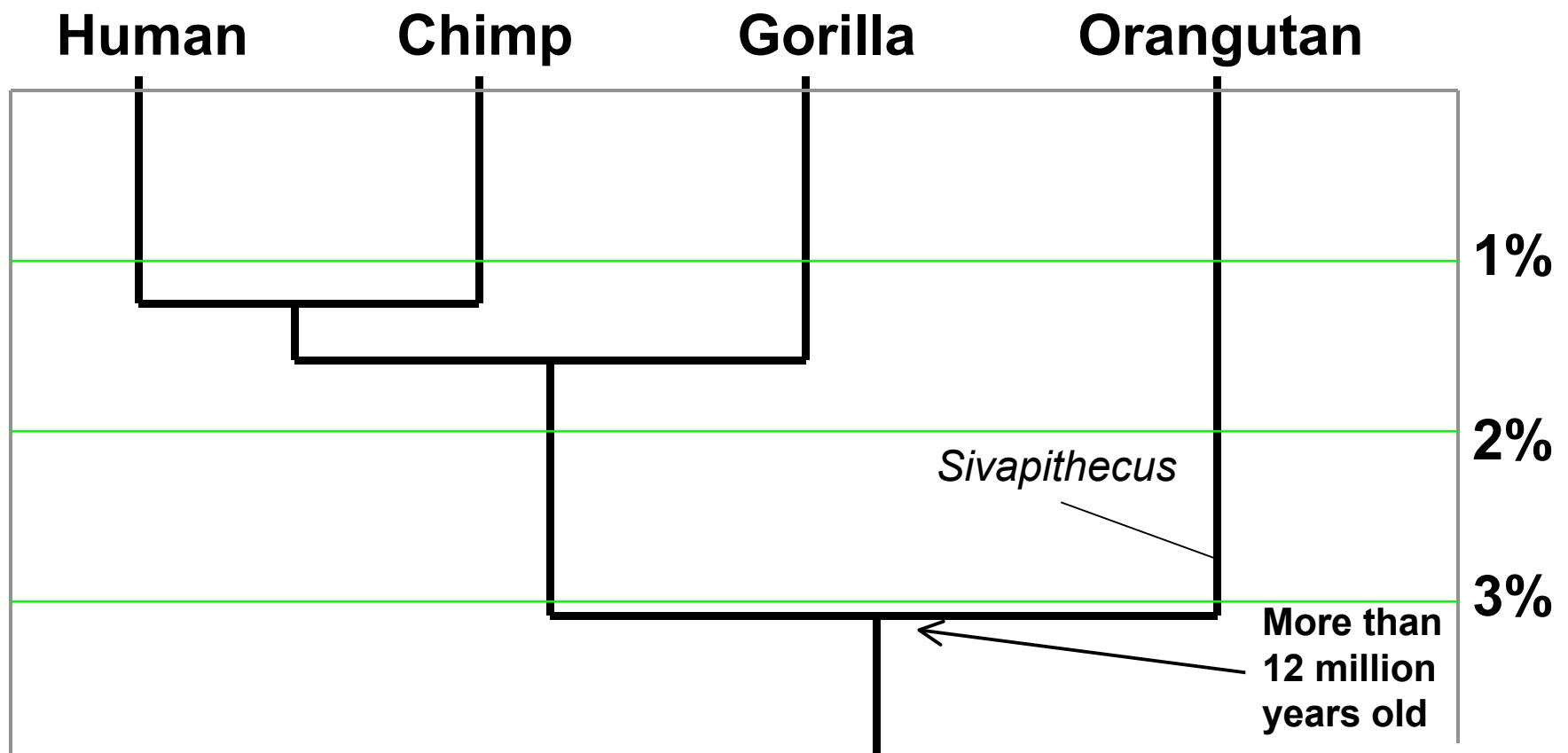
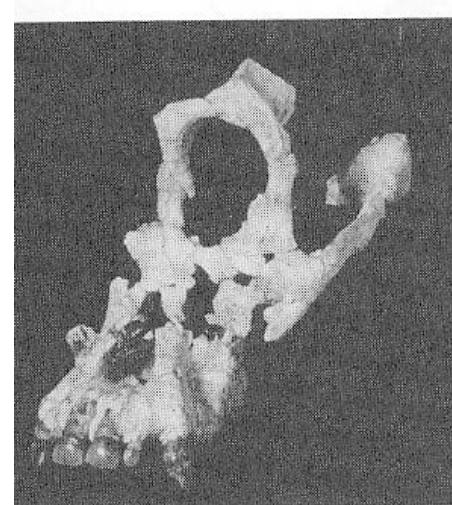
	Chimp	Gorilla	Orangutan
Human	1.24%	1.62%	3.08%
Chimp		1.63%	3.12%
Gorilla			3.09%

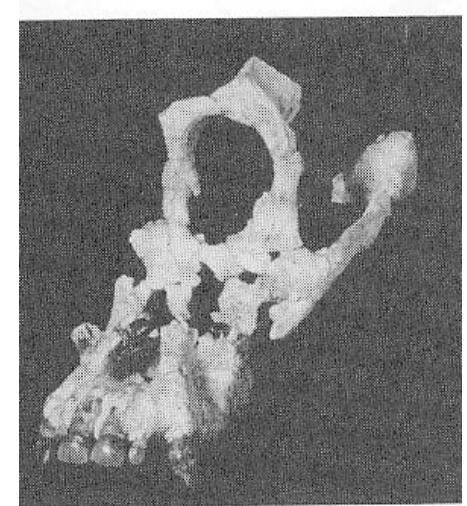
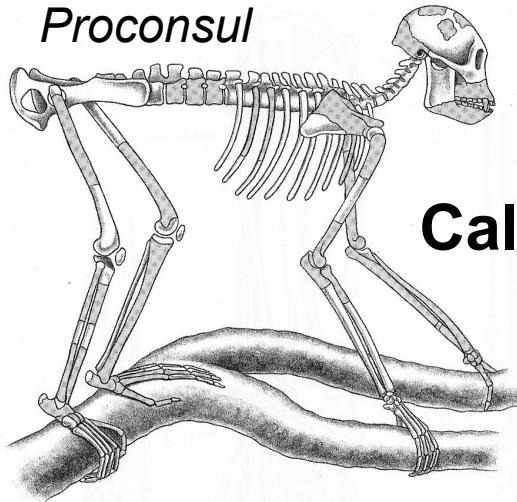


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Calibrating the molecular clock





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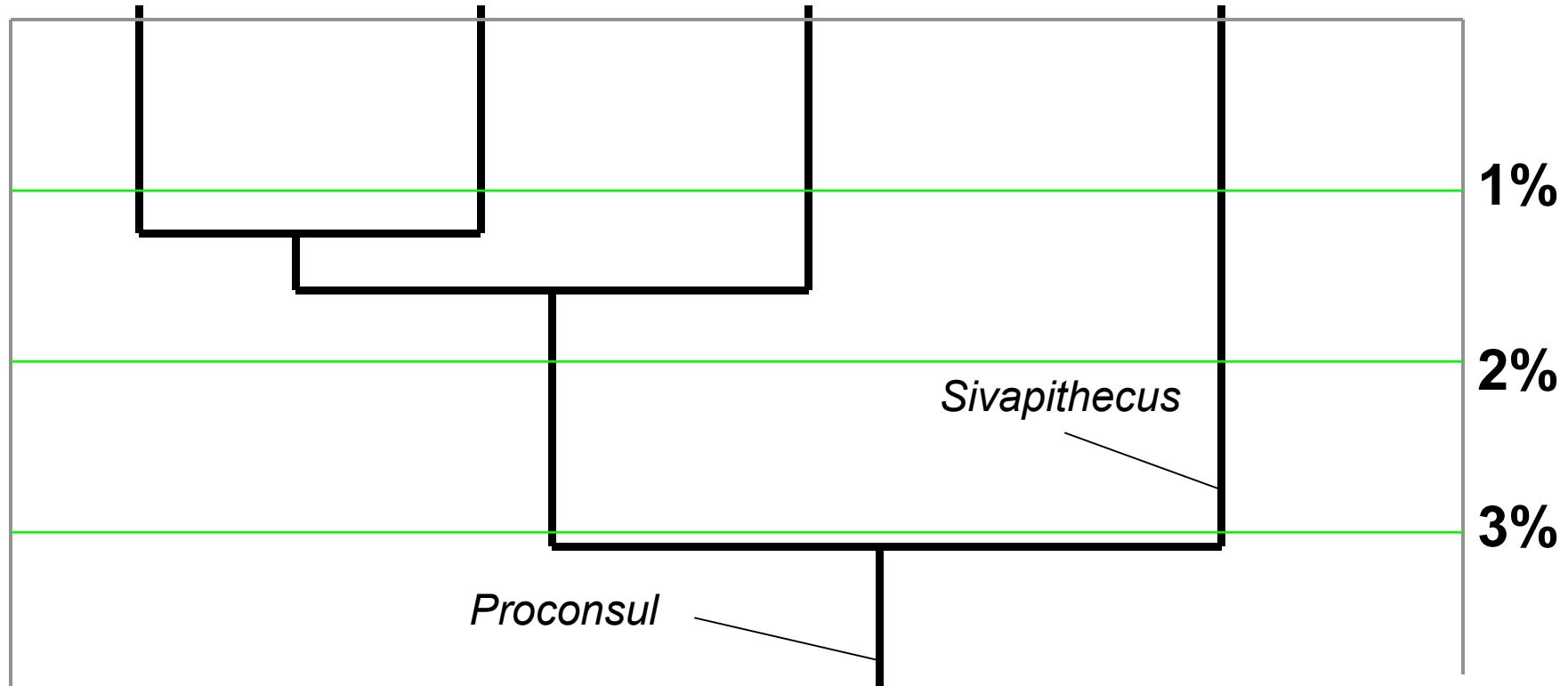
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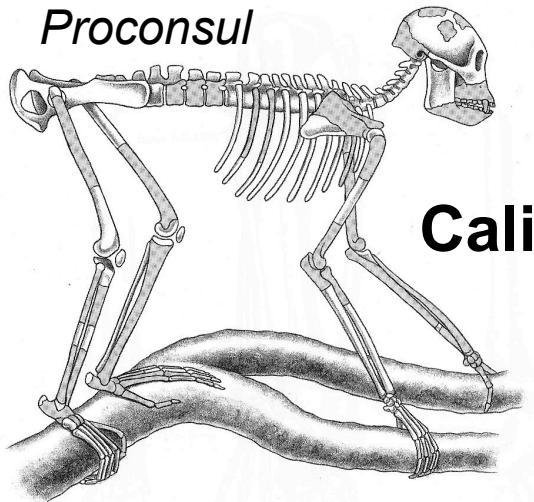
Human

Chimp

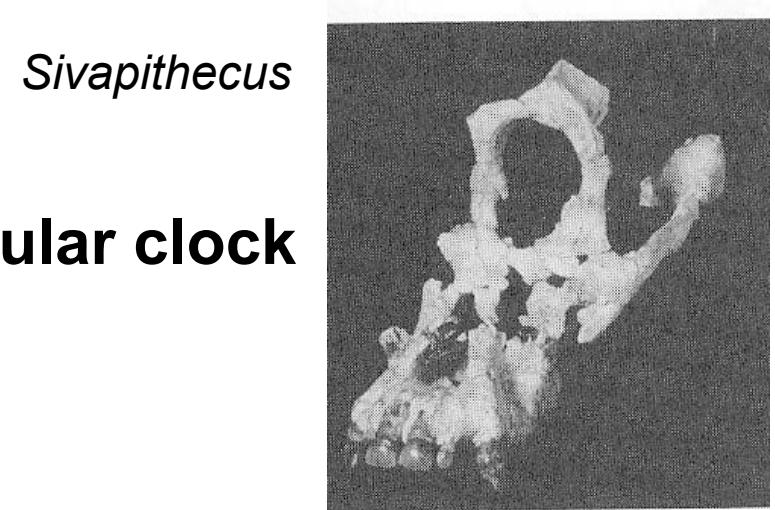
Gorilla

Orangutan



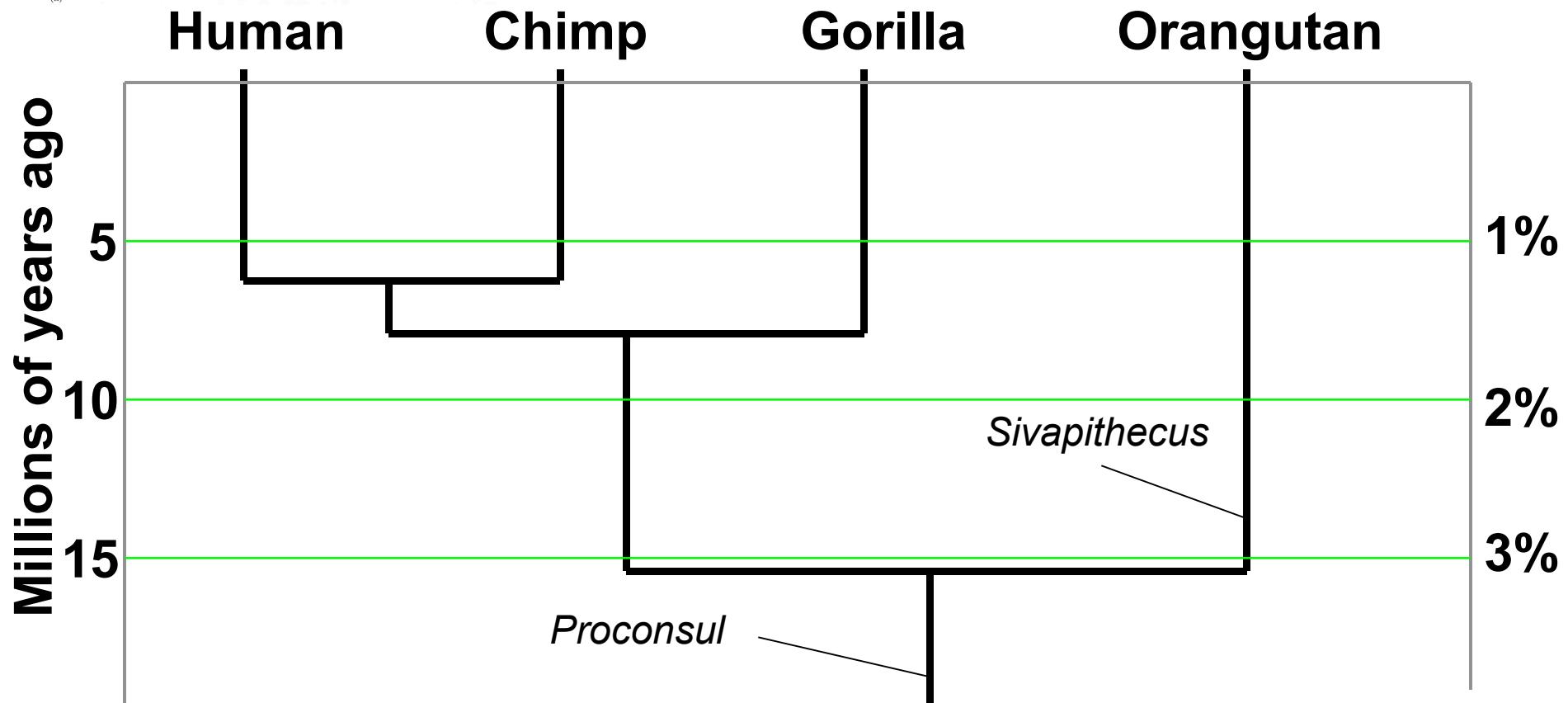


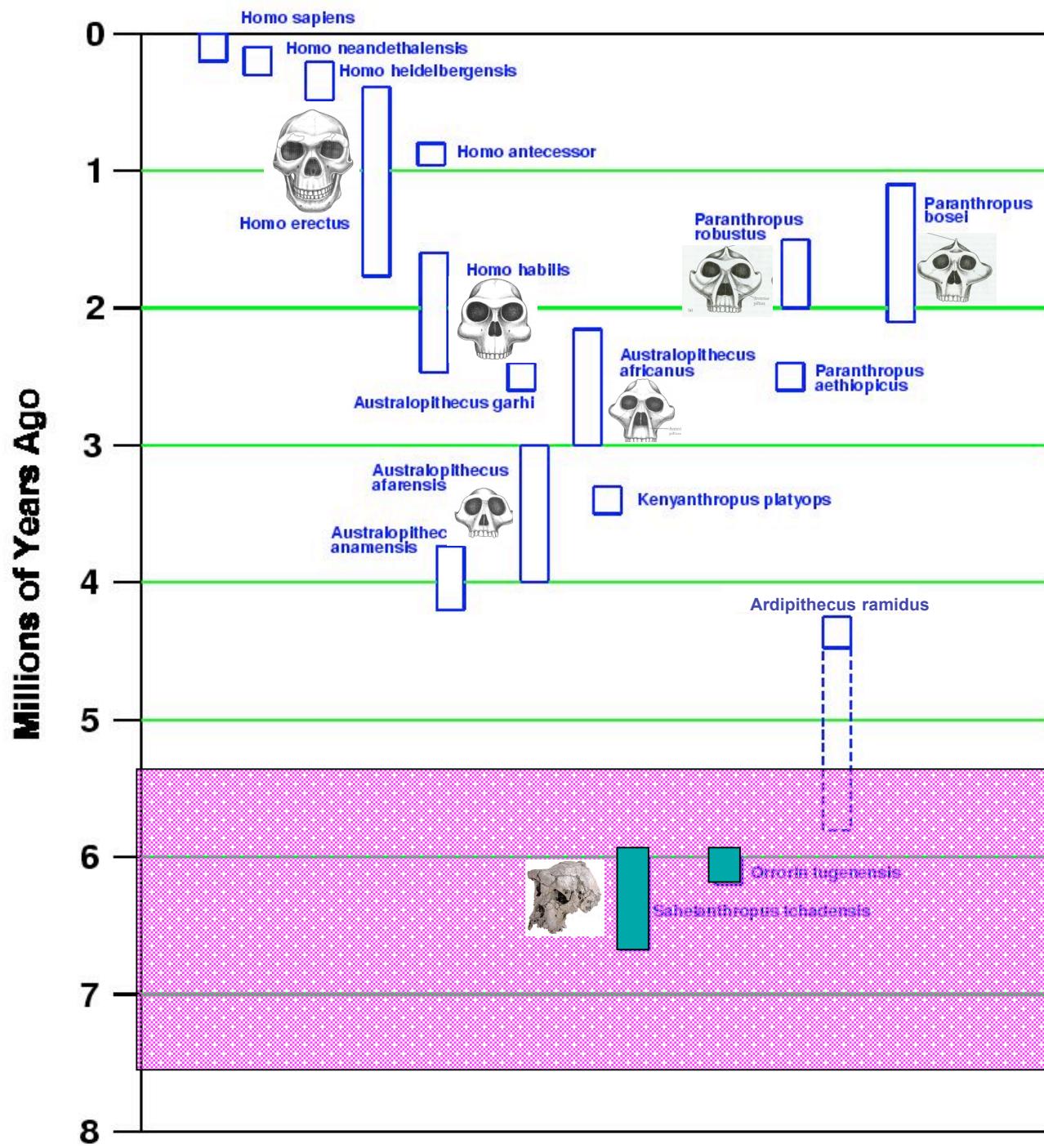
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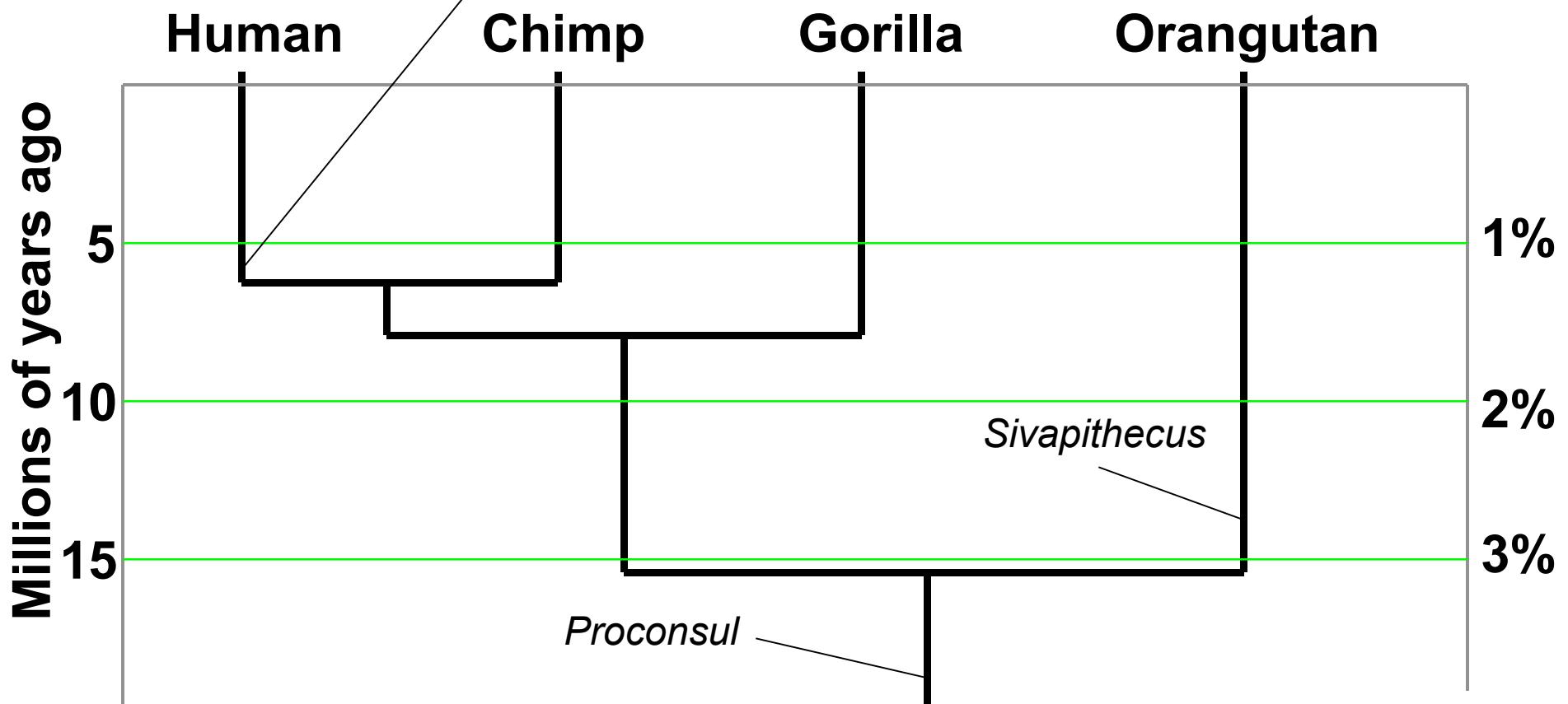
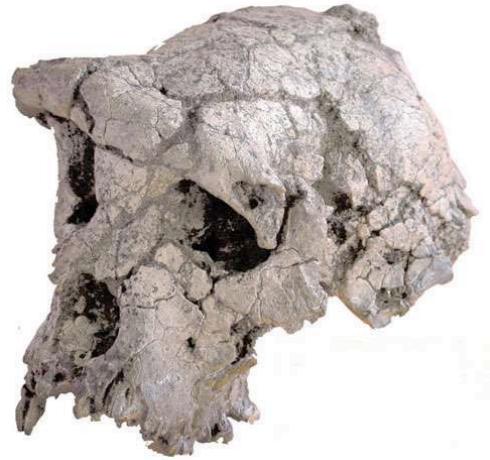
Sivapithecus

Calibrating the molecular clock



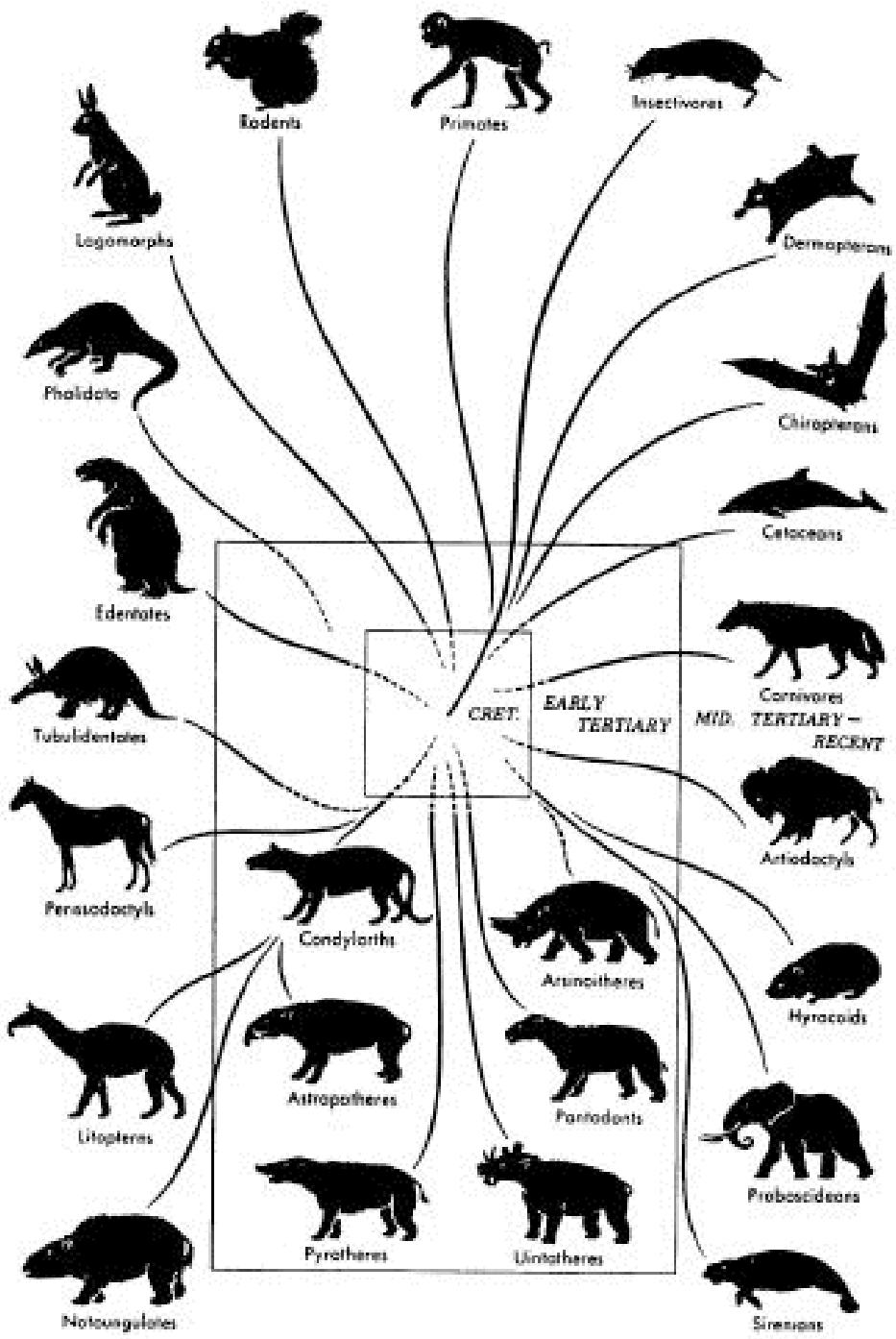


**Estimated time when
humans and chimps
last had a common
ancestor**



Next Time:

Molecular Dating and the Many Kinds of Mammals



Relationships of the orders of placental mammals.