Studiare l’evoluzione del sistema nervoso

La vita sulla terra è evoluta una sola volta attraverso un meccanismo molecolare unico e modificabile

Il materiale genetico è trasferibile alla progenie (trasmissione verticale), ma non ad altri individui (trasmissione orizzontale). Di conseguenza le modificazioni di genotipo e di fenotipo (l’evoluzione) si manifestano solo attraverso le generazioni.
Questo vale per l’evoluzione biologica, ma non per quella culturale.

Caratteri simili in specie diverse riflettono il mantenimento dell’informazione genetica, mentre caratteri diversi sono il risultato di modificazioni della stessa informazione

Principali pregiudizi sull’evoluzione

Le teorie dell’evoluzione sono necessariamente speculative e non verificabili

L’evoluzione è un processo progressivo con una singola direzione

L’ontogenesi ricapitola la filogenesi ed i caratteri nuovi sono aggiunti alla fine dello sviluppo

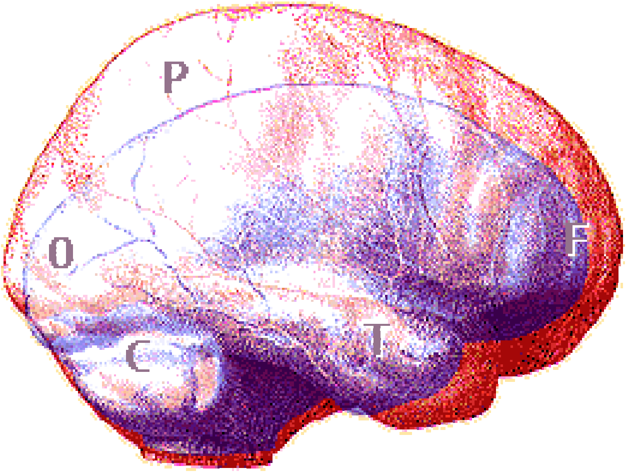
Metodi per lo studio dell’evoluzione

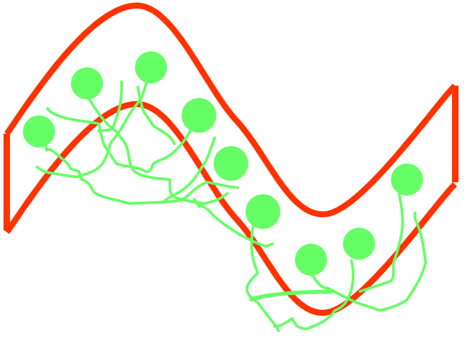
Analisi dei resti fossili
- dimensioni del cervello
- aspetto superficie (impronta endocranica)
- connessioni (attraverso la disposizione delle scissure)

Analisi comparativa di specie viventi (o estinte)
- studio dei caratteri
- struttura e funzione: omologie ed analogie

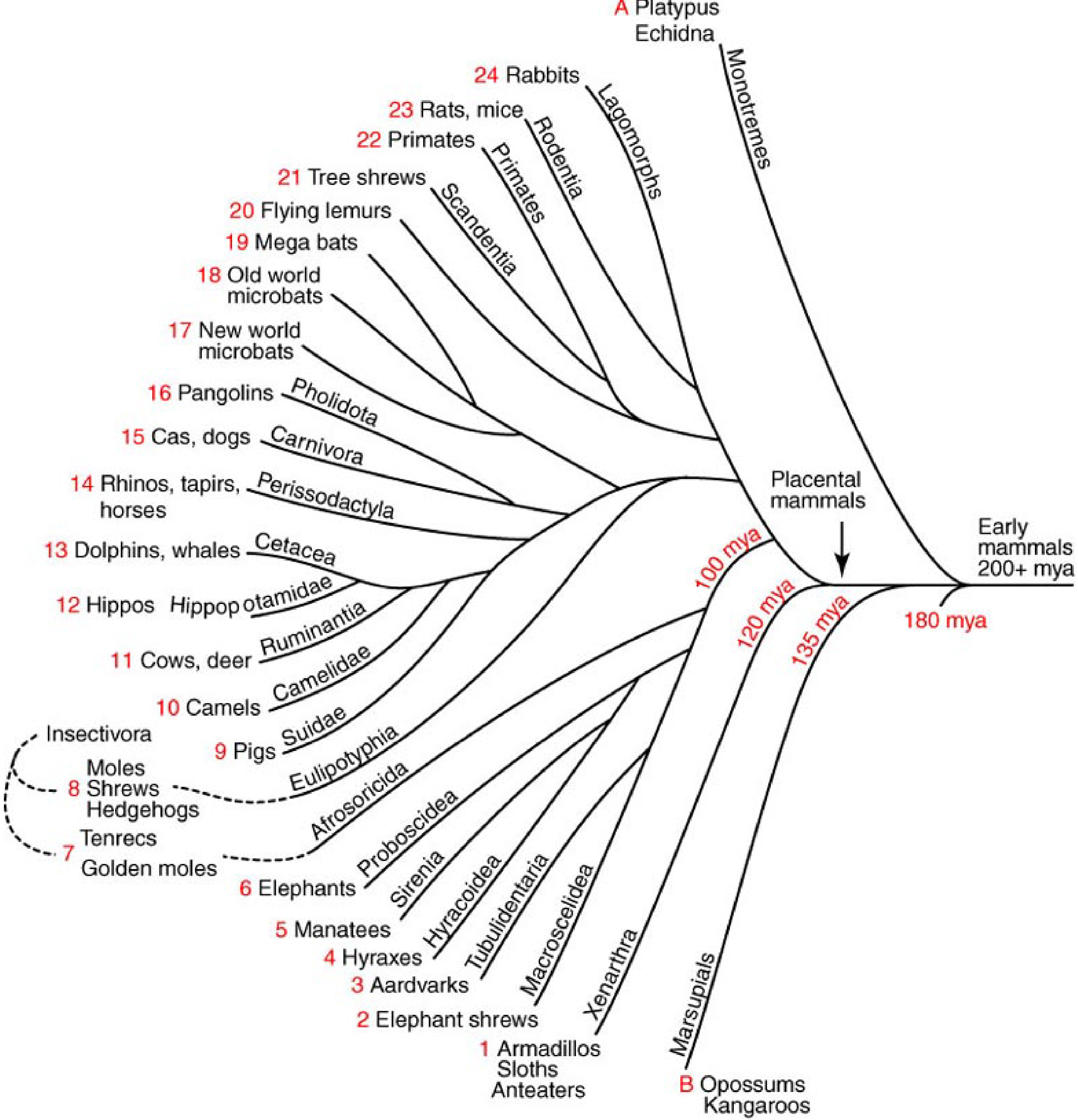
Analisi dei meccanismi ontogenetici
- progetti di sviluppo
- dimensioni dell’organismo e dimensioni del cervello
- sequenza spazio-temporale di sviluppo delle parti

Metodi biochimici e genetici
- studio delle proteine (sequenze aminoacidiche)
- studio delle mutazioni del DNA
- analisi del DNA mitocondriale
- analisi del cromosoma Y

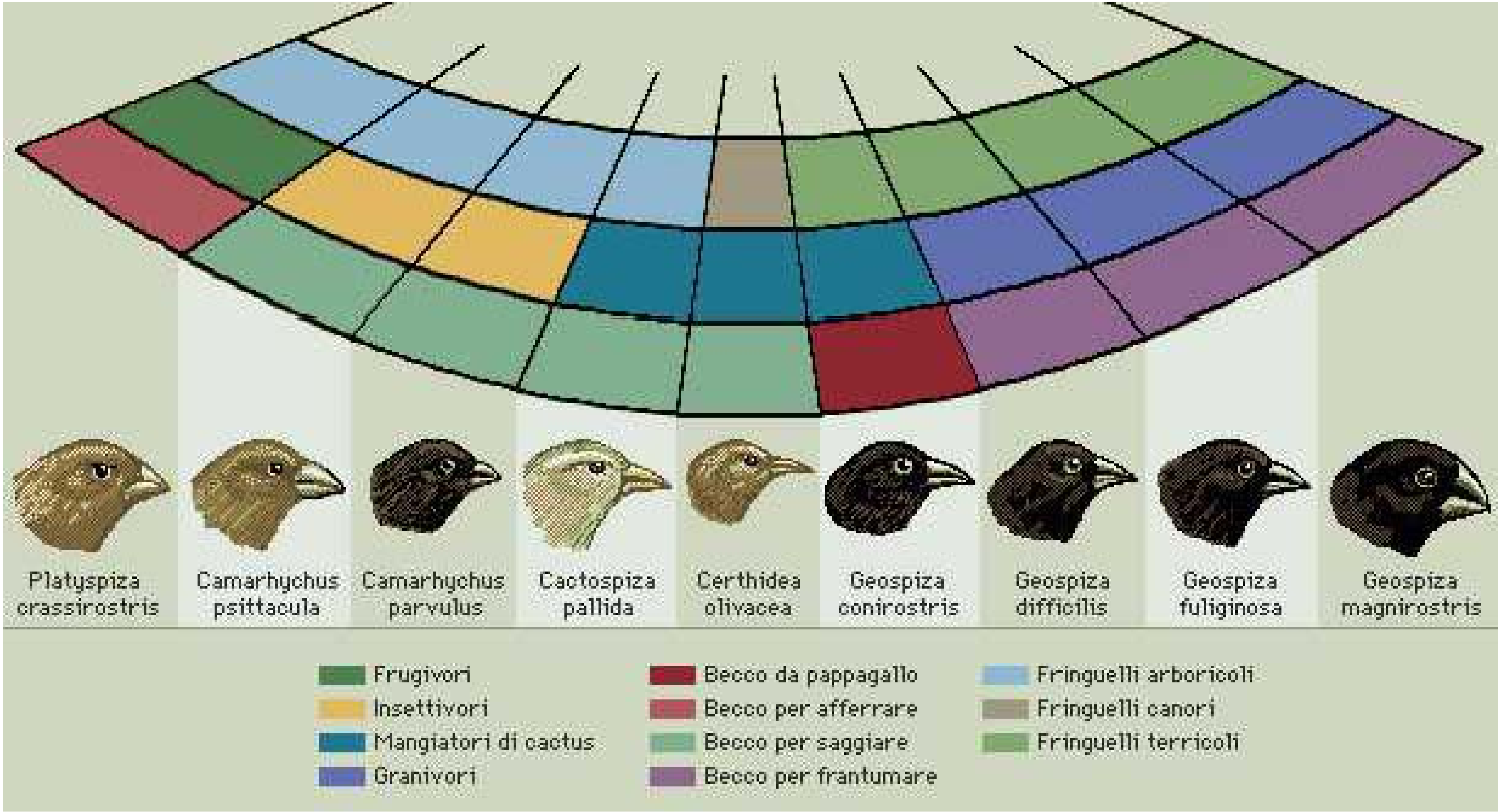


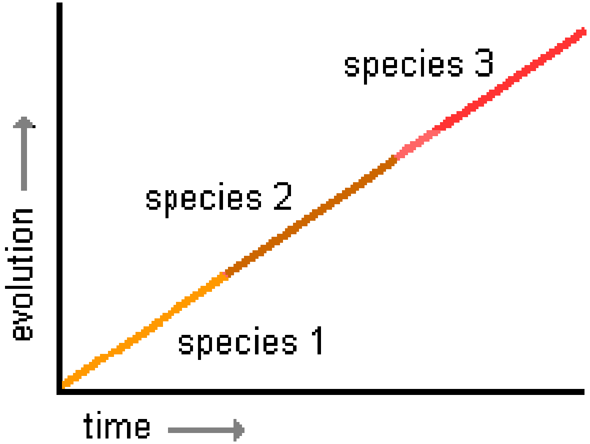


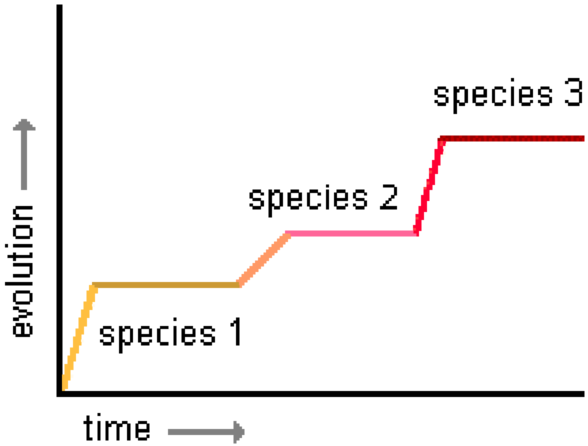
Molte connessioni --- giro
Poche connessioni --- fissura

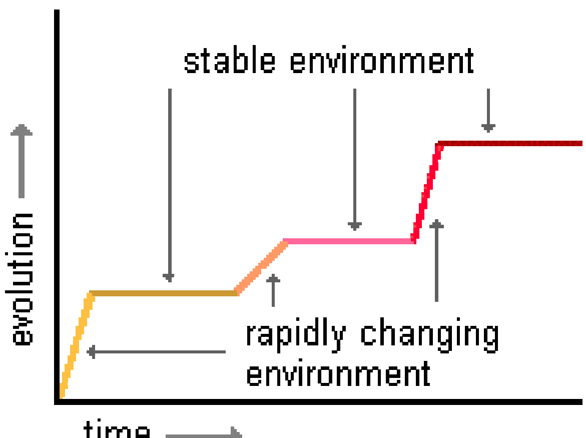

A Platypus
Echidna
Monotremes
24 Rabbits
Lagomorphs
23 Rats, mice
Rodentia
22 Primates
Primates
21 Tree shrews
Scandentia
20 Flying lemurs
19 Mega bats
18 Old world microbats
17 New world microbats
16 Pangolins
Pholidota
15 Cas, dogs
Carnivora
14 Rhinos, tapirs, horses
Perissodactyla
13 Dolphins, whales
Cetacea
12 Hippos
Hippopotamidae
11 Cows, deer
Ruminantia
10 Camels
Camelidae
9 Pigs
Suidae
Insectivora
8 Moles Shrews Hedgehogs
Eulipotyphia
7 Tenrecs Golden moles
Afrosoricida
6 Elephants
Proboscidea
5 Manatees
Sirenia
4 Hyraxes
Hyracoidea
3 Aardvarks
Tubulidentaria
2 Elephant shrews
Macroscelidea
1 Armadillos Sloths Anteaters
Xenarthra
Marsupials
B Opossums Kangaroos
Placental mammals
100 mya
120 mya
135 mya
180 mya
Early mammals 200+ mya

Fringuelli delle Galapagos









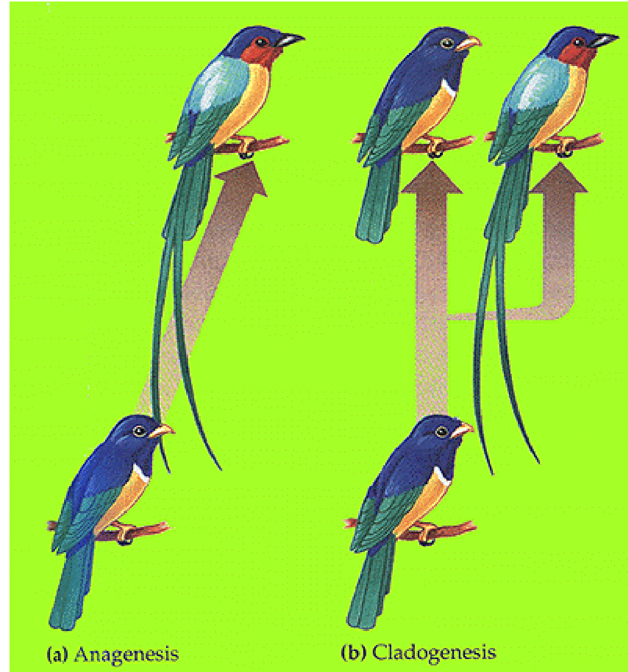
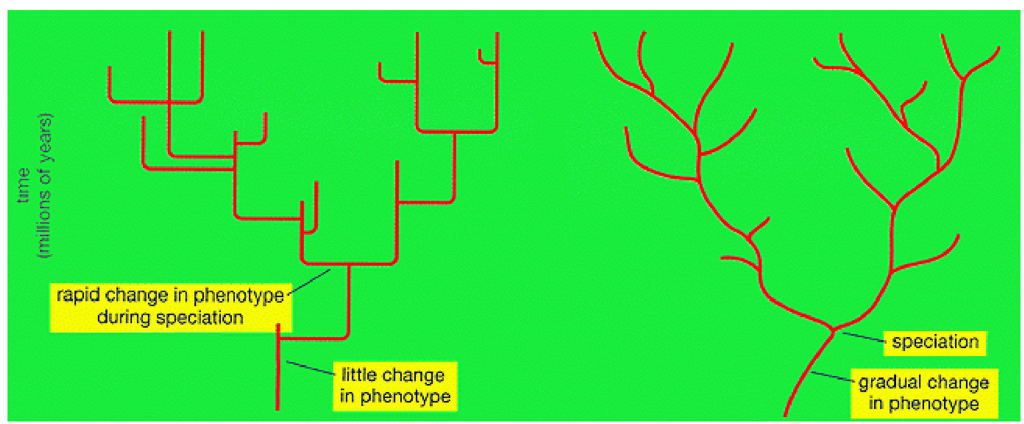


FIGURE 22.1

Two patterns of speciation. (**a**) In anagenesis (phyletic evolution), a single population is transformed enough to be designated a new species. (**b**) Cladogenesis is branching evolution, in which a new species arises from a small population that buds from a parent species. Most new species probably evolve by cladogenesis, the branching evolution that is the basis for biological diversity.



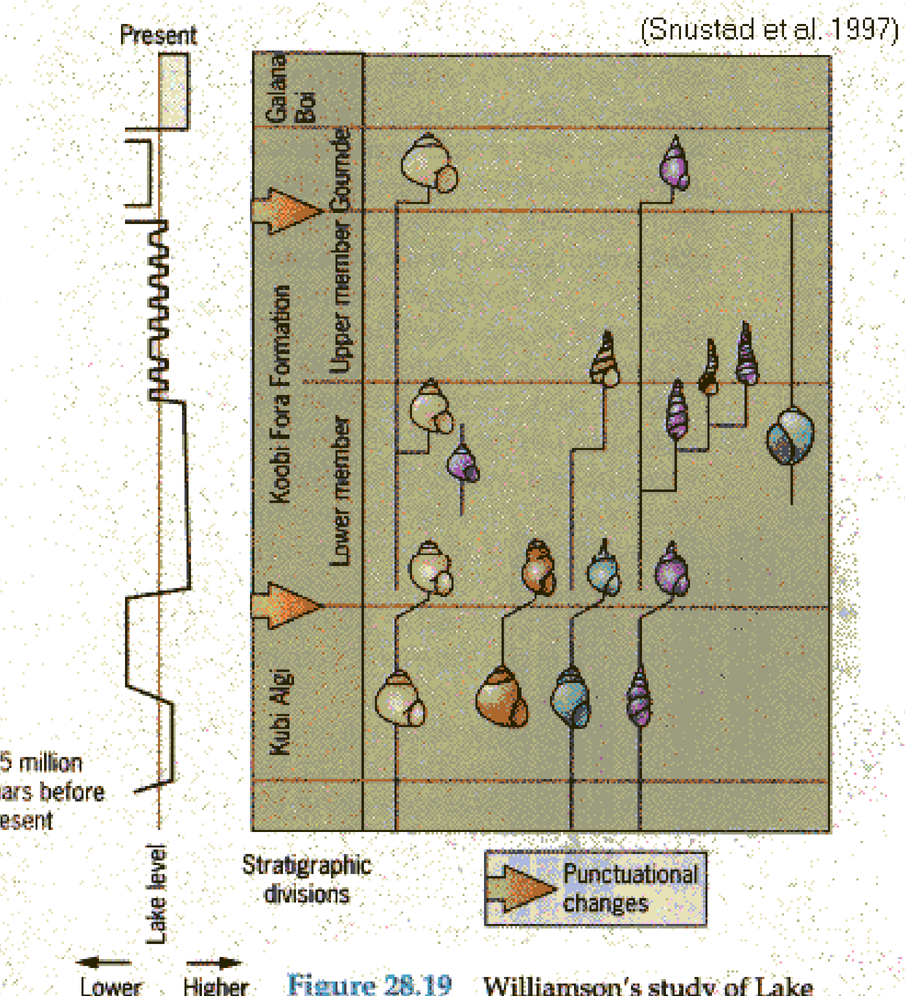
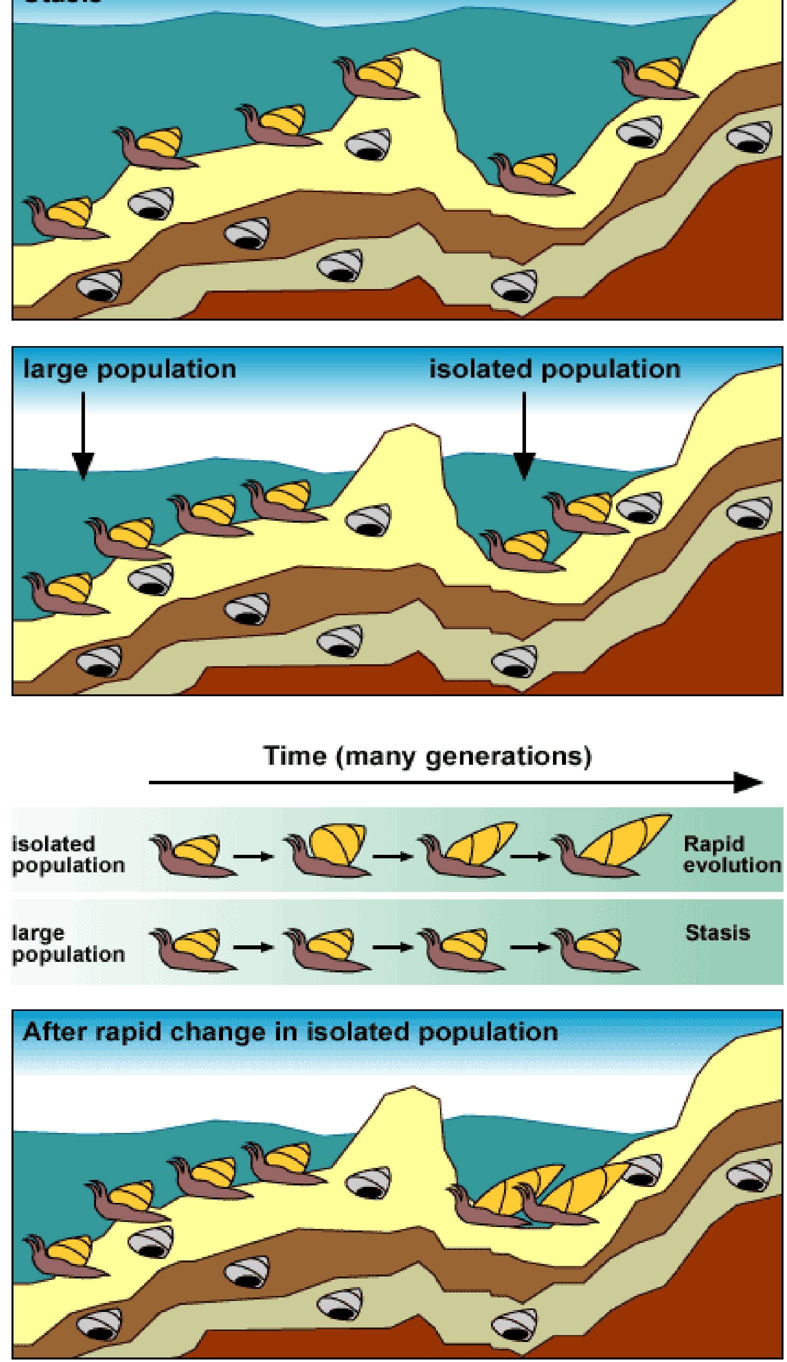


Figure 28.19 Williamson's study of Lake Turkana snails showing a punctuated equilibrium pattern of evolution. Changes in the lake level are shown on the left. Speciation events often accompany changes in the lake level.

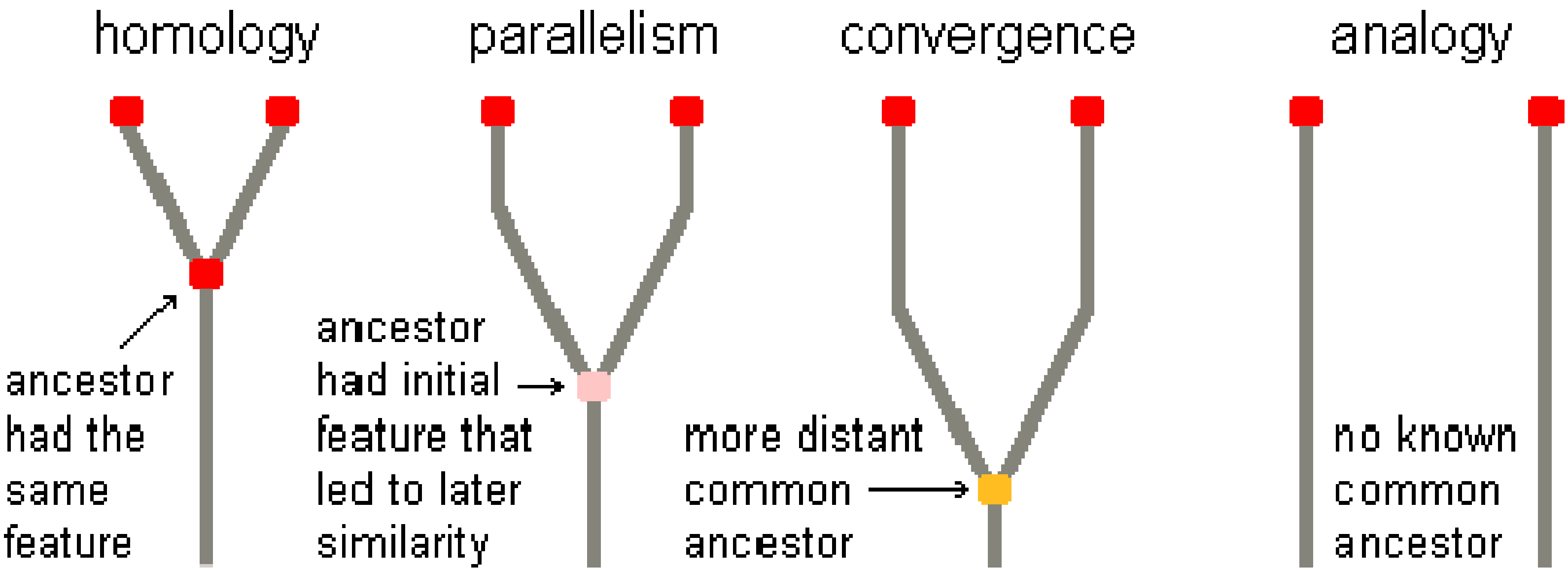


Omologia ed analogia

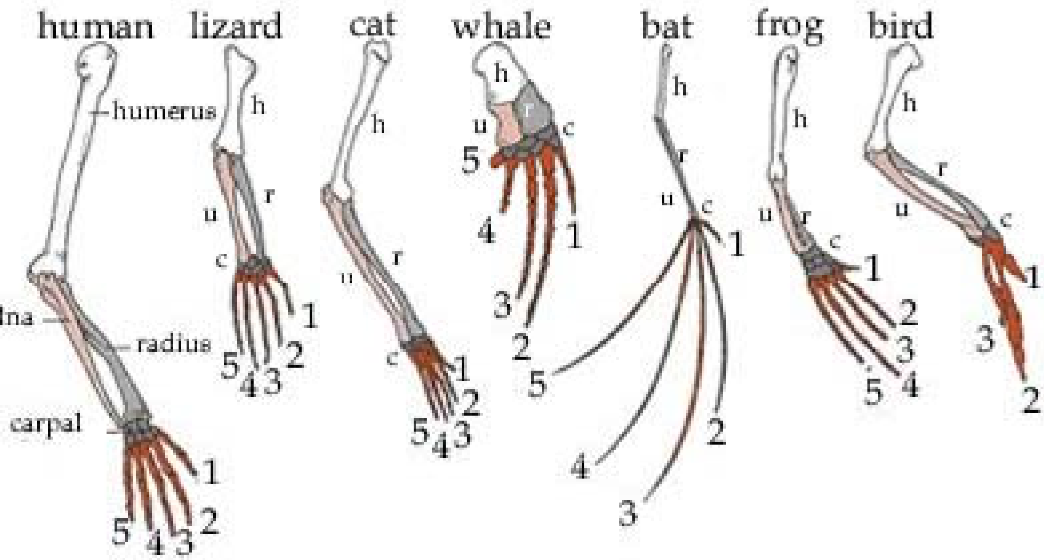
Caratteri omologi sono derivati dallo stesso carattere ancestrale

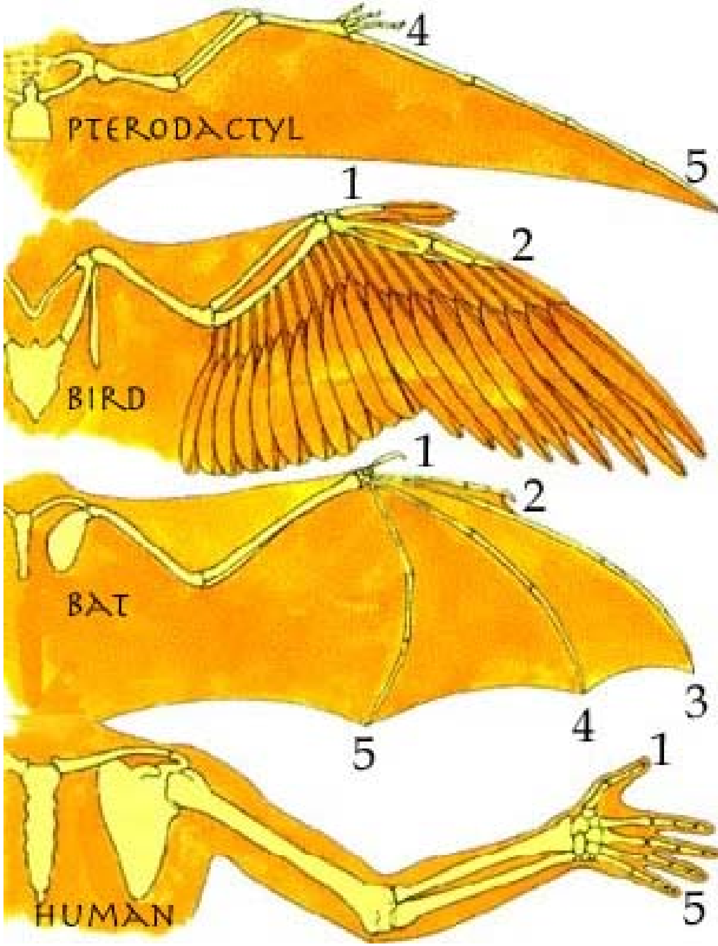
Caratteri analoghi sono derivati indipendentemente da caratteri ancestrali divers

Analisi morfologica, funzionale e genetica



omologie


human
lizard
cat
whale
bat
frog
bird
humerus
lna
radius
carpal
h
u
r
c
1
2
3
4
5


PTERODACTYL
BIRD
BAT
HUMAN
1
2
3
4
5

parallelismi e convergenze

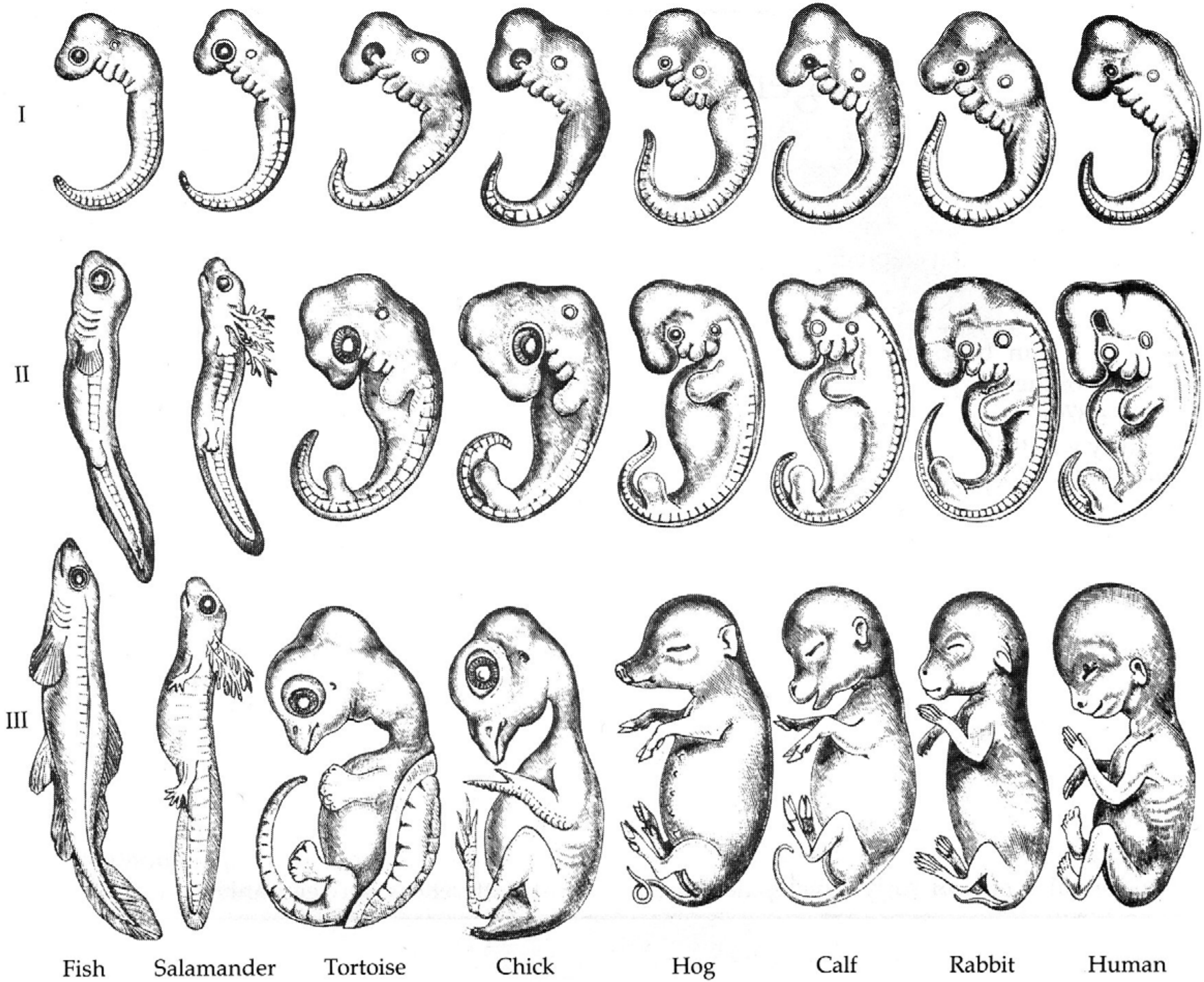
Figure 45-17 THE NECTAR-FEEDING NICHE. The availability of nectar-laden flowers in four parts of the world resulted in the convergent evolution of four unrelated birds: (a) Costa's hummingbird (*Calypte costae*) in the western United States; (b) the eastern spinebill (*Acanthorychus tenuirostris*), a honeyeater, in eastern Australia; (c) the Ecuadorian honeycreeper (*Cyanerpes cyaneus*), called the Iiwi; (d) the sunbird (*Nectarinia mediocris*) in Africa.

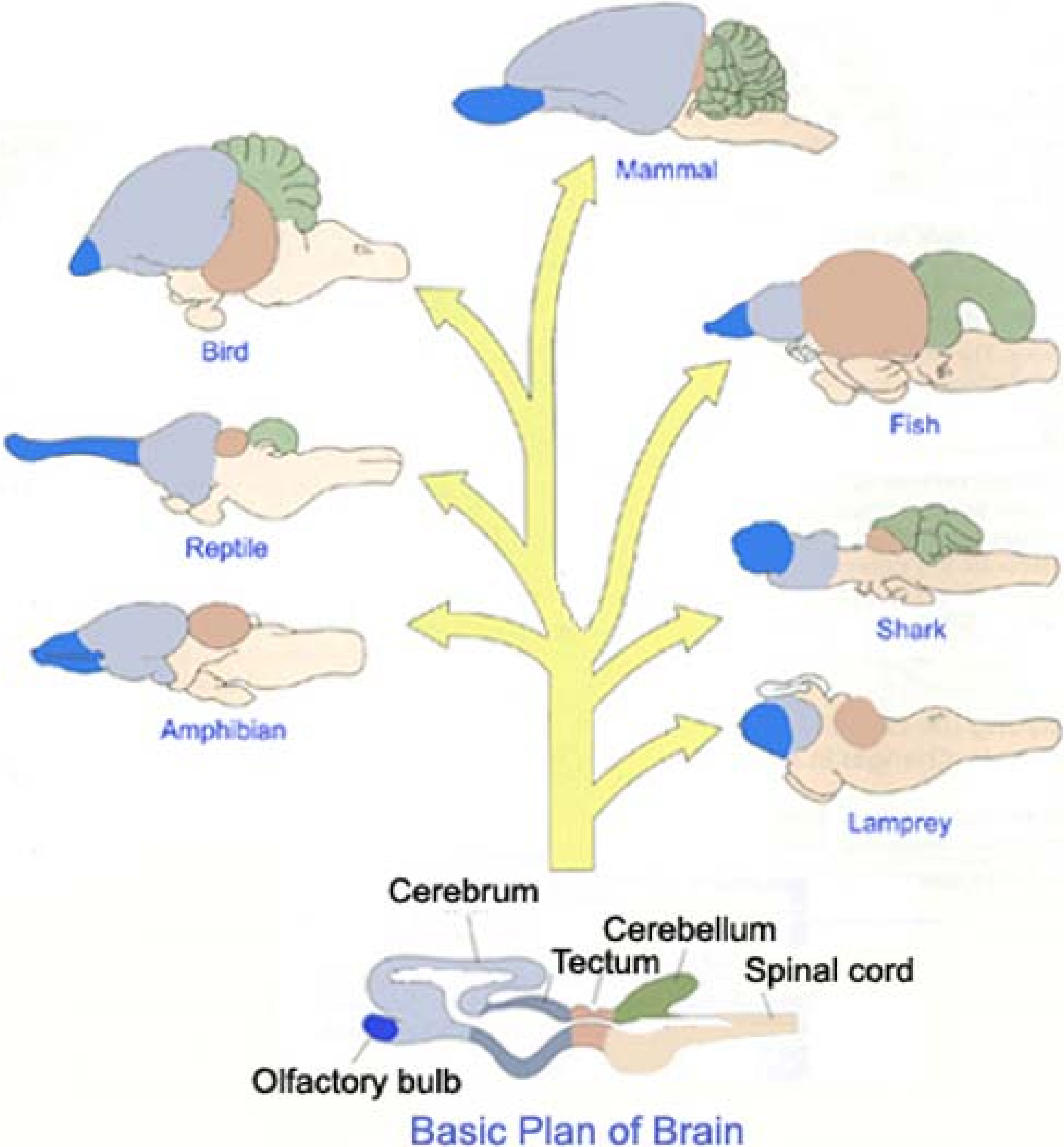
(a) (b) (c)

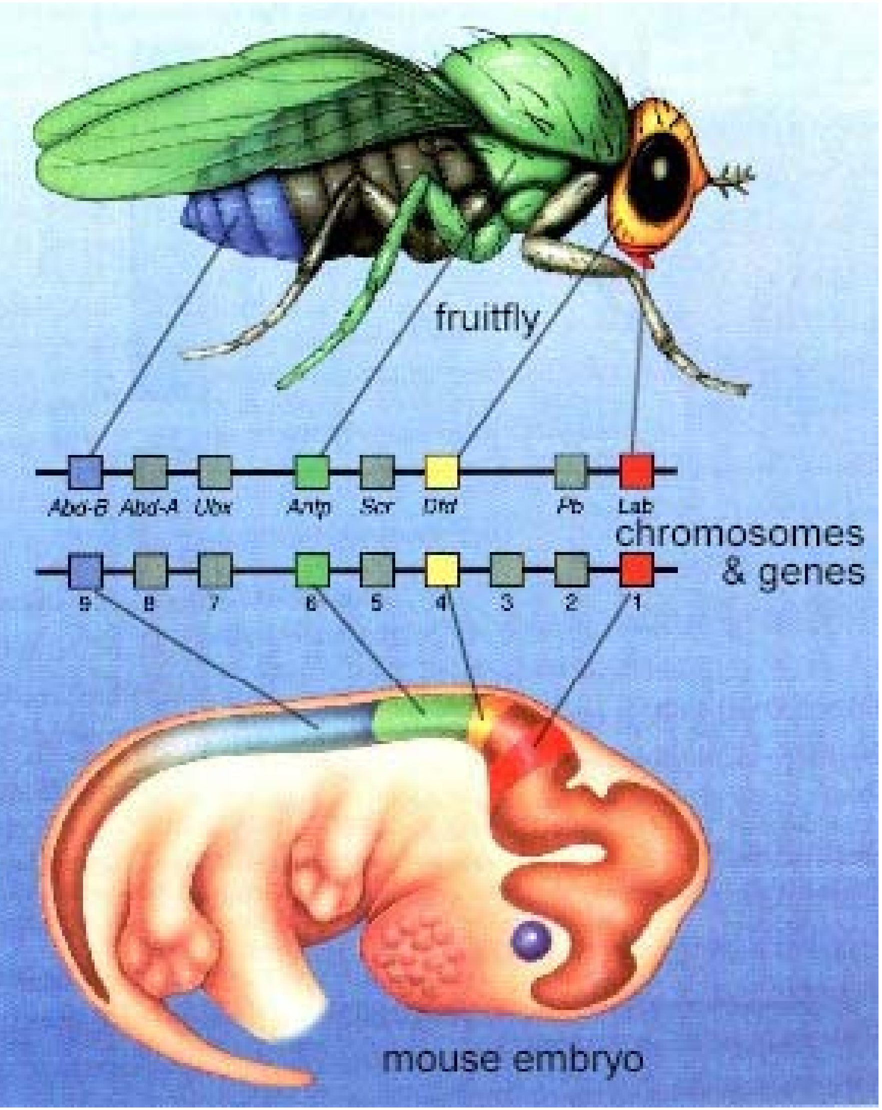
21–1 Although these three mammals are similar in appearance and have similar life styles, they are not closely related. (a) The European rabbit, a placental mammal, is classified as a lagomorph. (b) The Patagonian hare, or cavy, also a placental mammal, is classified as a rodent. (c) The Australian "banded hare" is actually a wallaby, a member of the kangaroo family. Like almost all of the other native mammals of Australia, it is a marsupial.

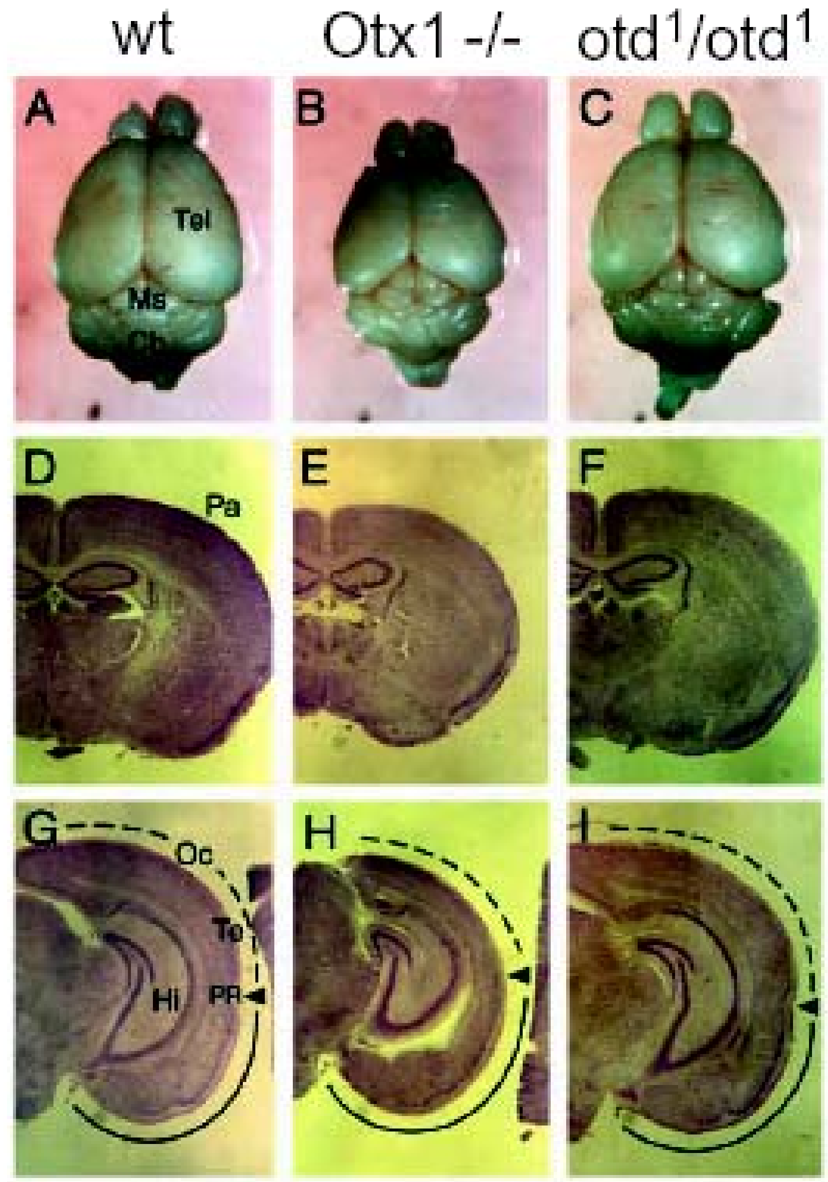
The scientific study of the distribution of plants and animals in the various regions of the world, known as biogeography, was initially developed by Alfred Russel Wallace.

Ontogenesi e filogenesi




Mammal
Bird
Fish
Reptile
Shark
Amphibian
Lamprey
Cerebrum
Cerebellum
Tectum
Spinal cord
Olfactory bulb
Basic Plan of Brain


fruitfly
Abd-B
Abd-A
Ubx
Antp
Scr
Otd
Pb
Lab
chromosomes
& genes
9
8
7
6
5
4
3
2
1
mouse embryo

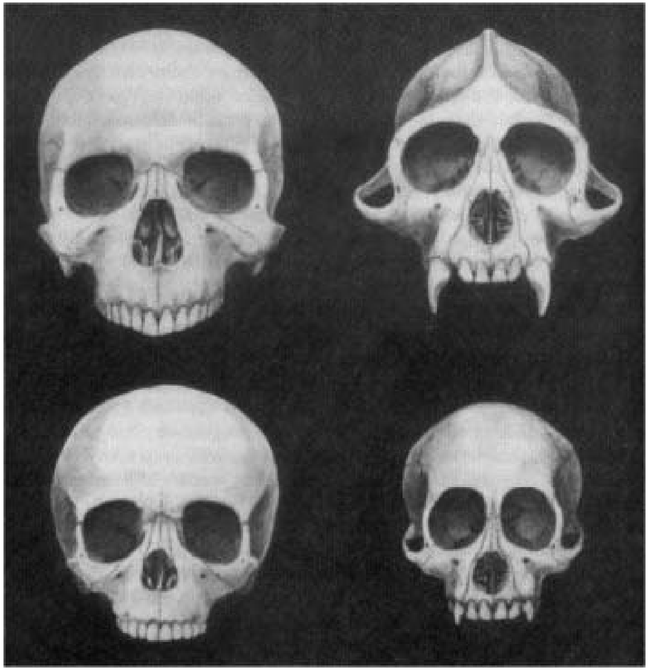

wt
Otx1 -/-
otd1/otd1
A
B
C
Tel
Ms
D
E
F
Pa
G
H
I
Oc
Te
Hi
PR

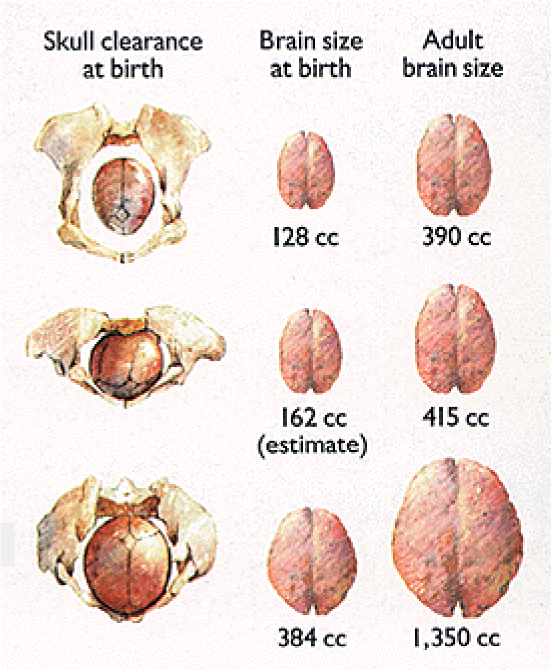
Neotenia (S. J. Gould)

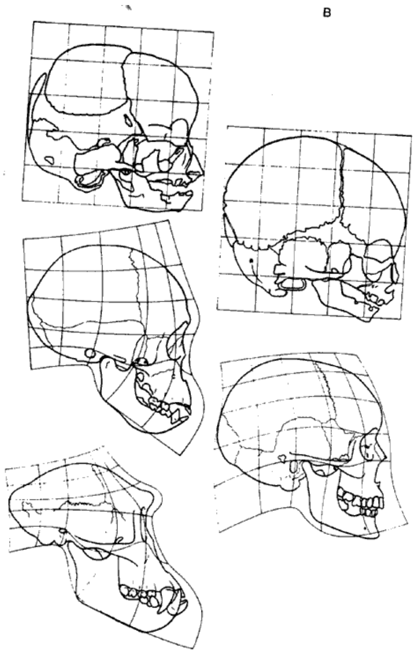
Maturità sessuale con forme giovanili

Diversi esempi nel regno animale; associata ad aumento delle dimensioni corporee e della durata di vita

In the head of the young orang, we find the childlike and gracious features of man...We find the same correspondence of habits, the same gentleness and sympathetic affection, also some traits of sulkiness and rebellion in response to contradiction...on the contrary, if we consider the skull of the sdult, we find truly frightening features of a revolting bestiality." (Geoffrey St. Hilaire, 1836)

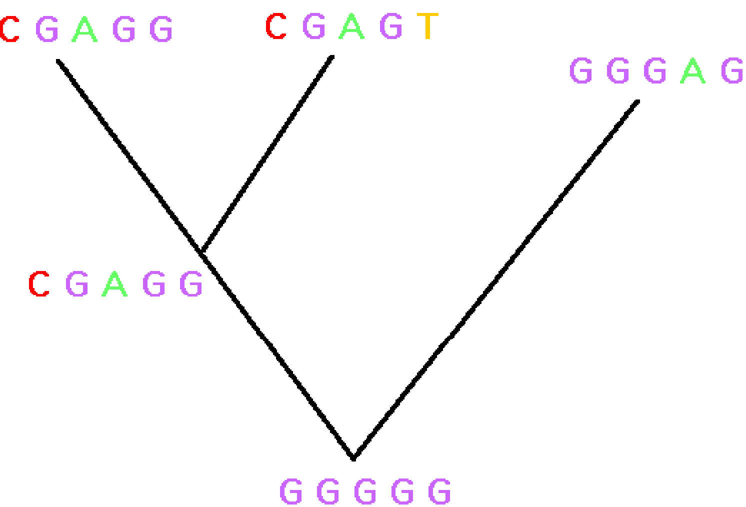


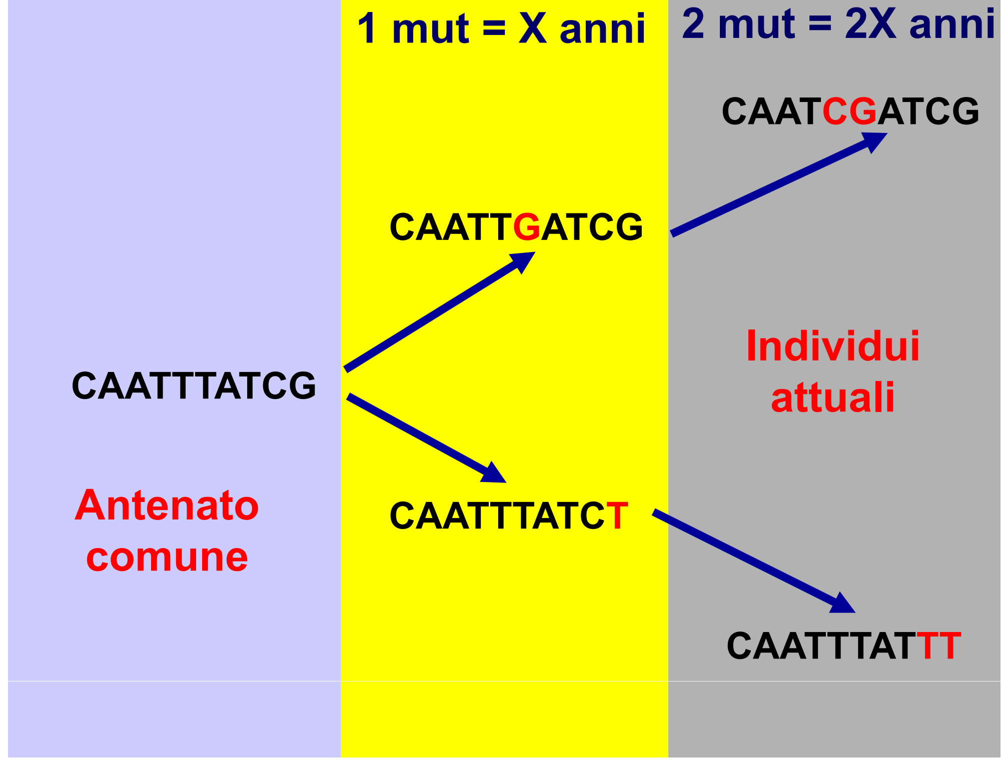


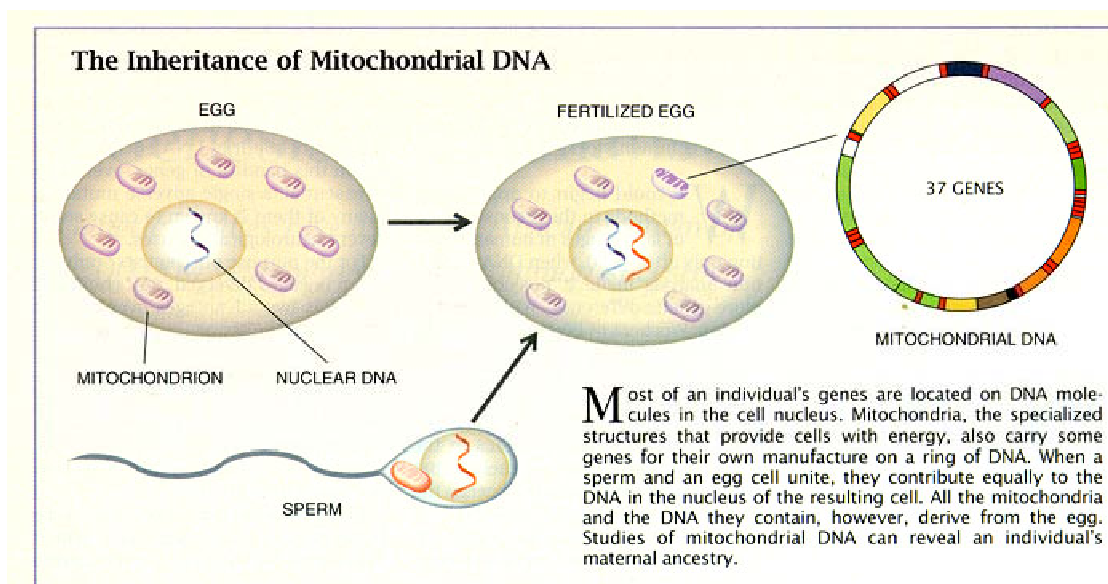


a-most mammals brain formed at birth
b-macaques are at 65% of final cranial capacity
c-chimps at 40%
d-fossil australopithecus at from 37% to 25%
e-humans at 23% of final cranial capacity.

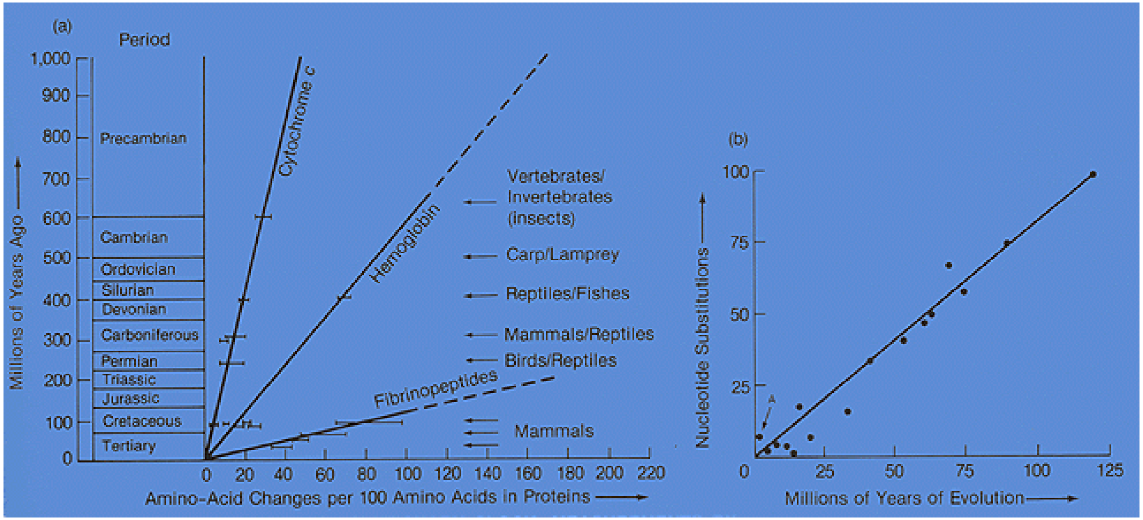
Orologi molecolari

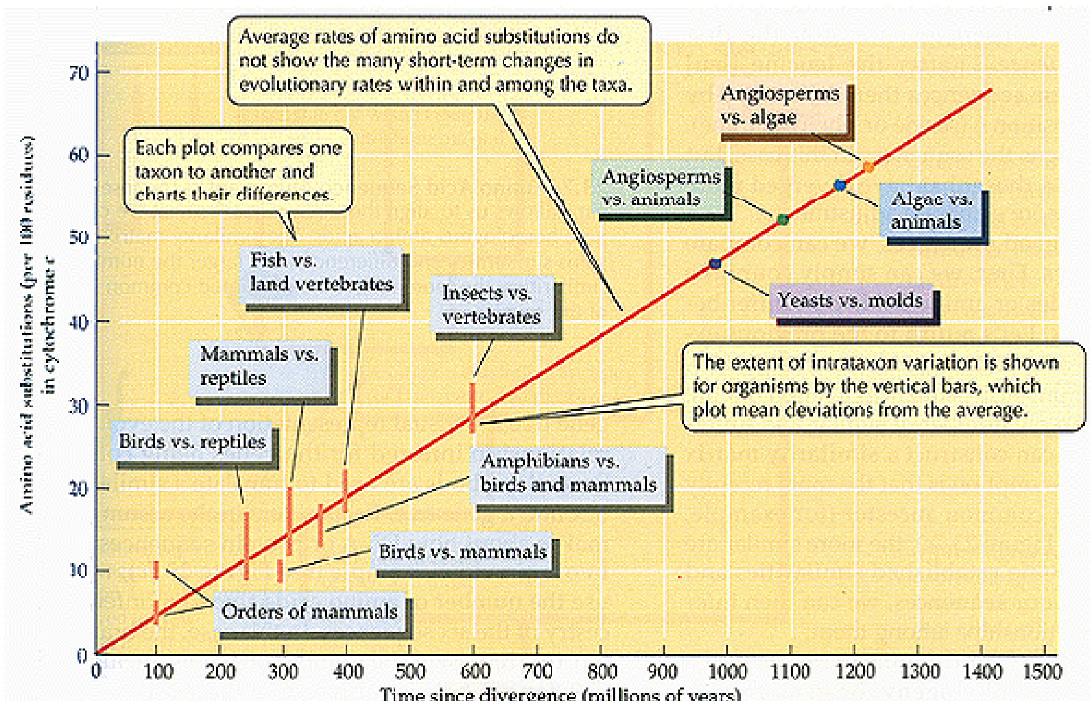


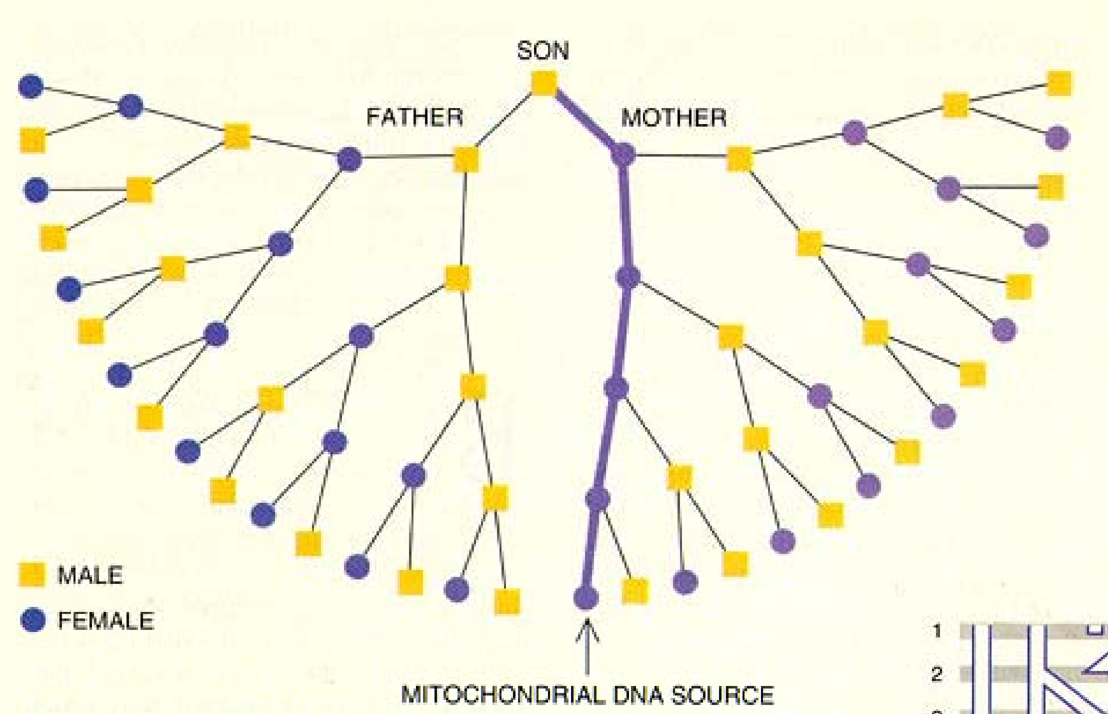


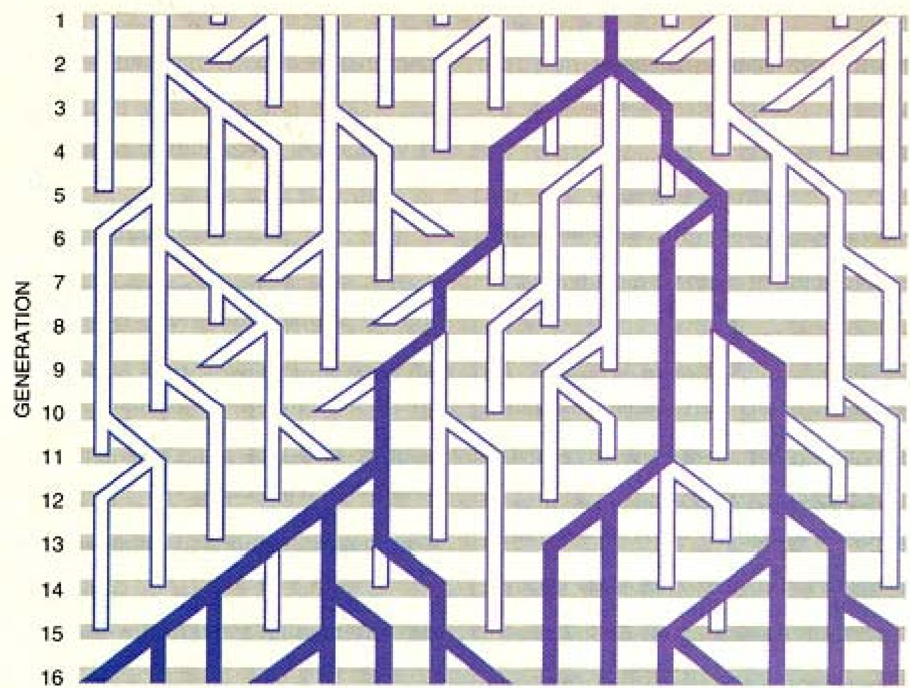


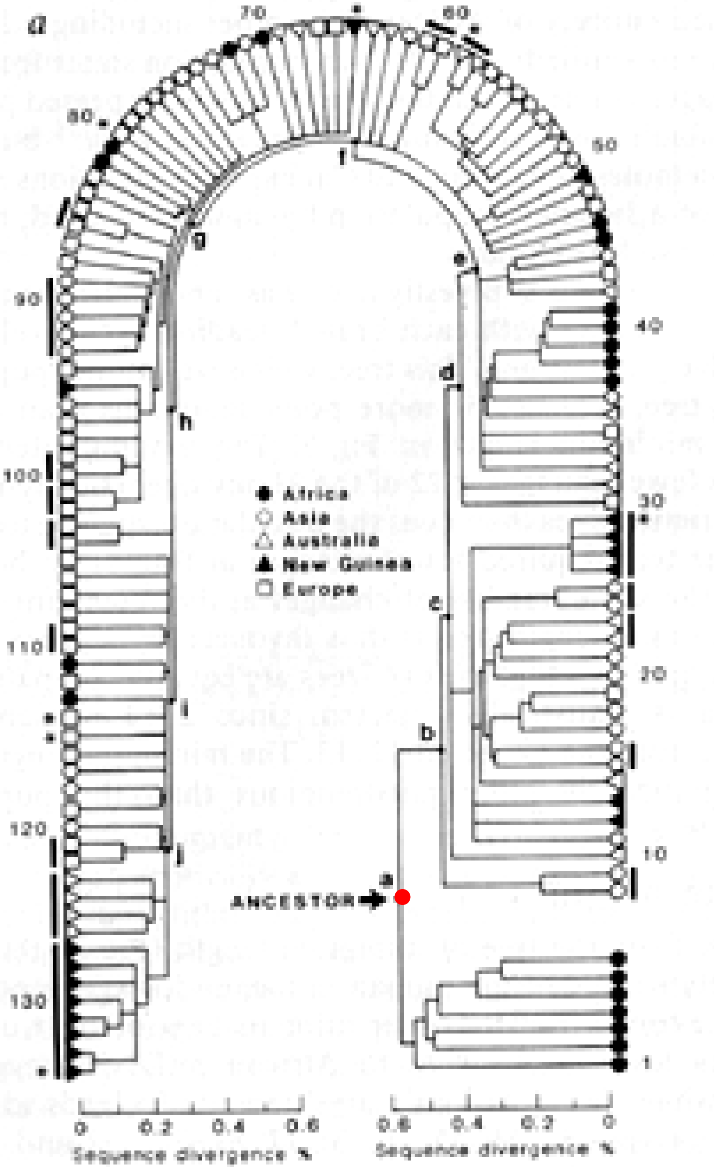
Analisi delle proteine

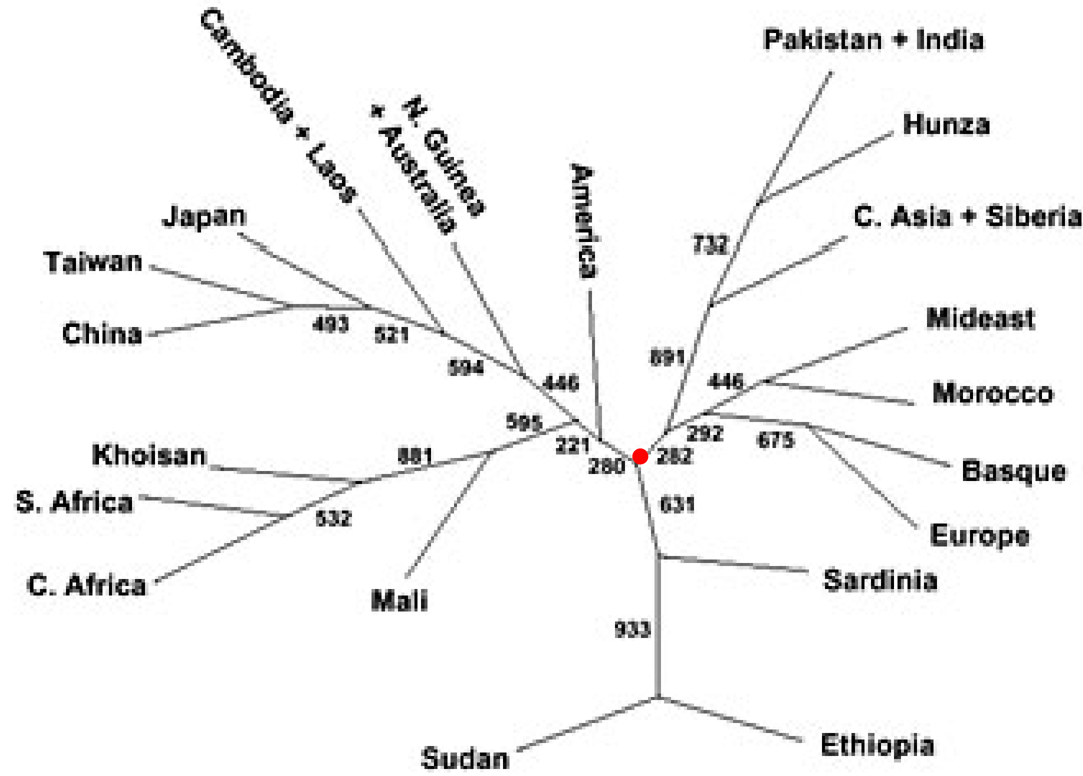





SON
FATHER
MOTHER
MALE
FEMALE
MITOCHONDRIAL DNA SOURCE

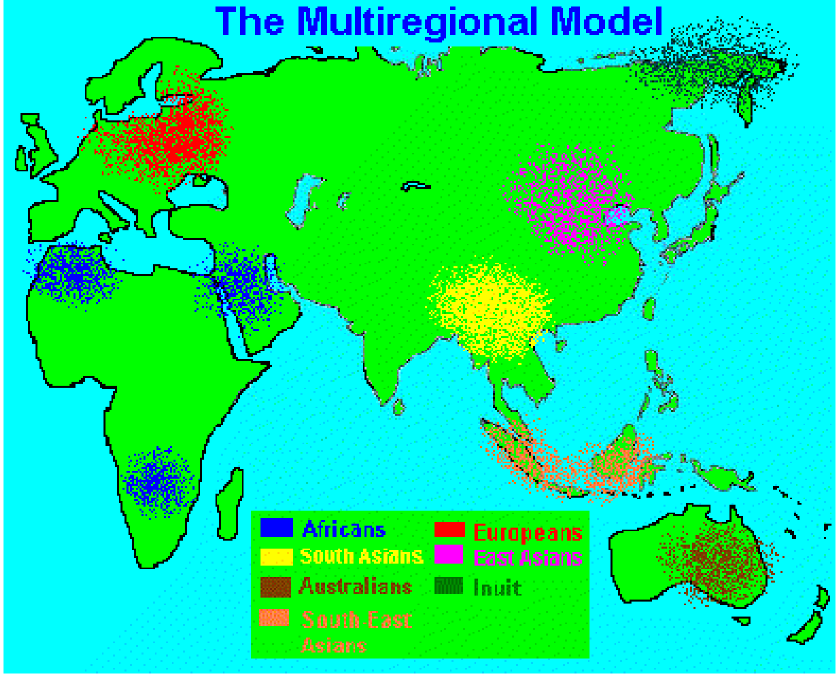

GENERATION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

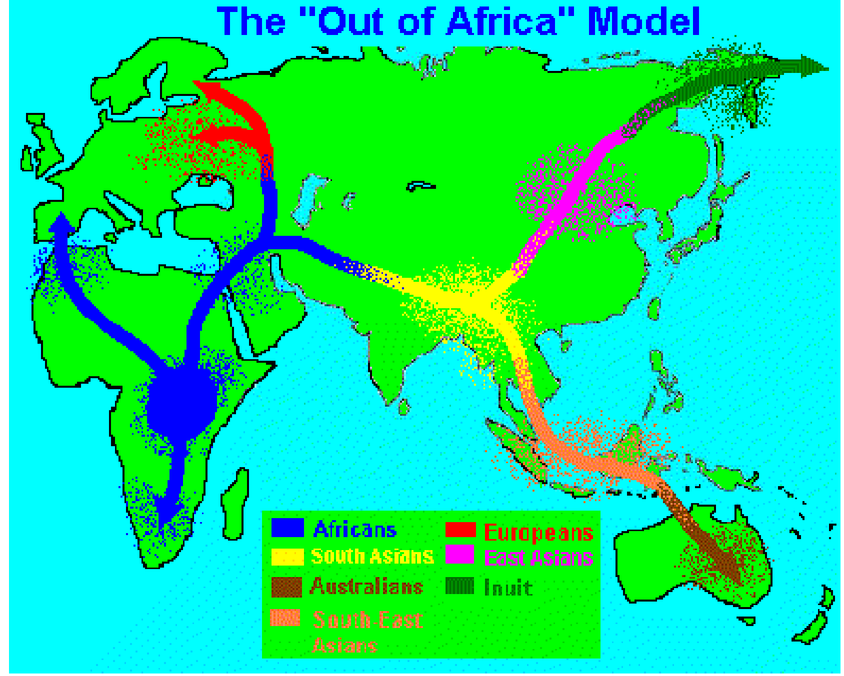


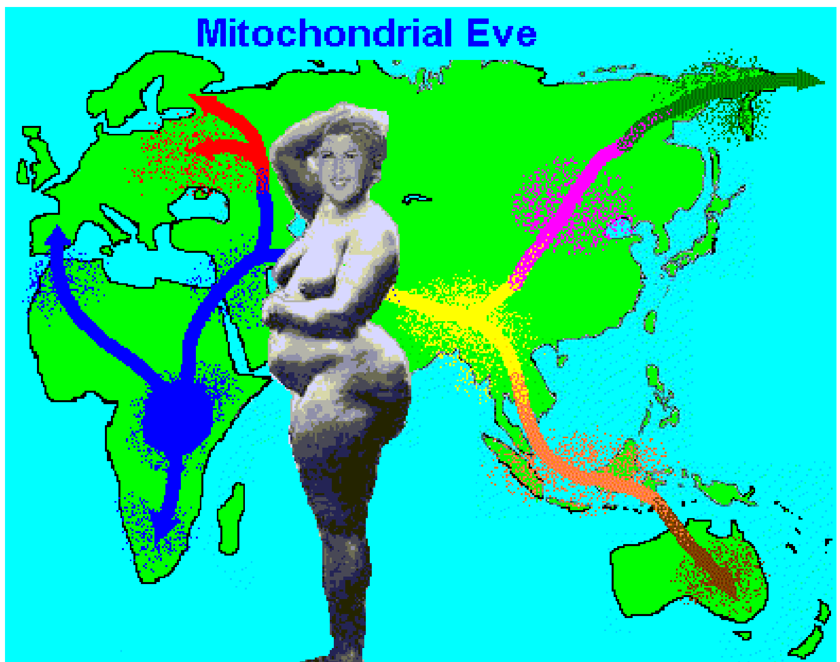


Eva mitocondriale: 200.000 anni

Adamo cromosoma Y: 59.000 anni


The Multiregional Model
Africans
Europeans
South Asians
East Asians
Australians
Inuit
South-East Asians


The "Out of Africa" Model
Africans
Europeans
South Asians
East Asians
Australians
Inuit
South-East Asians


Mitochondrial Eve

40,000
YEARS AGO
15,000 TO 35,000
YEARS AGO
PERHAPS 60,000
YEARS AGO
EQUATOR
100,000
YEARS AGO
PERHAPS 50,000 TO
60,000 YEARS AGO

Tom Moore

Evolution of the brain

Neo-cortex

Control for better life

Limbic system

Drive to live (Instinct, Id)

Brain stem

Maintaining life

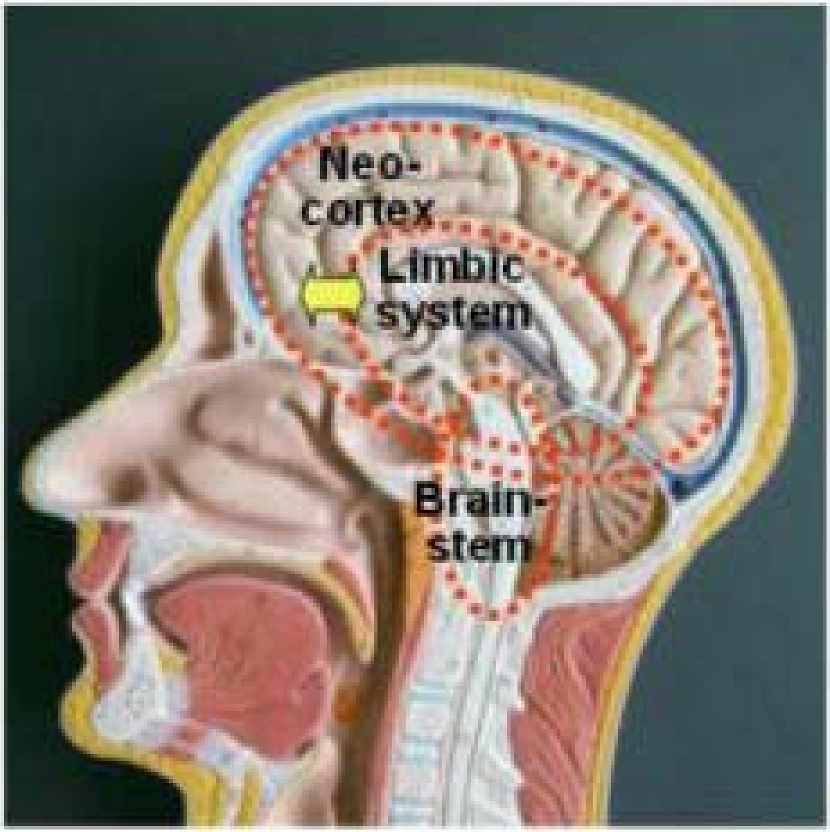
Reason

Mammals

Emotion

Instinct

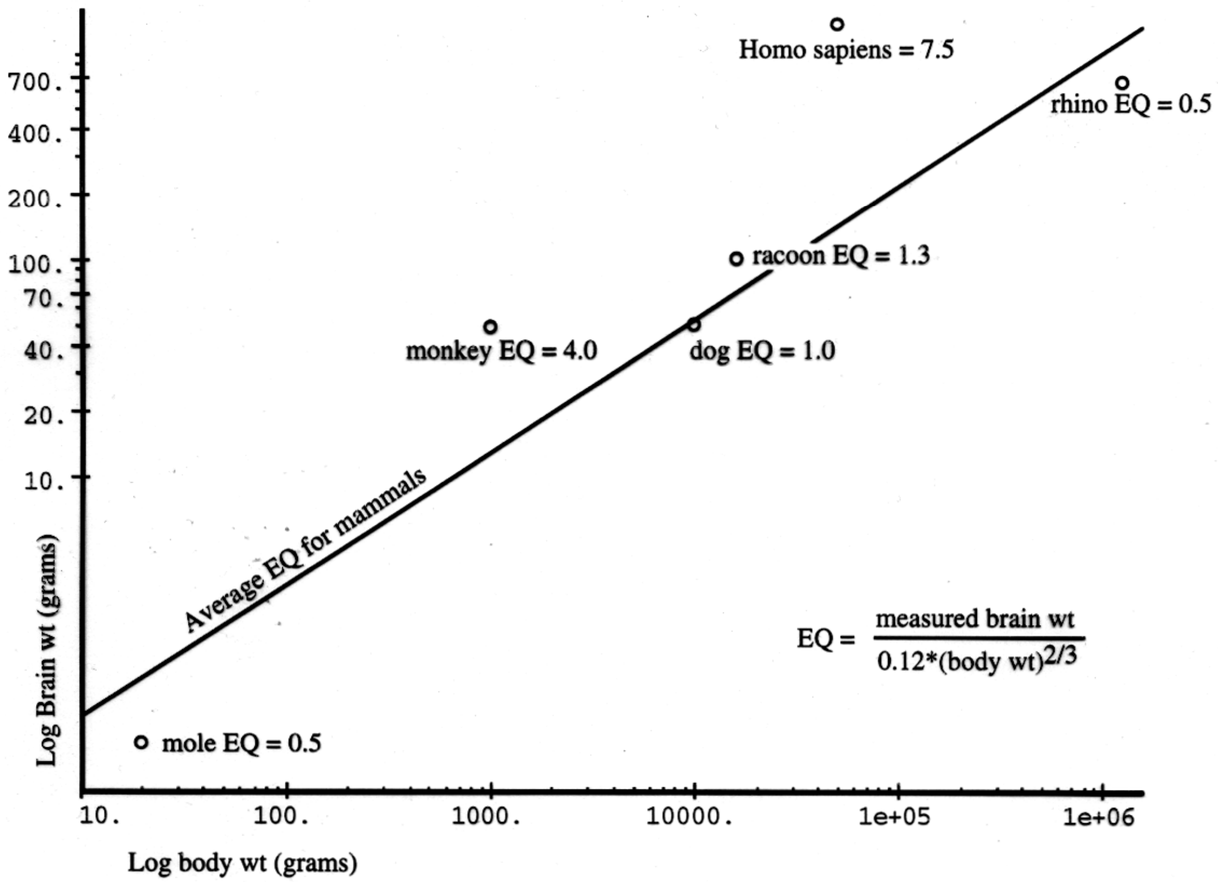
Reptiles



Quoziente di encefalizzazione. Misura relativa delle dimensioni cerebrali data dal rapporto fra il peso cerebrale stimato e quello atteso dalle dimensioni corporee del taxon

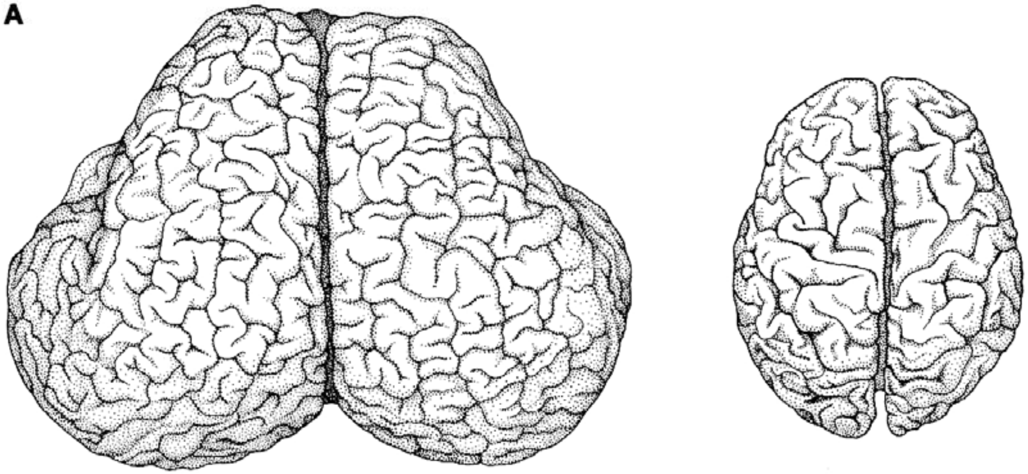
EQ = peso cervello/ 0.005(peso corporeo)$^{0.66}$ rettili

EQ = peso cervello/ 0.12(peso corporeo)$^{0.66}$ uccelli/mammiferi



Dimensioni del cervello e dimensioni del corpo

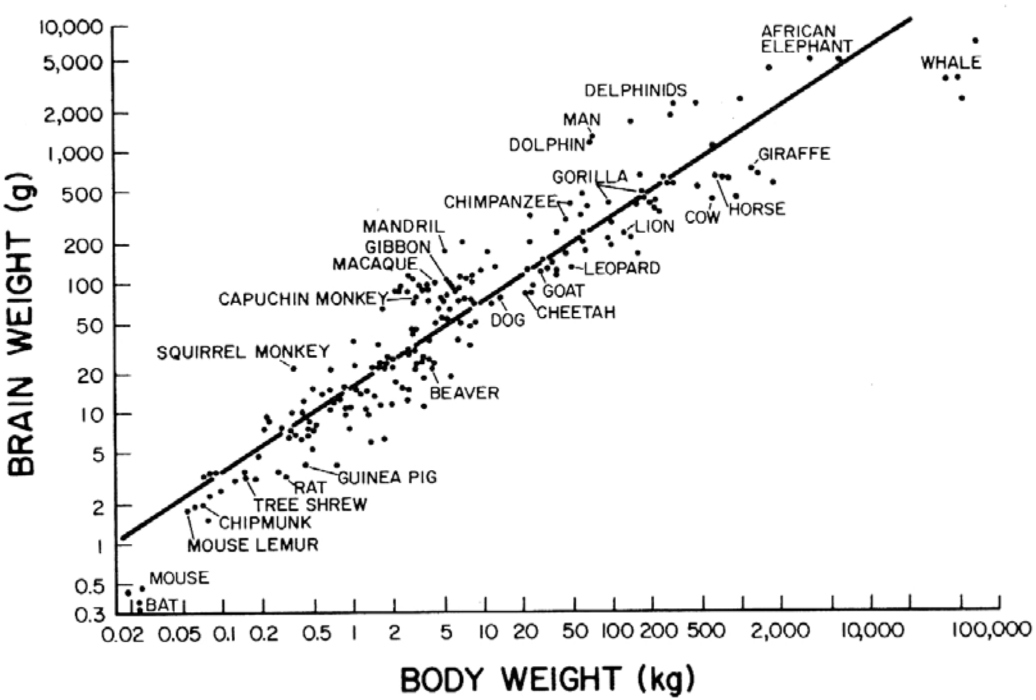
A



balena

uomo

B

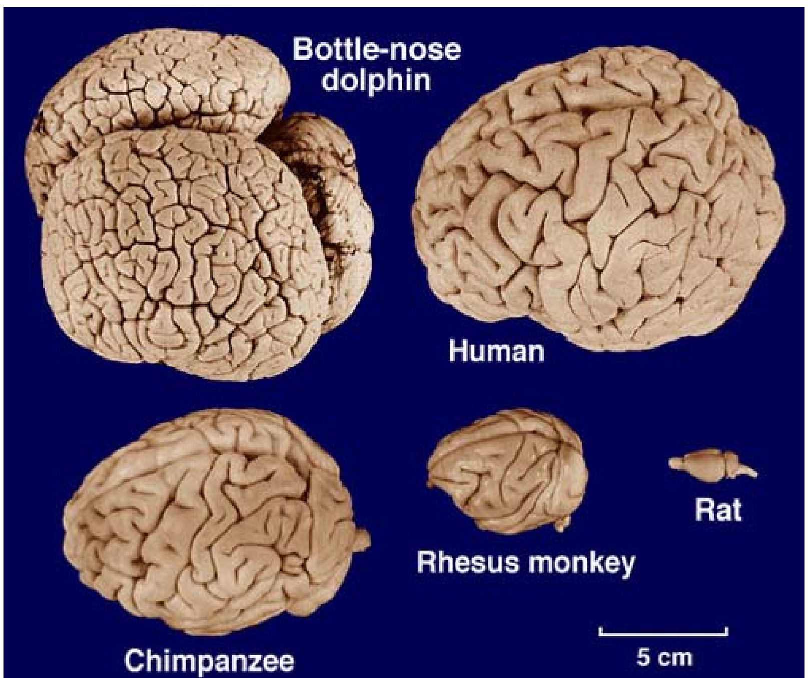


Rapporto uomo/balena

Peso corporeo 1/5000

Peso cerebrale 1/5

Cervelli grandi o cervelli piccoli?


Bottle-nose dolphin
Human
Chimpanzee
Rhesus monkey
Rat
5 cm

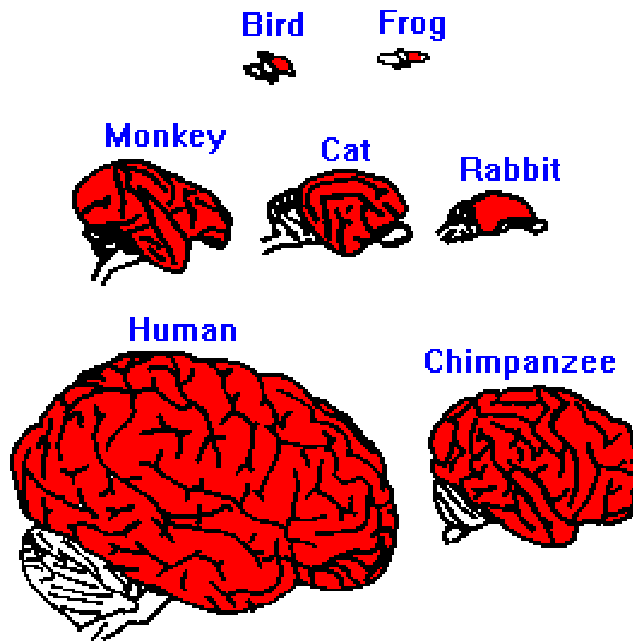
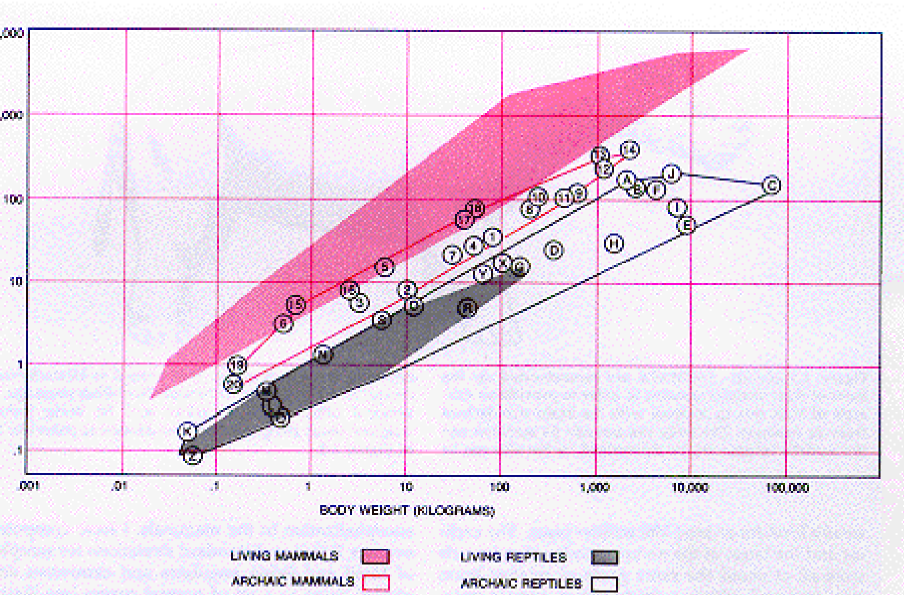
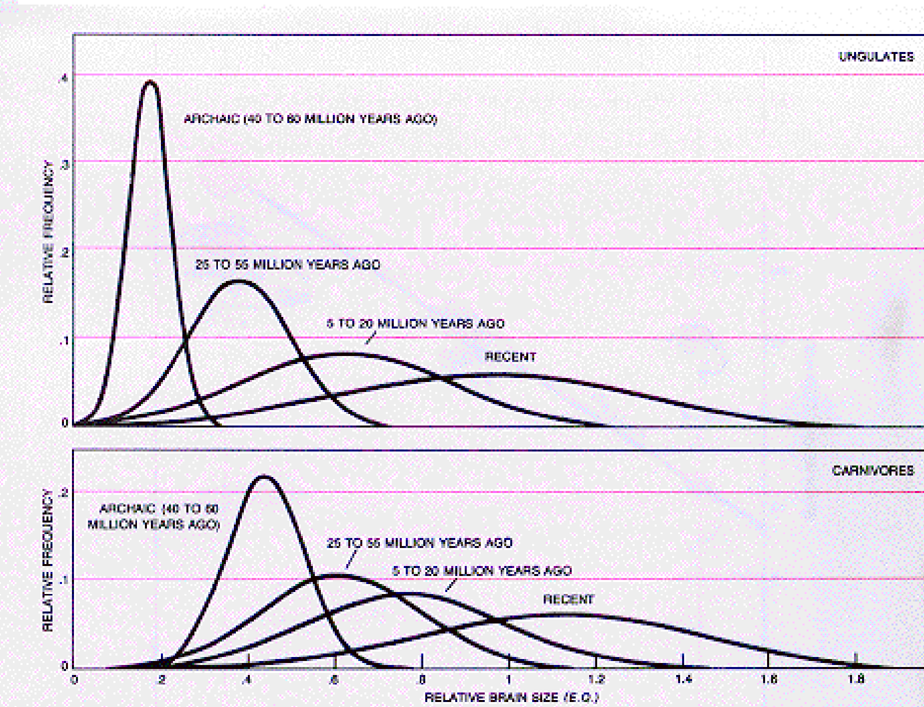
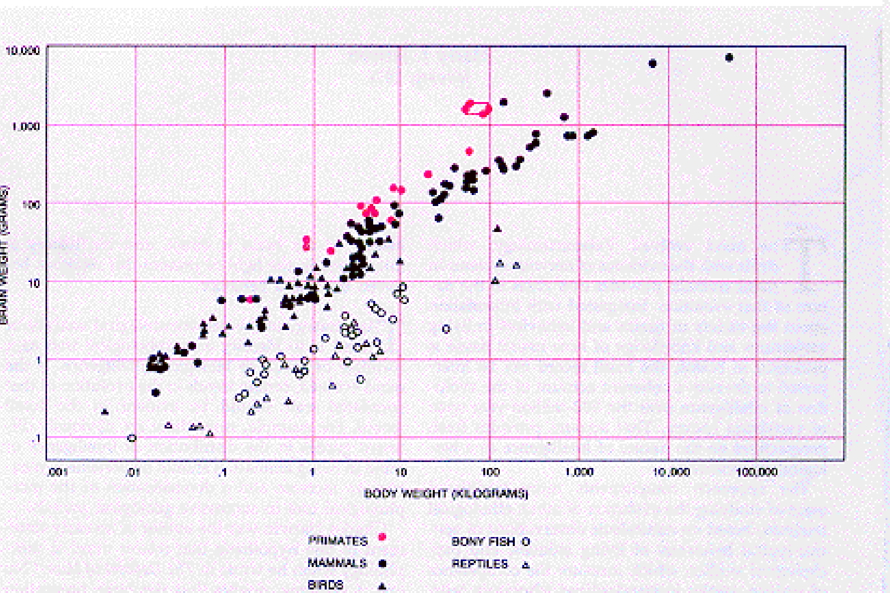

Bird
Frog
Monkey
Cat
Rabbit
Human
Chimpanzee

Figure 1

Generale tendenza verso cervelli più grandi nel corso dell'evoluzione

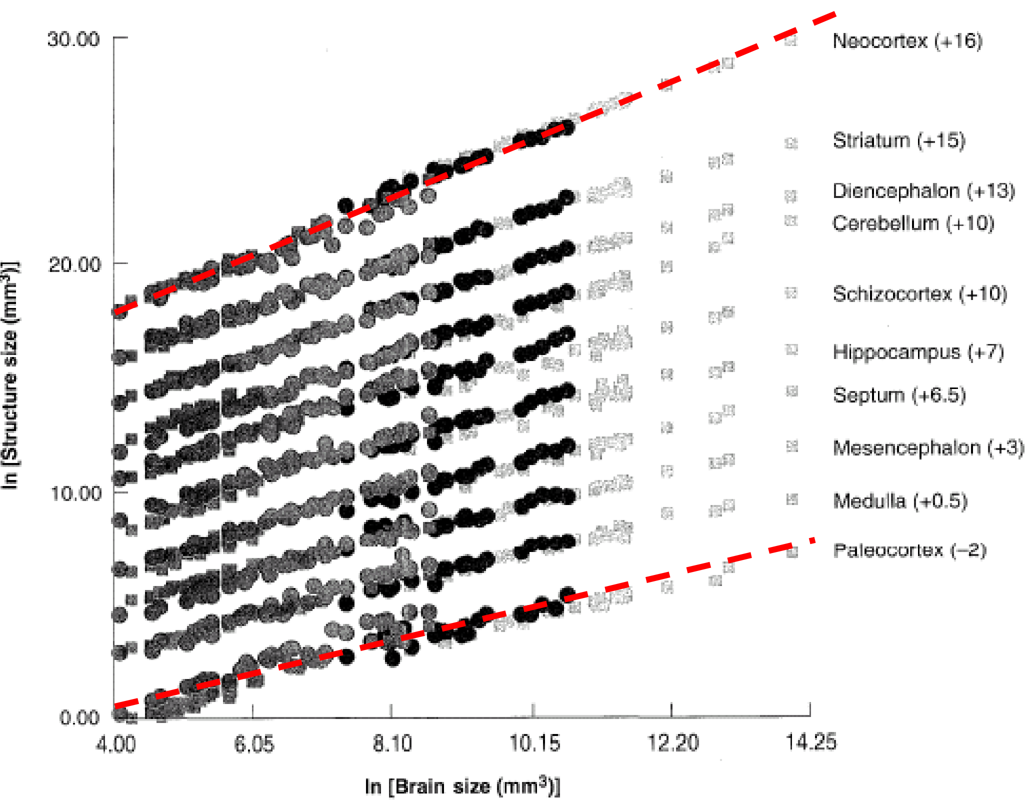


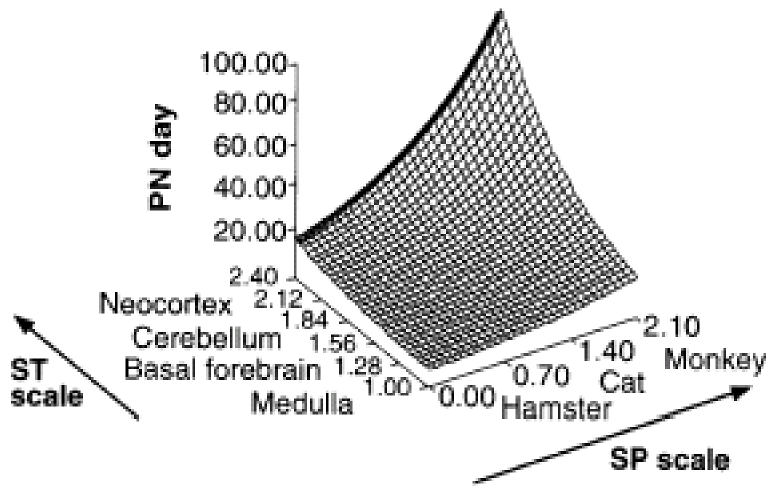


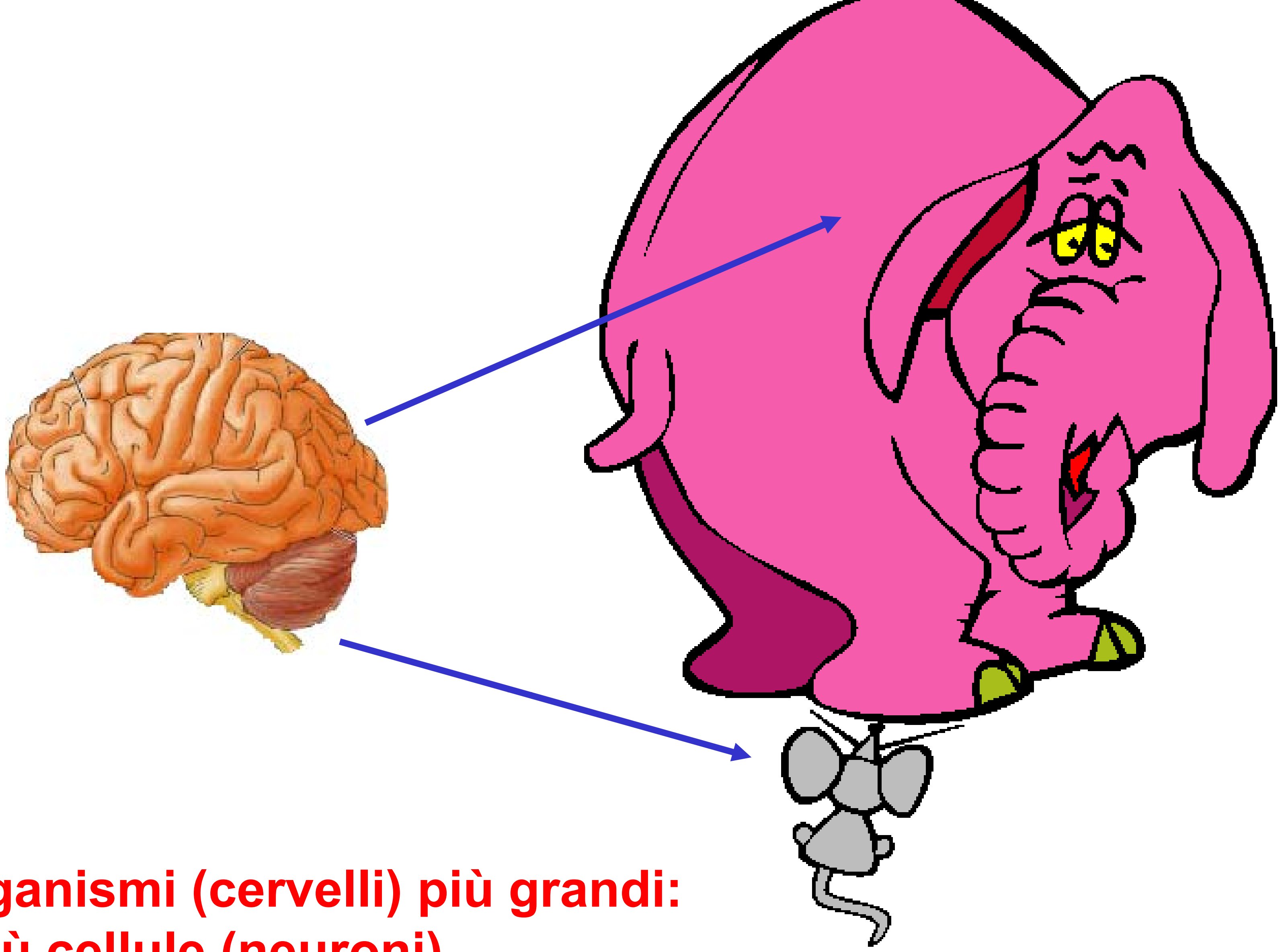


Tutte le regioni cerebrali generalmente tendono a crescere con l'evoluzione (anche se con ritmi diversi)

Ne deriva che se l'espansione di una certa regione avviene sotto la spinta selettiva per un carattere, anche altri caratteri dipendenti da quella regione potranno risultare favoriti







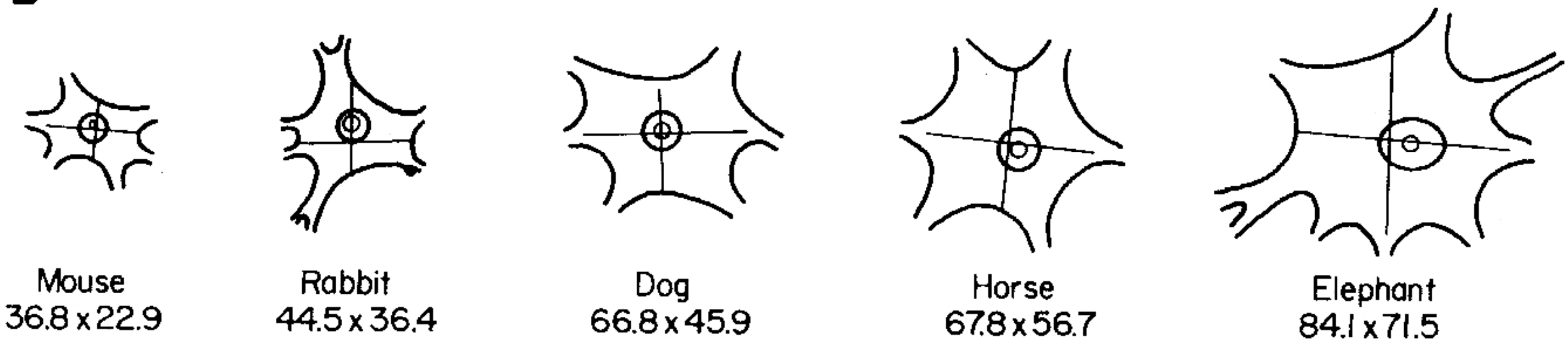
Organismi (cervelli) più grandi:
- **più cellule (neuroni)**
- **cellule (neuroni) più grandi**

Dimensioni di diversi tipi cellulari in specie con dimensioni corporee diverse

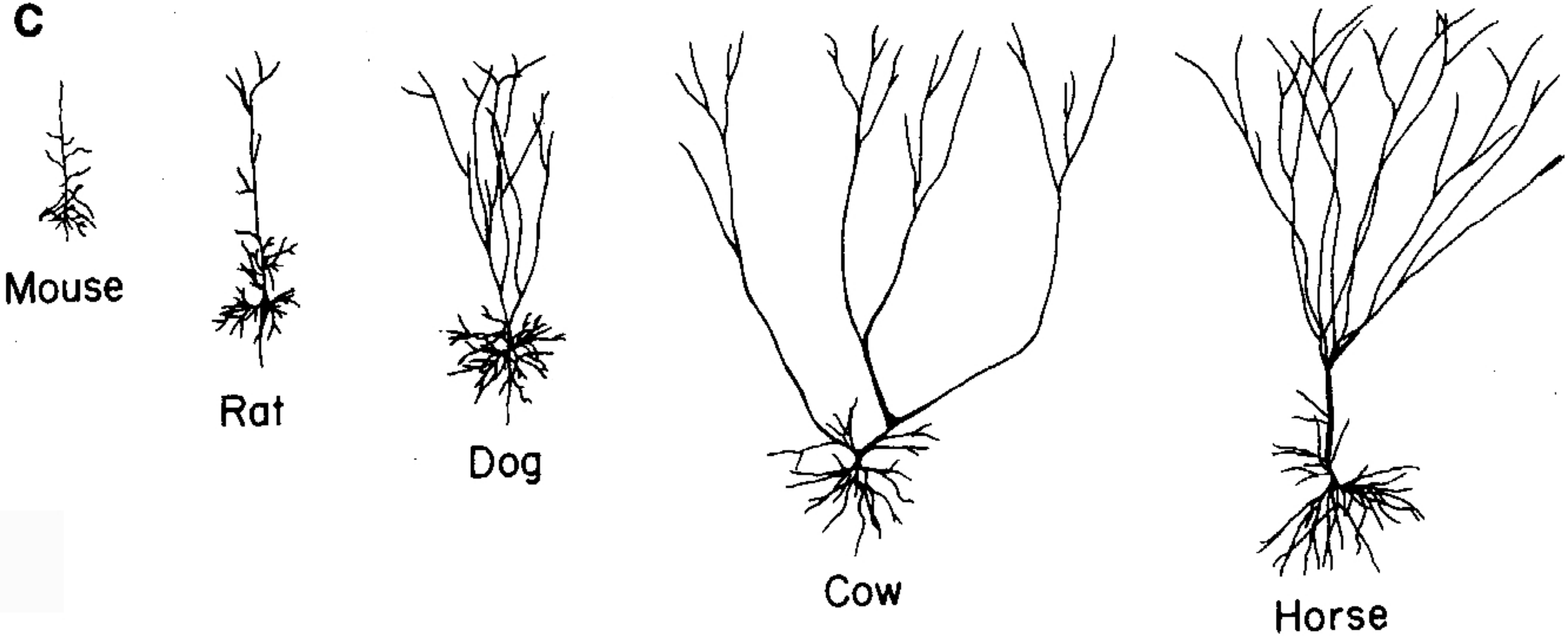
Species	Liver cells	Thyroid epithelial cells	Renal epithelial cells	Pancreatic acinar cells	Red blood cells
Shrew	—	—	—	—	7.5
Mouse	390	123	177	211	6.6
Guinea pig	373	142	243	210	—
Rabbit	441	—	272	156	—
Cat	343	91	228	230	—
Dog	201	55	—	155	7.1
Pig	296	74	208	127	5.9
Ox	302	—	139	182	—
Horse	—	—	—	—	5.5
Elephant	—	—	—	—	9.2
Whale	—	—	—	—	8.2

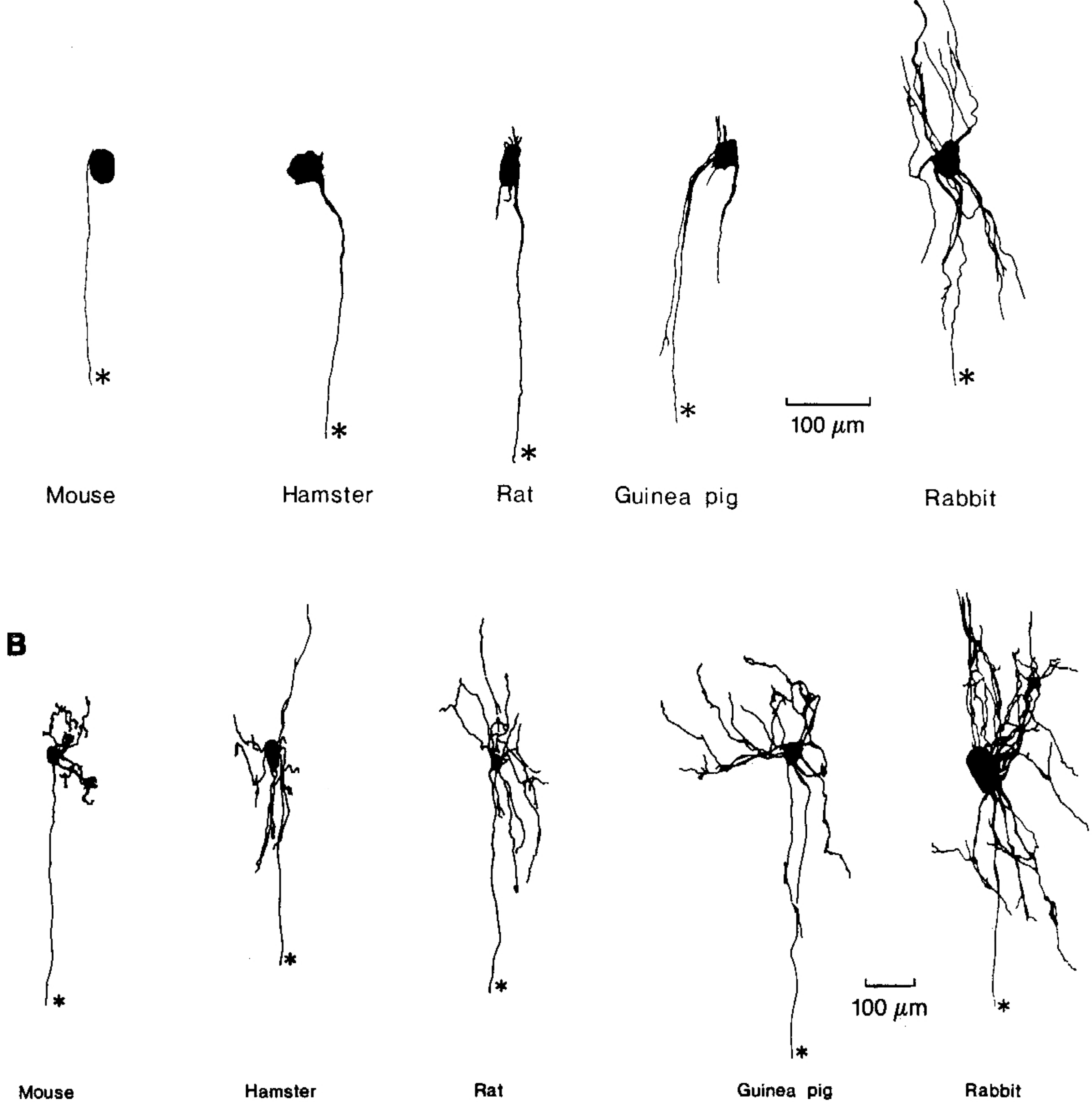
Species	Weight of animal (g)	Number of superior cervical neurons	Number of preganglionic neurons innervating superior cervical ganglion	Reference
Mouse	25	10,000	700	Purves, Rubin, et al., 1986
Hamster	100	17,000	700	Purves, Rubin, et al., 1986
Rat	200	26,000	1,000	Purves, Rubin, et al., 1986
Guinea pig	400	36,000	1,300	Purves, Rubin, et al., 1986
Rabbit	1,600	41,000	1,500	Purves, Rubin, et al., 1986
Cat	3,000	114,000	—	Levi-Montalcini and Booker, 1960
Macaque	4,000	243,000	4,900	Ebbesson, 1968a,b
Baboon	13,500	397,000	6,500	Ebbesson, 1968a,b
Chimpanzee	38,000	753,000	7,700	Ebbesson, 1968a,b
Man	70,000	911,000	8,300	Ebbesson, 1963
man/mouse	**2800**	**91**	**11,9**	

B

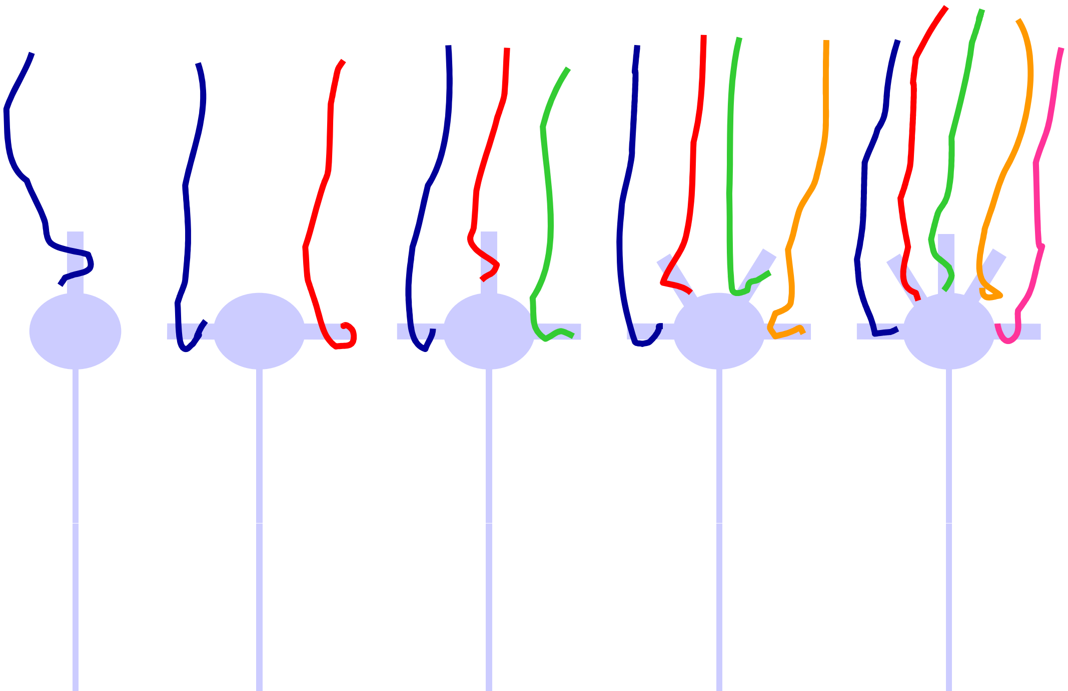

Mouse
36.8 x 22.9
Rabbit
44.5 x 36.4
Dog
66.8 x 45.9
Horse
67.8 x 56.7
Elephant
84.1 x 71.5

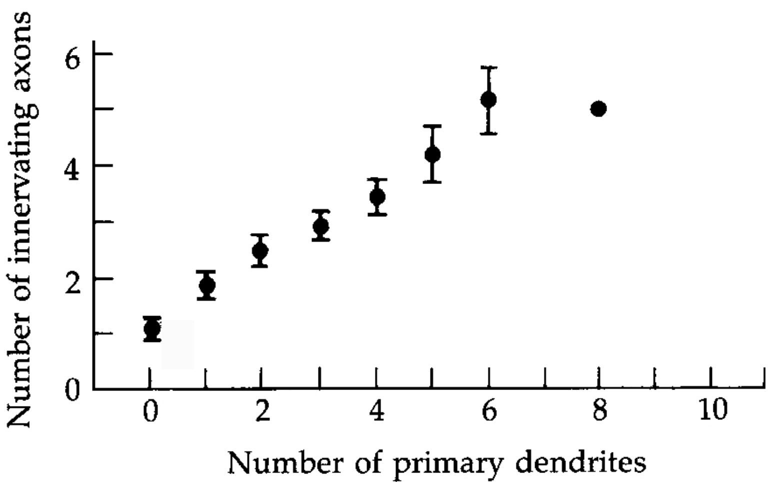
C

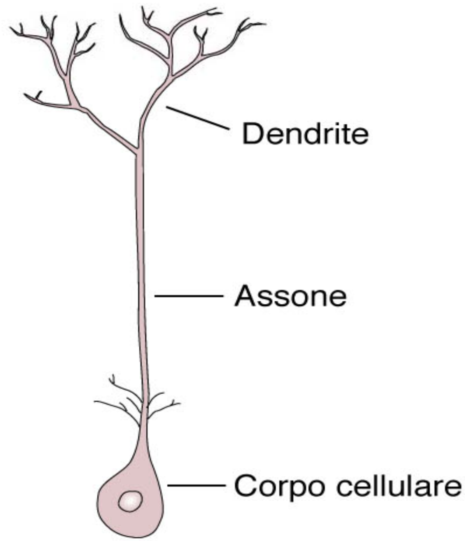

Mouse
Rat
Dog
Cow
Horse


100 μm
Mouse
Hamster
Rat
Guinea pig
Rabbit
B
100 μm
Mouse
Hamster
Rat
Guinea pig
Rabbit

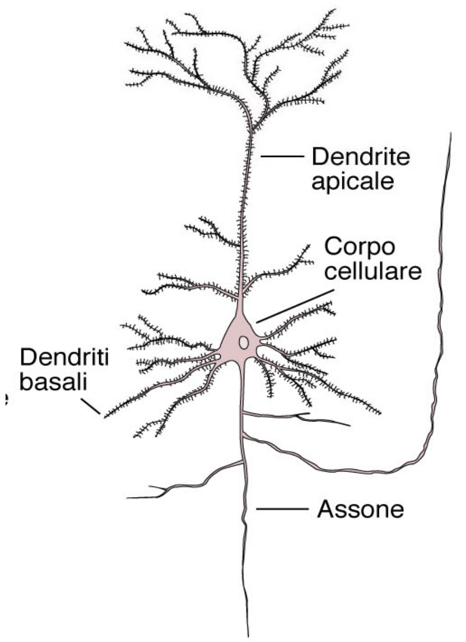
Perché i neuroni hanno i dendriti?







Neurone di invertebrato



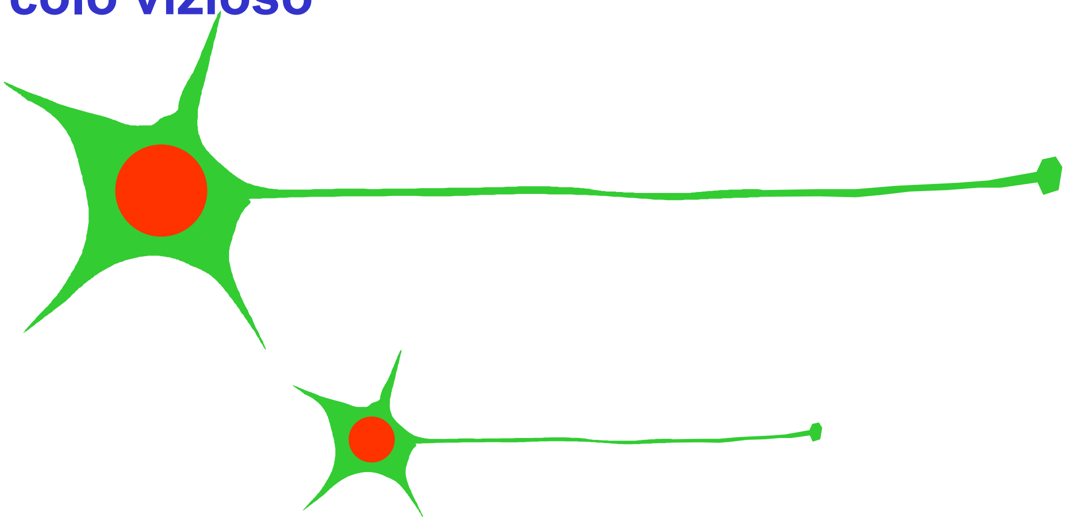
Cellula piramidale dell'ippocampo

Cervelli più grandi generalmente hanno neuroni più grandi.

Tuttavia, per mantenere la velocità di conduzione i processi devono aumentare di diametro.
Nonostante che l'evoluzione della mielina abbia permesso di migliorare le prestazioni risparmiando sulle dimensioni, per ogni raddoppio di lunghezza:

Il diametro dei dendriti deve aumentare di 4 volte
Il diametro dell'assone deve aumentare di 2 volte

questo aumenta ulteriormente le dimensioni dell'intero cervello creando un circolo vizioso




Dendriti,
Arborizzazione assonale
Assone
m

Assoni amielinici

$V = k \sqrt{D}$ (k = 1)

D = 625 µm → V = 25 m/s

Assoni mielinizzati

V= 6*D

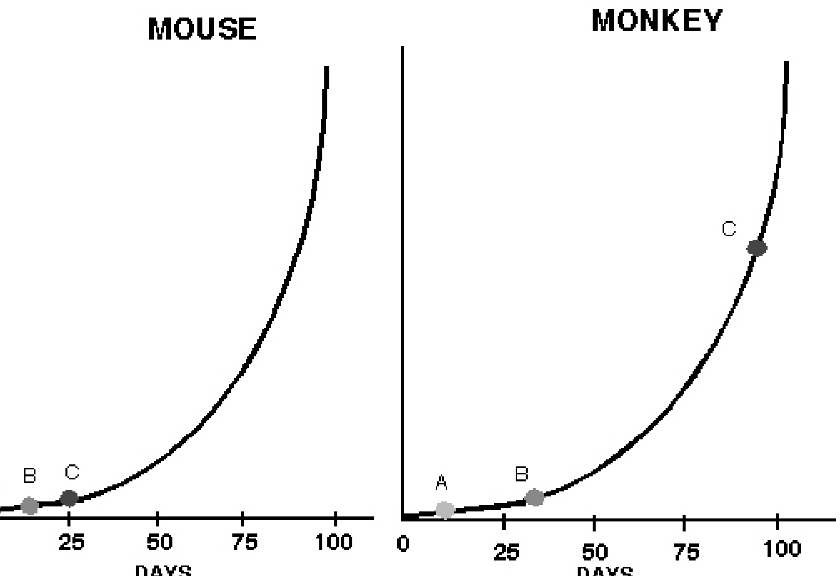
D = 20 µm → V = 120 m/s

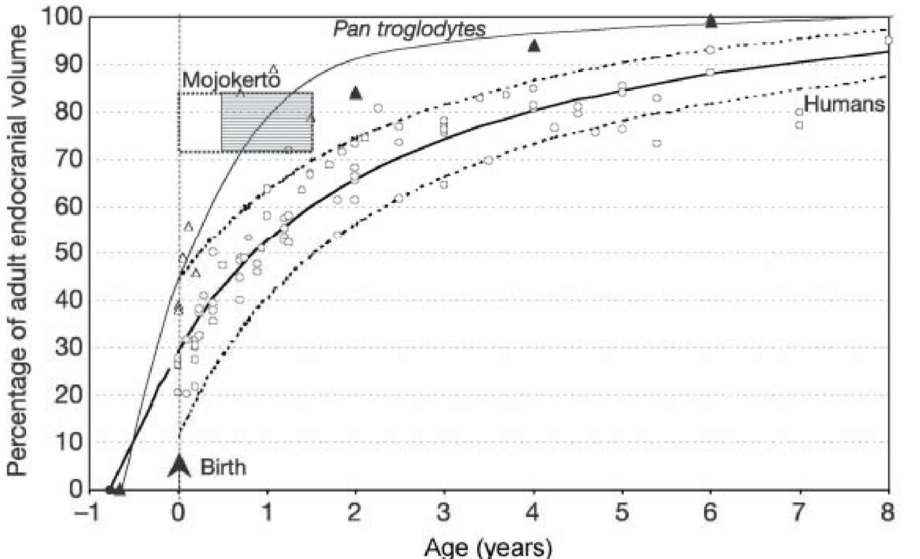
Se non esistesse la mielina per ottenere la stessa V,
D dovrebbe essere uguale a **14400 µm** (1.44 cm)

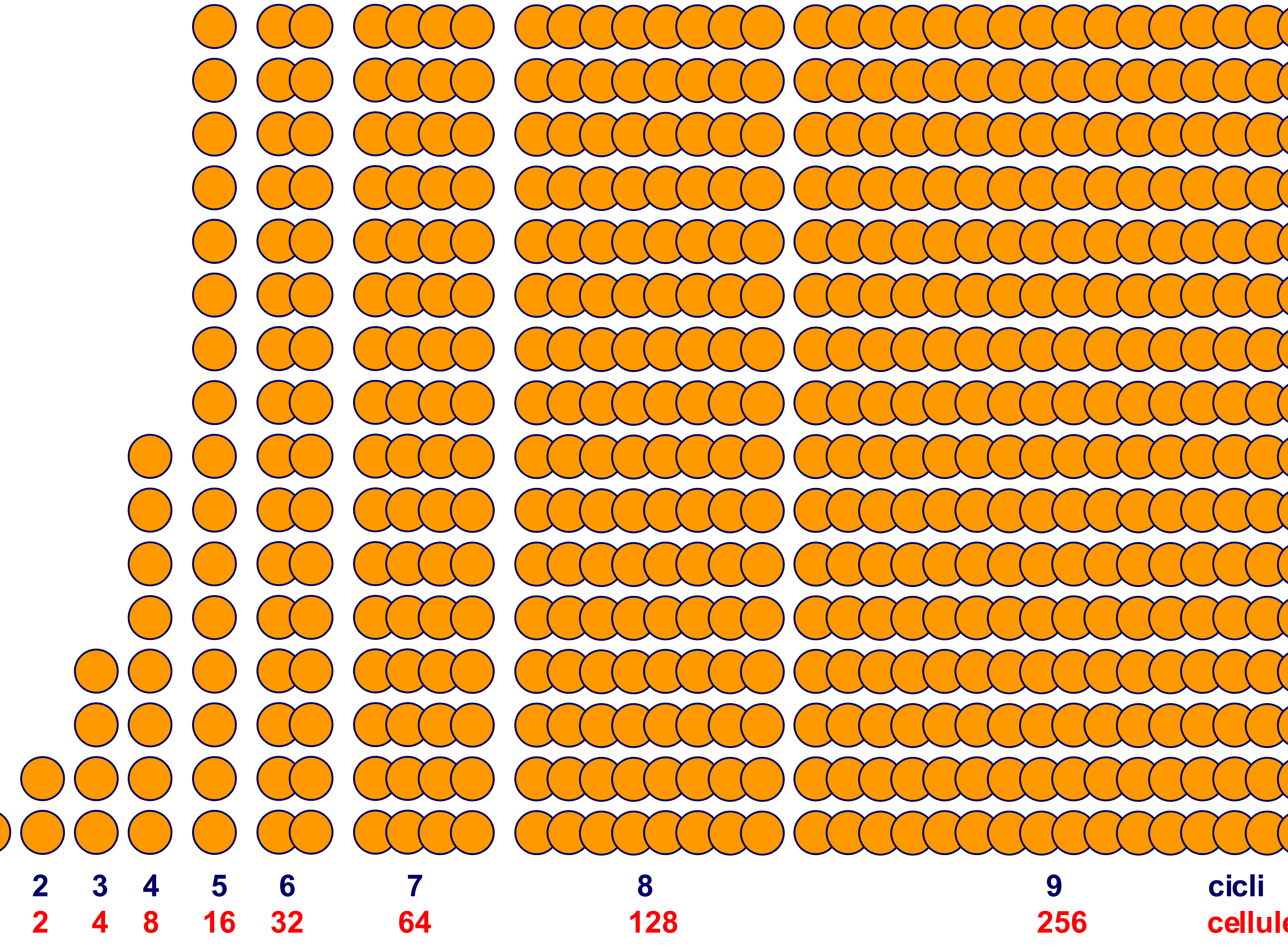
Come si può aumentare il numero dei neuroni?

- Aumentare il ritmo di produzione di neuroni
- Prolungare il tempo di generazione dei neuroni
- Diminuire la morte cellulare

Tutti e tre i meccanismi contribuiscono. Tuttavia il più efficiente consiste nel prolungare il tempo di neurogenesi
Di conseguenza, specie con cervelli più grandi hanno tempi di sviluppo più lunghi



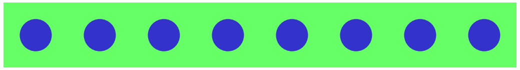



2 3 4 5 6 7 8 9 cicli
2 4 8 16 32 64 128 256 cellule

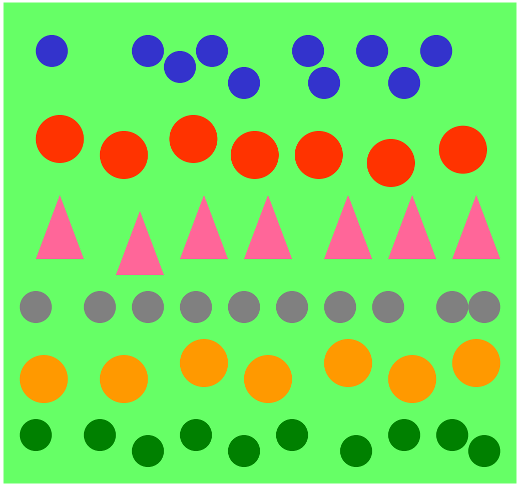
Evoluzione della neocorteccia

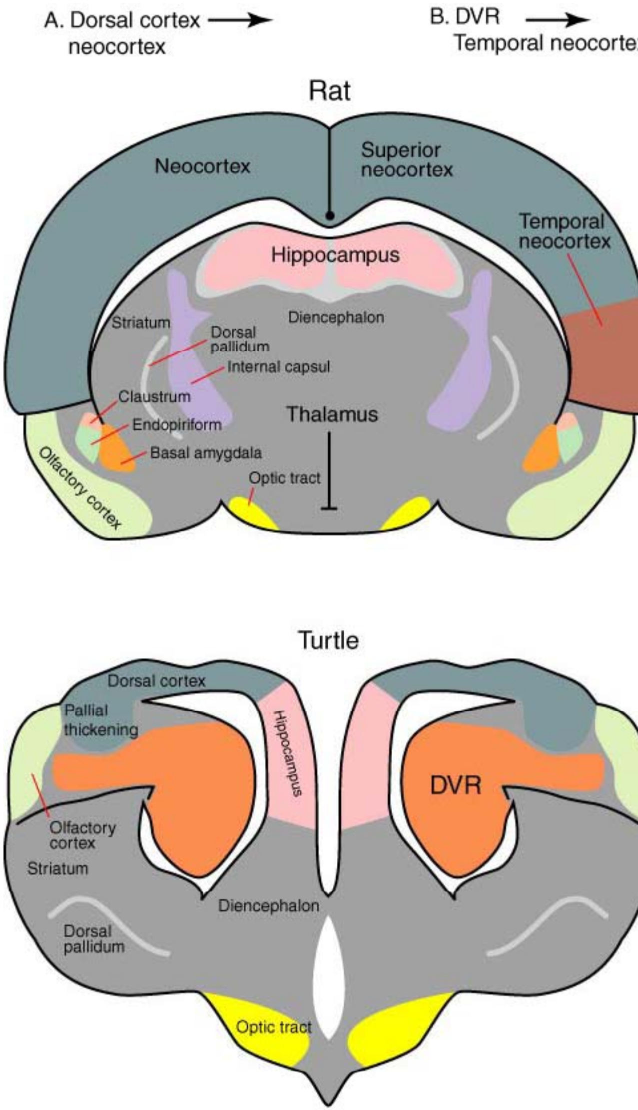
Archicortex paleocortex (rettili)
Dorsal cortex (rettili) neocortex/isocortex (mammiferi)
Laminazione della neocortex
Espansione della neocortex
Differerenziazione morfo-funzionale delle aree corticali

Dorsal cortex



neocortex





Paleocortex
Archicortex
Neocortex
Basal ganglia