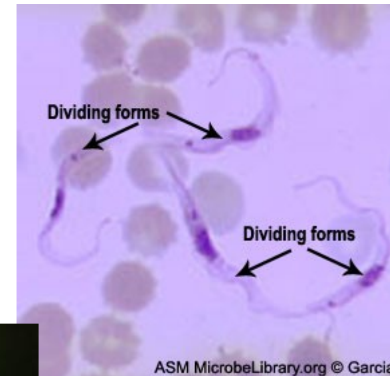
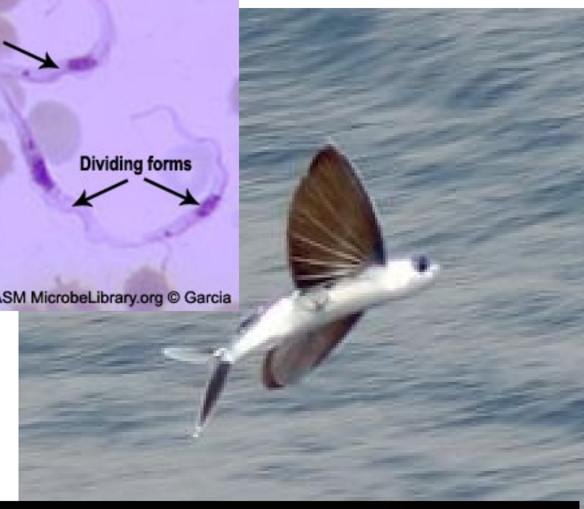
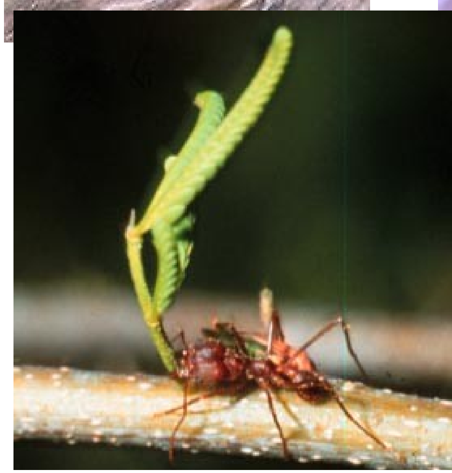
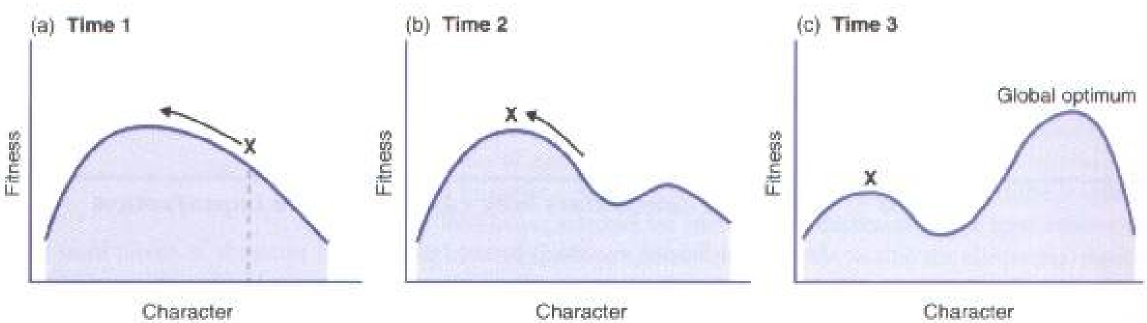
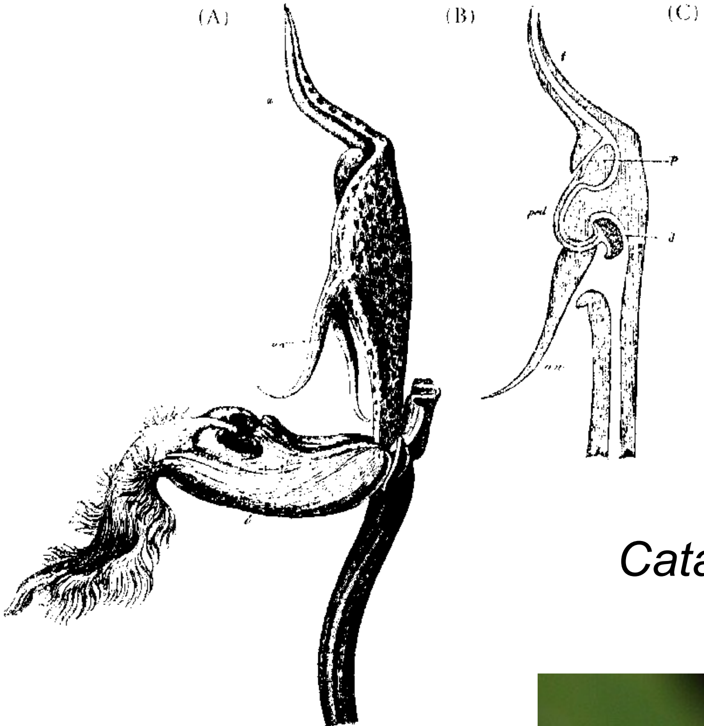
ADAPTATION AND NATURAL SELECTION









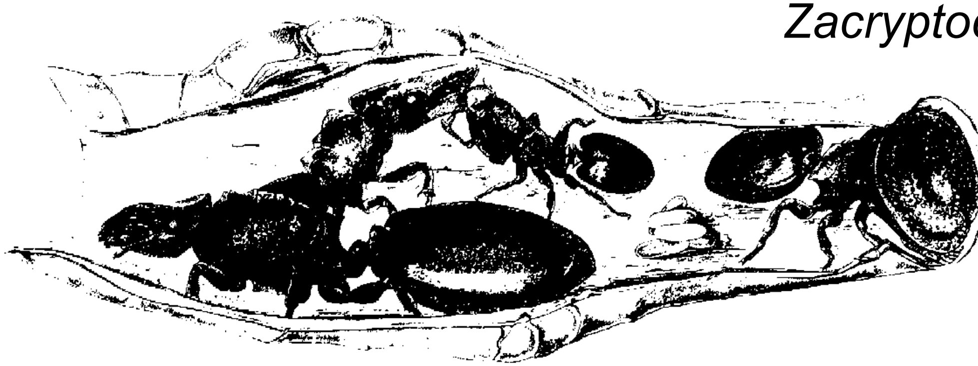


Catasetum saccatum

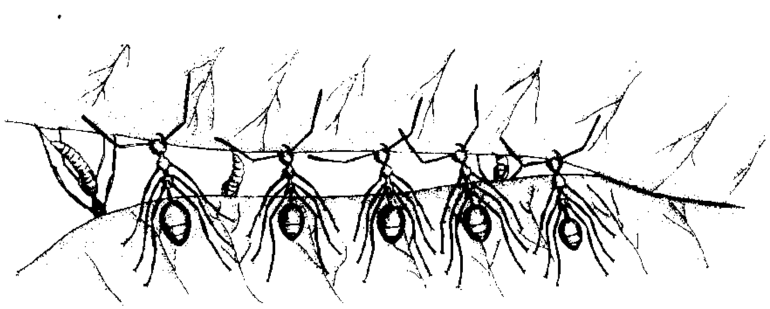
Chiloglottis formicifera

Atta, Acromyrmex: bigger workers – cutting leaves,
soldiers – their protection,
small workers – chewing leaves, growing fungi

Zacryptocerus varians



Oecophylla smaragdina



parasites × hosts

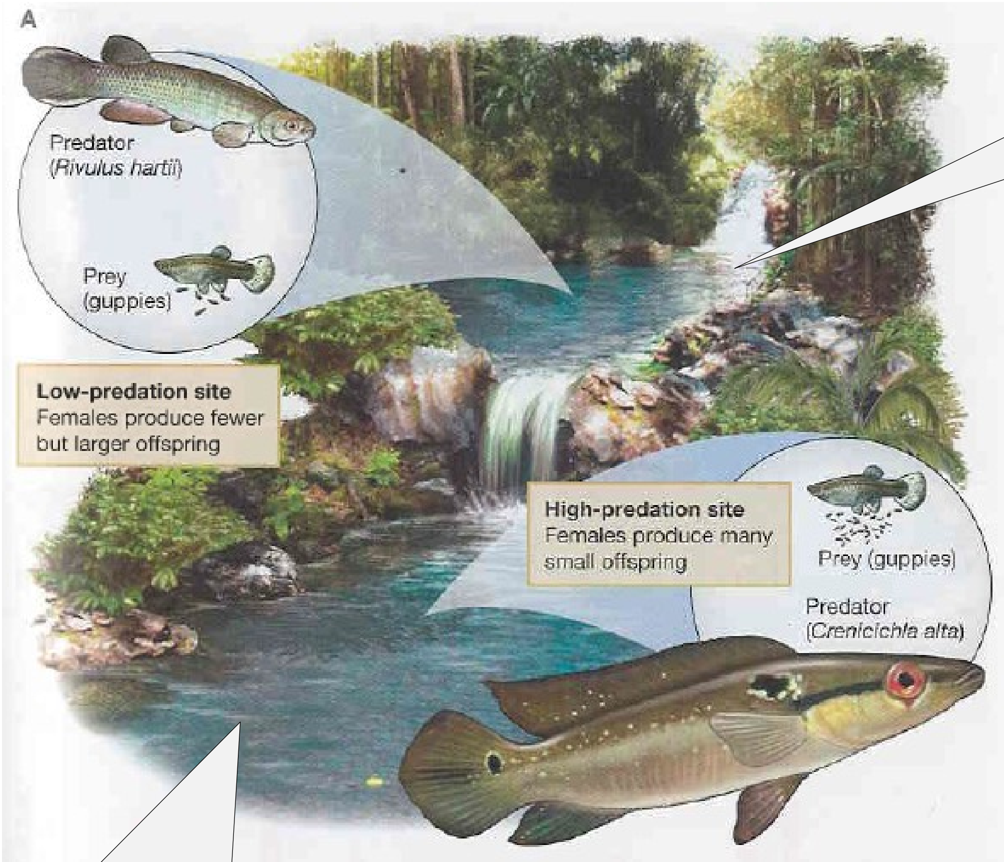
life-history strategies = timing and way of investing to survival and reproduction through the whole life of an individual

eg. timing of sexual maturity, aging,
number and size of offspring,
semelparity *vs.* iteroparity

Eg.: guppies, northern Trinidad and Tobago:

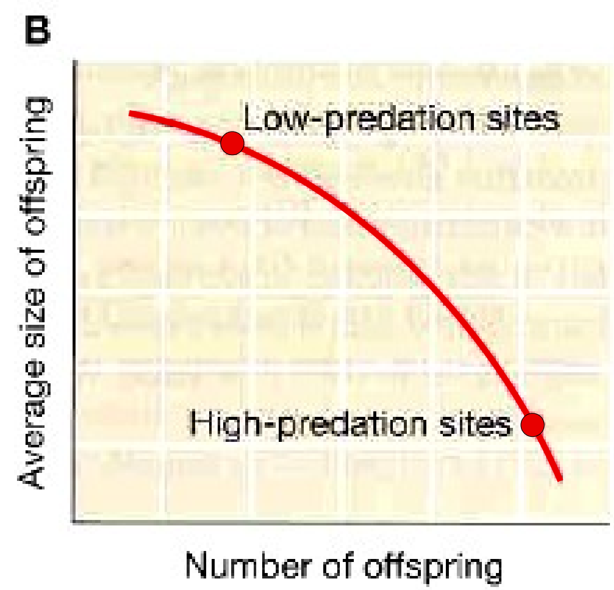
upper and lower part of the river separated by waterfalls → barrier both for guppies and predators
upper: moderate predation pressure (*Rivulus hartii*)
lower: strong predation pressure (eg. *Crenicichla alta*)

→ different coloration, antipredatory behaviour, life-history parameters (different number and size of offspring, age of the first reproduction, timing of senescence)



fewer but larger offspring, later reproduction

many small offspring, early reproduction

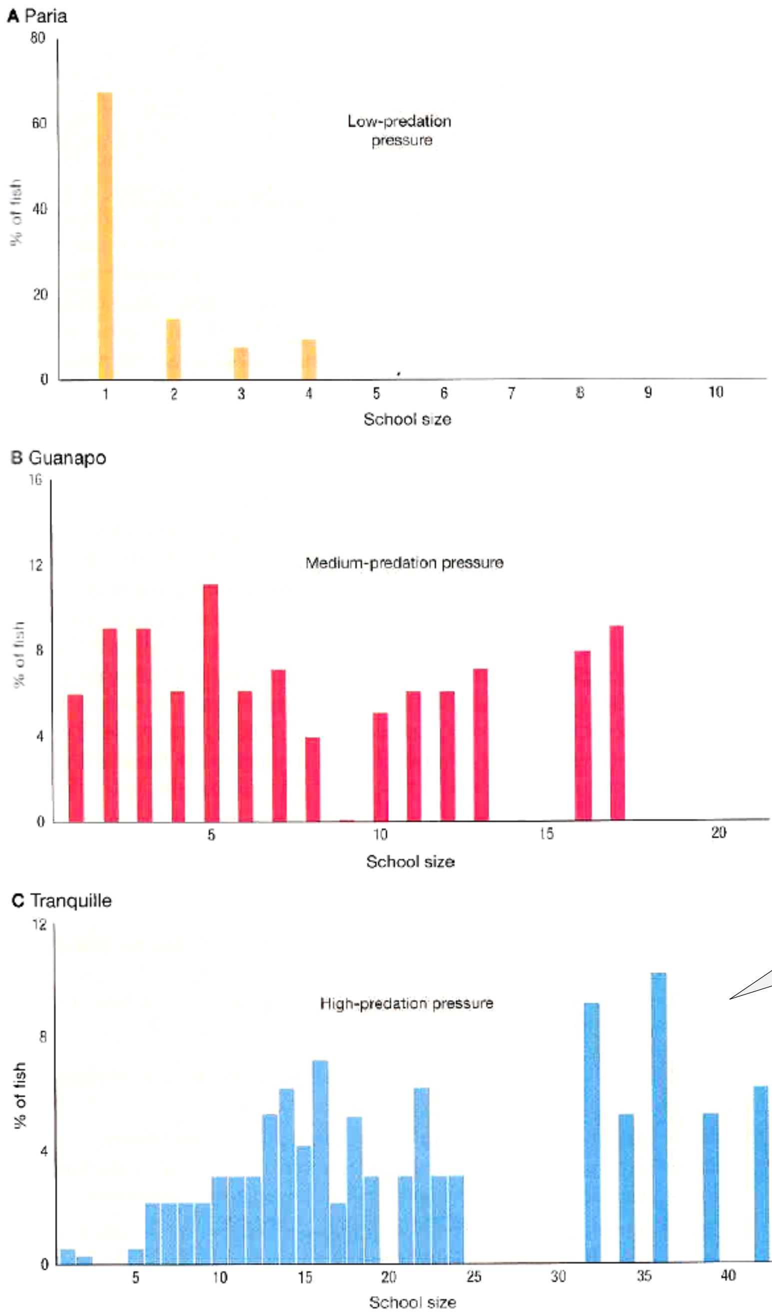


evolutionary trade-off

David Reznick, John Endler et al. (1990):

transfer of 100 males and 100 females from high-predation site to low-predation site → after 5 and 12 years females produced fewer larger offspring

this characteristic heritable



high-predation site guppies form larger and tighter shoals

What the evolutionary theory must explain:

origin of complex adaptation

origin of traits such as recombination, sexual reproduction, programmed life span including senescence and death, segregation distortion etc. which do not (or seemingly do not) provide organisms any benefit

cooperation within and between $\times$ antagonism within species (eg. infanticide) and between species (eg. host castration by parasites)

„harmful“ adaptations (eg. bee sting)

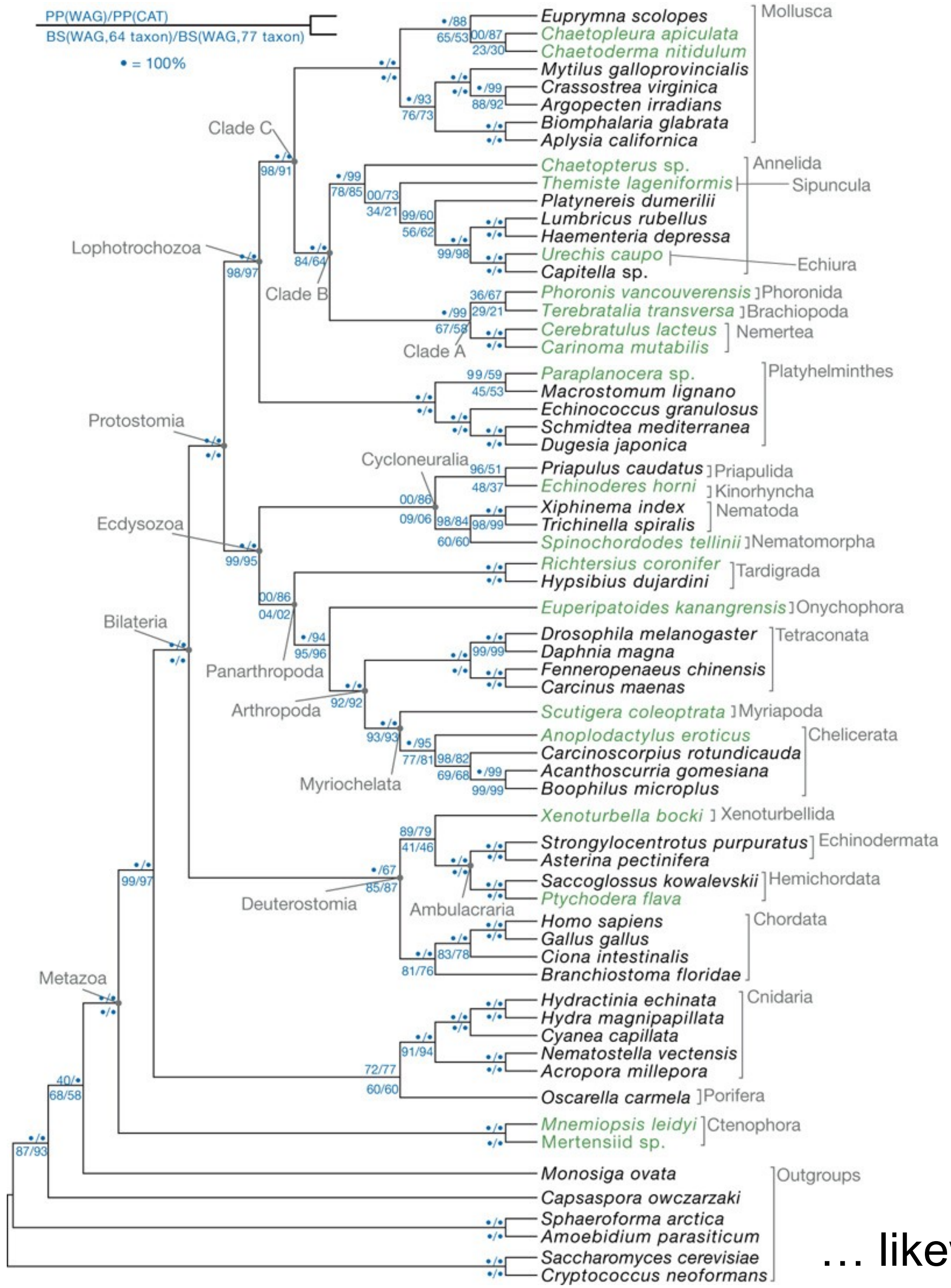
ADAPTATION → process of adapting

ADAPTATION → <u>trait of an organism</u>

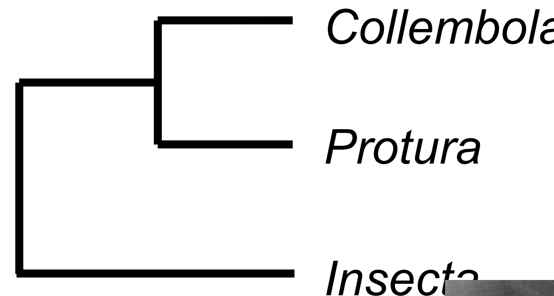
trait which allows better survival and reproduction

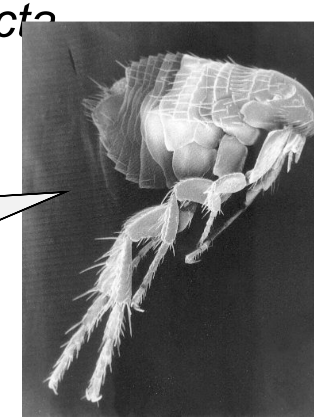
natural selection necessary but also considering history

(flea winglessness × Collembola)



springtail has no wings because all its ancestors were wingless

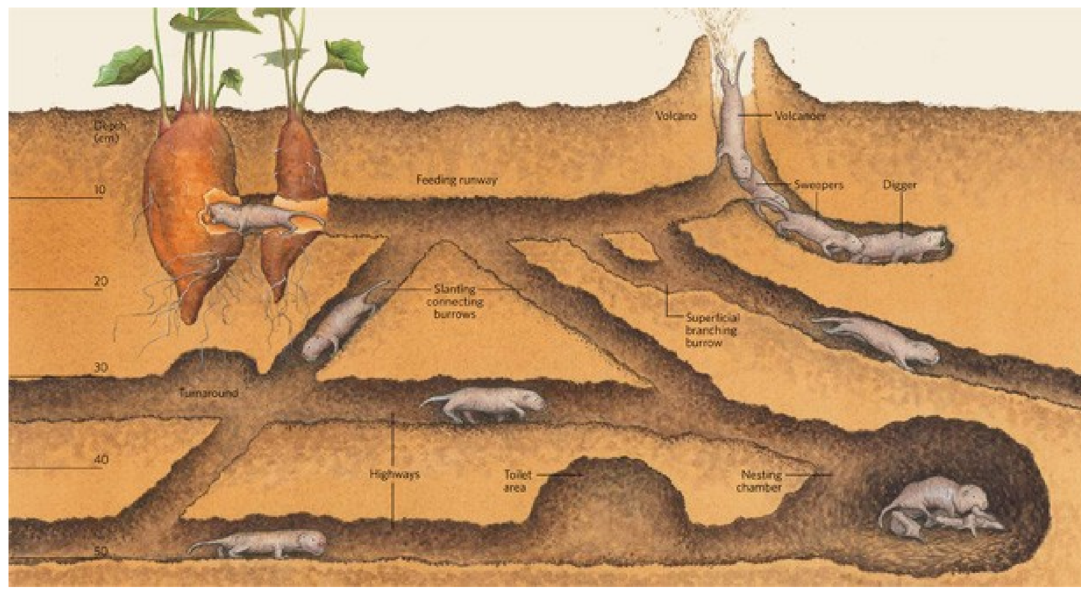




flea has lost its wings secondarily

… likewise wingless species of fruit flies etc.

Heterocephalus glaber



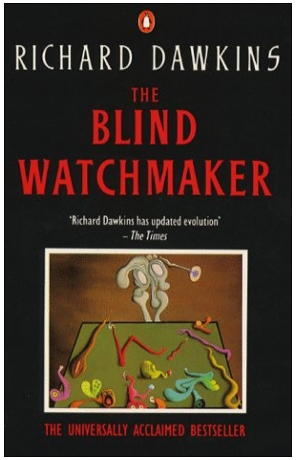
Fukomys sp.

adaptations known for a long time - philosophers,
natural theologians (St. Augustine, St. Thomas Aquinas, William Paley)

notion of a watchmaker, today „argument from design“

× David Hume

Richard Dawkins: Blind Watchmaker



Explaining adaptations:

supernatural being

lamarckism, adaptive mutation
zebra and lion: the ability of muscle strengthening is itself adaptive

orthogenesis ... mechanism?

natural selection

Coadaptation

= complex adaptation requiring coordinated changes of more than 1 part

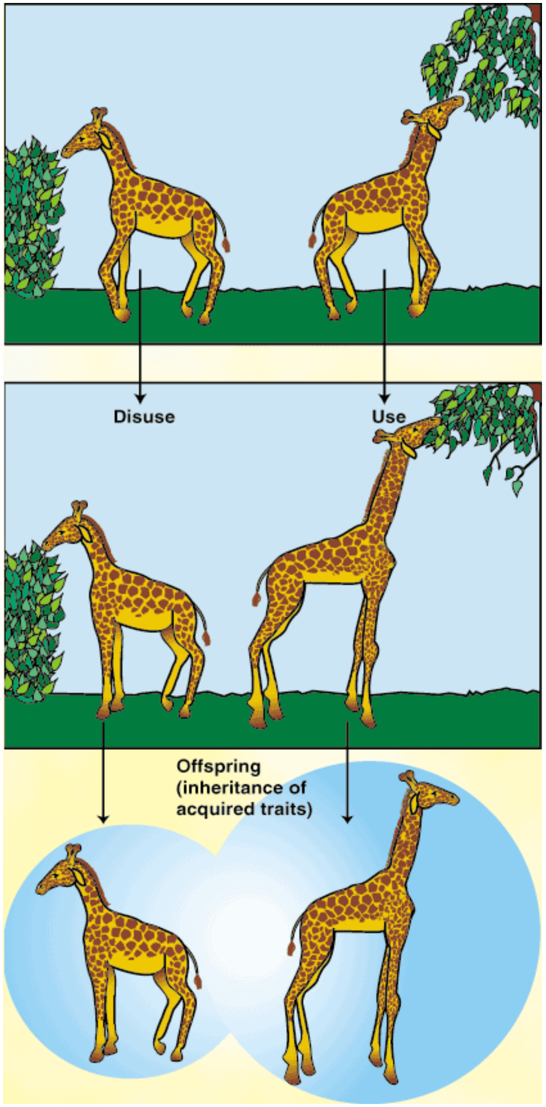
Herbert Spencer: giraffe´s neck – parallel changes of bones, muscles, and vessels

× genes do not act independently

gene level (→ gene complexes, „supergenes“)

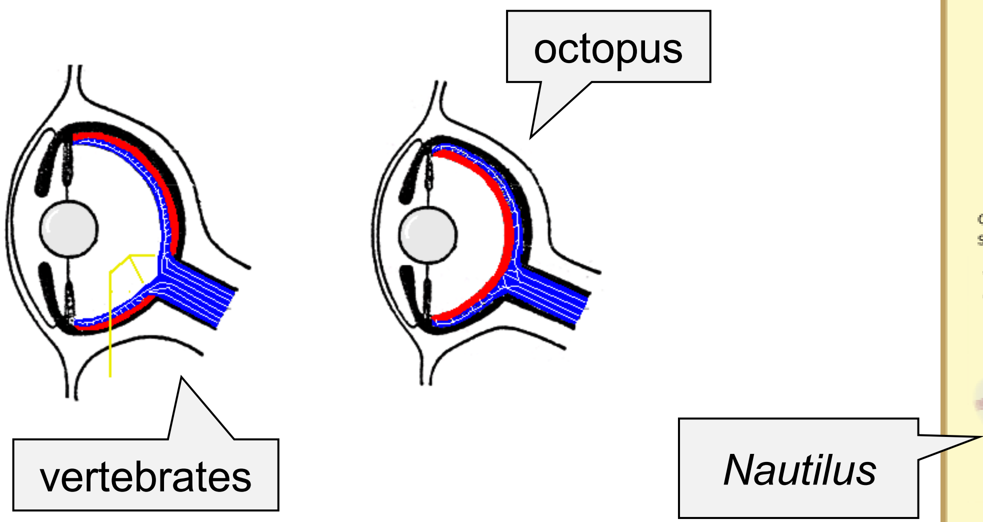
organ level

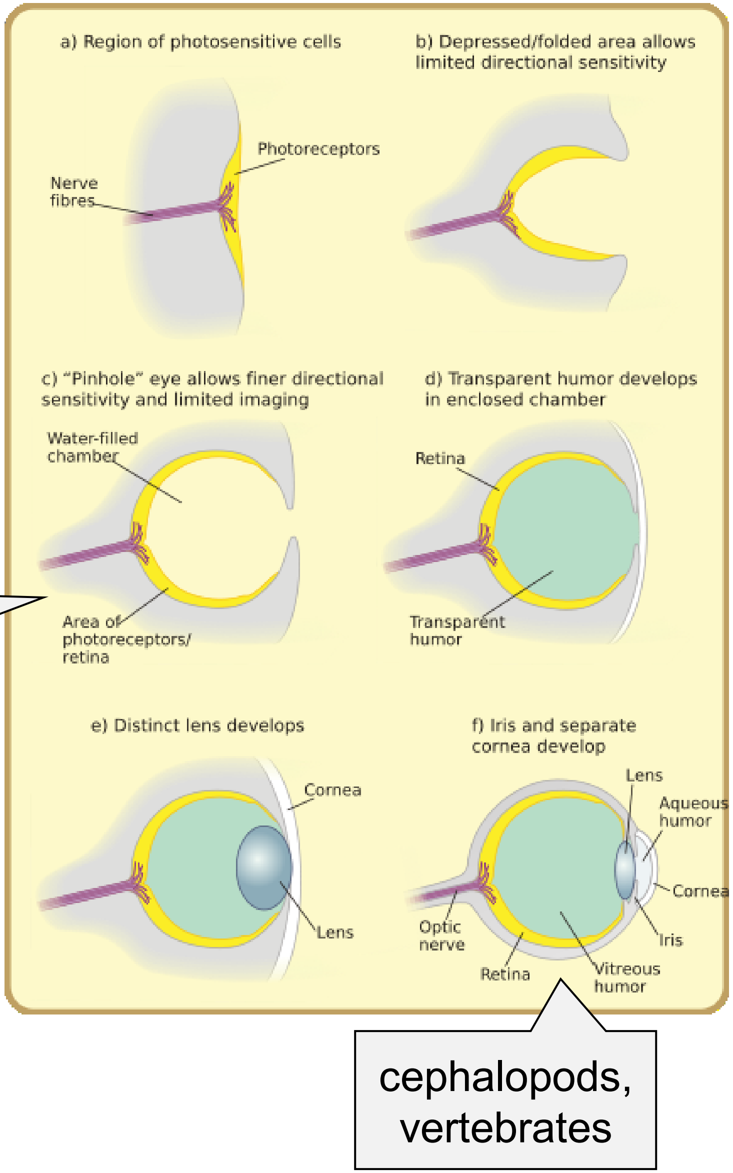
species level ... see also Origin of sexual reproduction



EVOLUTION OF COMPLEX TRAITS

1. Functional intermediary traits

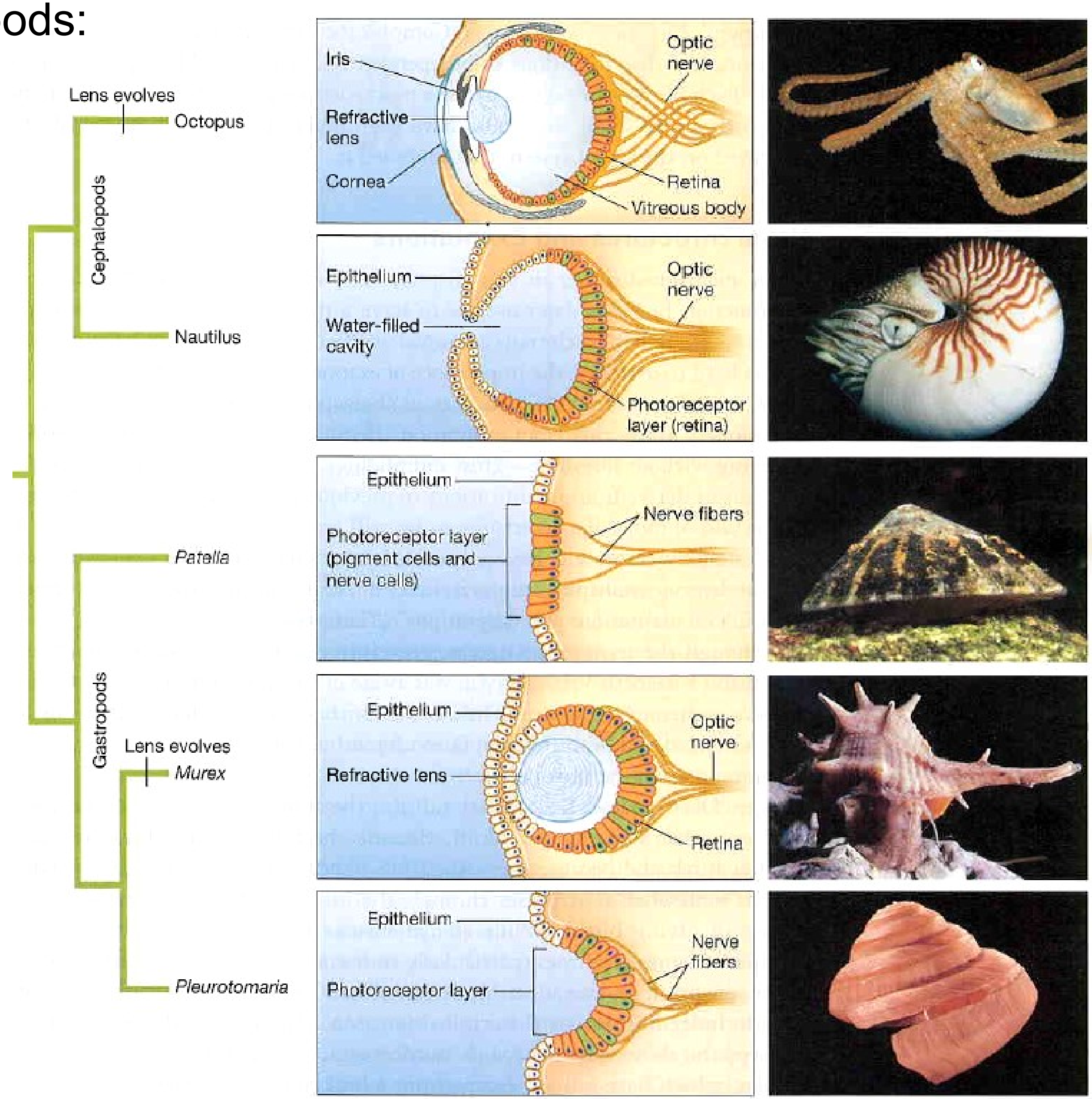




Evolution of camera-type eye:

How can a half-eye be functional?

cephalopods:



Evolution of a complex camera-type eye – computer simulation:

photosensitive organs → independent origin 50-100× in different groups of invertebrates

Nilsson & Pelger (1994):

layer of photosensitive cells between dark cell layer below and transparent protective layer on top

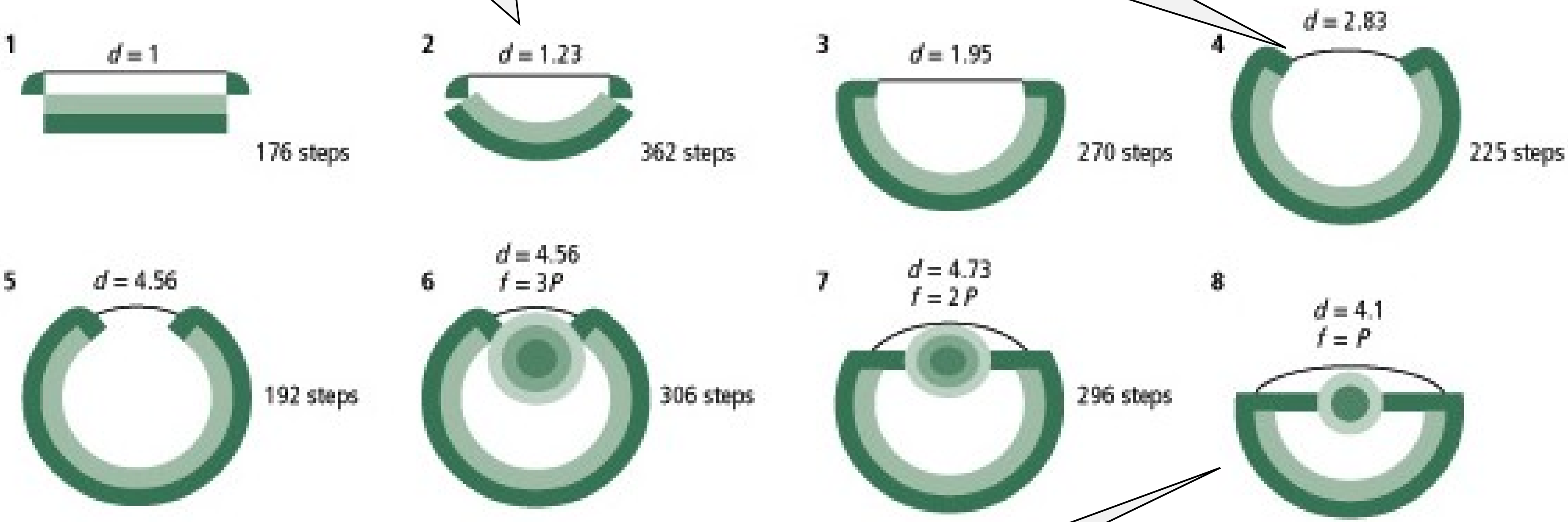
random changes <1% → less advantageous changes rejected

criterion = ability to distinguish objects in space (optical physics → potential for quantification)

Evolution of a complex camera-type eye – computer simulation:

d = diameter

~ 1000 steps: pinhole eye



~ 2000 steps: camera-type eye

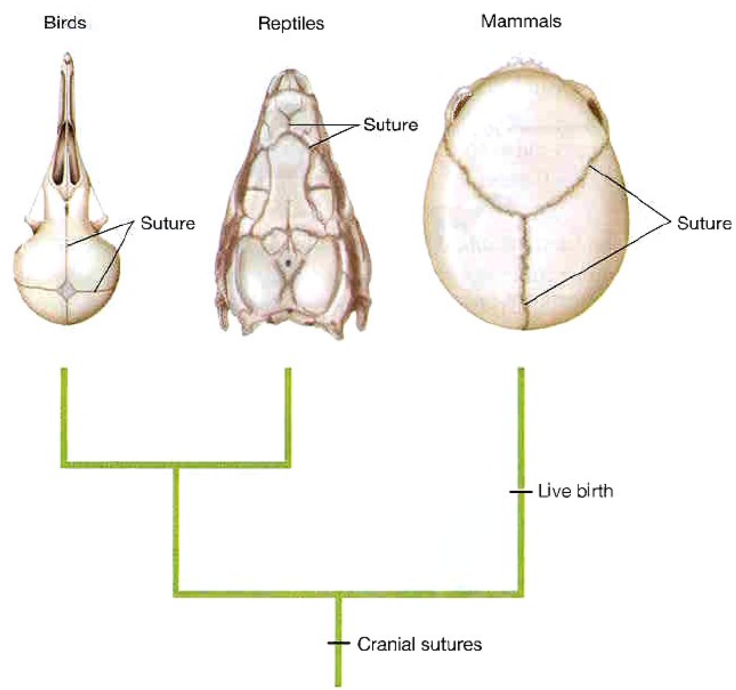
~ 400 000 generations

2. Exaptation

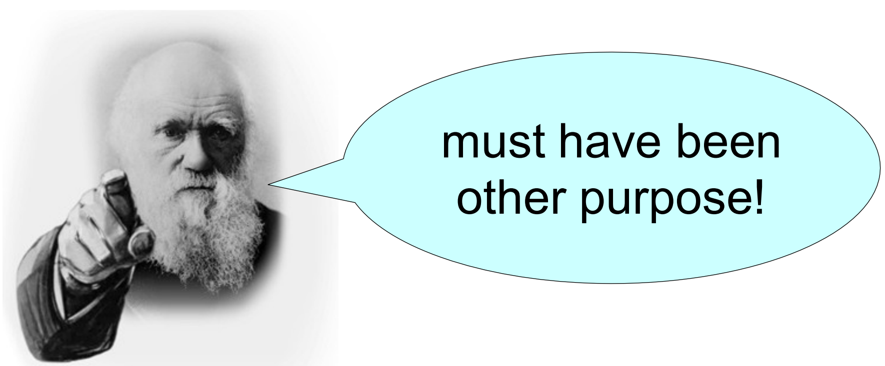
Complex traits seldom originate *de novo*, rather modification of existing structures

François Jacob (1977): evolutionary tinkering

exaptation = function shift,
ie. usage of a trait for another purpose



Eg.: mammal cranial sutures (birth relief)



suture probably enabled brain growth

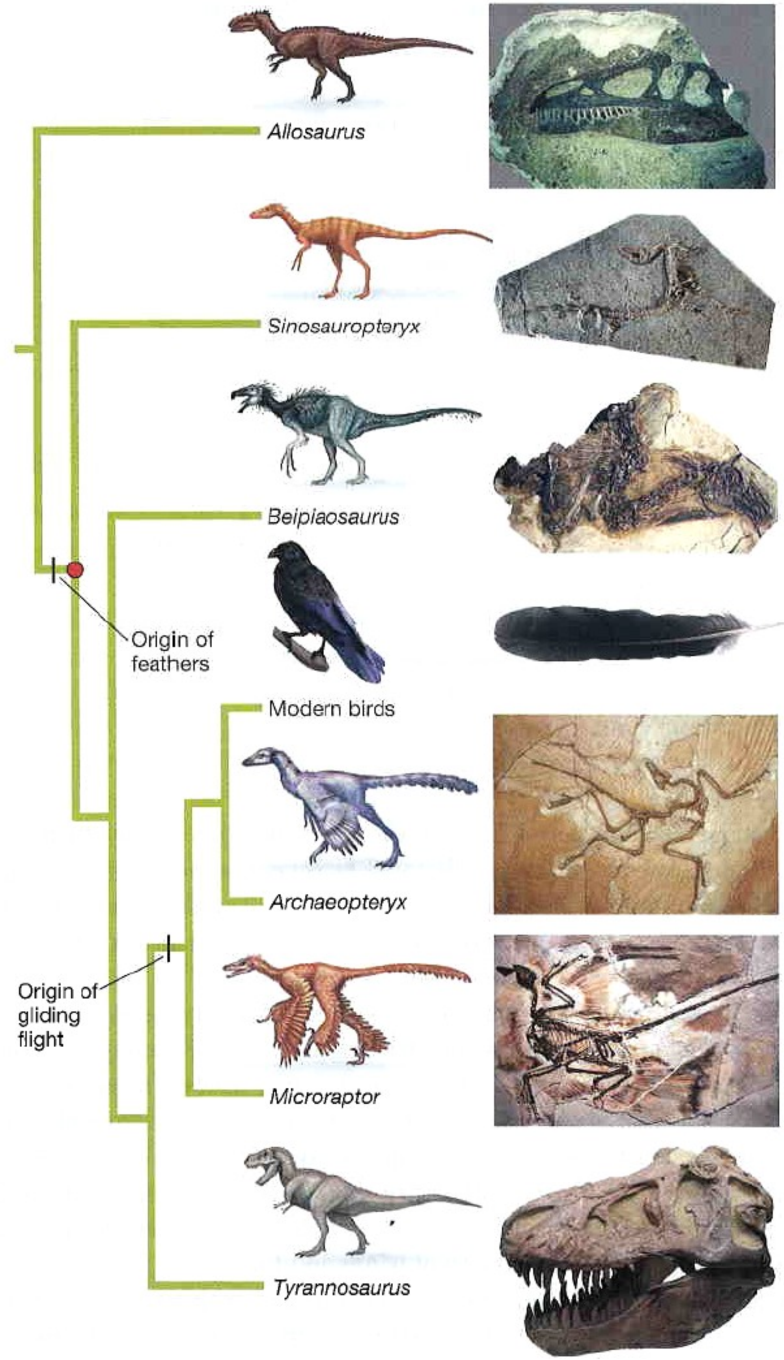
Eg.: bird feathers

single origin

theropod dinosaurs

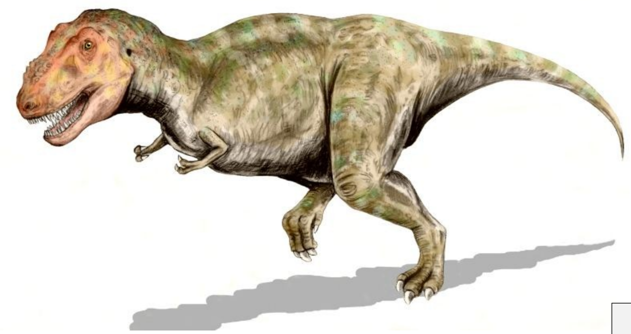
Prum and Brush (2002):

„Concluding that feathers evolved for flight is like maintaining that digits evolved for playing the piano.“

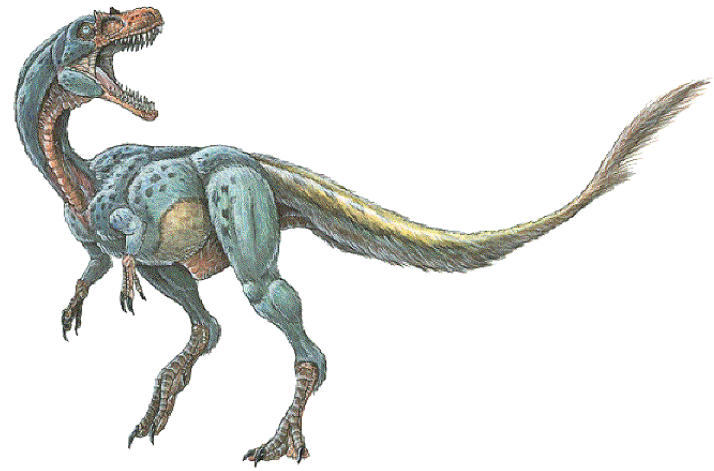


Bird feathers:

1. thermoregulation
2. protection against solar radiation
3. signaling
4. sense of touch (like vibrisses)
5. pray catching
6. defence
7. water protection



T. rex



radoxus
gulation

Microraptor gui:
gliding

birds:
active flight

Eg.: lobe-finned fishes – seabed movement → shore climbing

Panderichthys (Rhipidistia)

Tiktaalik

Acanthostega

Eg.: insect cuticle (integument → skeleton); mammalian mammary glands (sweat glands)

Stephen J. Gould, Elizabeth Vrba (1982):

avoiding teleology: the term „preadaptation“ → exaptation

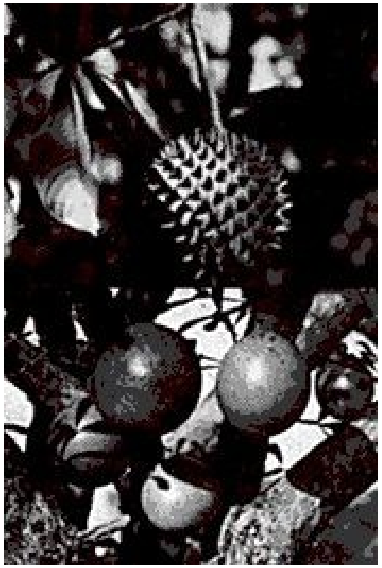
= broader meaning – including originally neutral traits

likewise term co-option

Evolutionary constraints

Are adptations always optimal?

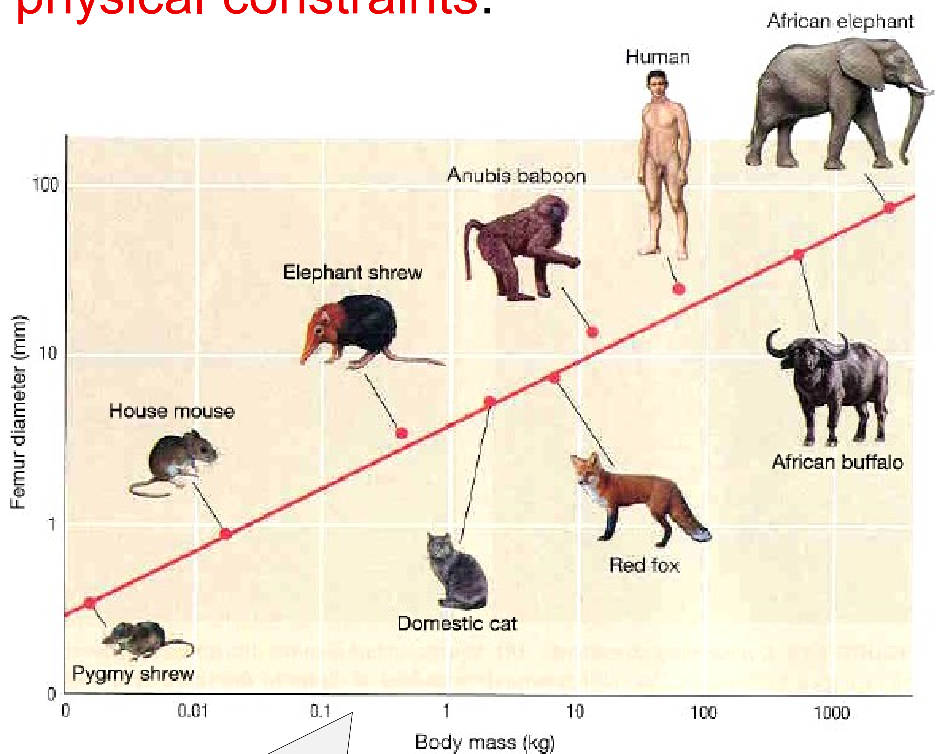
time lag: neotropical anachronisms



Cresentia alata

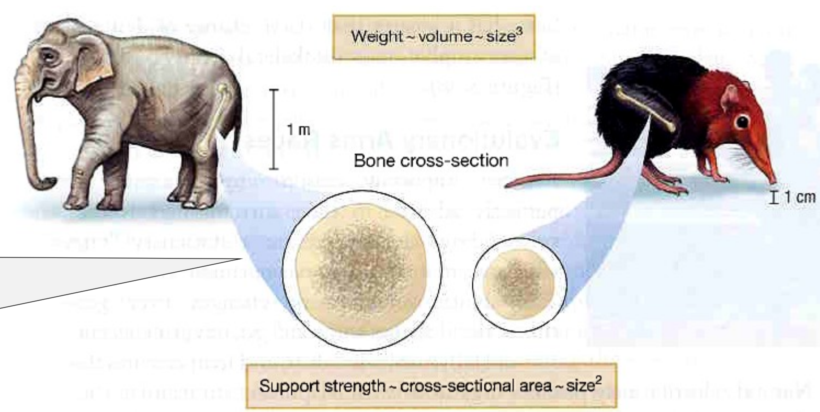
genetical constraints: overdominance
(lethal system of chromosome 1 in *Triturus cristatus*)

physical constraints:



mass grows with third power

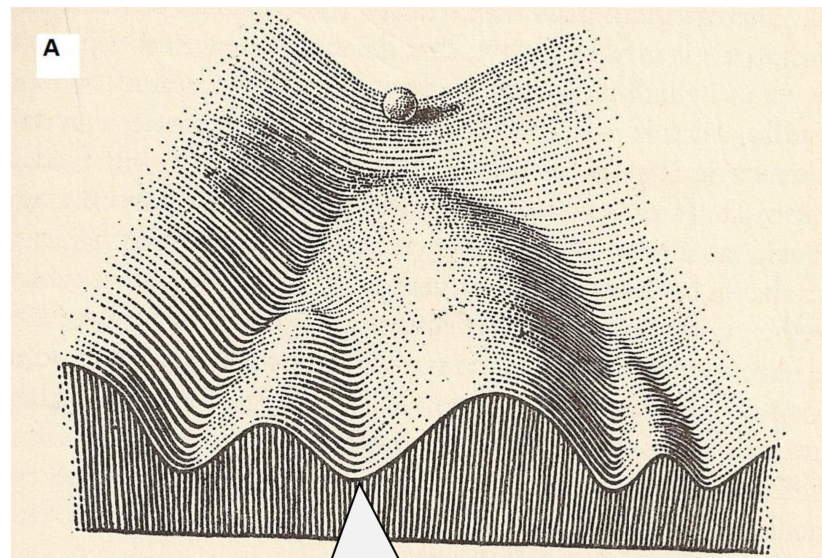
bone strength grows with second power (bone cross-section)



ontogenetic constraints:

deviation of production of various phenotypes or restriction of phenotypic variation caused by structure, character, composition or dynamics of the ontogenetic system

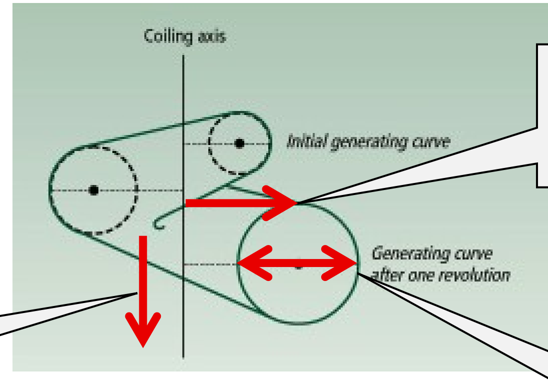
Pegasus´s wings cannot arise *de novo*



ontogeny is „canalized“

David Raup (1966):

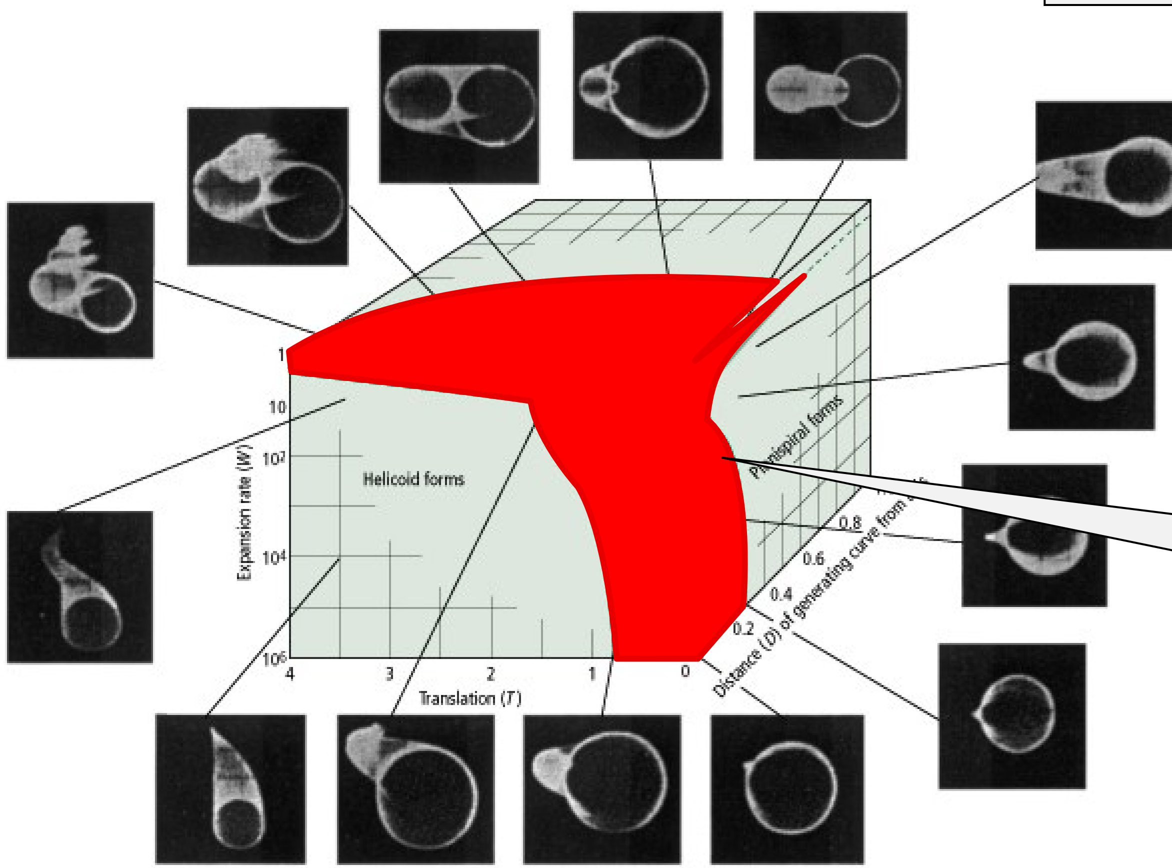
morphospace described by 3 variables



D = tightness of the coil

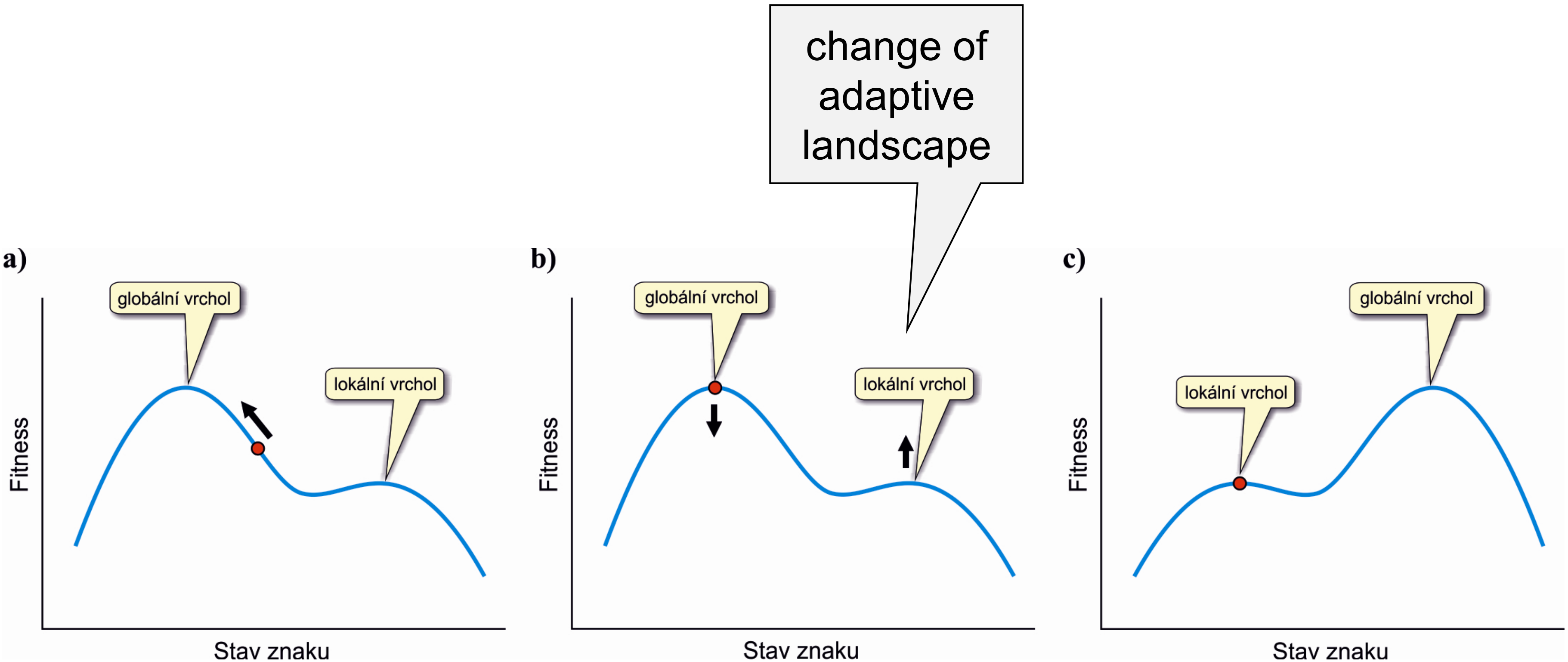
T = translation rate

W = expansion rate

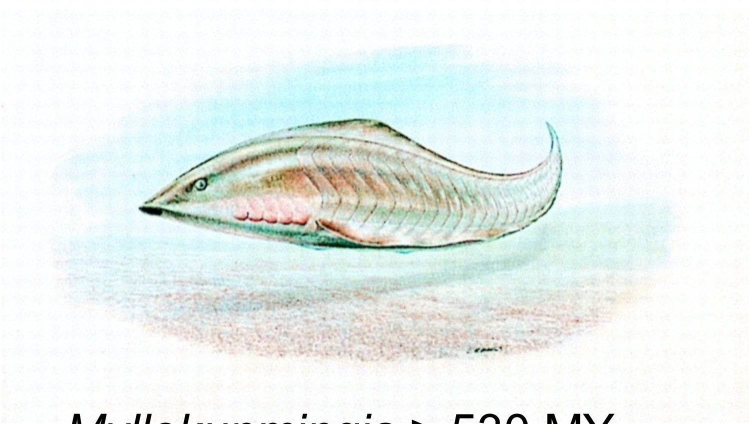


only some shapes realized

historical constraints

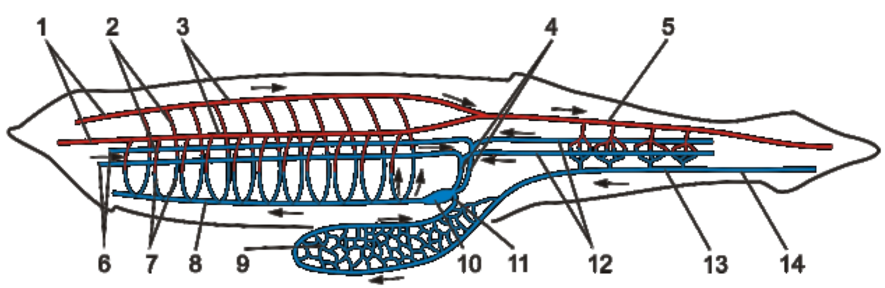


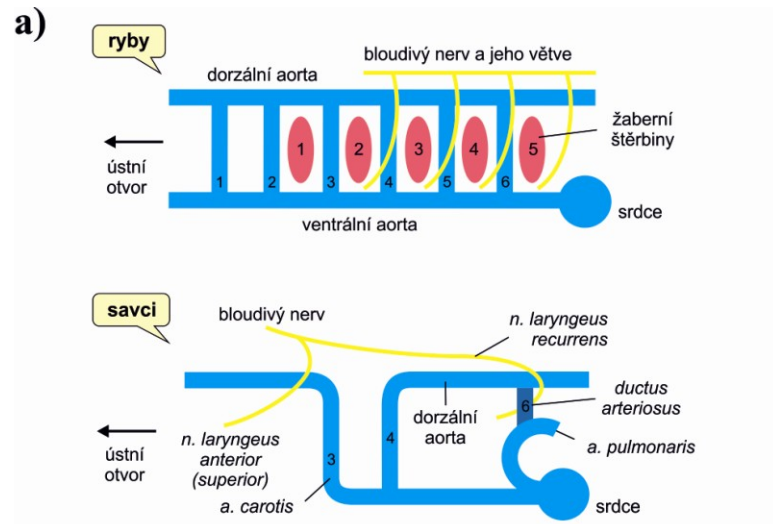
Eg.: laryngeal nerve – one of branches of the vagus nerve (*nervus vagus*)

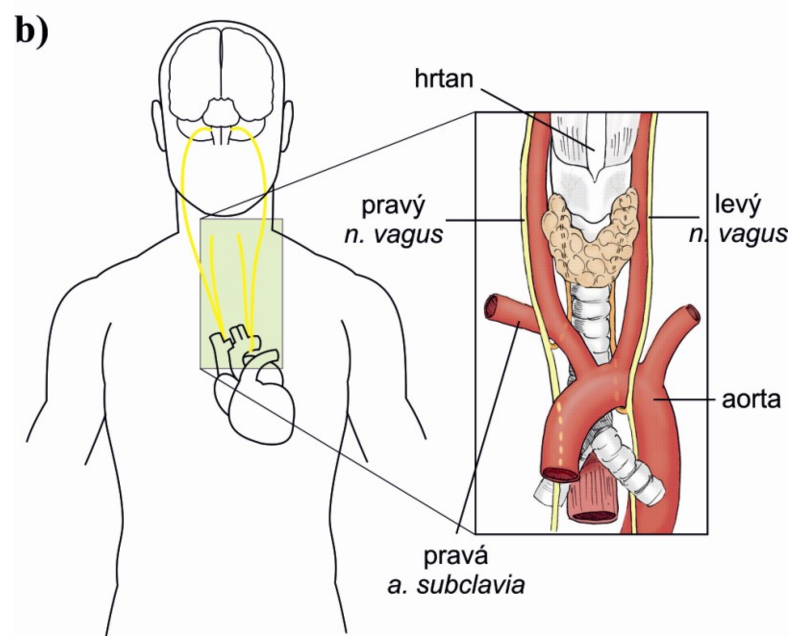


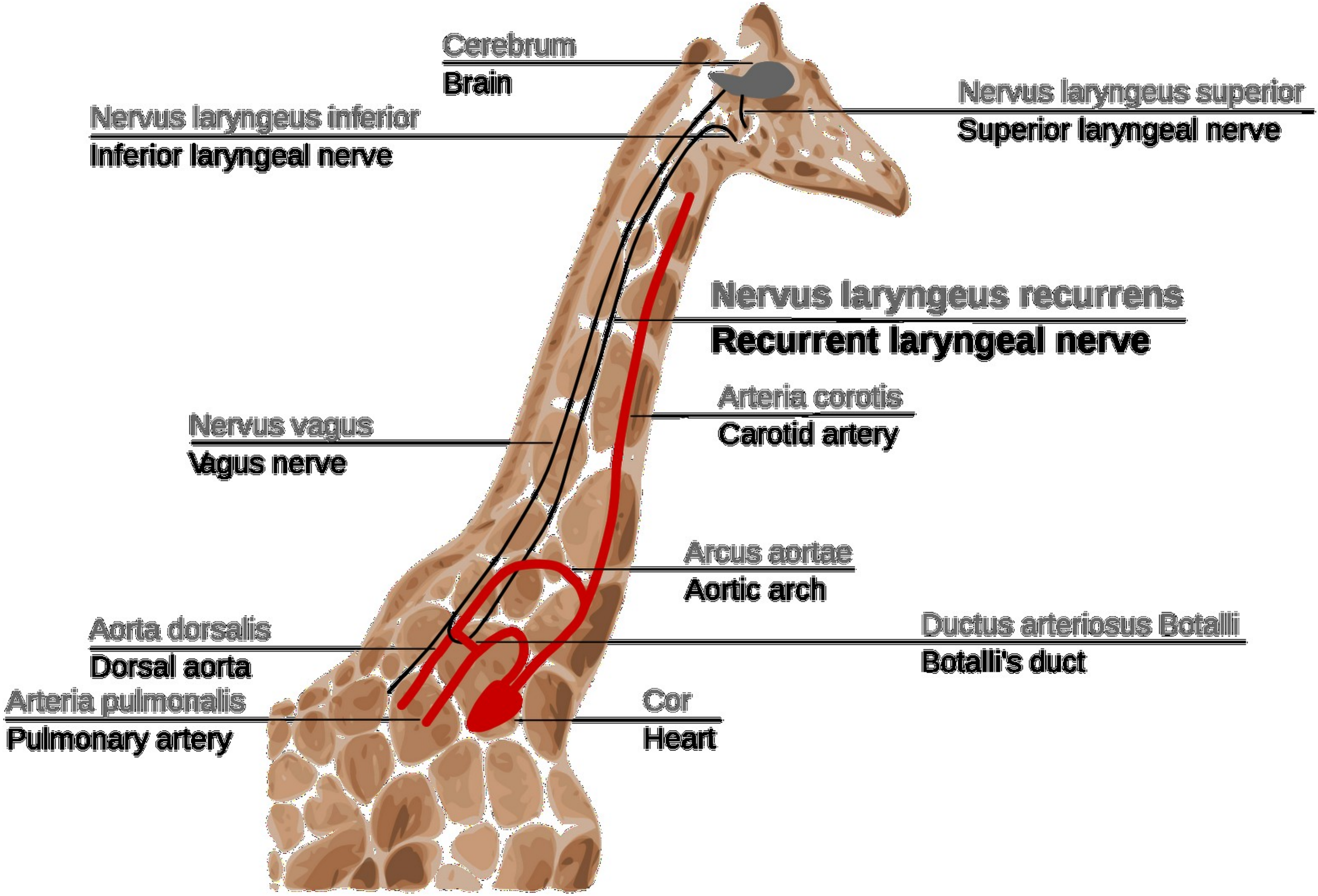
Myllokunmingia > 530 MY

amphioxus









Cerebrum
Brain
Nervus laryngeus inferior
Inferior laryngeal nerve
Nervus laryngeus superior
Superior laryngeal nerve
Nervus laryngeus recurrens
Recurrent laryngeal nerve
Arteria corotis
Carotid artery
Nervus vagus
Vagus nerve
Arcus aortae
Aortic arch
Aorta dorsalis
Dorsal aorta
Ductus arteriosus Botalli
Botalli's duct
Arteria pulmonalis
Pulmonary artery
Cor
Heart

conflict at different levels:

selection at the gene level vs. selection at the organismal level

trade-off of various adaptive needs:

parallel breathing and eating when the secondary palate is absent

trade-off between life-history parameters (number of offspring × age of the first reproduction)

time distribution between various activities (eating, recreation, …)

Methods of study of adaptation:

structural complexity:

the more complex, the higher probability of a trait being adaptive

usefulness, demonstration of function

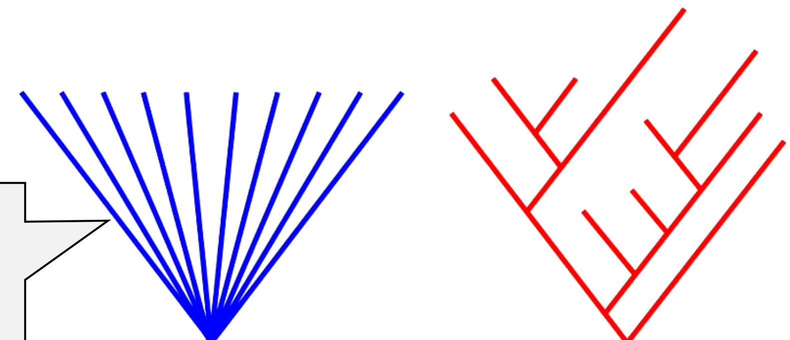
Bergmann and Allen rule,
falcon wing × accipiter wing etc.

comparative method:

association with phylogenetic analýysis

experiment

non-phylogenetic statistical methods assume that all the compared species are equally related ...



Sometimes even an experiment is not conclusive whether the trait is adaptive → <u>danger of confusing function and effect</u>:
eg. alkaloids and terpenes of plants (repelling insects × waste products of metabolism)

Is every trait adaptive?

physical and chemical laws:

hemoglobine colour, return of a fish to water

cultural inheritance of some behavioural patterns

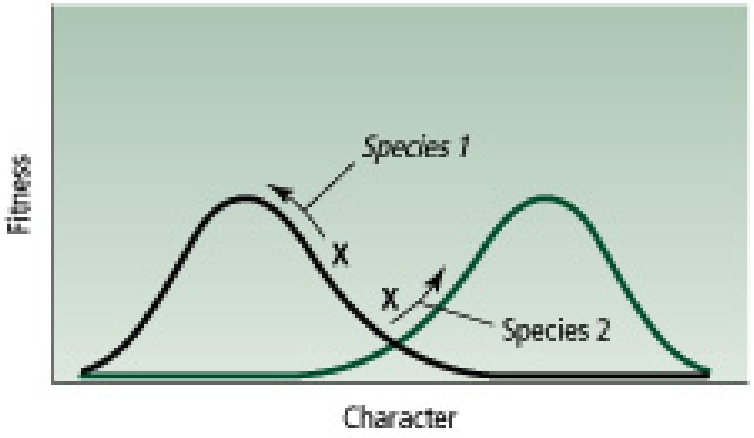
drift:

pseudogenes; shift to parthenogenesis in *Drosophila mercatorum*; loss of structures due to accumulation of lethal mutations

correlation with the selected trait:

hitchhiking, pleiotropy

multiple peaks in the adaptive landscape



Is every trait adaptive?

multiple peaks in adaptive landscape:

cryptic or aposematic colouration;

locomotion of kangaroos × zebras

skunk

zorilla

antelope

kangaroo

phylogeny:

winglessness,

eusocial behaviour of mole rats

Stephen Gould, Richard Lewontin (1979): The spandrels of San Marco and the Panglossian paradigm: A critique of the adaptationist programme. *Proceedings of the Royal Society of London, Series B*, 205: 581-598.