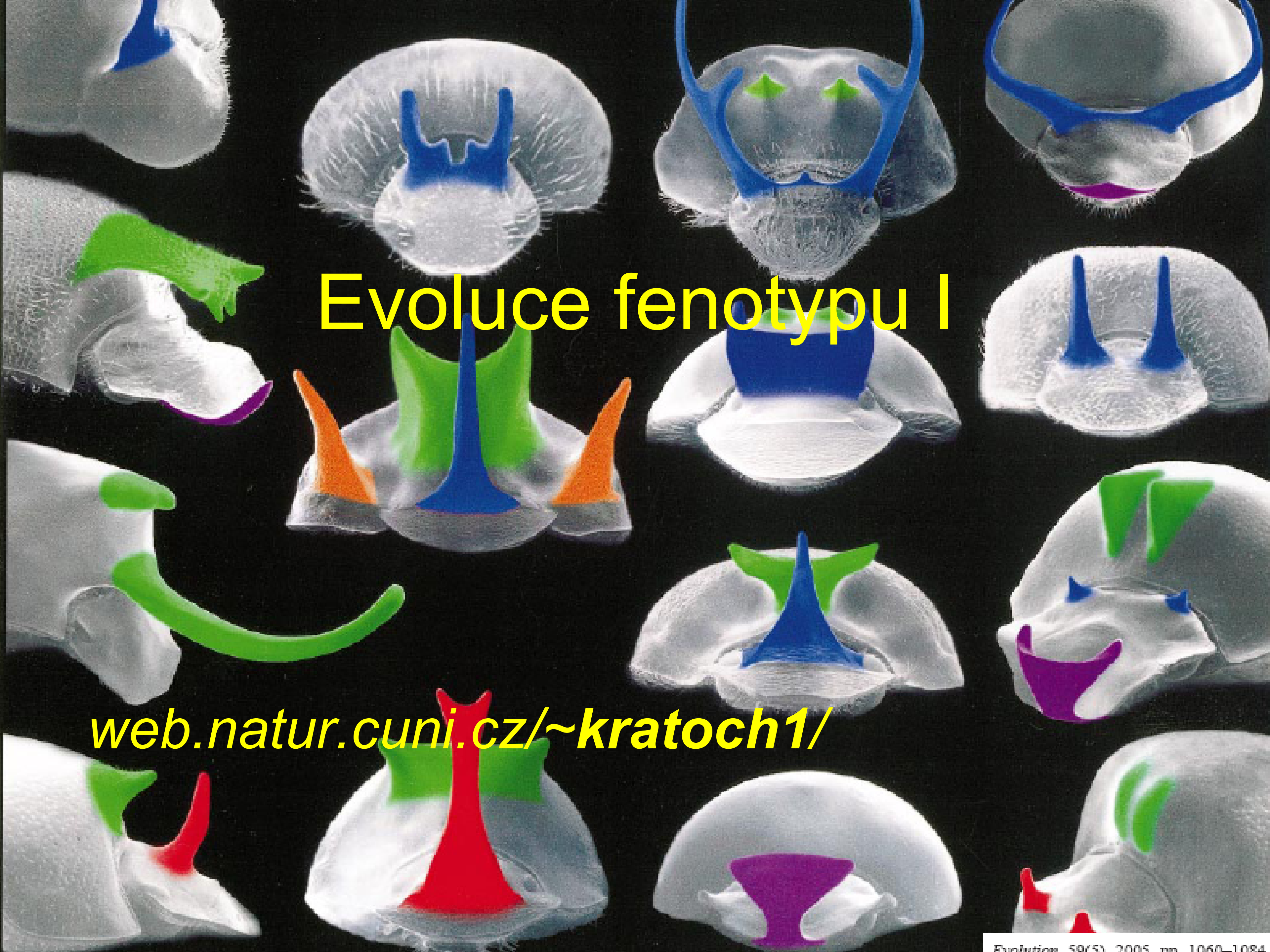
Evoluce fenotypu I

*web.natur.cuni.cz/~**kratoch1**/*



Pojem fenotyp:

- genotyp – dnes zpravidla chápán jako sekvence DNA

- fenotyp – soubor všech vlastností organismu (např. morfologie, fyziologie, vývin, chování)

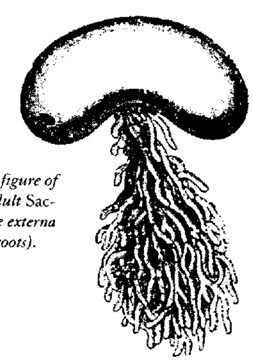
  (zavedl Johanssen r. 1911 kvůli vymezení vůči genotypu)

  („rozšířený fenotyp“ – Dawkins)

- negenetické a epigenetické vlastnosti (maternální efekt, inaktivace X chromosomu apod., nukleotyp, faktory prostředí)

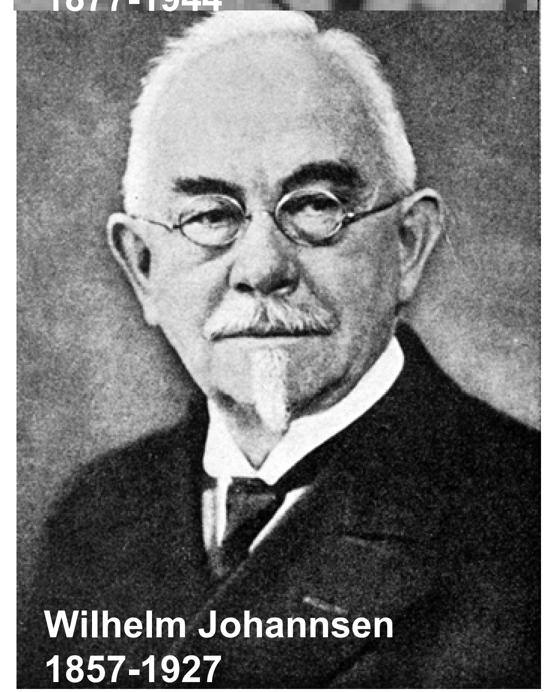
Klasické vyjádření kvantitativní genetiky:

$$V_P = V_G + V_E + V_{GxE}$$



E. Ray Lankester's figure of the "degenerate" adult Sacculina, showing the externa (sac) and interna (roots).

Richard Woltereck 1877-1944



Wilhelm Johannsen 1857-1927

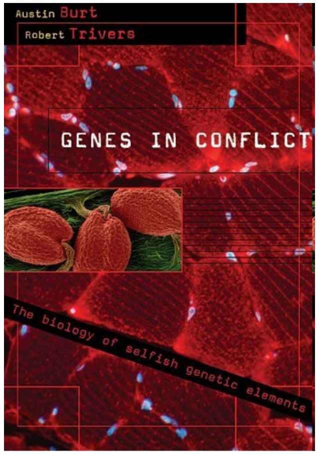
Cíle přednášky

- zdůraznit historickou povahu evoluce vs. adaptacionalismus (např. sociobiologie)

- zdůraznit roli prostředí ve formování fenotypů

- vymezit se proti striktně genocentrickému pohledu:
  - „nová syntéza“ – soustředila se na změnu frekvence prohlásila za evoluci
  - Hamilton, Dawkins – „sobecký gen“
  vysvětluje výborně některé fenomény, soustředí se na vnitropopulační (vnitrodruhovou) úroveň

- prozkoumat (proximátní) faktory ovlivňující fenotyp



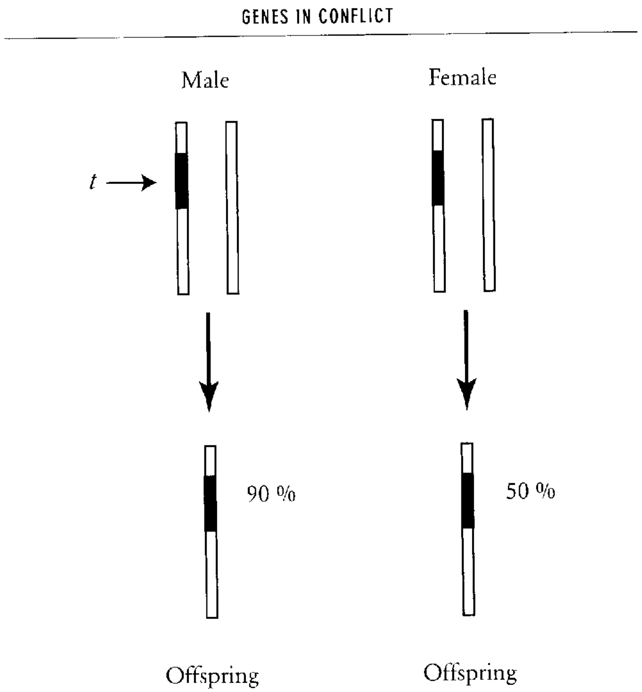


Figure 2.1 Drive of the *t* haplotype in male mice. A male mouse heterozygous on his 17th chromosome for a *t* haplotype transmits the *t* to 90% of offspring. By contrast, *t* transmission is normal (50%) in female heterozygotes.

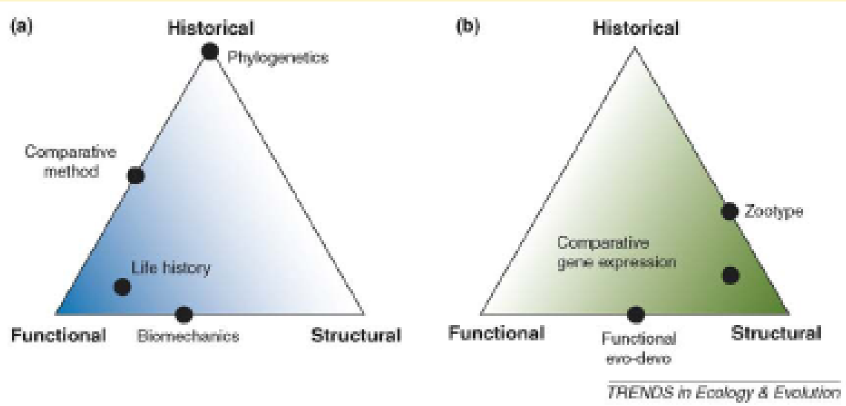
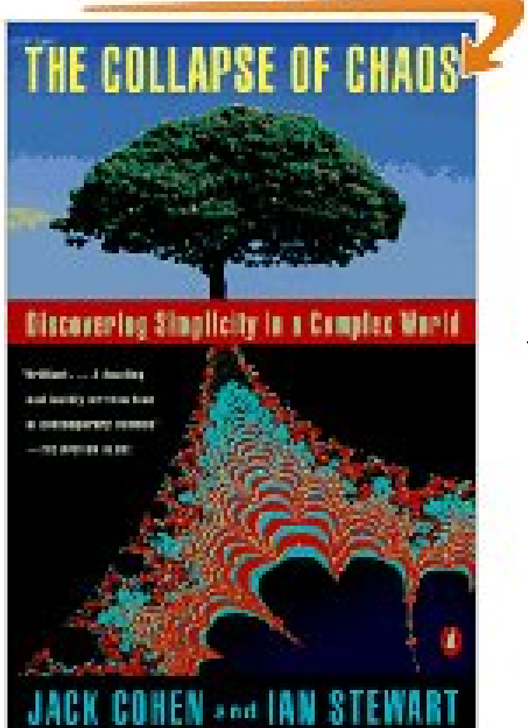
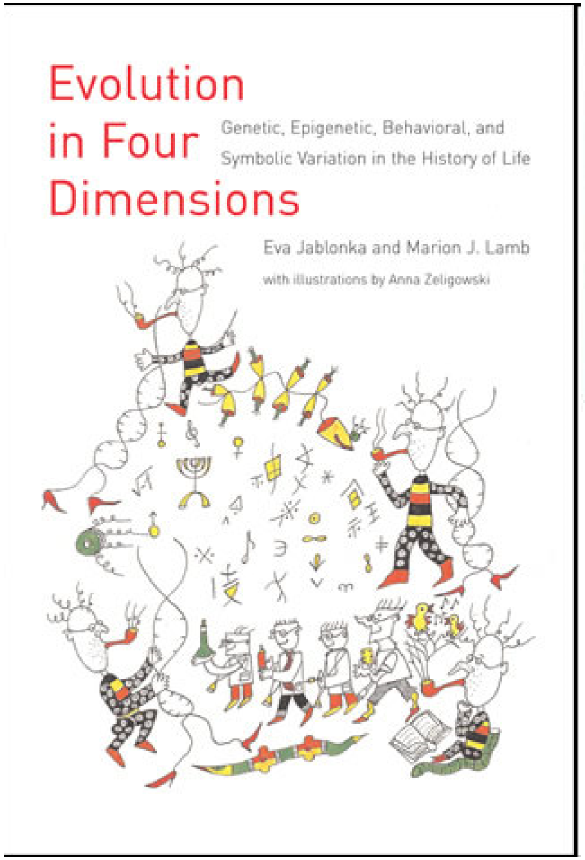
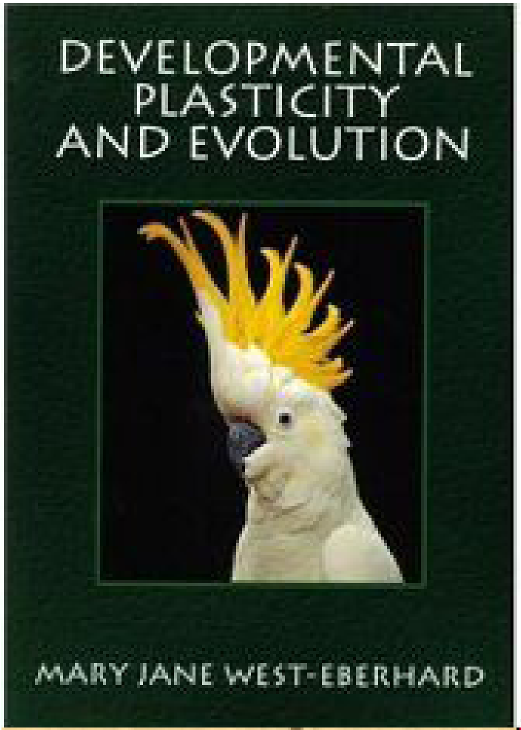
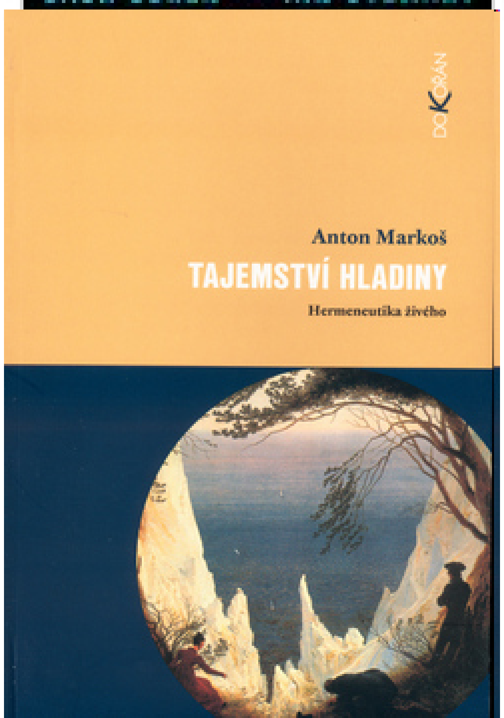


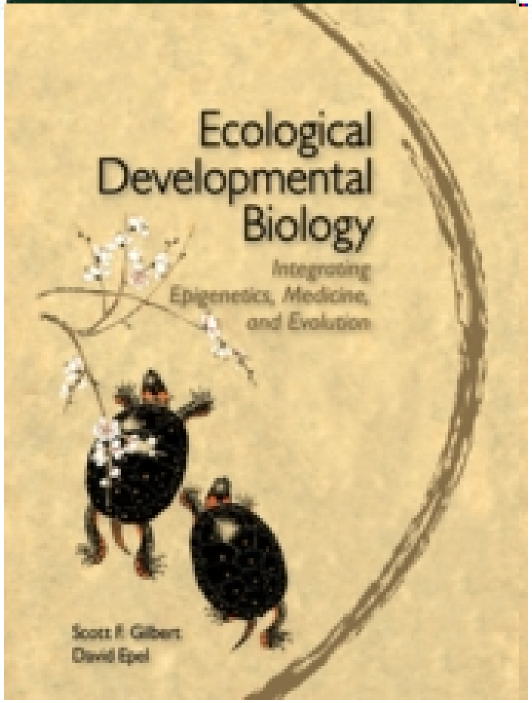
Figure I. Differences in emphasis of explanatory factors (bold print) in different fields of evolutionary biology (dots). (a) Some of the traditional disciplines in evolutionary biology. (b) Some areas that have emerged as parts of evo-devo. The shading indicates the overall emphasis in neo-darwinian evolutionary biology (a) and in evo-devo (b).


THE COLLAPSE OF CHAOS
Discovering Simplicity in a Complex World
JACK COHEN and IAN STEWART


Evolution in Four Dimensions
Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life
Eva Jablonka and Marion J. Lamb
with illustrations by Anna Zeligowski


DEVELOPMENTAL PLASTICITY AND EVOLUTION
MARY JANE WEST-EBERHARD


DOKOŘÁN
Anton Markoš
TAJEMSTVÍ HLADINY
Hermeneutika živého


Ecological Developmental Biology
Integrating Epigenetics, Medicine, and Evolution
Scott F. Gilbert
David Epel

ECO-DEVO

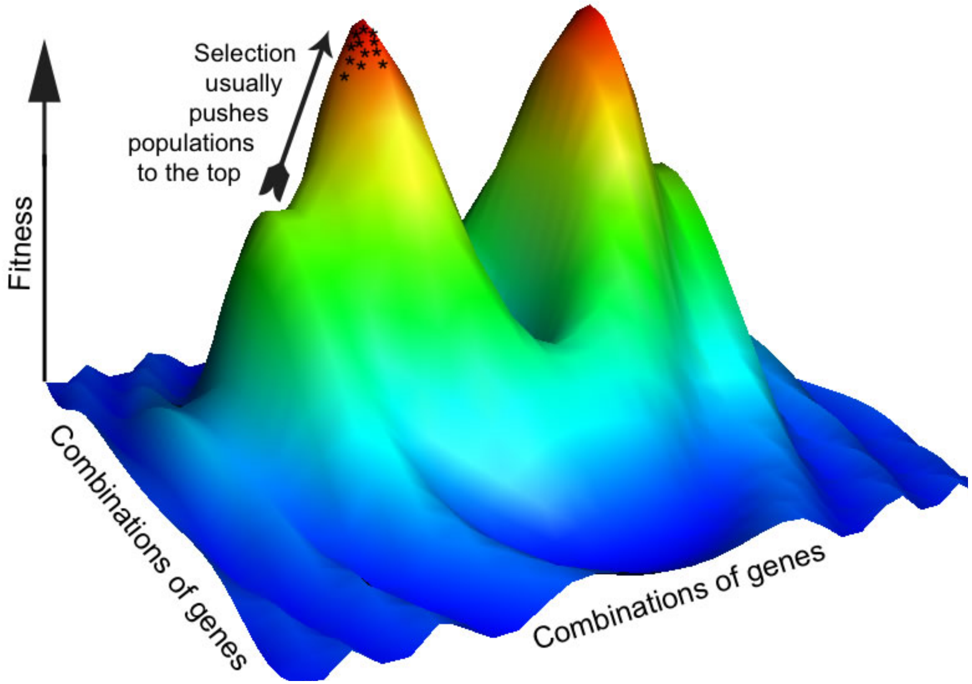
Potřebujeme se zabývat historickou složkou evoluce?

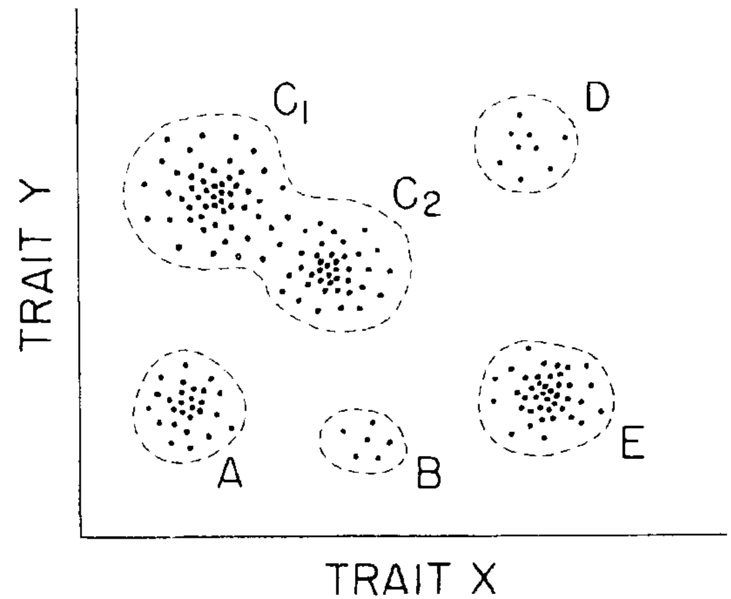
THE LOGIC OF MONSTERS :
EVIDENCE FOR INTERNAL CONSTRAINT IN DEVELOPMENT AND EVOLUTION

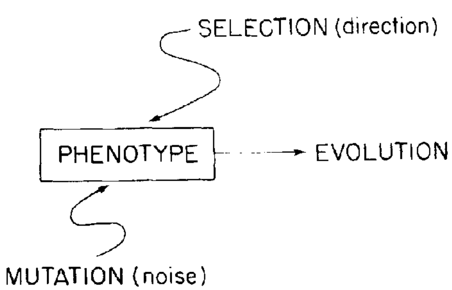
Geobios, mémoire spécial n° 12

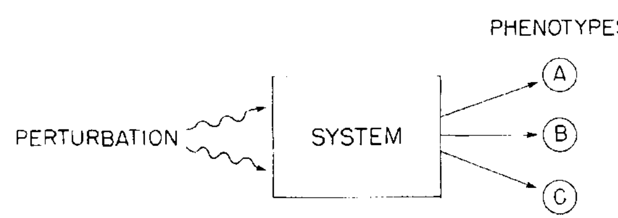
by
Pere ALBERCH*

externalismus versus internalismus

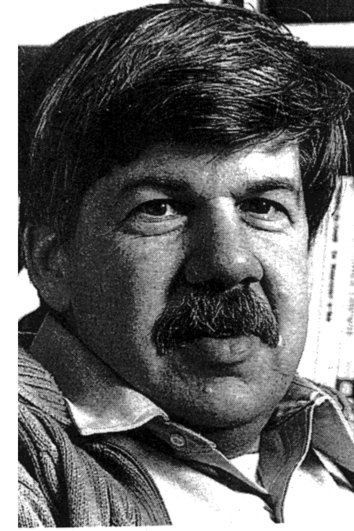








Potřebujeme se zabývat historickou složkou evoluce?
O (ne-)unikátnostnosti fenotypů



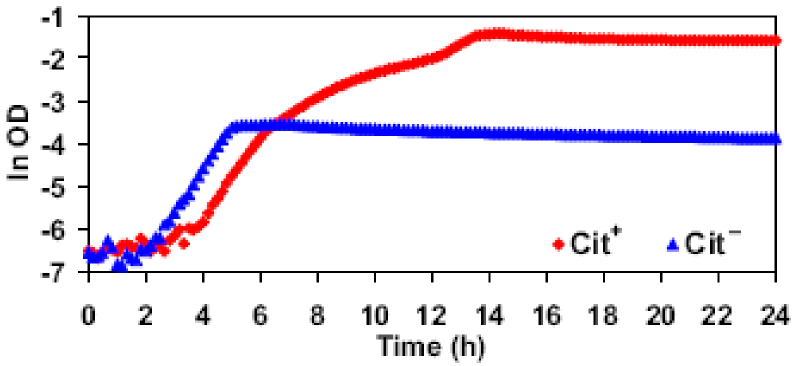
PROFESSOR STEPHEN JAY GOULD

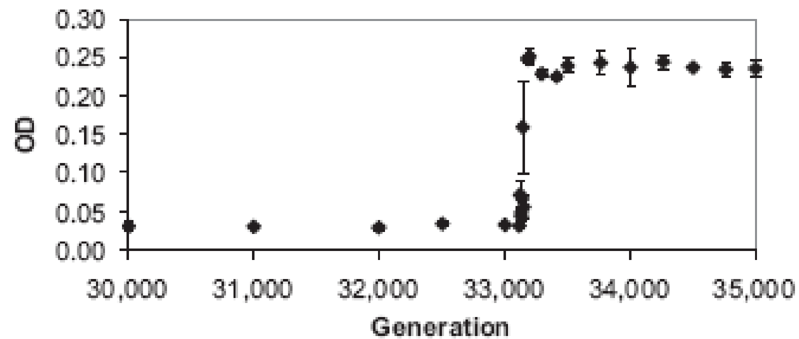
Historical contingency

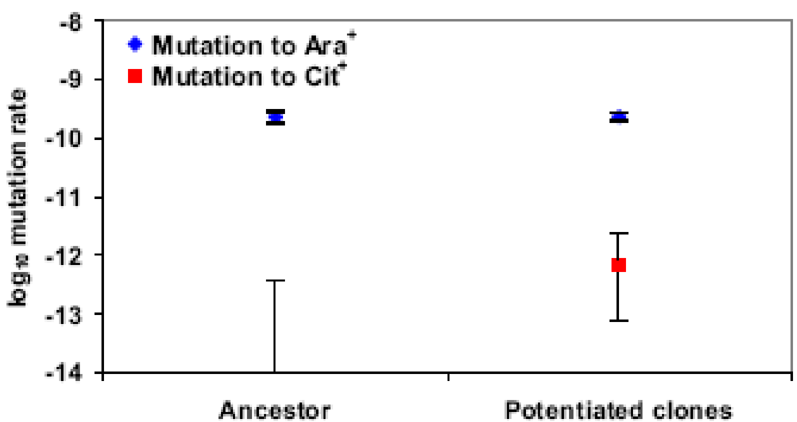
Historical contingency and the evolution of a key innovation in an experimental population of *Escherichia coli*

Zachary D. Blount, Christina Z. Borland, and Richard E. Lenski*

PNAS | June 10, 2008 | vol. 105 | no. 23 | 7899–7906

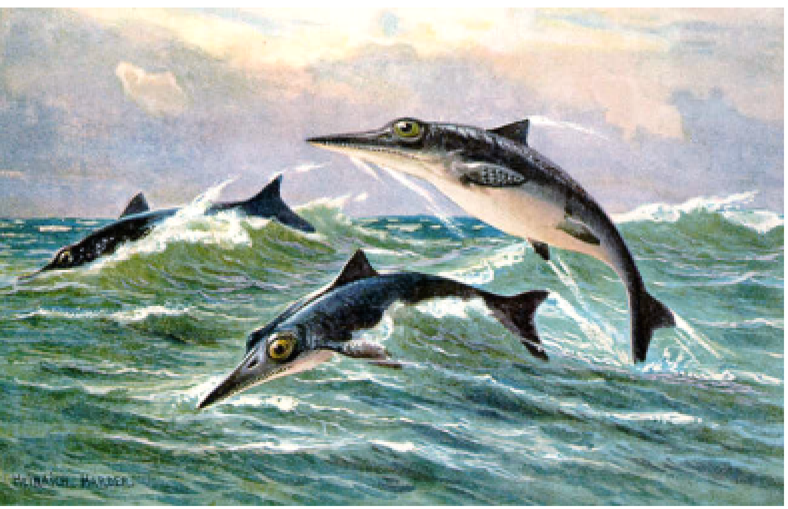






O (ne-)unikátnostnosti fenotypů

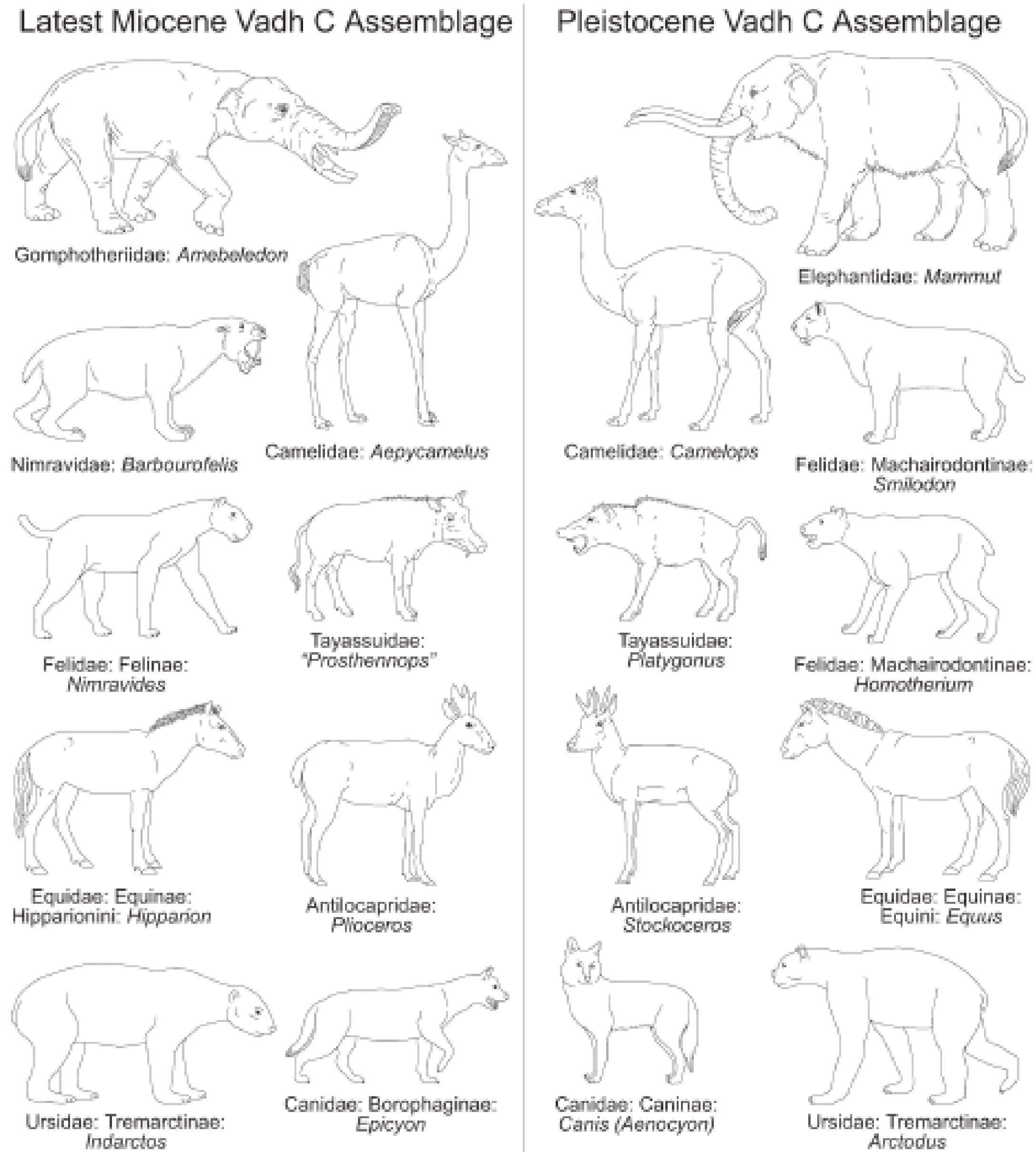
- konvergence



Naturwissenschaften (2005) 92:1–19

L. D. Martin · T. J. Meehan

Extinction may not be forever



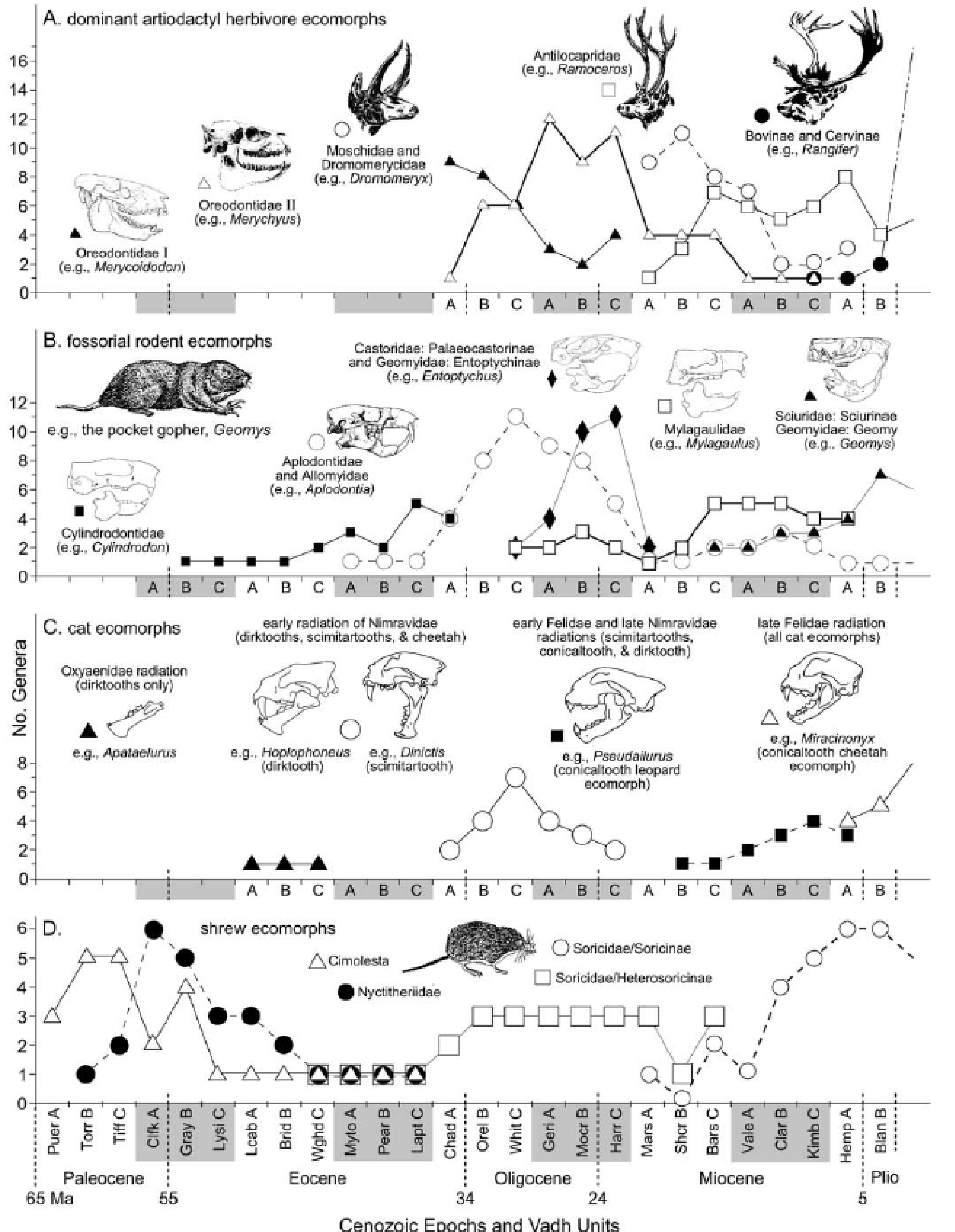
(Ne)unikátnost fenotypů

konvergence savčích společenstev
– odpovídají klimatickým cyklům

L. D. Martin · T. J. Meehan

Extinction may not be forever

Naturwissenschaften (2005) 92:1–19



O (ne-)unikátnostnosti fenotypů

Historical contingency and the purported uniqueness of evolutionary innovations

Geerat J. Vermeij*

Table 1. Times of origin of purportedly singular innovations

Innovation	Time of origin	Ref.
Origin of Earth's life	Before 3.5 Ga	8
Compartments (protocells)	Before 3.5 Ga	8
Universal genetic code	Before 3.5 Ga	6, 8
Coordinated chromosomal replication	Before 3.5 Ga	8
Oxygenic photosynthesis	3.5 Ga	17, 18
Formation of eukaryote	2.7 Ga	8, 19–21
Primary symbiosis between cyanobacterium and eukaryote	2.7 Ga	22
Sexual populations	1.2 Ga	23
Eumetazoan nervous system	600 Ma	24
Eumetazoan extracellular digestion	600 Ma	24
Bilaterian pattern formation	600 Ma	24
Cnidarian nematocysts	550 Ma	24
Triplobastian three-layered construction	550 Ma	24
Ecdysozoan molting	550 Ma	25
Echinoderm water-vascular system	550 Ma	26, 27
Brachiopod cyrtomatodont hinge	450 Ma	28
Land-plant seed	370 Ma	29
Amniote amnion	340 Ma	30
Arthropod wings	340 Ma	7, 31, 32
Chelonian turtle construction	225 Ma	11, 33
Theropod feathers	160 Ma	34, 35
Angiosperm endosperm	140 Ma	36
Human language	1 Ma	8

Details of initial conditions evolutionary pathways, phenotypes, and timing are contingent,
but important ecological, functional, and directional aspects of the history of life are replicable and predictable.

Table 2. Times of first instantiation of repeated innovations

Innovation	Time	Ref.
Fixation of CO_2 into organic compounds	Before 3.5 Ga	17
Nitrogen fixation	3.5 Ma	37
Aerobic respiration	2.7 Ma	17
Multicellularity	1.7 Ga	38, 39
Plant apical growth	650 Ma or earlier	23
Animal coloniality	550 Ma	40–42
Mineralized skeleton	550	13, 43
Planktotrophic larvae	550 Ma	44
Secondary symbiosis between plastids and eukaryotes	550 Ma	18, 45
Venom injection	540 Ma	1
Animal muscularized appendages	540 Ma	12
Molluscan operculum	520 Ma	46
Image-forming eyes	520 Ma	30, 47
Bivalved accretionary shell	520 Ma	46, 48
Arthropod conglobation	490 Ma	49
Gastropod siphonal indentation	450 Ma	46
Vertebrate teeth	435 Ma	50
Vertebrate mineralized endoskeleton	430 Ma	51
Plant vascular structure	435 Ma	52
Cemented bivalved shell	400 Ma	53
Arthropod silk production	390 Ma	54, 55
Plant differentiated megaspores	390 Ma	56
Plant leaves	390 Ma	57, 58
Trees and secondary growth	390 Ma	59
Insect stylet	390 Ma	60
Tetrapod ear	370 Ma	30, 61, 62
Land-plant vines	300 Ma	63, 64
Network leaf venation	300 Ma	57, 65, 66
C4 photosynthesis by land plants	300 Ma	30, 67
Insect asynchronous flight muscules	300 Ma	31
Tetrapod jaw propaliny	290 Ma	68
Tetrapod bipedalism	290 Ma	69
Tetrapod turbinates	260 Ma	70
Tetrapod secondary palate	260 Ma	70
Vertebrate gliding	260 Ma	71
Vertebrate endothermy	225 Ma	70
Tetrapod fully erect posture	225 Ma	72
Tetrapod wings	225 Ma	1
Crustacean crab form	180 Ma	73, 74
Mammalian middle earbones	180 Ma	75–77
Animal eusociality	125 Ma	78
Plant heat production	125 Ma	79
Plant alkaloids	125 Ma	80
Vertebrate placenta	125 Ma	30
Plant basal growth	90 Ma	1
Free-floating aquatic multicellular plants	80 Ma	1
Gastropod labral tooth	80 Ma	14
Excretion of molecular oxygen by fishes	80 Ma	81
Stereoscopic vision in tetrapods	80 Ma	82
Electrical sensation by fishes	80 Ma	30
Mammalian hypsodonty	60 Ma	83
Crab heterochely	60 Ma	49
Burrowing ratchet sculpture in bivalves	55 Ma	84
Sand-dollar eccentricity	10 Ma	85

O (ne-)unikátnostnosti fenotypů

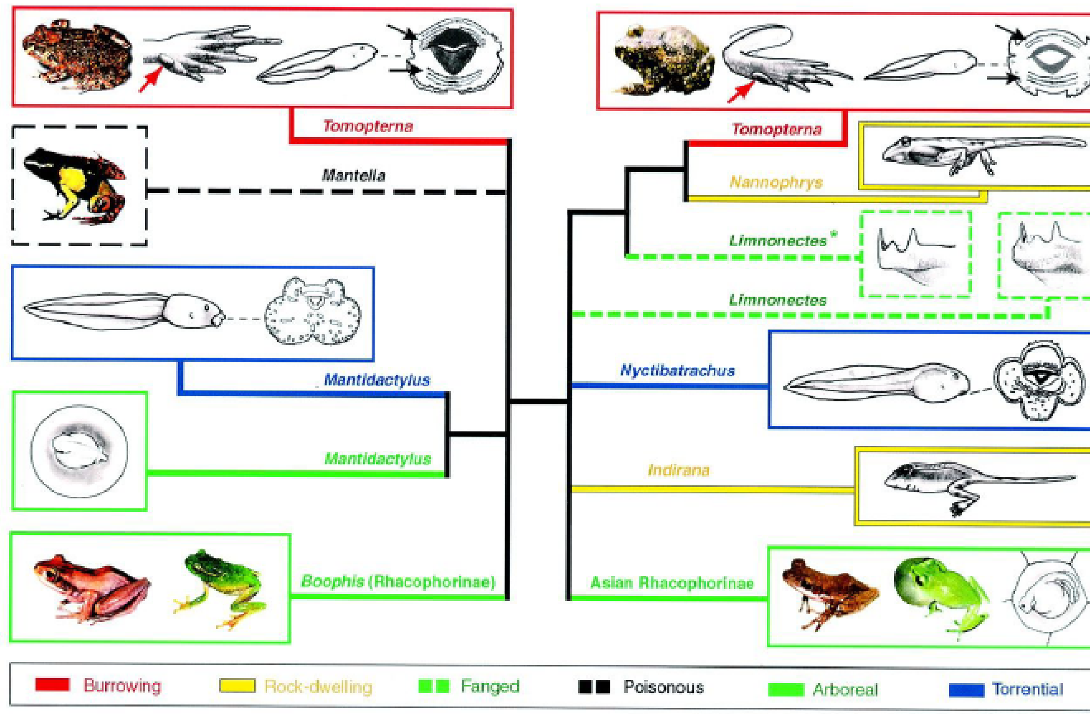
something very like a human is an evolutionary inevitability

Evolution: like any other science it is predictable

Simon Conway Morris*

Phil. Trans. R. Soc. B (2010) 365, 133–145

Convergences in larval and adult ecomorphs between and within Madagascan and Asian ranids

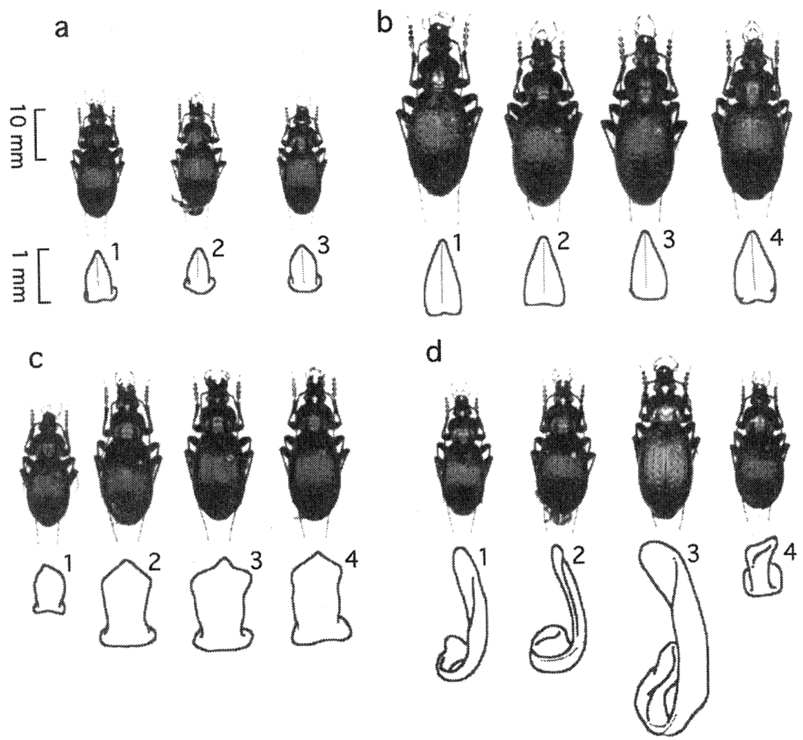


Convergences in larval and adult ecomorphs between and within Madagascan and Asian ranids. All Asian species are from the Indian subcontinent, except one (*Limnonectes kuhlii*, indicated by an asterisk) coming from Vietnam. Adult burrowing frogs (red boxes), beside having a toad-like general morphology and short hind limbs, exhibit a suite of characters [such as feet with a crescentic inner metatarsal tubercle (red arrows) and partly connected lateral metatarsals] that are adaptations to the fossorial zone. Their tadpoles have a general body shape and mouth parts [such as rows of keratinized teeth (black arrows)] which are of the typical ancestral aquatic type. Arboreal frogs (green boxes) exhibit similar adult ecomorphs in Madagascan and Indian Rhacophorinae. Some Asian tree frogs exhibit a development on land with complete metamorphosis in the egg, showing a remarkable convergence with some Madagascan arboreal species (*Mantidactylus*). Some rock-dwelling frogs (yellow boxes) have semiterrestrial larvae with stout hind-limbs, a strongly developed tail with much reduced fin membranes, and with the ventral side of the body and the spiracle tube (as well as, sometimes, the anal tube) flattened. Certain torrential frogs (blue boxes) have larvae that lack horny teeth and exhibit, around the mouth, enlarged lobes that are richly provided with papillae. Fanged frogs (dashed green boxes) have protruding fangs in the lower jaw. Although poisonous frogs do not occur in Asia, some poisonous mantellas (black dashed box) exhibit aposematic colors and are remarkably convergent with the neotropical poison arrow frogs, Dendrobatidae.

Bossuyt F., Milinkovitch M. C. PNAS 2000;97:6585-6590

PNAS

O (ne-)unikátnostnosti fenotypů - paralelismus



ig. 19.9. Four recurrent suites of traits in male carabid beetles (*Ohomopterus* species). Each s ontains a representative male of different species with similar size, genitalic structure, and oth hology. The copulatory piece (shown below each specimen) is a chitinous part of the male g a–c in dorsal view, d in lateral view). From Su et al. (1996). Courtesy of Z.-H. Su.

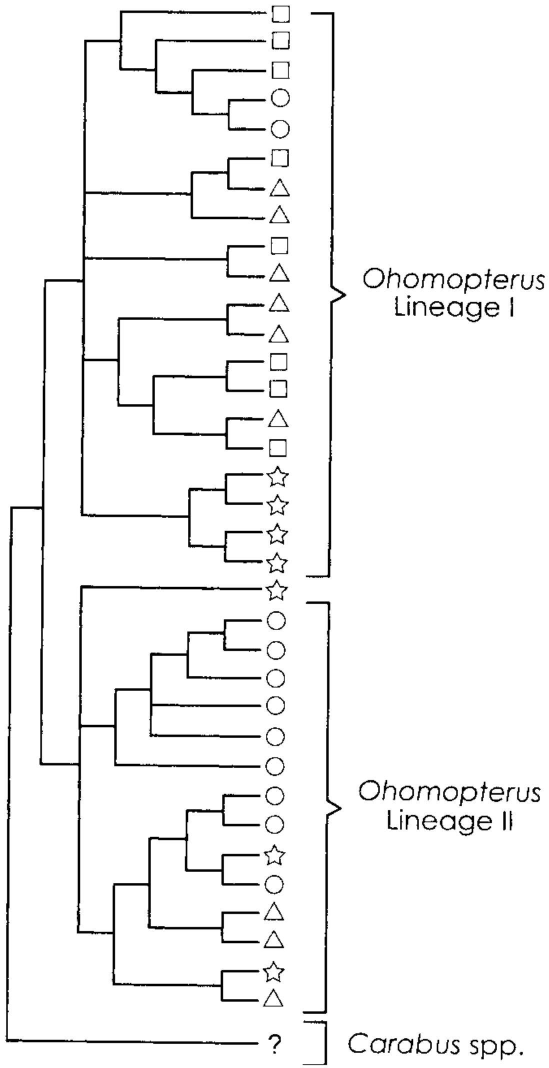


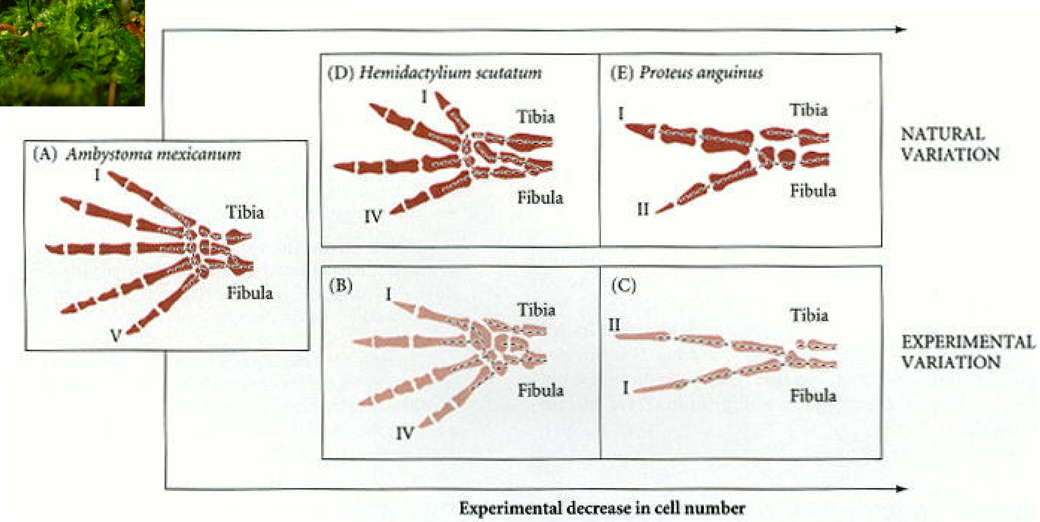
Fig. 19.10. "Type switching" in male carabid beetles (*Ohomopterus* species). The four suites of traits (a–d) shown in figure 19.9 recur independently many times, as shown on a molecular phylogeny of two major lineages of the genus *Ohomopterus*. Symbols correspond to groups of figure 19.9: a = squares; b = triangles; c = stars; d = circles. Phylogeny after Su et al. (1996).

O (ne-)unikátnostnosti fenotypů - paralelismus

From genes to phenotype: dynamical systems and evolvability

P. Alberch

Ocasatí: při redukci zachovány prsty I-IV



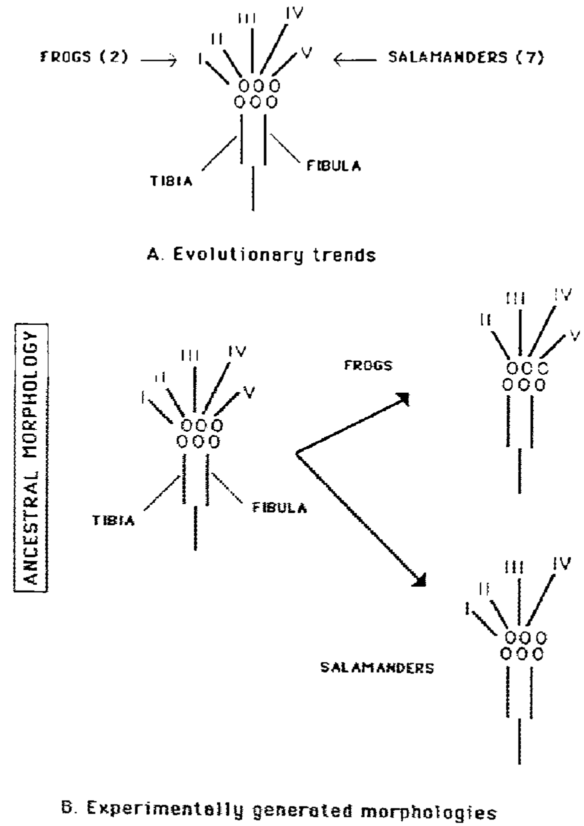
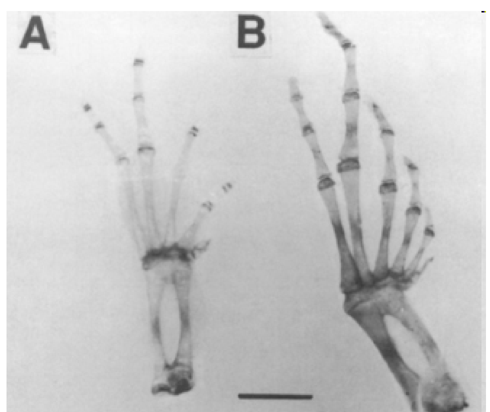


Fig. 6. An empirical approach to the study of ordered phylogenetic transformations. (A) Two anuran lineages have lost toes independently during phylogeny. In both cases the first toe ('the thumb') is the one that has been lost. In salamanders digital loss has occurred in at least seven independent cases during evolution. In all of the instances the forms have converged in the loss of the fifth toe; — (B) Identical treatment of an embryonic limb bud with a mitotic inhibitor with reversible effects results in the loss of pre-axial digits in frogs while salamanders lose post-axial elements. These differences in experimentally generated forms parallel observed evolutionary trends (from Alberch & Gale, 1985).

Žáby: při redukci zachovány prsty II-V

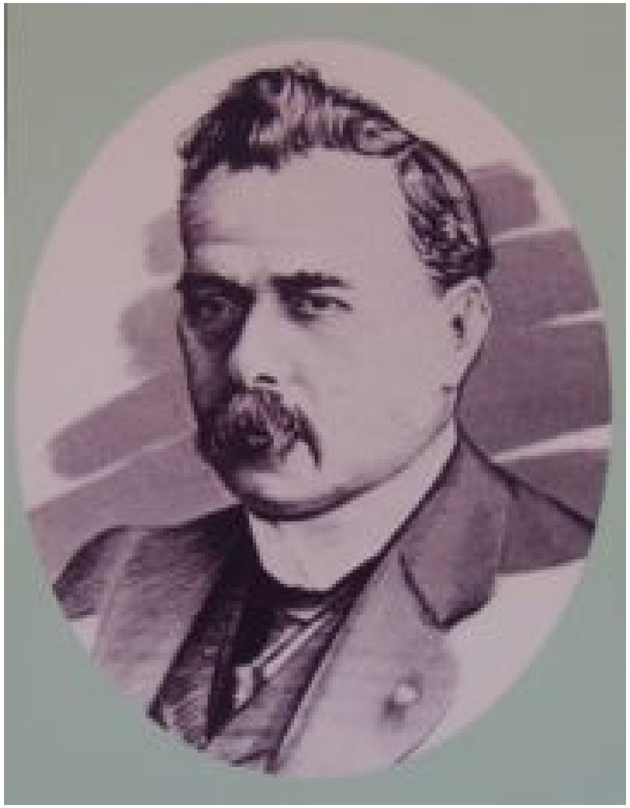


O (ne)unikátnost fenotypů

- re-evoluce, recurrence, reversals

Dollovo pravidlo

„Organismy se nemohou, a to dokonce ani částečně, vrátit do předchozího stavu, který charakterizoval jejich předky."



Louis Antoine Marie Joseph Dollo (1857-1931)

Jaký může být mechanismus Dollova pravidla?

Hen's teeth with enamel cap: from dream to impossibility

Jean-Yves Sire*[1], Sidney C Delgado[1] and Marc Girondot[2]

BMC Evolutionary Biology

- u ptáků úplná ztráta nebo ztráta funkčnosti genů spojených s enamelem (amelogenin, AMEL; ameloblastin, AMBN; enamelin, ENAM) a dentinem (dentin sialophosphoprotein, DSPP)

Kde platí Dollovo pravidlo?

REPTILIAN VIVIPARITY AND DOLLO'S LAW

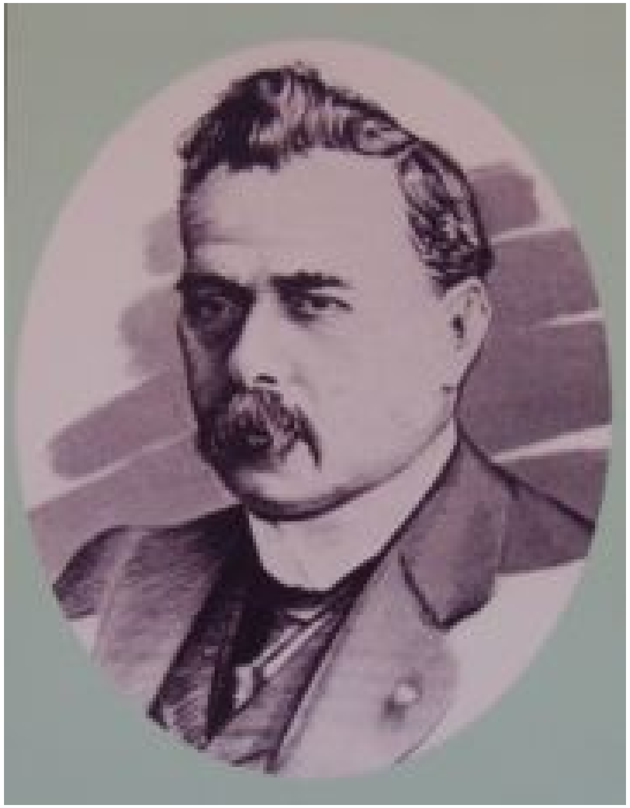
Michael S. Y. Lee[1,2] and Richard Shine[1,3]

Evolution, 52(5), 1998, pp. 1441–1450

- partenogeneze, živorodost, altricialita …

- reverze vyžaduje několik korelovaných změn podmíněných různými proximátními mechanismy (např. je možná indukce fertilních samců u partenogenetických teidů)

Jo, jo, vždyť jsem vám to říkal …



Louis Antoine Marie Joseph Dollo (1857-1931)

(Ne)unikátnost fenotypů

- re-evoluce komplexních orgánů

Loss and recovery of wings in stick insects

Michael F. Whiting*, Sven Bradler† & Taylor Maxwell‡

NATURE | VOL 421 | 16 JANUARY 2003 |

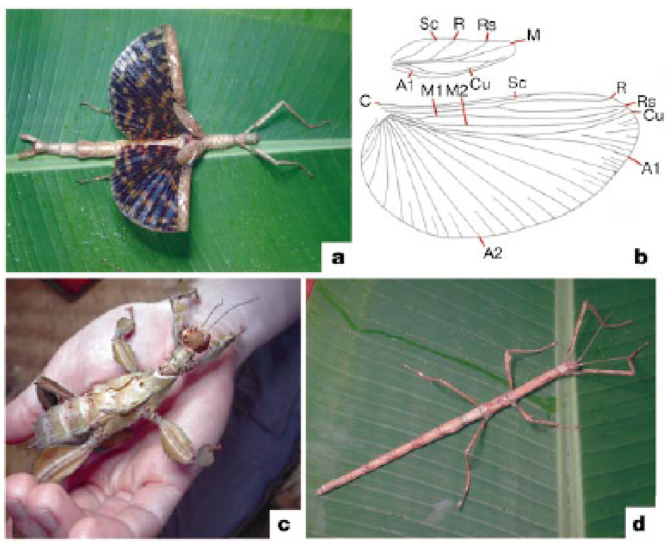
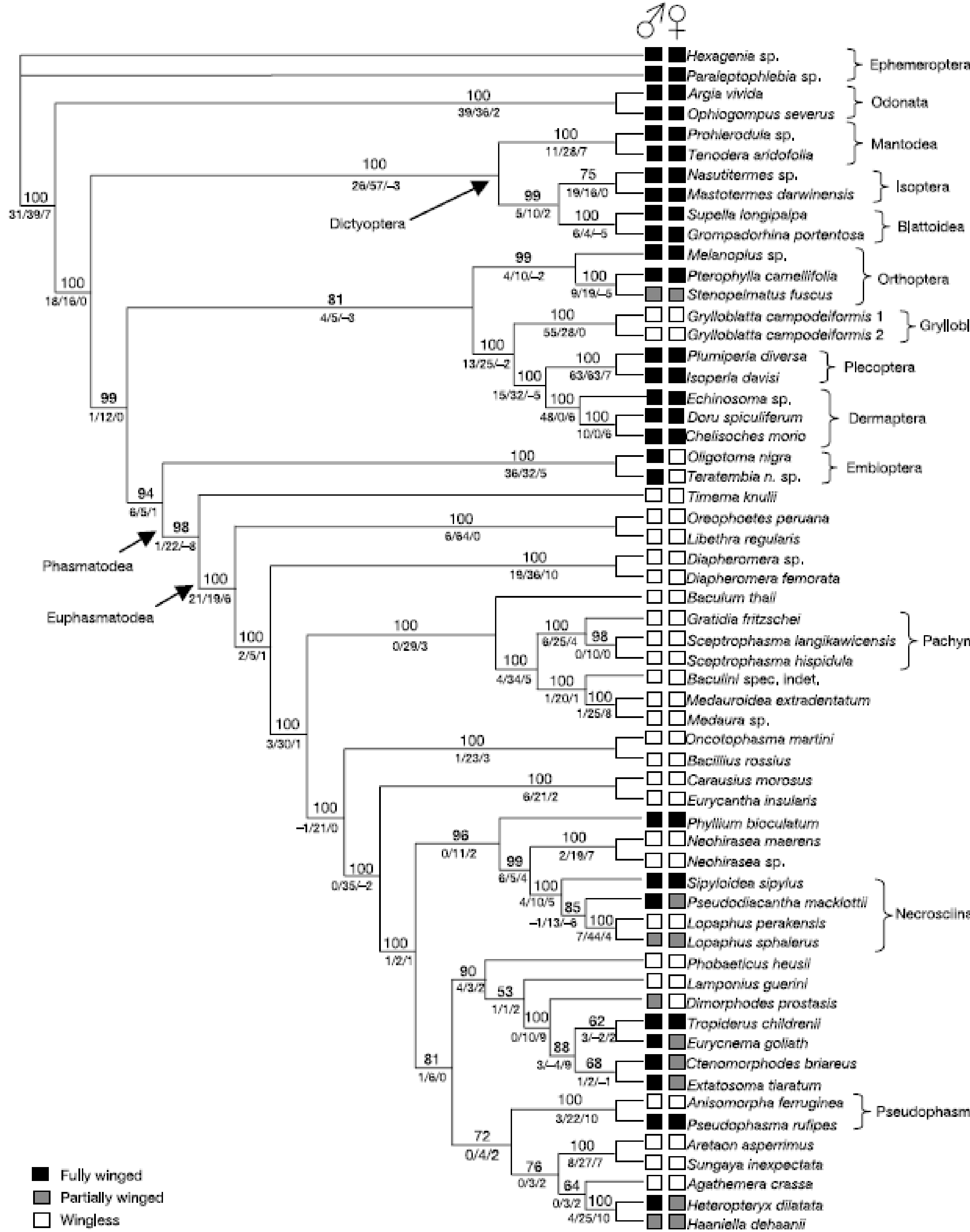


Figure 1 Examples of wing features in stick insects. **a**, Example of a fully winged (macropterous) female phasmid (*Phasma gigas*) with enlarged hindwings and thickened forewings. **b**, Wing venation of male *Phyllium celebicum* with major veins labelled, demonstrating homology with other insect wing veins. A, anal vein; C, costa vein; Cu, cubitus vein; M, medial vein; R, radius vein; Rs, radial sector vein; Sc, subcosta vein. **c**, Example of a partially winged (brachypterous) female phasmid (*Extatosoma popa*) with reduced hindwings. **d**, Example of a wingless (apterous) female phasmid (*Leprocaulinus* sp.) with wings entirely absent.

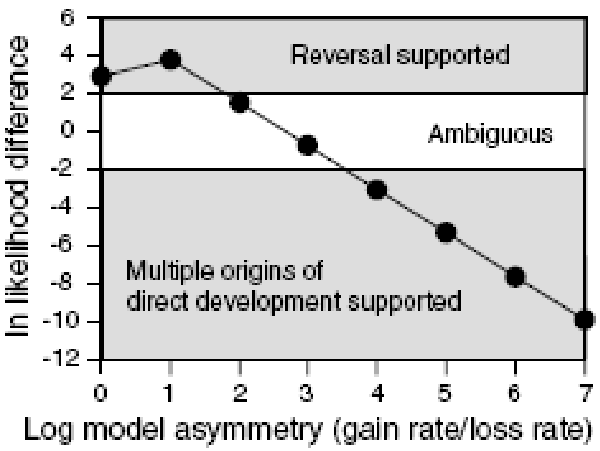


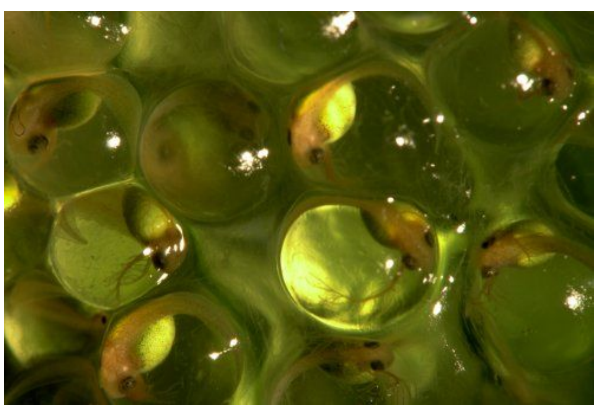
Jak testovat platnost Dollova pravidla? – fylogenetické srovnávací metody

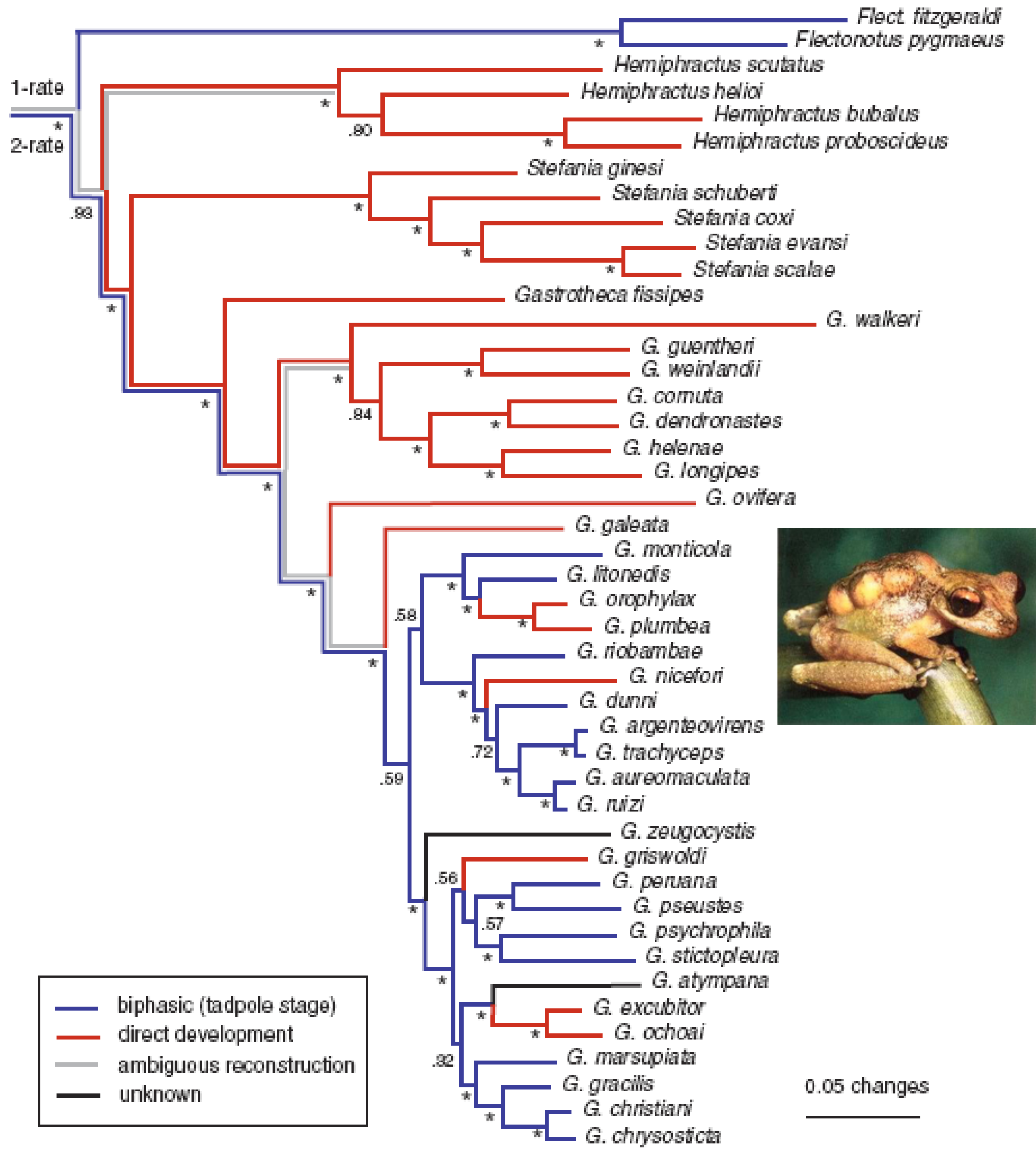
LOSS AND RE-EVOLUTION OF COMPLEX LIFE CYCLES IN MARSUPIAL FROGS: DOES ANCESTRAL TRAIT RECONSTRUCTION MISLEAD?

Evolution 61-8: 1886–1899

John J. Wiens,[1,2] Caitlin A. Kuczynski,[1] William E. Duellman,[3] and Tod W. Reeder[4]







Evolution, 60(9), 2006, pp. 1896–1912

Jak testovat platnost Dollova pravidla?

EVIDENCE FOR THE REVERSIBILITY OF DIGIT LOSS: A PHYLOGENETIC STUDY OF LIMB EVOLUTION IN *BACHIA* (GYMNOPHTHALMIDAE: SQUAMATA)

TIANA KOHLSDORF[1,2] AND GÜNTER P. WAGNER[1,3]

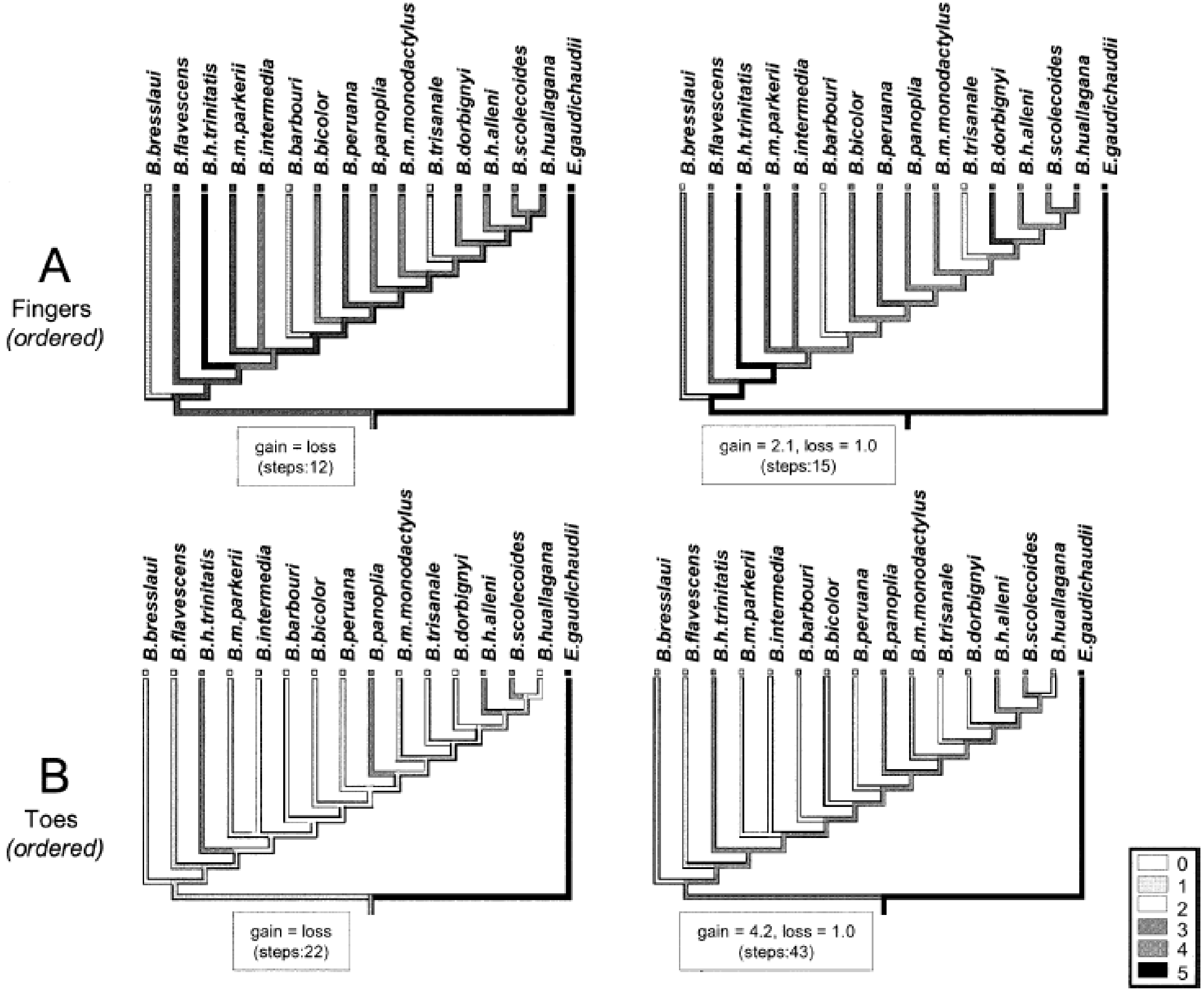


FIG. 2. Ancestral reconstructions of number of fingers (top panel) and number of toes (bottom panel) in *Bachia* species, based on the topology presented in Figure 1. On the left side reconstructions are based on the model where gains and losses of digits have the same weight. On the right side reconstructions follow models increasing the weight of digit gain, in relation to loss, until the point where gains are not observed anymore on the reconstructions. Number of evolutionary steps are shown within parentheses.

Jak testovat platnost Dollova pravidla?

Evolution, 60(9), 2006, pp. 1896–1912

EVIDENCE FOR THE REVERSIBILITY OF DIGIT LOSS: A PHYLOGENETIC STUDY OF LIMB EVOLUTION IN *BACHIA* (GYMNOPHTHALMIDAE: SQUAMATA)

TIANA KOHLSDORF[1,2] AND GÜNTER P. WAGNER[1,3]

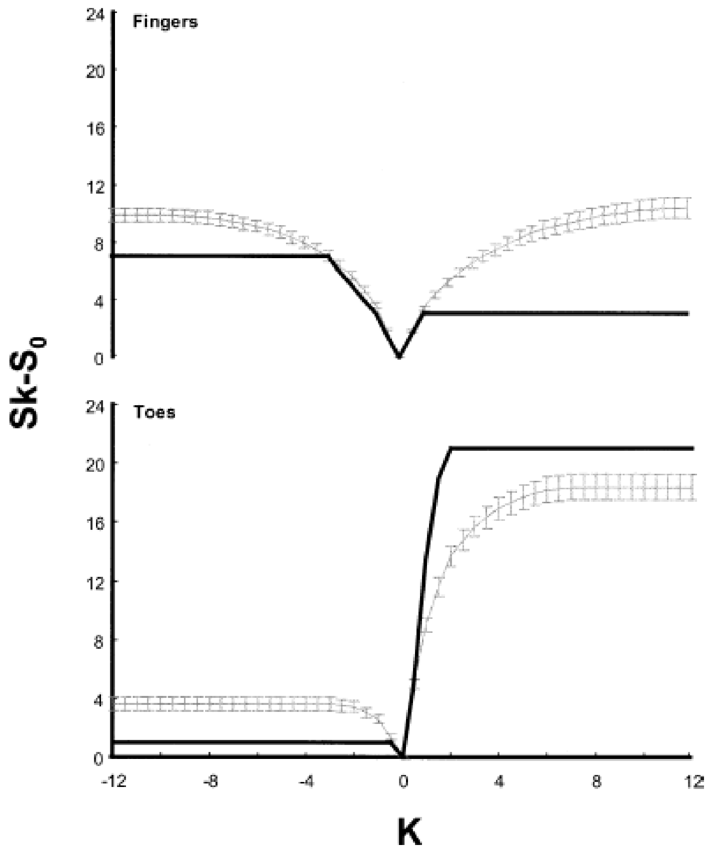
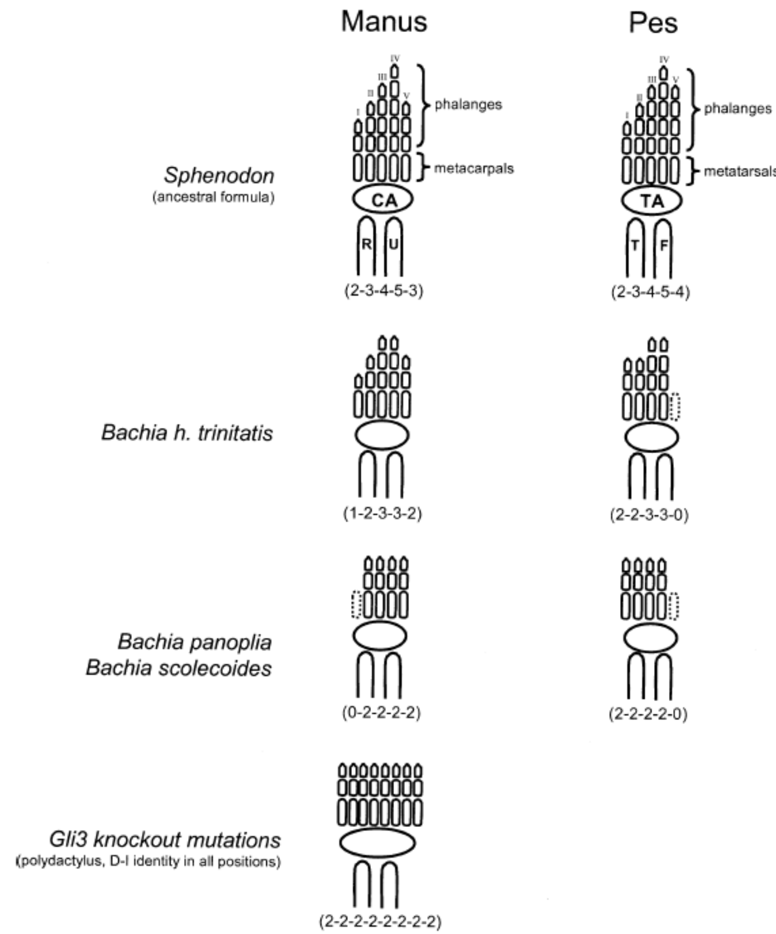


FIG. 3. Relationship between changes in cost of morphological changes (K) and the difference between number of total steps (S_K, under the model of gains and losses with different weights) and initial steps (S_0, under the model of equal weights for gains and losses). The graph on the top relates to fingers (forelimb) and the graph in the bottom relates to toes (hind limb). The thick line indicates results obtained under our proposed phylogeny (real data), and the thin line indicates mean ± standard error obtained from 50 permutations.



Jak testovat platnost Dollova pravidla?

DID EGG-LAYING BOAS BREAK DOLLO'S LAW? PHYLOGENETIC EVIDENCE FOR REVERSAL TO OVIPARITY IN SAND BOAS (*ERYX*: BOIDAE)

Evolution

Vincent J. Lynch[1,2] and Günter P. Wagner[1]

Figure 3. Parsimony-based character reconstructions. (A) Character state reconstruction under a reversible model that allows both transitions from oviparity to viviparity and from viviparity to oviparity. Viviparous lineages are in black and oviparous lineages are in white. This model requires three steps. (B) Character state reconstruction under an irreversible model that does not allow transitions from viviparity to oviparity. This model requires five steps.

Jaký může být mechanismus re-evoluce (porušení Dollova pravidla)?

atavismy
- spontánní
- experimentálně navozené
- fixované (taxické): *Amphignathodon* (zuby na mandibule), pavouci?

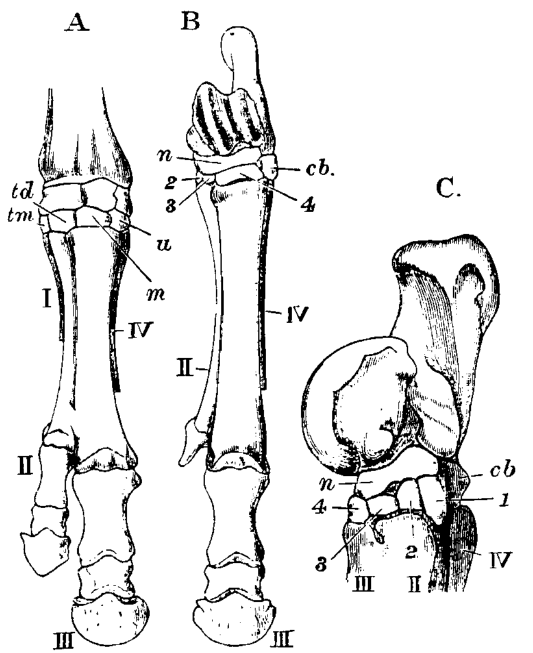


Fig. 12.2. Atavistic polydactyly in a modern horse: (A) left fore foot; (B) left hind foot; (C) tarsus of right hind foot from the inside. I–IV, bones homologous to metacarpals I–IV. Other labels indicate navicular (n), cuboid (cb.), trapezoid (td), trapezium (tm), unciform (u), magnum (m), ectocuneiform (4) and cuneiform (1–3) bones. From Bateson (1894).

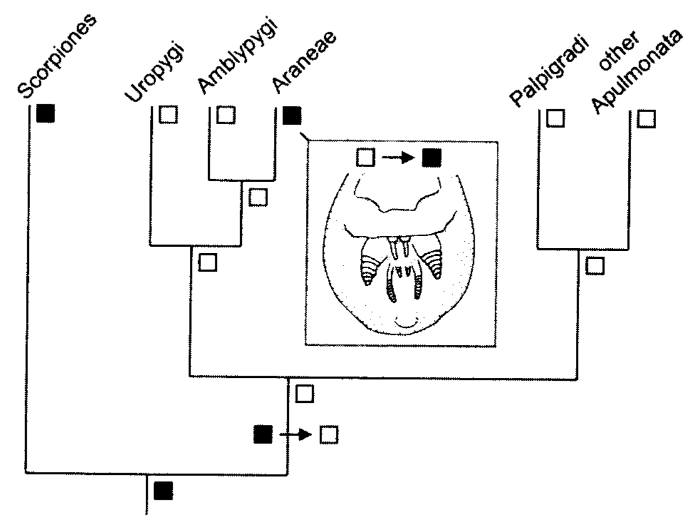
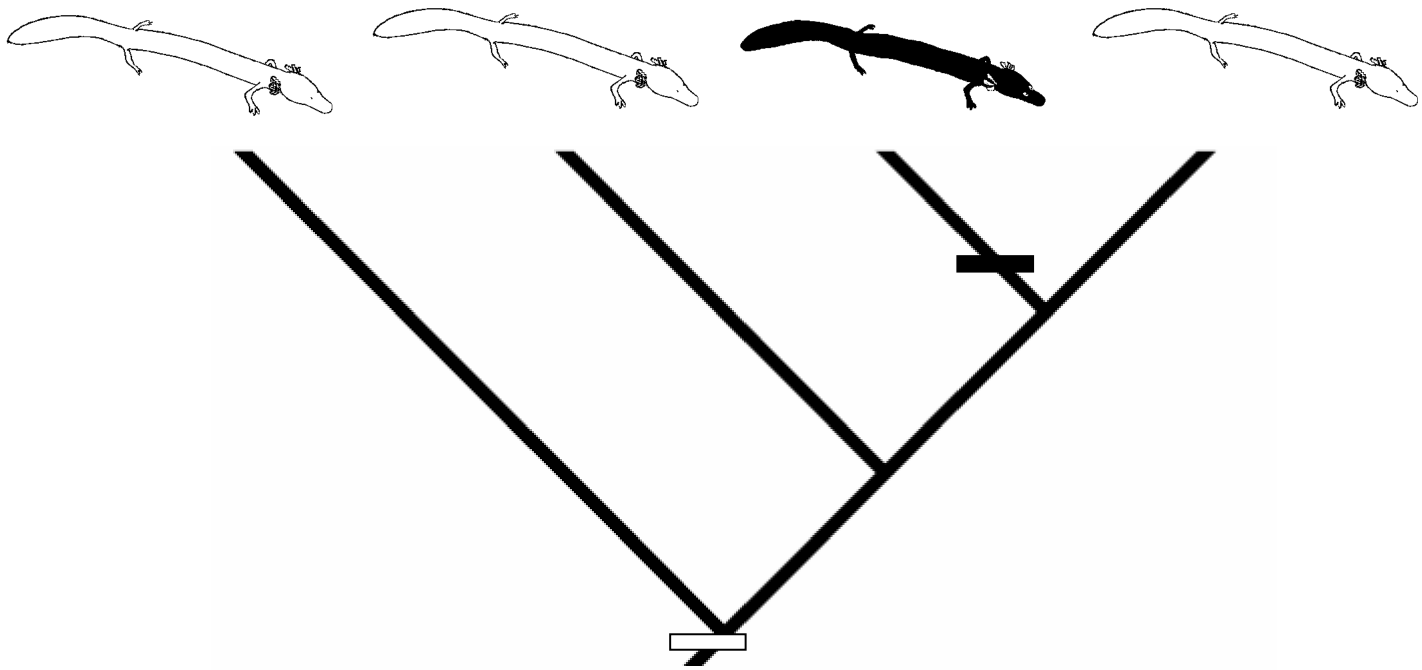


FIGURE 1. Intrarelationships of arachnid orders after Schultz (1986). Superimposed onto the scheme are the hypothesized character state changes. Black squares indicate the presence of opisthosomal appendages in adults, and white squares indicate their absence. Here the presence of opisthosomal appendages in Araneae is recognized as an example of taxic atavism. Inset illustrates opisthosomal appendages in ventral view of *Liphistius*, a primitive spider. Modified from Stiassny (1992).

Jaký může být mechanismus re-evoluce (porušení Dollova pravidla)?

fenotypová plasticita a změna prostředí



Souhrn

- pojmy fenotyp, rozšířený fenotyp, genotyp
- evoluce je historický jev, evoluční biologie proto nutně musí balancovat mezi zkoumáním jednotlivostí a hledáním obecností
- v evoluci docházelo ve značné míře ke konvergentní a paralelní evoluci podobných organismů (např. k opakovanému vyvinutí ekomorf), konvergentně mohla vznikat i celá společenstva
- re-evoluce některých znaků v určité linii se zdá nepravděpodobná (Dollovo pravidlo), ale někdy došlo ke ztrátě a následné re-evoluci celého orgánu či orgánové soustavy
- re-evoluce komplexních znaků ztracených u předka vs. alternativní vysvětlení mnohem častějších ztrát než znovunabytí znaku se dá statisticky testovat pomocí fylogenetických srovnávacích metod, vždy však záleží na naší víře v nepoměr mezi rychlostmi přechodu v každém směru
- pro re-evoluci však někdy také hovoří další nepřímé důkazy (relativně málo komplexní změny potřebné k re-evoluci, rozdíly ve znaku podezřelém z re-evoluce proti původnímu stavu)
- některé případy re-evoluce lze vysvětlit zafixováním atavismu či změnou prostředí vyvolané změně fenotypu