# Convergent evolution: concepts, database, roadmap and case studies

Isabelle Hue, Justine Dardaillon, Pierre Pontarotti, George Mc Ghee

# Convergent Evolution: concepts, database, road map and case studies


## Isabelle Hue, Justine Dardaillon, Pierre Pontarotti & George McGhee

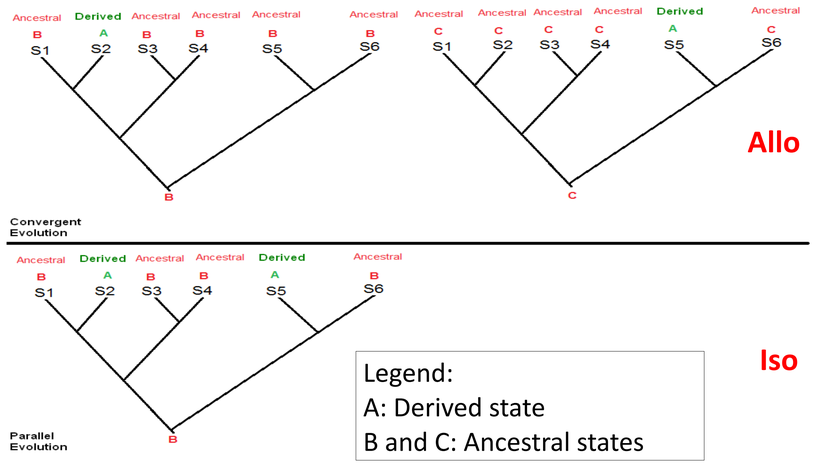
### UMR 1198, BDR, INRA; I2M, UMR AMU, CNRS 7373; Rutgers University, USA



**Abstract**

Most of the authors studying convergent evolution think about the apparition of a similar phenotype in two evolutionary independent lineages (Conway Morris 2003, McGhee 2011, Losos 2011, Gordon et al 2015). From this broad definition authors focused on case studies: echolocation (Parker et al 2013) or repetitive adaptations of marine mammals (Foote et al 2015). However, cases of "repetitive similarities" should be defined in a better way.

We so far: **1)** proposed **neologisms** that can apply to any biological level**: allo-convergent**, **iso-convergent** and **retro-convergent** evolution (both retro-iso and retro-allo). This is important since, in the case of **iso-**convergent evolution, one can suspect that the underlying molecular mechanism(s) could be similar (Stern and Orgozozo 2008). Such cases could then be used as meta-models (Kopp 2009) to decipher biological mechanisms at genetic, epigenetic, transcriptional or any biological level, 2) initiated the development of the **LEIA database** to store reported cases of convergent evolution at the phenotypic level and sort out cases of iso-convergence, 3) developed **a road map** to study these cases at different biological levels, and 4) illustrate cases of : dorsal or pectoral fin re-evolution , cuticule evolution and ovi-/vivi- parity transition (in mammals or amniotes).


**Allo-** and **Iso-** convergence at the phenotypic level

**The current use of the *parallel* and *convergent* evolution is confusing**

This came from the fact that: most authors gave sub-definitions based on the genetic mechanisms involved in the evolution of the convergent evolving character, while others used a phylogenetic-based definition

**We proposed instead the use of**

**Iso- & Allo- Convergence**

**Iso:** from the same ancestral state

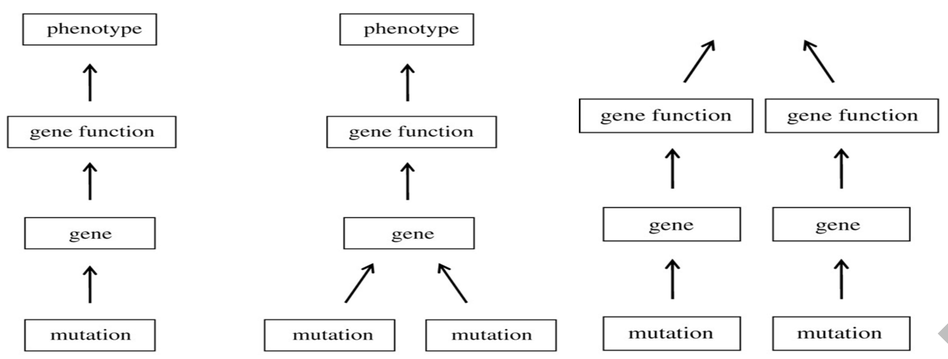
**Allo:** from a different ancestral state

**Retro- Convergence**

For the re-evolution of a lost character in two (or several ) sister species

**Retro-Iso:** from the same ancestral character

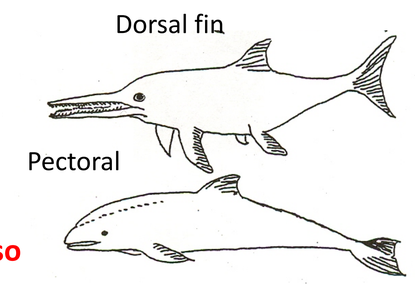
**Retro-Allo**: from a different character




**Iso** Convergence **at multiple biological levels**

**Retro-Iso**convergence (pectoral fins of ichthyosaur and dolphin, re-evolved by modifying tetrapod forelimbs with penta-dactylus bone arrangements in both species
*Ichthyosaur: reptile, extinct*
*Porpoise: mammal*

**Retro-Allo**




**Retro-Allo**convergence (dorsal fins of ichthyosaur and dolphin: i) in ichthyosaurs, re-evolution of rope-like structure of fine filaments, ii) in dolphins, of soft tissue with core placements of the blood vessels

## LEIA Database :

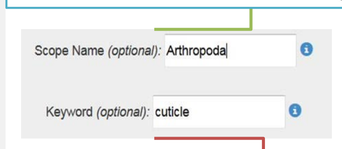
**L**eveled **E**vents **of I**so and Alloconvergence evolution **Database**

The LEIA Database is a **multi-level database.** Its different levels spread from the genotype to the phenotype, each one can be linked to one another.

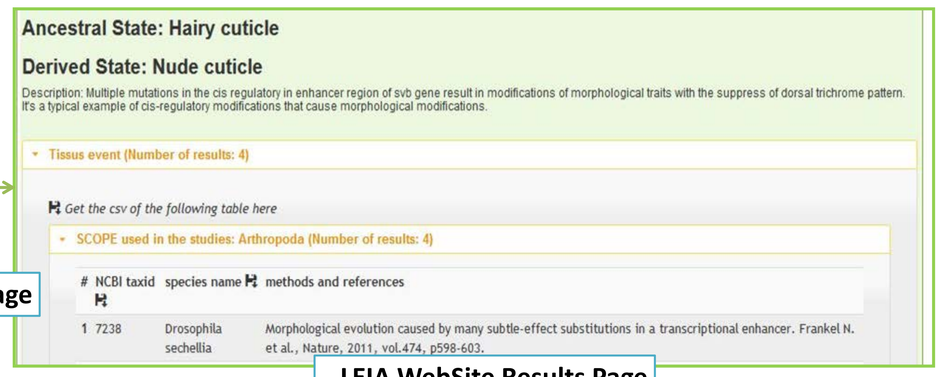
With an **interactive** and **easy-to-use visual interface**, the user can search for iso- and alloconvergences at morphological and/or genetic level and see the potential link between these two levels.

**Morphological Iso** convergence research

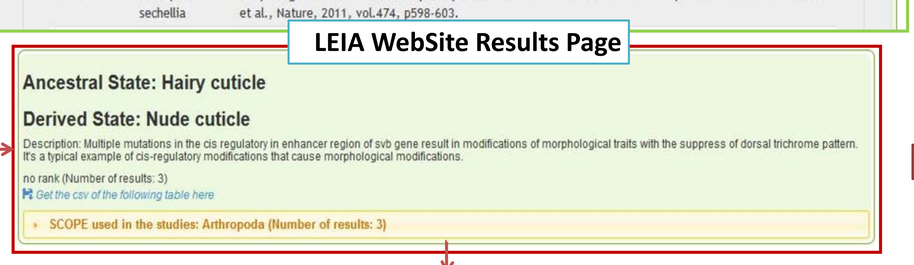
**LEIA WebSite Research Page**




**Genetic Iso** convergence research

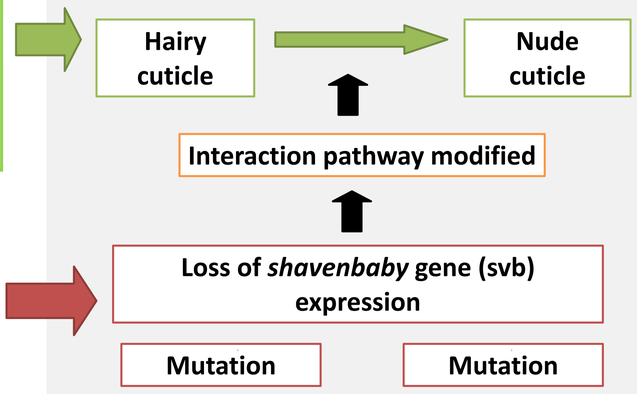



**LEIA WebSite Results Page**

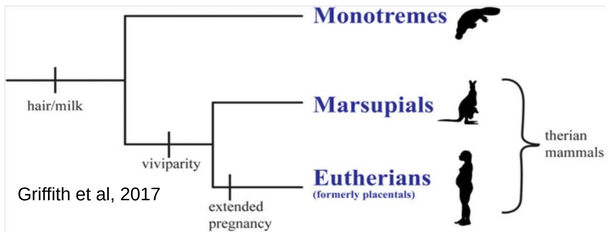



**Downloadable CSV files : indel/substitution event of candidates/known genes linked to the event**

Genetic changes in *shavenbaby*'s **promoter** lead to the apparition of **nude cuticule** in two different phyla of Drosophila (*D. melanogaster* and *D. littoralis*; Frankel et al., 2011)



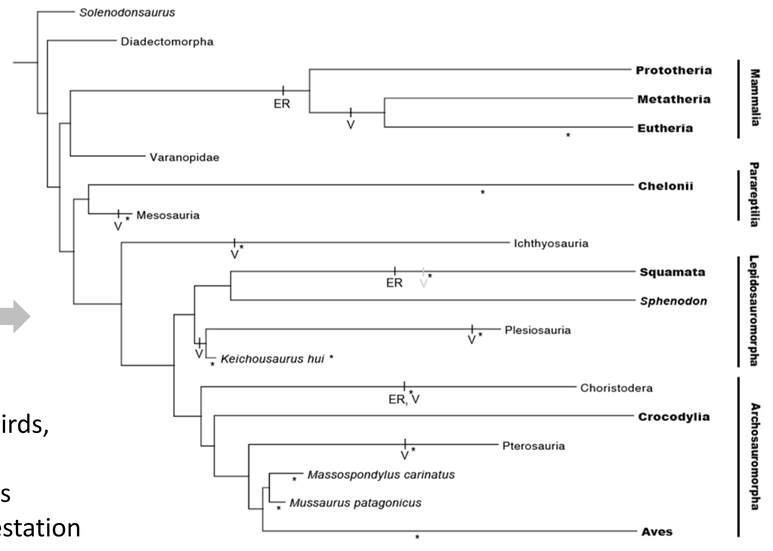

Pre-attachment, attachment, parturition (Opossum)
Pre-attachment, implantation, **extended pregnancy, parturition (**Human)




Mammals

**Ovi- /Vivi-** parity

Amniotes



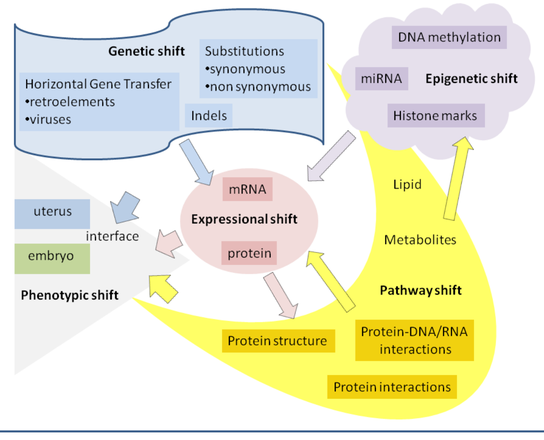

The ancestor was **oviparous** and laid **eggs** with a **solid shell** (still evidenced by birds, crocodiles, chelonians)

The **same evolutionary events** occurred repetitively in the evolution of Amniotes (**Morphological Iso** convergence): the **eggs** became **retained** until around mid-gestation and the **egg shell** became **softer** (ER: Egg Retention).

***** earliest fossiled embryos along each branch of the tree

**Different biological levels** and/or **mechanisms** possibly involved: **Iso- / Allo- convergence?**

**Another** evolutionary **novelty** occurred **once** in the common ancestor of eutherians and metatherians, **three times** in the squamates: the complex viviparity (V). This corresponds to:
i) loss of the the egg shell,
ii) interaction between the uterus and the embryo (attachment/implantation; see Griffith et al, 2017)
iii) angiogenis
iv) immunosuppression ( to prevent the immune response of the mother and the rejection of the embryo)





. Conway Morris. Life's Solution: Inevitable Humans in a Lonely Universe, Martin, The Loci of repeated evolution: a catalog of genetic hotspots of phenotypic variation. Evolution. 2013,67:1235-50.
. McGhee, Convergent Evolution: Limited Forms Most Beautiful. The MIT Press, Cambridge, 2011.
. Parker, Genome-wide signatures of convergent evolution in echolocating mammals, Nature. 2013,502(7470):22831
. Stern, The loci of evolution: how predictable is genetic evolution? Evolution. 2008, 62:2155-77
. Frankel N. et al, Morphological evolution caused by many subtle-effect substitutions in a transcriptional enhancer. Nature, 2011, vol.474, p598-603.
. Foote, Convergent evolution of the genomes of marine mammals, Nat Genet. 2015, 47:272-5
. Gordon, Can systems biology help to separate evolutionary analogies (convergent homoplasies) from homologies? Prog Biophys Mol Biol. 2015, 117:19-29.
. Griffith, Embryo implantation evolved from an ancestral inflammatory attachment reaction, PNAS July 2017
. Losos, Convergence, adaptation, and constraint. Evolution. 2011, 65:182740
. Krassilov, VA, *Scytophyllum* and the origin of angiosperm leaf characters. Paleontological 1995, 29: 63
. Zhong Q et al, An inter-species protein-protein interaction network across vast evolutionary distance, Mol Syst Biol 2016, 12:865
. Choate LA et al, Poised for development, Nat Genet, 2016, 48:222