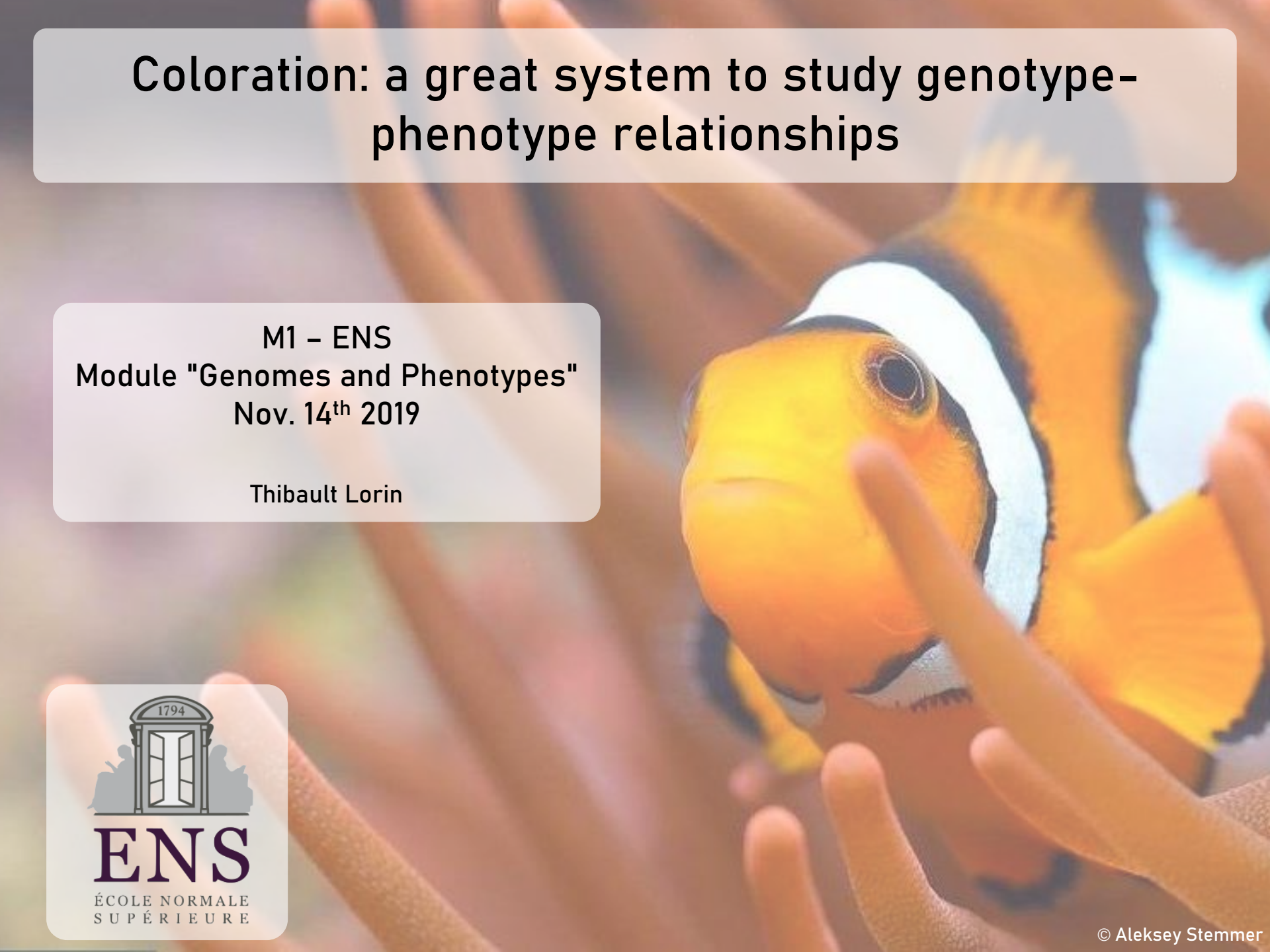
Coloration: a great system to study genotype-phenotype relationships

M1 – ENS
Module "Genomes and Phenotypes"
Nov. 14th 2019

Thibault Lorin



(No lab)

UNIVERSITÉ DE LYON

ENS DE LYON

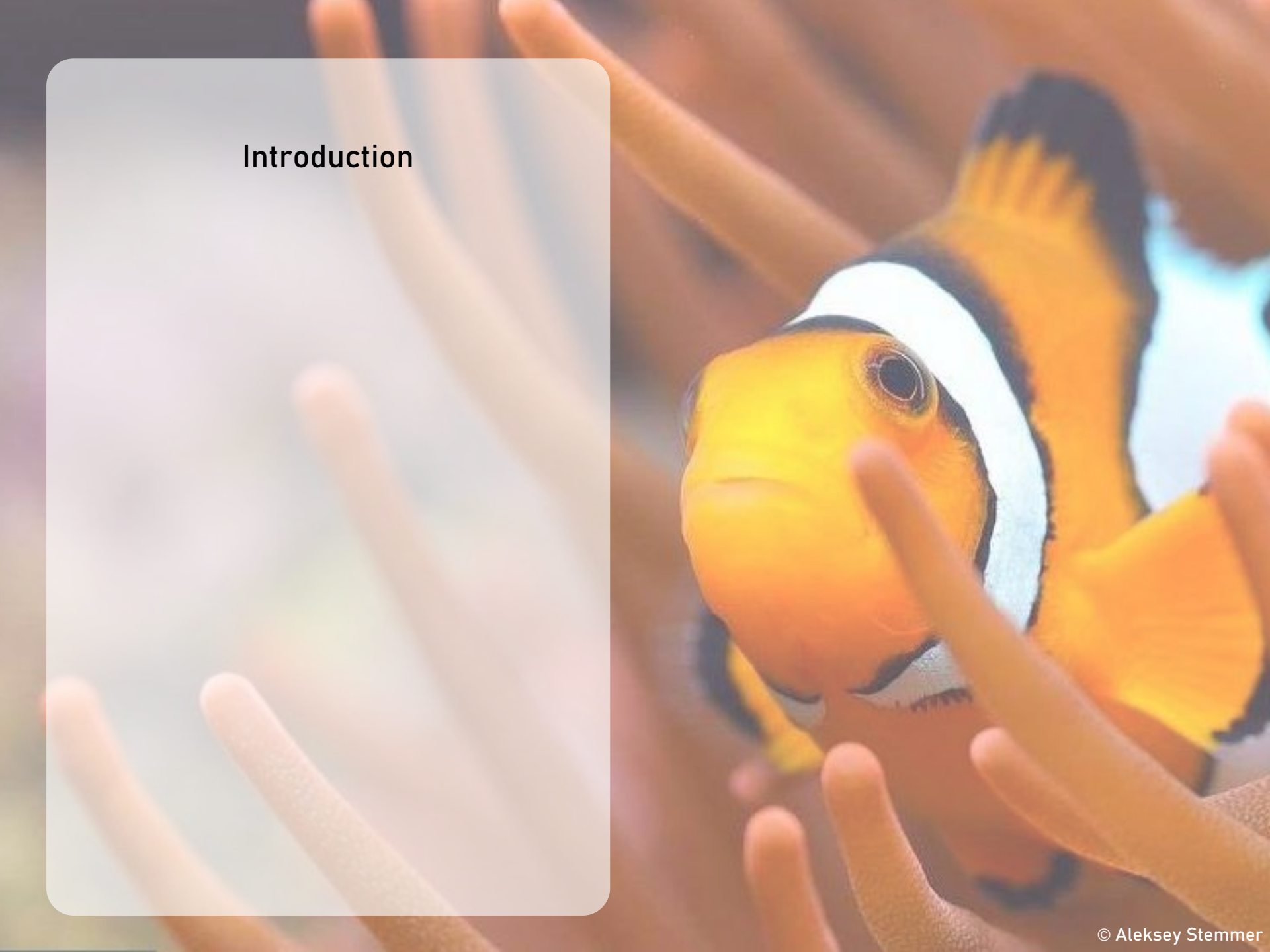
Institut de **Génomique Fonctionnelle** de Lyon

OBSERVATOIRE OCÉANOLOGIQUE de Banyuls/Mer 1882

Laudet's lab

Volff's lab

Introduction



"Coloration" or "pigmentation"?

"Structural colors"

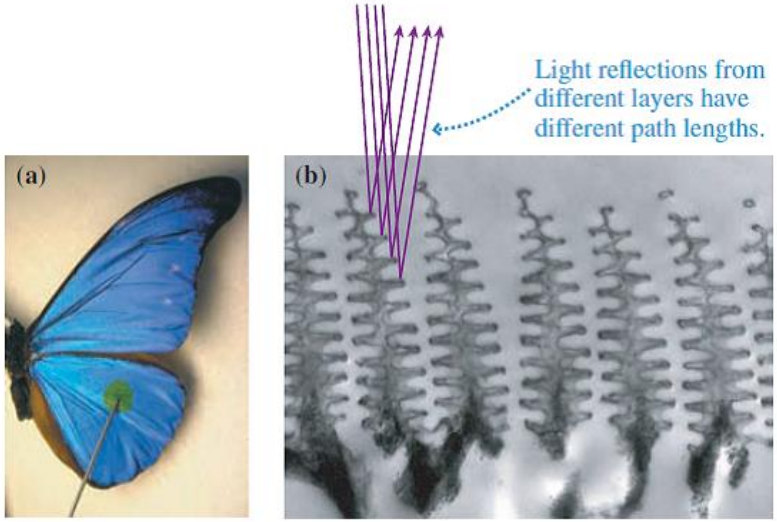
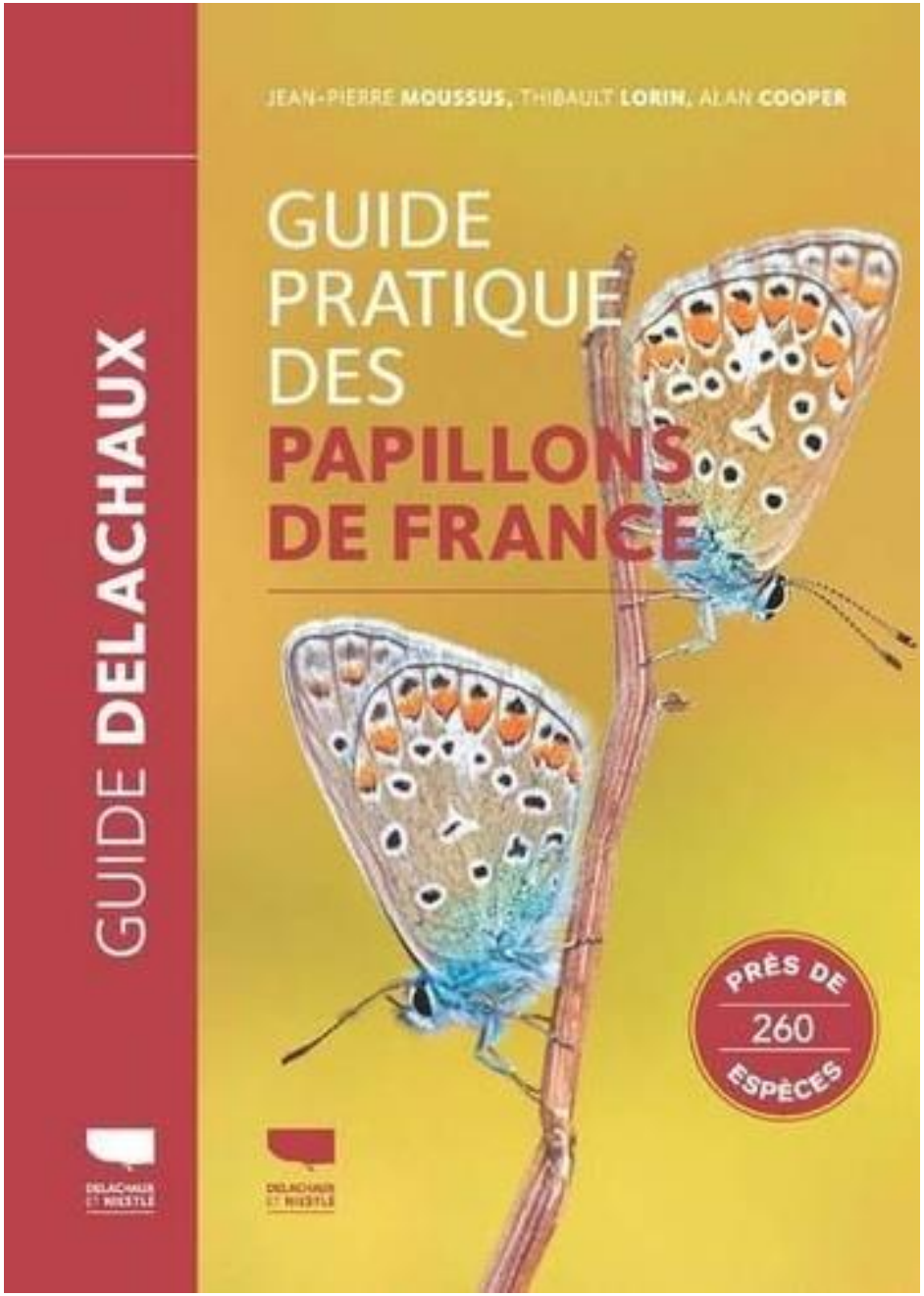


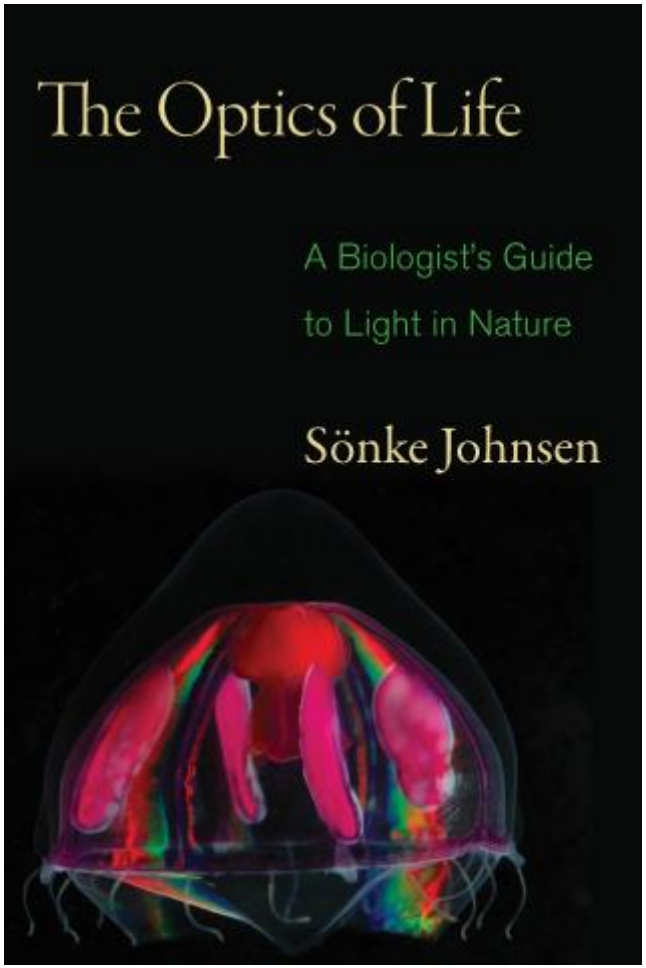
FIGURE P17.73


AVAILABLE NOW
AVAILABLE NOW
AVAILABLE NOW


JEAN-PIERRE MOUSSUS, THIBAULT LORIN, ALAN COOPER
GUIDE DELACHAUX
GUIDE PRATIQUE DES PAPILLONS DE FRANCE
PRÈS DE 260 ESPÈCES
DELACHAUX ET NIESTLÉ
DELACHAUX ET NIESTLÉ

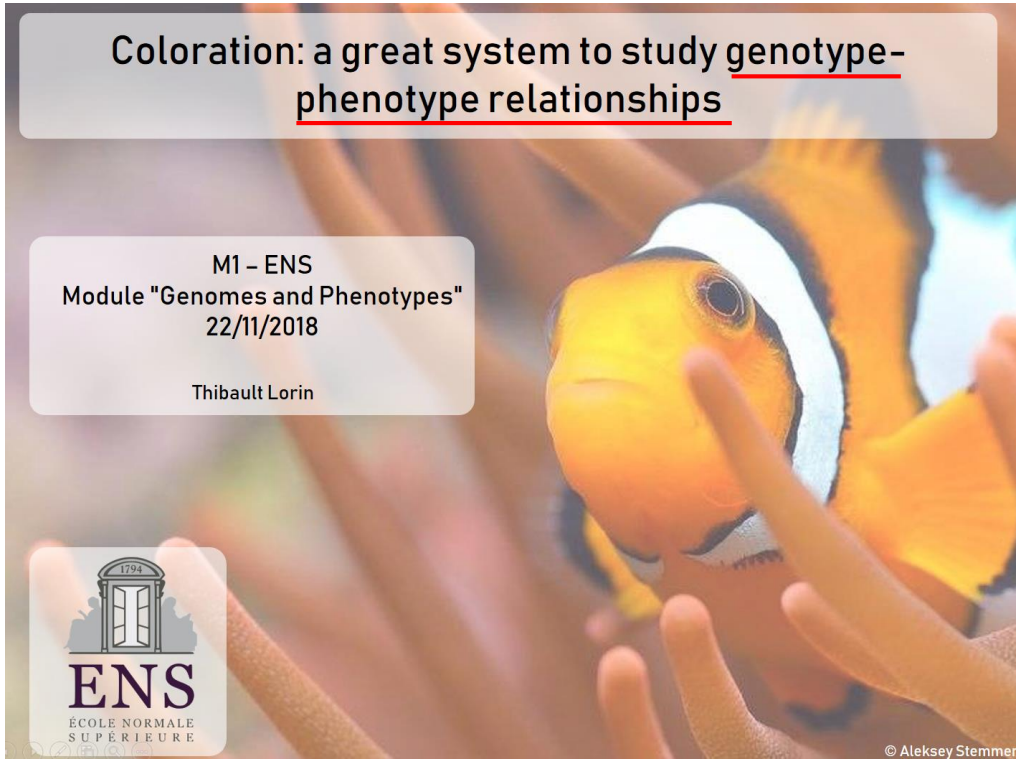
"Coloration" ≠ "pigmentation"

"Coloration" ≠ "pigmentation"



2011

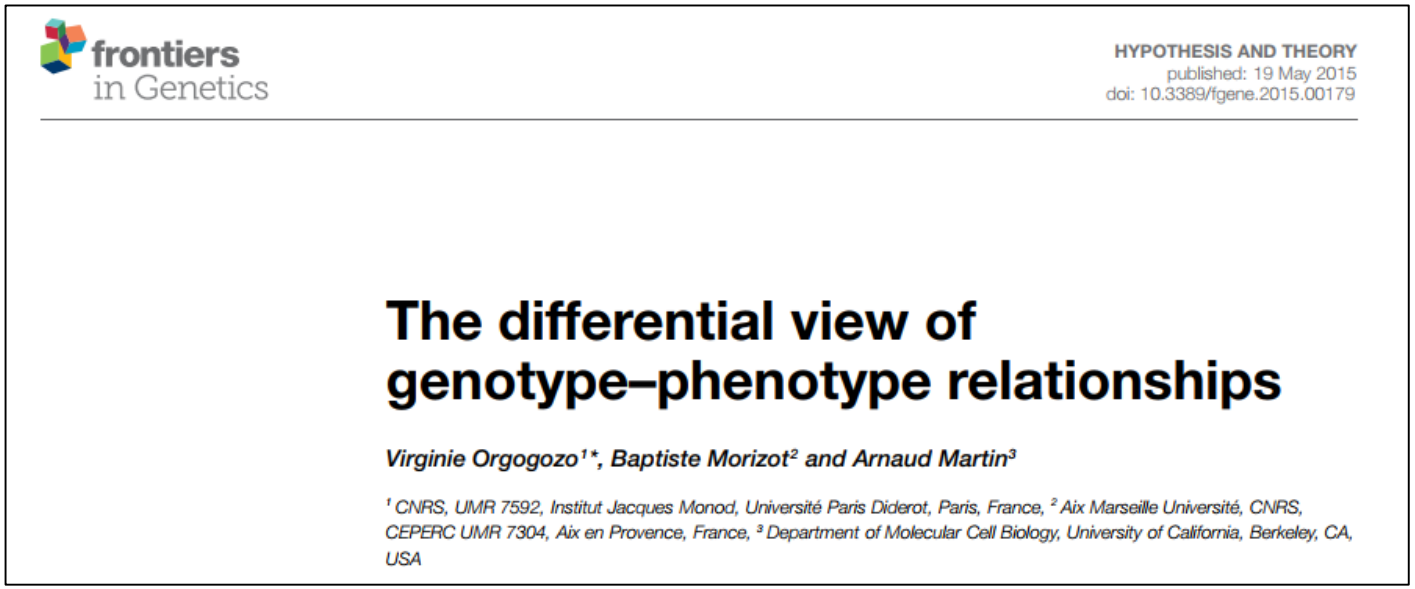
Genotype-phenotype relationships



Relationships between genes and the phenotype, and their modulation by the environment

Genotype-phenotype relationships

(more detail and info here)



frontiers in Genetics

HYPOTHESIS AND THEORY
published: 19 May 2015
doi: 10.3389/fgene.2015.00179

The differential view of genotype–phenotype relationships

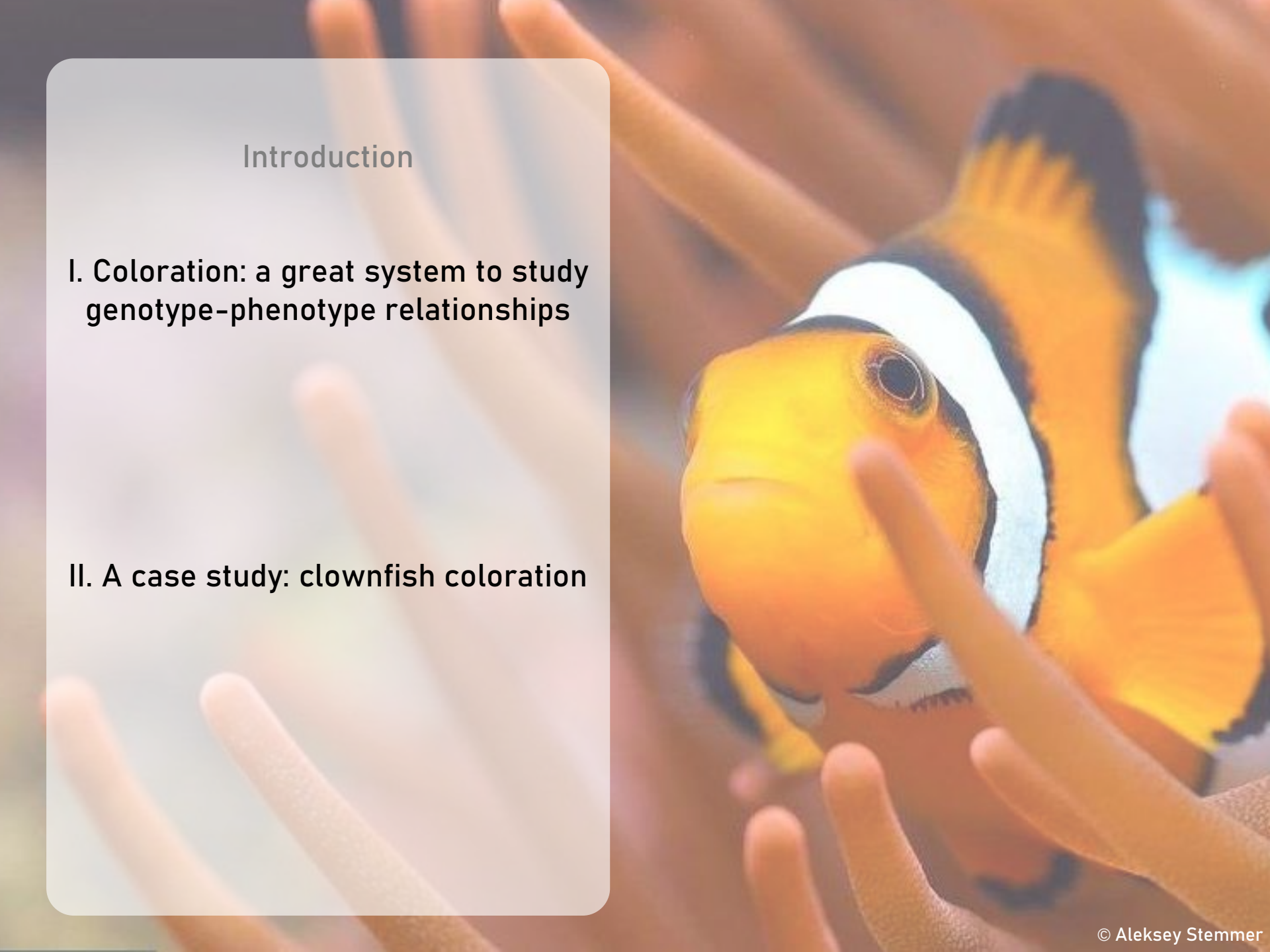
Virginie Orgogozo[1], Baptiste Morizot[2] and Arnaud Martin[3]*

[1] CNRS, UMR 7592, Institut Jacques Monod, Université Paris Diderot, Paris, France, [2] Aix Marseille Université, CNRS, CEPERC UMR 7304, Aix en Provence, France, [3] Department of Molecular Cell Biology, University of California, Berkeley, CA, USA

Introduction

I. Coloration: a great system to study genotype-phenotype relationships

II. A case study: clownfish coloration

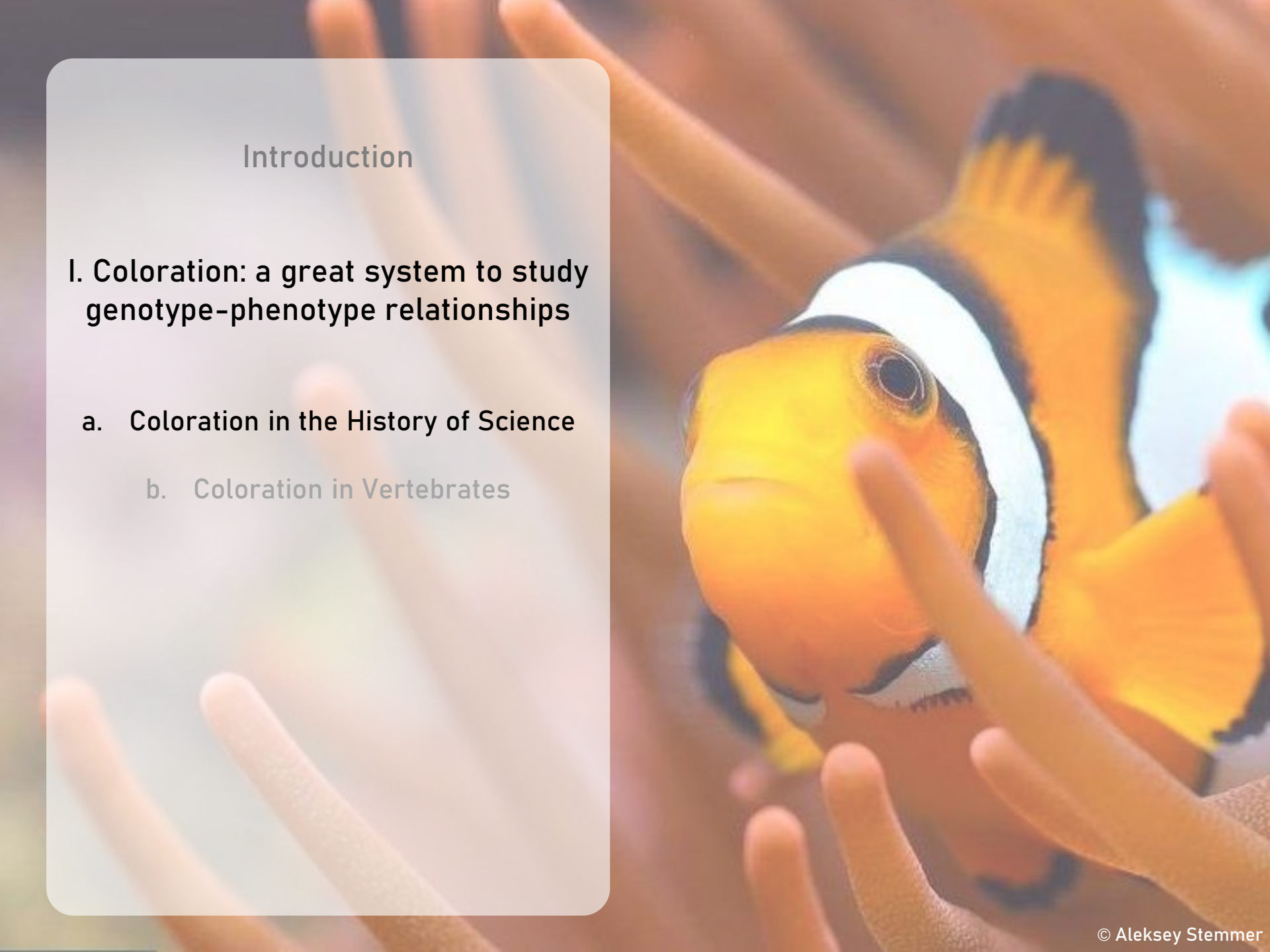


Introduction

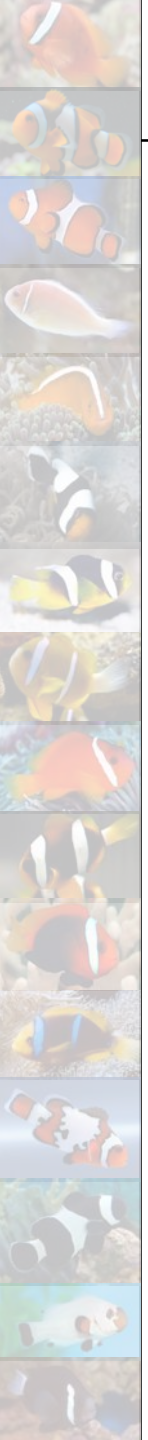
I. Coloration: a great system to study genotype-phenotype relationships

a. Coloration in the History of Science

b. Coloration in Vertebrates



Why study coloration?



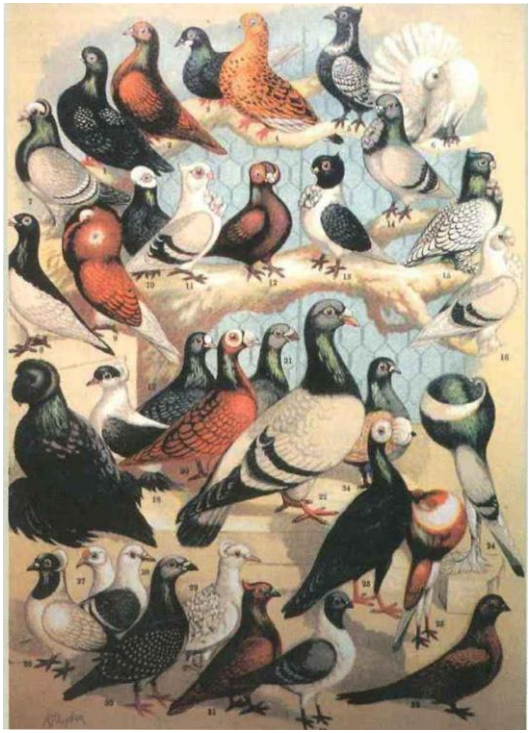
Why study coloration?

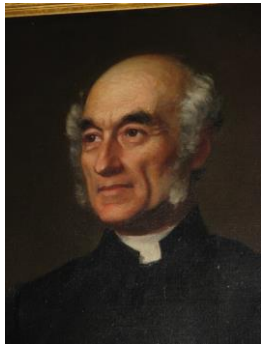
→ Aesthetic

→ Profitable

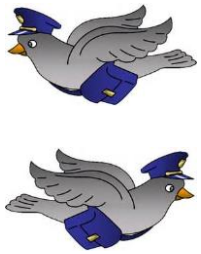
→ Convenient

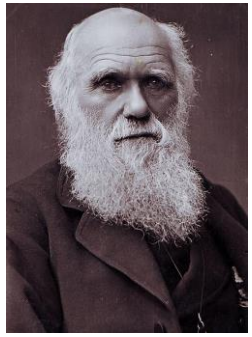
Coloration and naturalists' interest





Whitwell Elwin

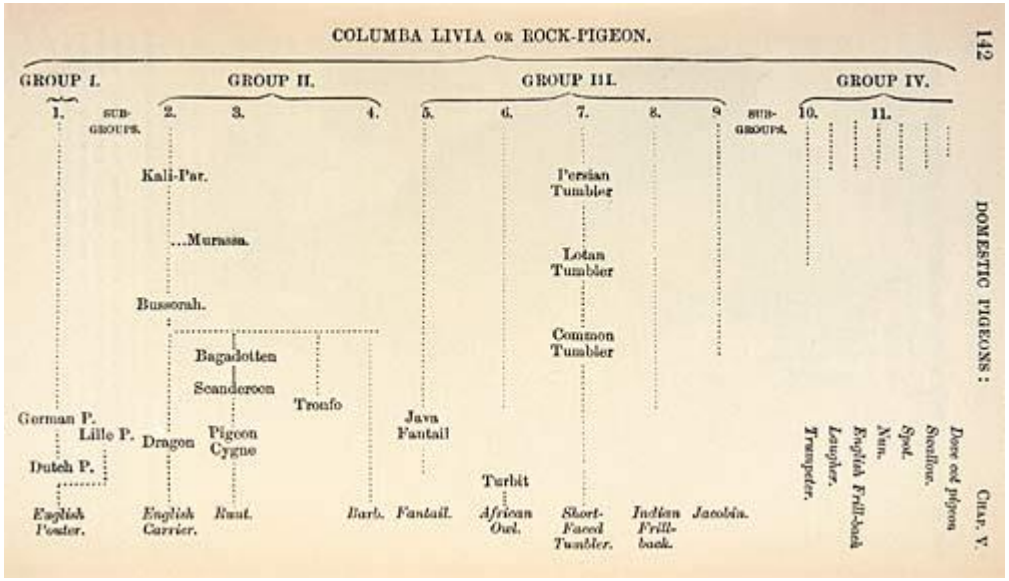




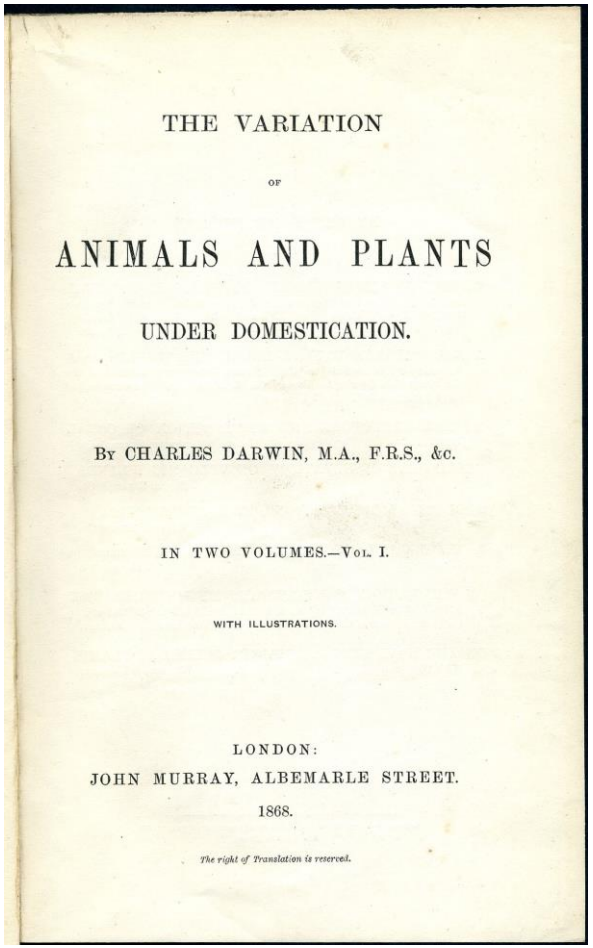
Charles Darwin

“Everybody is interested in pigeons”. [A book like this would] “be reviewed in every journal in the kingdom and soon be on every table.”

Coloration and naturalists' interest



"I do not hesitate to affirm that some domestic races of the rock-pigeon differ fully as much from each other in external characters as do the most distinct natural genera."



THE VARIATION

OF

ANIMALS AND PLANTS

UNDER DOMESTICATION.

By CHARLES DARWIN, M.A., F.R.S., &c.

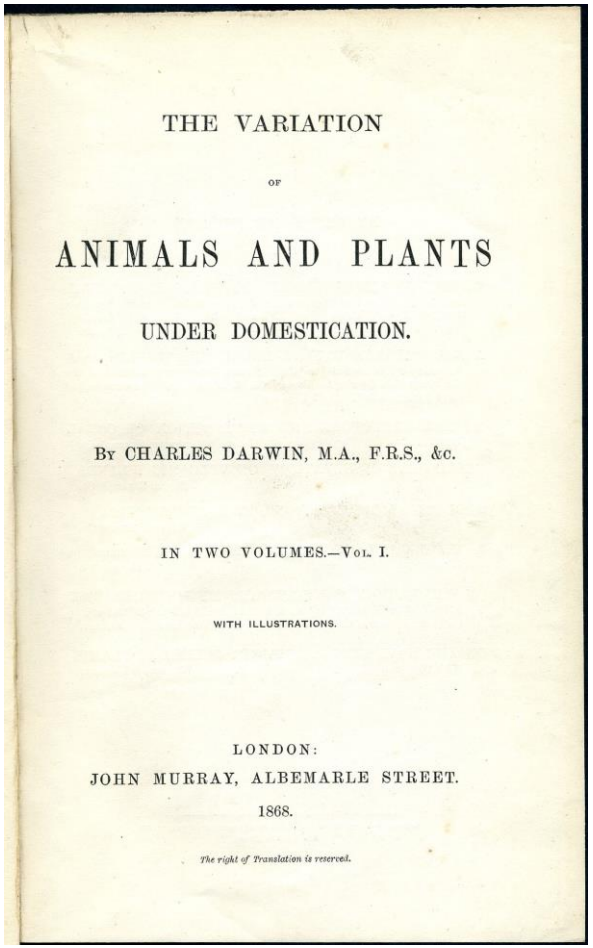
IN TWO VOLUMES.—Vol. I.

WITH ILLUSTRATIONS.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1868.

Coloration and naturalists' interest… also in plants!

Maize has varied in an extraordinary and conspicuous manner ….. <u>The seeds are coloured – white, pale-yellow, orange, red, violet …</u>



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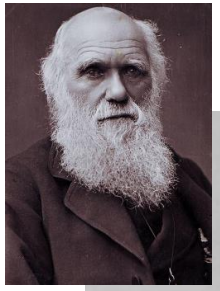
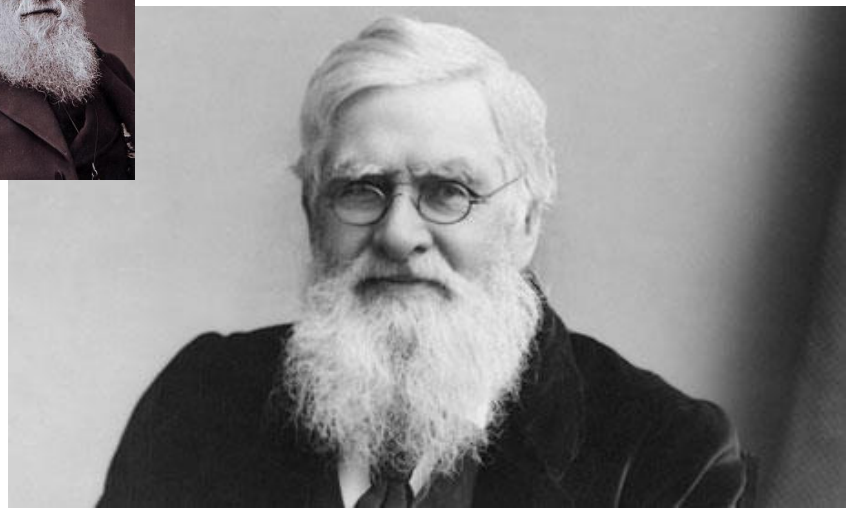
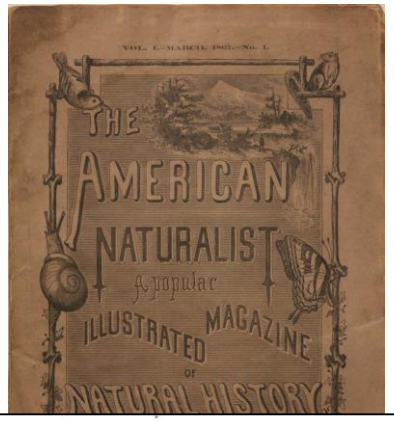
Wallace and "coloration"





Alfred R. Wallace (1823-1913)

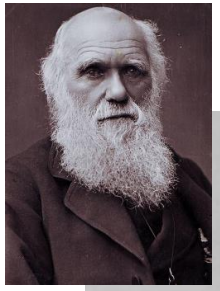


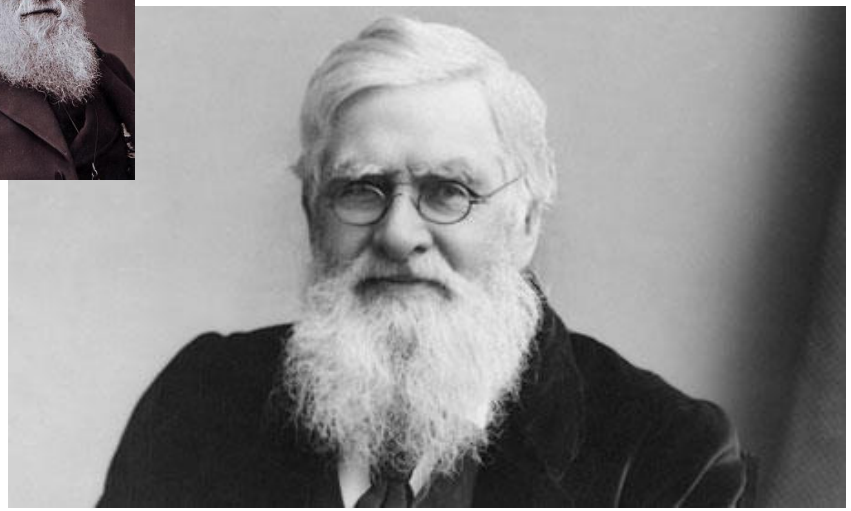
Vol. xi. — NOVEMBER, 1877. — No. 11.

THE COLORS OF ANIMALS AND PLANTS.[1]

BY ALFRED RUSSEL WALLACE.

Wallace and "coloration"





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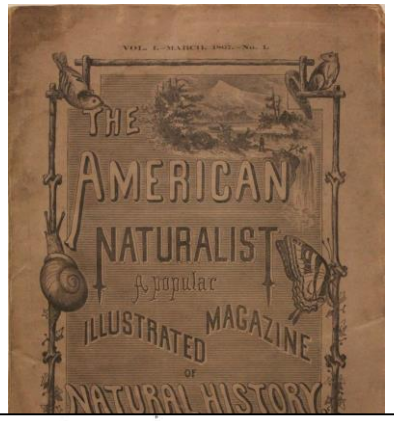


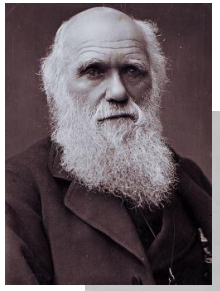
VOL. XI. — NOVEMBER, 1877. — NO. 11.

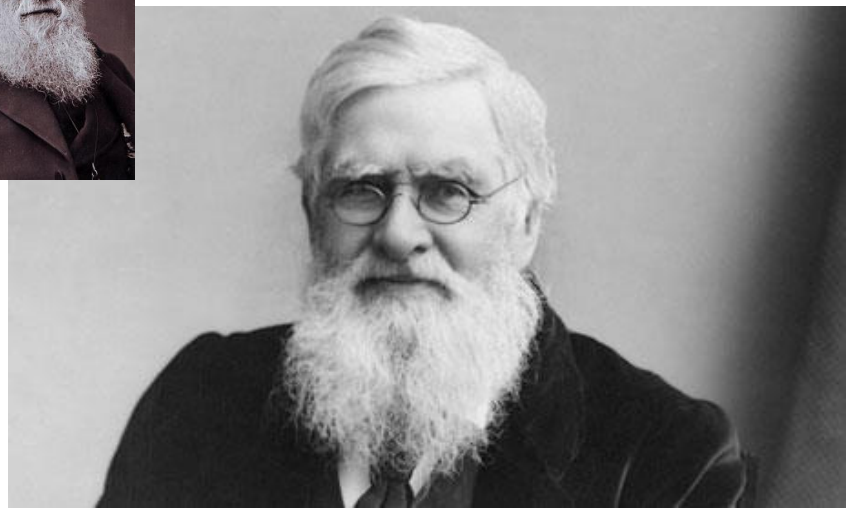
THE COLORS OF ANIMALS AND PLANTS.[1]

BY ALFRED RUSSEL WALLACE.

Animals.	1. Protective colors.
	2. Warning colors.
	3. Sexual colors.
	4. Typical colors.
Plants.	5. Attractive colors

Wallace and "coloration"





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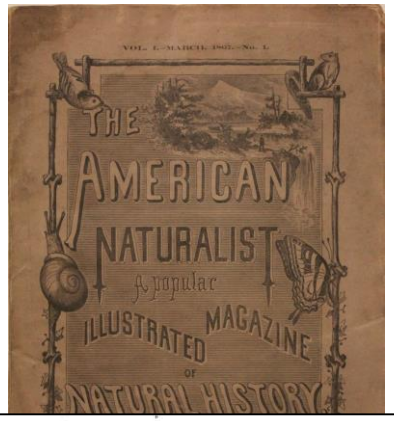


Vol. xi. — NOVEMBER, 1877. — No. 11.

THE COLORS OF ANIMALS AND PLANTS.[1]

BY ALFRED RUSSEL WALLACE.

Camouflage

Animals.
1. Protective colors.
2. Warning colors.
3. Sexual colors.
4. Typical colors.

Intra- or Interspecific communication colors

Trends in Ecology & Evolution

CellPress

Opinion

Wallace on Coloration: Contemporary Perspective and Unresolved Insights

Tim Caro[1,2,*]

I examine Alfred Russel Wallace's six biological categories of coloration of animals and plants, and review how they have been developed over the subsequent century and a half. These categories are: protective colors; warning colors; mimicry; sexual colors; 'typical colours'; and attractive colors in flowers and fruits. Incredibly, Wallace missed little in his appraisal of the evolutionary drivers of coloration, despite being out of step with modern sexual selection theory, and his categories still characterize much of the way that this burgeoning field is organized. Even now his encyclopedic knowledge of natural history raises intriguing functional questions about coloration that still demand investigation.

Trends

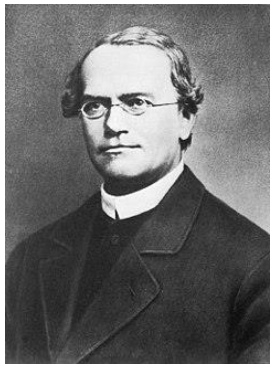
Wallace wrote extensively on animal and plant coloration and organized the field into six functional categories that are still highly relevant.

These categories are crypsis, aposematism, mimicry, sexually selected traits, coloration involved in inter- and intraspecific signaling, and floral and fruit colors.

While understanding of coloration in

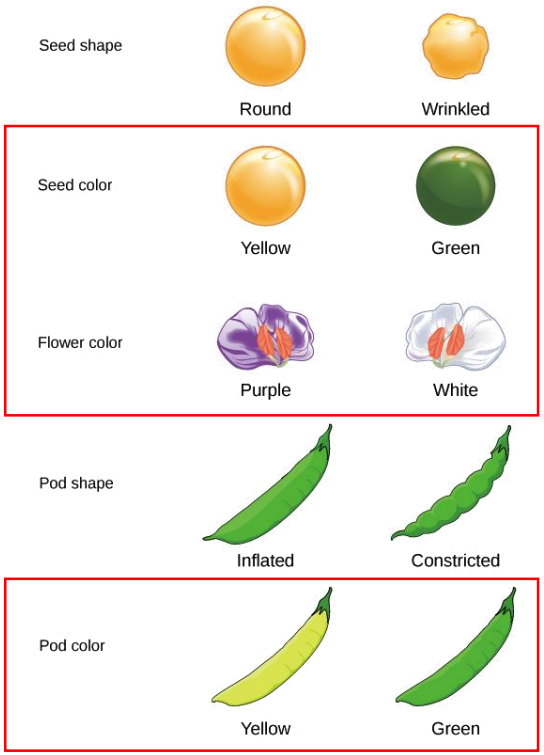
Coloration and the History of the comprehension of GP relationships

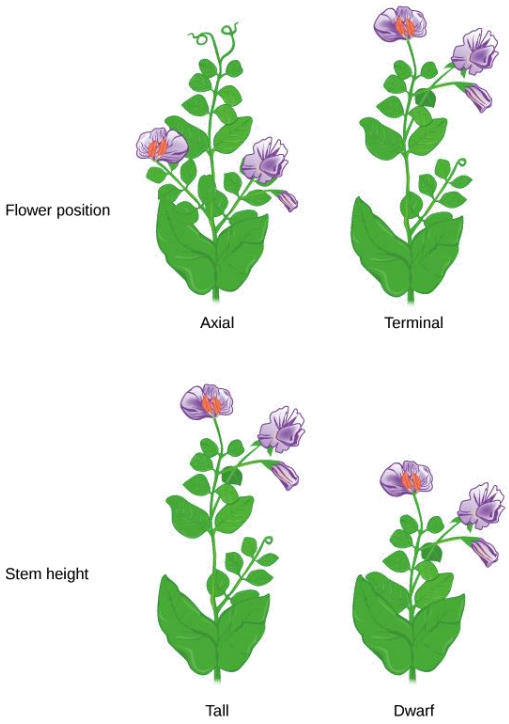
Mendel



Gregor Mendel
(1822-1884)

"Father of modern genetics“
→ Discovery of “heredity factors”

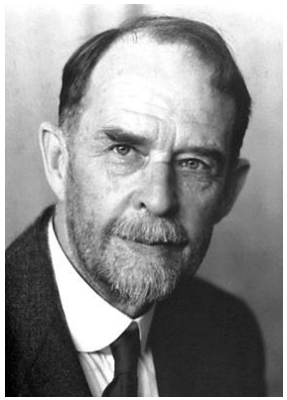




→ Coloration at the basis of the Mendel's Laws of Inheritance:

Law of Segregation, Law of Independent Assortment, Law of Dominance

Morgan



Thomas Hunt MORGAN (1866-1945)

Lilian MORGAN (1870-1952)

1909 (Nobel 1933)

WHAT ARE "FACTORS" IN MENDELIAN EXPLANATIONS?

By Prof. T. H. Morgan.

Columbia University, New York, N. Y.

In the modern interpretation of Mendelism, facts are being transformed into factors at a rapid rate. If one factor will not explain the facts, then two are invoked; if two prove insufficient, three will sometimes work out. The superior jugglery sometimes necessary to account for the results may blind us, if taken too naively, to the common-place that the results are often so excellently "explained" because the explana-

white gene

McClintock

Barbara McClintock
(1902–1992)

Maize variegation

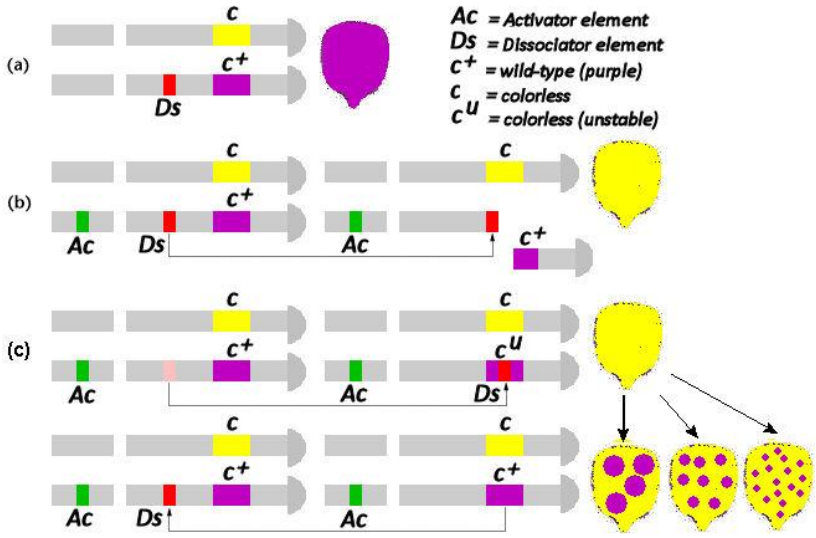
THE ORIGIN AND BEHAVIOR OF MUTABLE LOCI IN MAIZE

By Barbara McClintock

Department of Genetics, Carnegie Institution, Cold Spring Harbor, New York

Communicated April 8, 1950

In the course of an experiment designed to reveal the genic composition of the short arm of chromosome 9, a phenomenon of rare occurrence (or recognition) in maize began to appear with remarkably high frequencies in the cultures. The terms mutable genes, unstable genes, variegation,

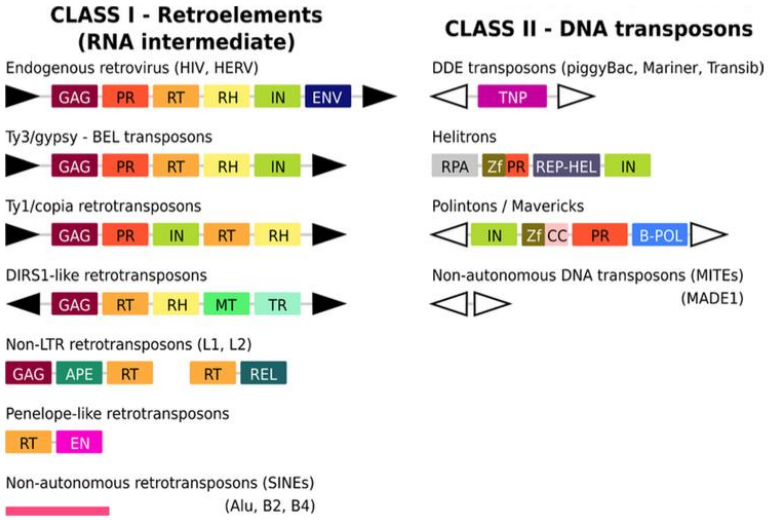


McClintock

Barbara McClintock
(1902-1992)

Maize variegation

→ Coloration at the basis of the discovery of major genome sequences, transposable elements ("controlling elements")



Warren, Naville, Chalopin et al. (2015)

Coloration and the History of genetics: a summary (in Vertebrates only)

Table 1 Timeline of some milestones and fundamental discoveries using pigmentation phenotypes

Date	*Milestone*	*Representative reference*
1700s	Establishment of laboratory mouse strains with 'fancy' coat color patterns	Morse (1978)
1902–1904	Demonstration of Mendelian inheritance in vertebrates using the albino locus	Castle and Allen (1903), Cuenot (1904)
1915	Establishment of genetic linkage in mammals using two pigmentation loci	Haldane *et al* (1915)
1917	Seminal papers on coat color genetics in laboratory animals	Wright (1917a, b, c, d)
1920s	Natural history studies linking vertebrate pigmentation to environmental variation	Sumner (1921, 1929a, b), Benson (1933), Dice and Blossom (1937)
1948	First mathematical treatment of clinal variation based on adaptive pigmentation traits	Haldane (1948)
1950s	First estimate of radiation-induced mammalian mutation rates at six coat color loci	Russell (1951), Russell and Major (1957)
1960s	Estimates of spontaneous mammalian mutation rates using coat color phenotypes	Schlager and Dickie (1966, 1969)
1986	Cloning of the first pigmentation gene	Shibahara *et al* (1986)
2000s	Linking mutations in pigmentation genes to adaptive phenotypic variation in the wild	

Hoekstra (2006) *Genetics, development and evolution of adaptive pigmentation in vertebrates*

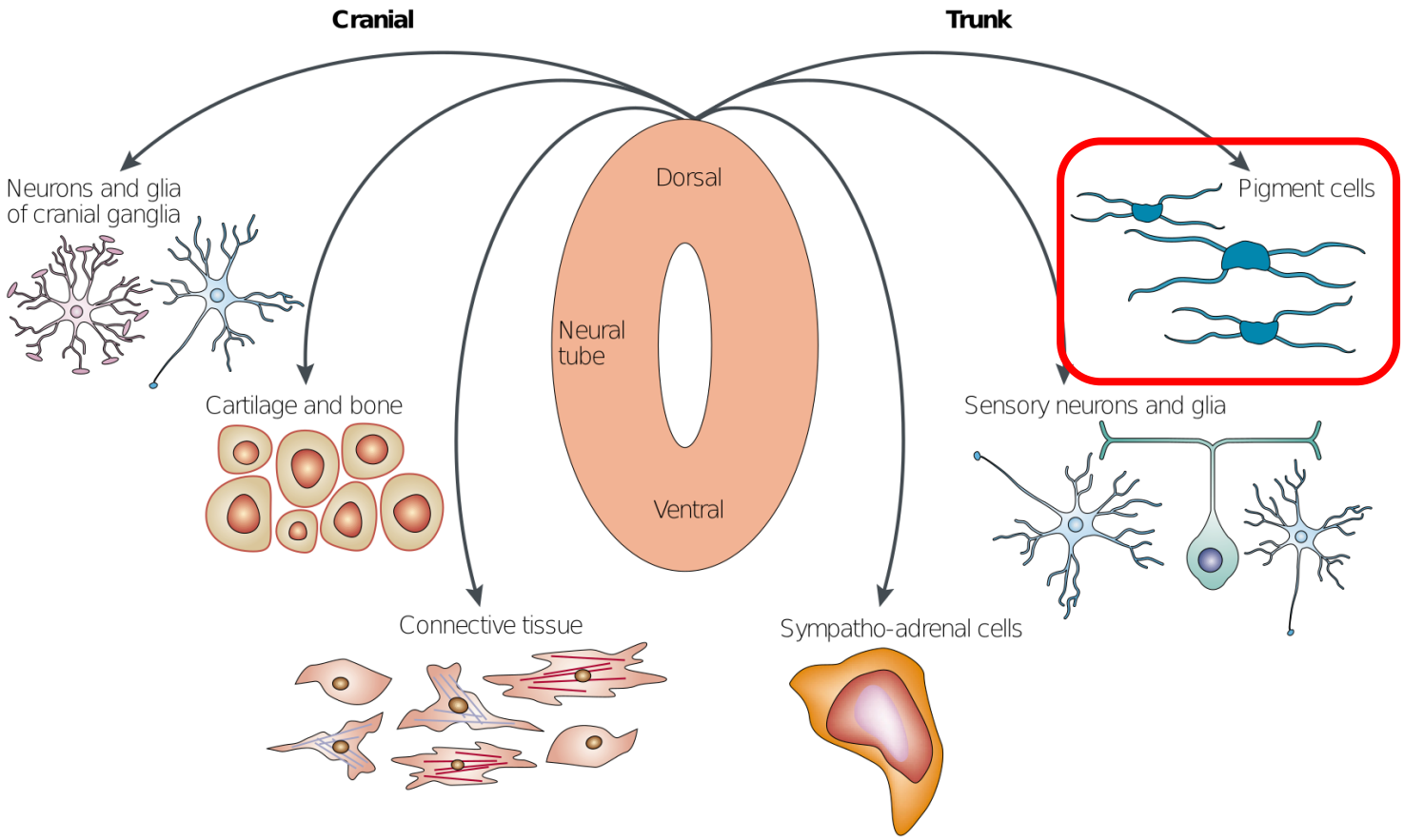
Introduction

I. Coloration: a great system to study genotype-phenotype relationships

a. Coloration in the History of Science

b. Coloration in Vertebrates

Pigment cells in vertebrates originate from the neural crest

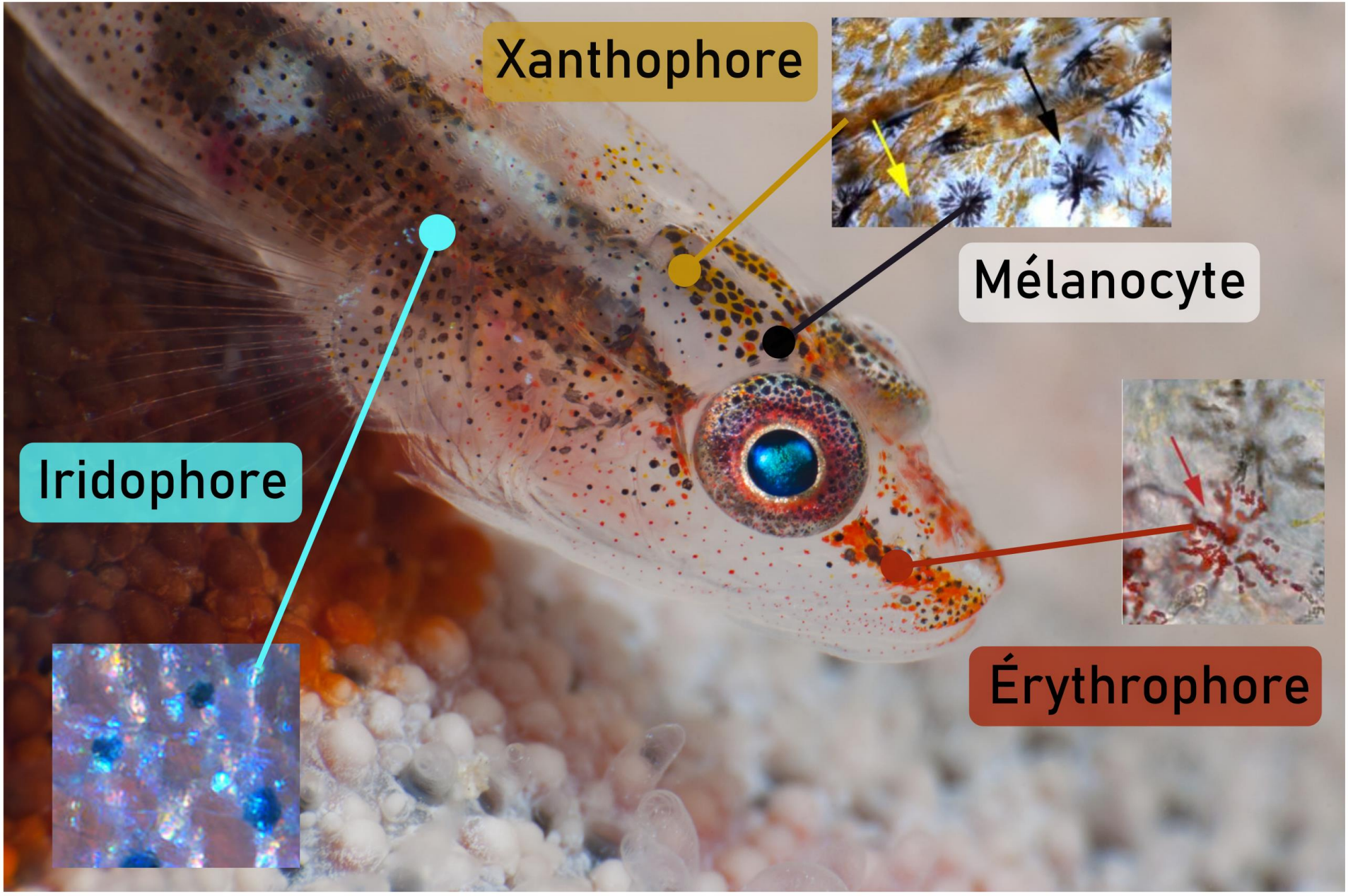


PLANET VIE

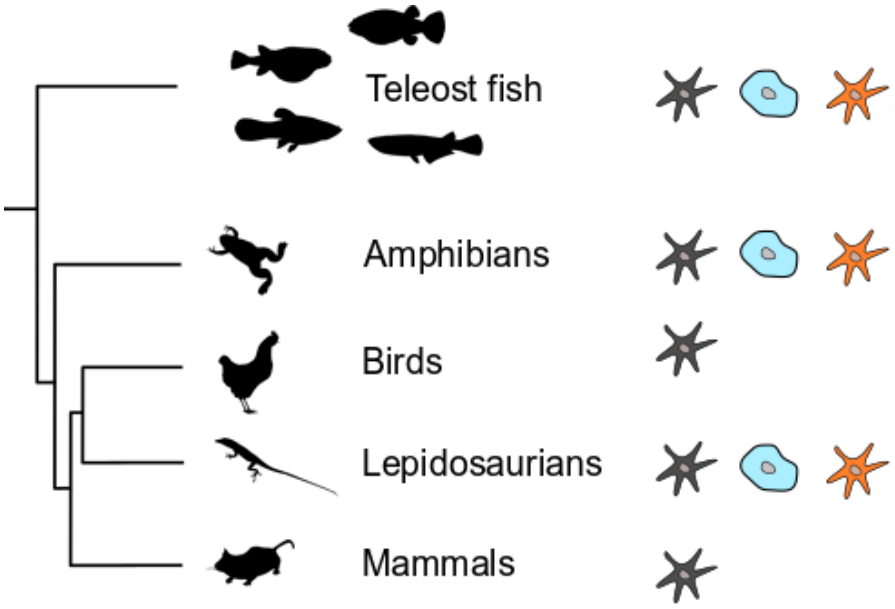
Les cellules des crêtes neurales : « la seule chose intéressante » chez les Vertébrés ?

Thibault Lorin

Knecht *et al.* (2002) *Nat. Rev. Gen.*


Xanthophore
Mélanocyte
Iridophore
Érythrophore

Developmental, cellular and molecular basis of pigmentation in Vertebrates



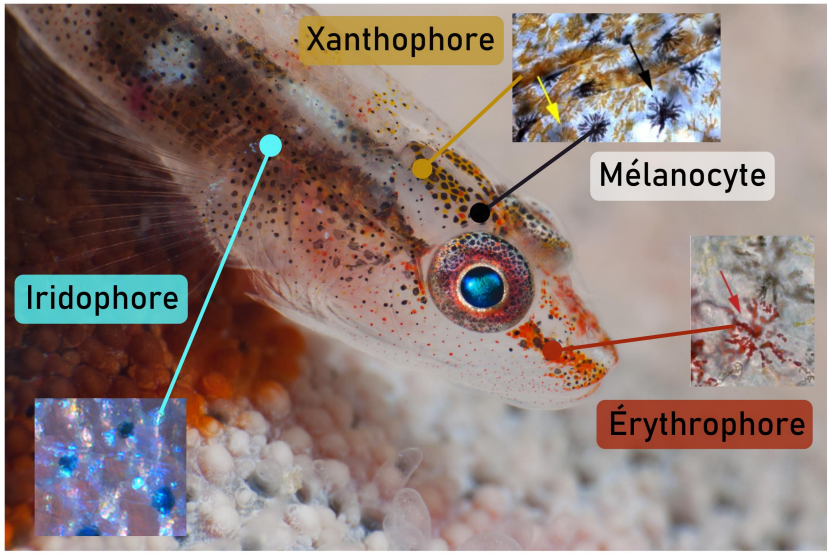
Melanocytes (eu- or pheo-melanin)

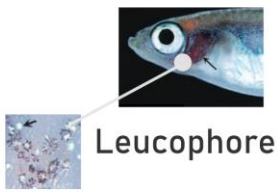
Iridophores (purines)

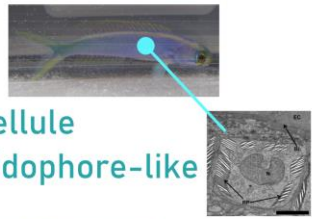
Xanthophores/ erythrophores (pteridins, carotenoids)

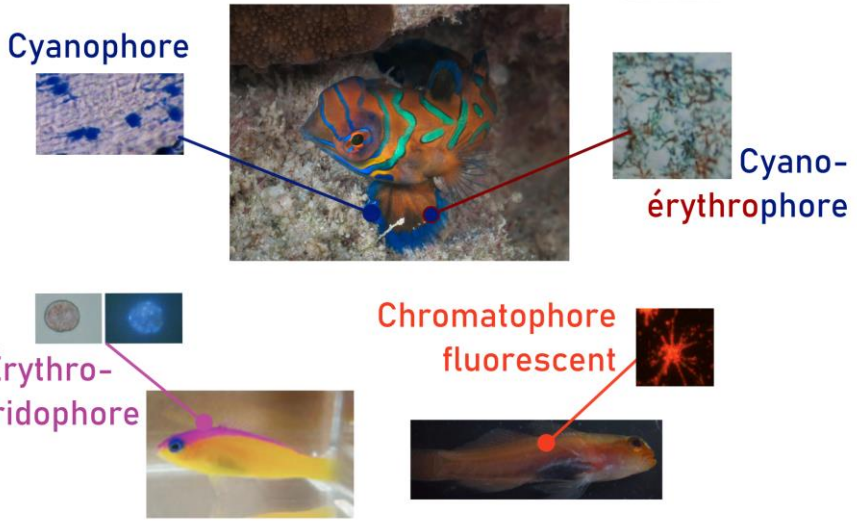
Lorin *et al.* (2018) *G3: Genes/Genomes/Genetics*

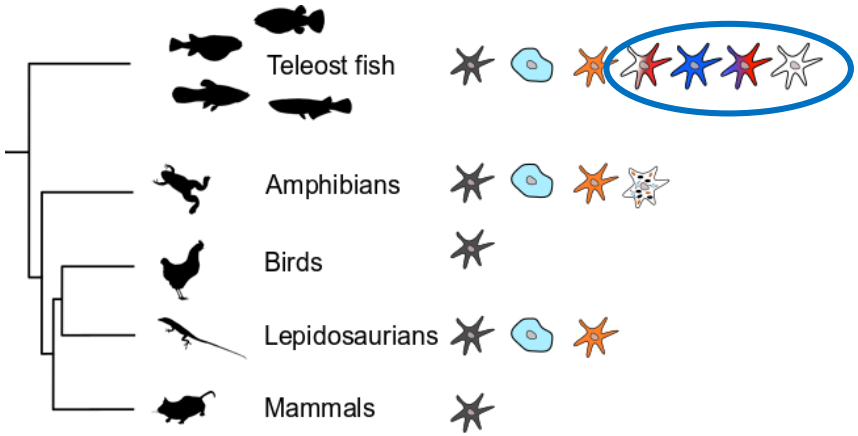
Developmental, cellular and molecular basis of pigmentation in Vertebrates



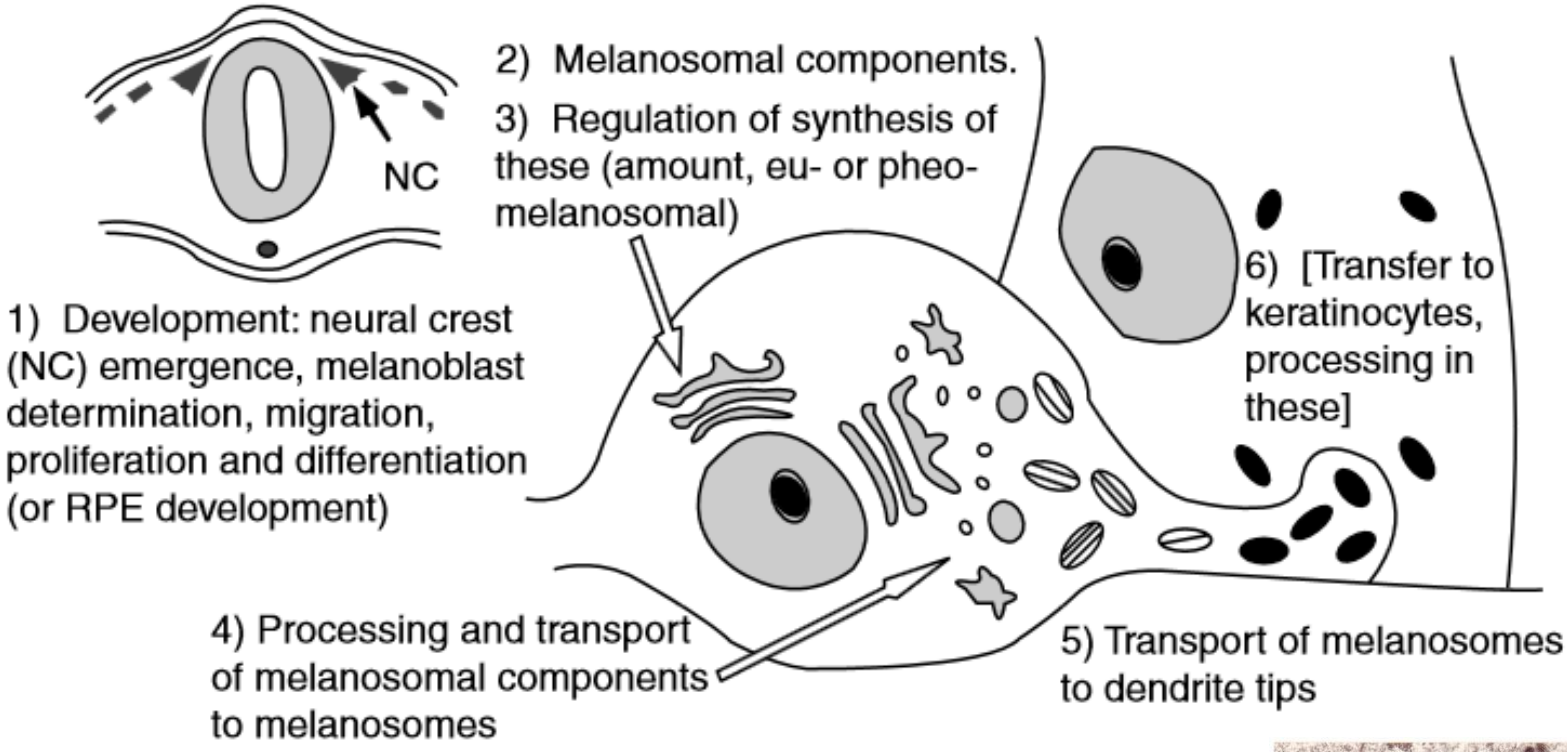


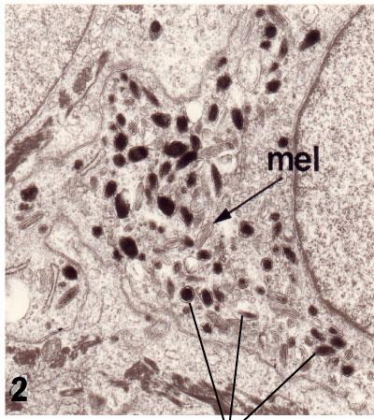






Coloration is a very diverse trait…





Bennett and Lam

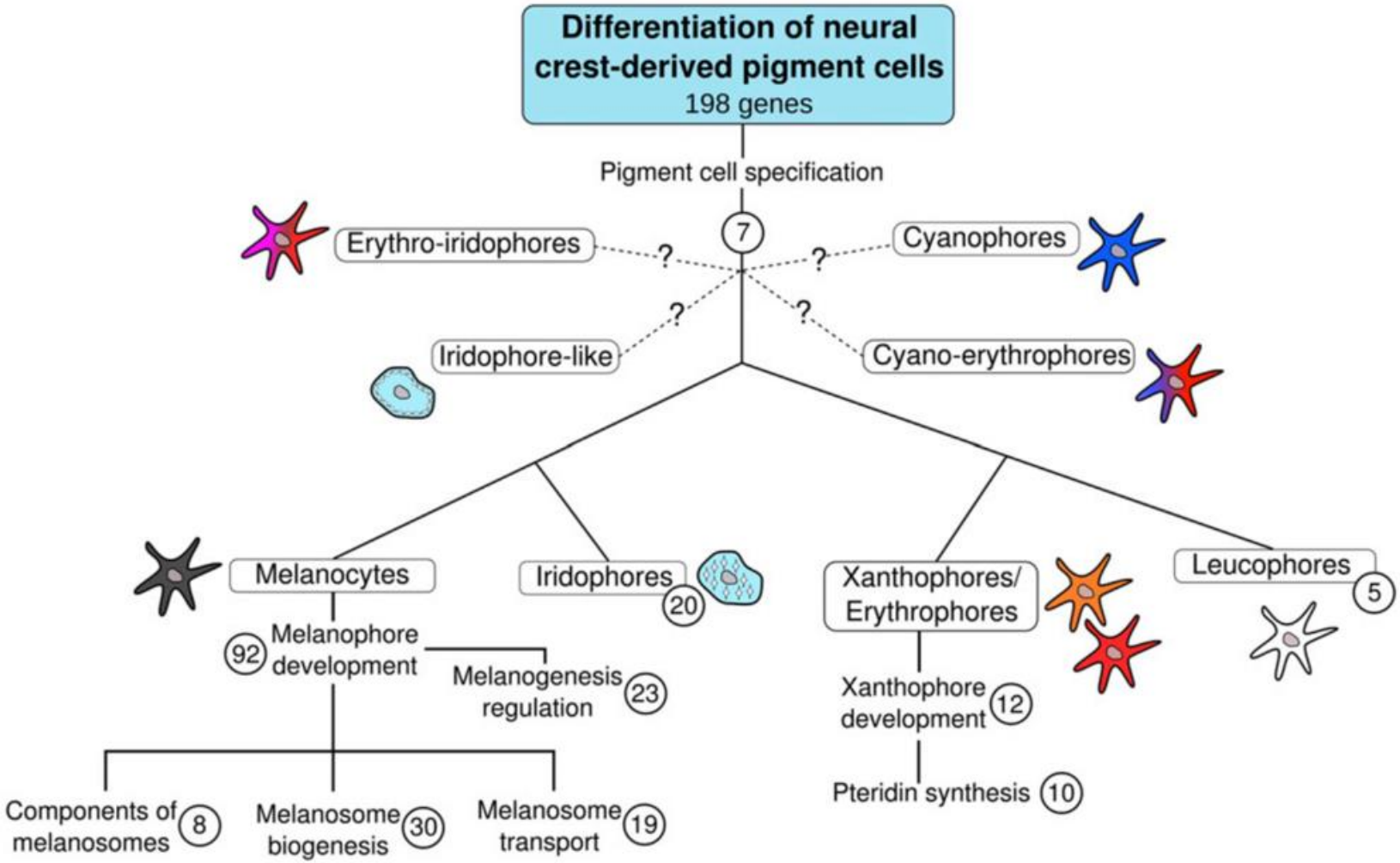
Coloration is a very diverse trait… encoded by a plethora of genes

Table 1. Summary of the cloned mouse color genes

Symbol (old symbol)	Name (old name)	Chromosome	Function	Human symbol	Human chr'some	Syndrome
(a) Melanocyte development						
Adam17	A disintegrin and metalloprotease domain 17	12	Protease, processing various bioactive proteins	*ADAM17*	2p25	N
Adamts20 (bt)	A disintegrin and metalloprotease domain (reprolysin type) with thrombospondin type 1 motif, 20 (belted)	15	Metalloprotease. Melanoblast migration?	*ADAMTS20*	12q12	N
Brca1	Breast cancer 1	11	Development of various organs; tumor suppressor	*BRCA1*	17q21	BC
Eda (Ta)	Ectodysplasin-A (tabby)	X	Sweat gland, tooth and hair morphogenesis	*ED1*	Xq12-q13	EDA/HED
Edn3 (ls)	Endothelin 3 (lethal spotting)	2	Growth and differentiation factor	*EDN3*	20q13	HD, WSS
Ednrb (s)	Endothelin receptor type B (piebald spotting)	14	Growth factor receptor	*EDNRB*	13q22	HD, WSS
Egfr (Dsk5)	Epidermal growth factor receptor (dark skin 5)	11	Growth factor receptor	*EGFR*	7p12.3	N
Fgfr2	Fibroblast growth factor receptor 2	7	Growth factor receptor	*FGFR2*	10q26	CrS, PfS
Ikbkg	Inhibitor of κB kinase, γ subunit (NEMO)	X	IκB kinase. Required for NFκB signaling	*IKBKG*	Xq28	IP, HED-ID, EDA-ID
Kit (W)	Kit oncogene (white spotting)	5	Growth factor receptor	*KIT*	4q11-q12	PS
Kitl (Sl)	Kit ligand (steel)	10	Growth and differentiation factor	*KITLG*	12q22	N
Krt2–17 (Dsk2)	Keratin 2–17 (dark skin 2)	15	Cytoskeleton	*KRT2A*	12q11-q13	IBS
Lmx1a (dr)	LIM homeobox transcription factor 1α (dreher)	1	Transcription factor	*LMX1A*	1q22–23	N
Mcoln3 (Va)	Mucolipin 3 (varitint-waddler)	3	Cation channel	*MCOLN3*	1p22.3	N
Mitf (mi)	Microphthalmia-associated transcription factor (microphthalmia)	6	Transcription factor	*MITF*	3p12–14	WS2
Pax3 (Sp)	Paired box gene 3 (splotch)	1	Transcription factor	*PAX3*	2q35	WS1, WS3
Sfxn1 (f)	Sideroflexin 1 (flexed tail)	13	Tricarboxylate carrier	*SFXN1*	5q35.3	N
Snai2	Snail homolog 2/Slug	16	Transcription factor	*SNAI2*	8q11	WS2
Sox10 (Dom)	SRY-box containing gene 10 (dominant megacolon)	15	Transcription factor	*SOX10*	22q13.1	WSS
Sox18 (rg, Dcc1)	SRY-box containing gene 18 (ragged, dark coat color 1)	2	Transcription factor	*SOX18*	20q13.33	N
Wnt1	Wingless-related MMTV integration site 1	15	Growth factor/morphogen	*WNT1*	12q13	N
Wnt3a	Wingless-related MMTV integration site 3A	11	Growth factor/morphogen	*WNT3A*	1q42	N
(b) Components of melanosomes and their precursors						
Dct (slt)	Dopachrome tautomerase (slt)	14	Melanosomal enzyme	*DCT*	13q31-q32	N
Gpnmb	Glycoprotein (transmembrane) NMB	6	Apparent melanosomal component	*GPNMB*	7p15	N
Matp (uw)	Membrane-associated transporter protein (underwhite)	15	Apparent transporter	*MATP*	5p	OCA4
Rab38 (cht)	RAB38, member RAS oncogene family (chocolate).	7	Targeting of Tyrp1	*RAB38*	11q14	N
Sl (st)	Silver (silver)	10	Melanosome matrix	*SILV*	12q13-q14	N
Tyr (c)	Tyrosinase (color, albino)	7	Melanosomal enzyme	*TYR*	11q21	OCA1
Tyrp1 (b)	Tyrosinase-related protein 1 (brown)	4	Melanosomal protein	*TYRP1*	9p23	OCA3
(c) Melanosome construction/protein routing (HPS-related)						
Ap3b1 (pe)	Adaptor-related protein complex AP-3, β 1 subunit (pearl)	13	Organellar protein routing	*AP3B1* [HPS2]	15q15	HPS
Ap3d (mh)	Adaptor-related protein complex AP-3, δ subunit (mocha)	10	Organellar protein routing	*AP3D1*	19p13.3	N
Vps33a (bf)	Vacuolar protein sorting 33a (buff)	5	Organellar protein routing	*VPS33A*	12q24.31	N
cno (cno)	Cappuccino	5	Organelle biogenesis	*CNO*	4p16-p15	N
Hps1 (ep)	Hermansky-Pudlak syndrome 1 homolog (pale ear)	19	Organelle biogenesis and size	*HPS1*	10q24	HPS
Hps3 (coa)	Hermansky-Pudlak syndrome 3 homolog (cocoa)	3	Organelle biogenesis	*HPS3*	3q24	HPS
Hps4 (le)	Hermansky–Pudlak syndrome 4 homolog (light ear)	5	Organelle biogenesis and size	*HPS4*	22q11-q12	HPS
Hps5 (ru2)	Hermansky–Pudlak syndrome 5 homolog (ruby-eye 2)	7	Organelle biogenesis	*HPS5*	11p14	HPS
Hps6 (ru)	Hermansky–Pudlak syndrome 6 homolog (ruby-eye)	19	Organelle biogenesis	*HPS6*	10q24.31	HPS
Lyst (bg)	Lysosomal trafficking regulator (beige)	13	Organelle biogenesis and size	*LYST*	1q42	CHS

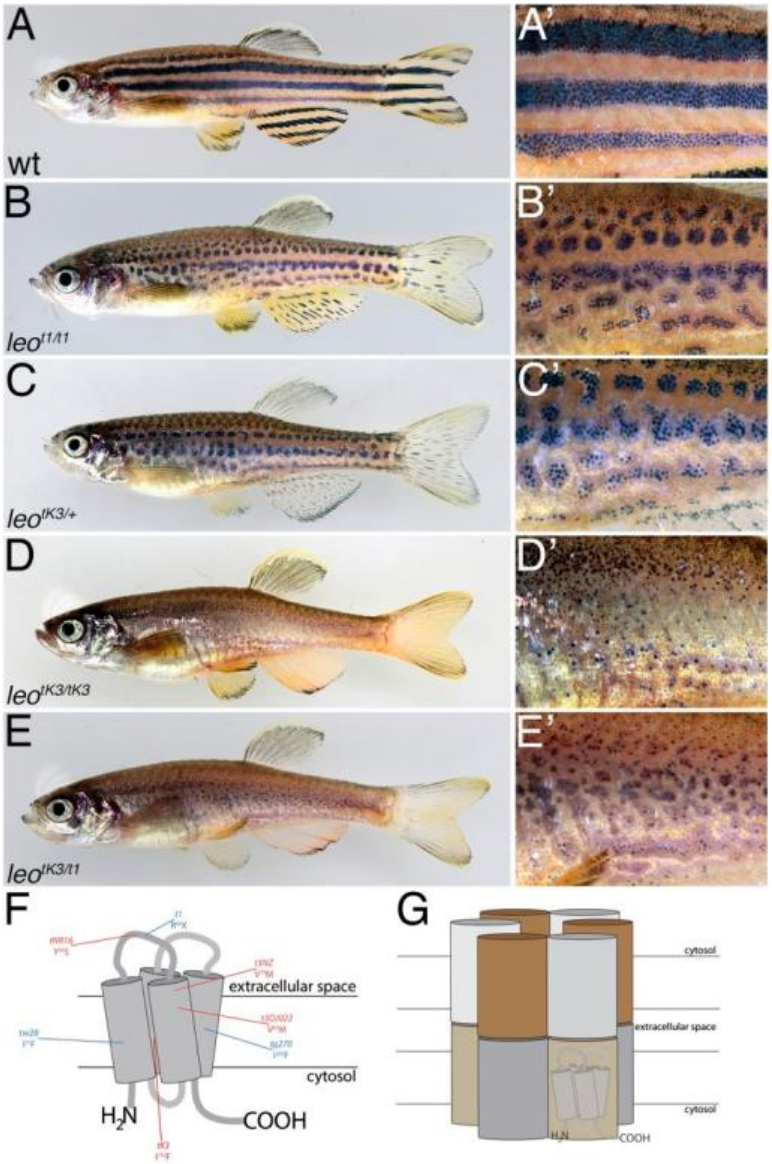
Bennett and Lamoreux (2003) *Pigment Cell Res.*

Coloration is a very diverse trait… encoded by a plethora of genes



Lorin et al. (2018) *G3*

Changes in "coding sequences" → changes in coloration: "direct GP relationship"



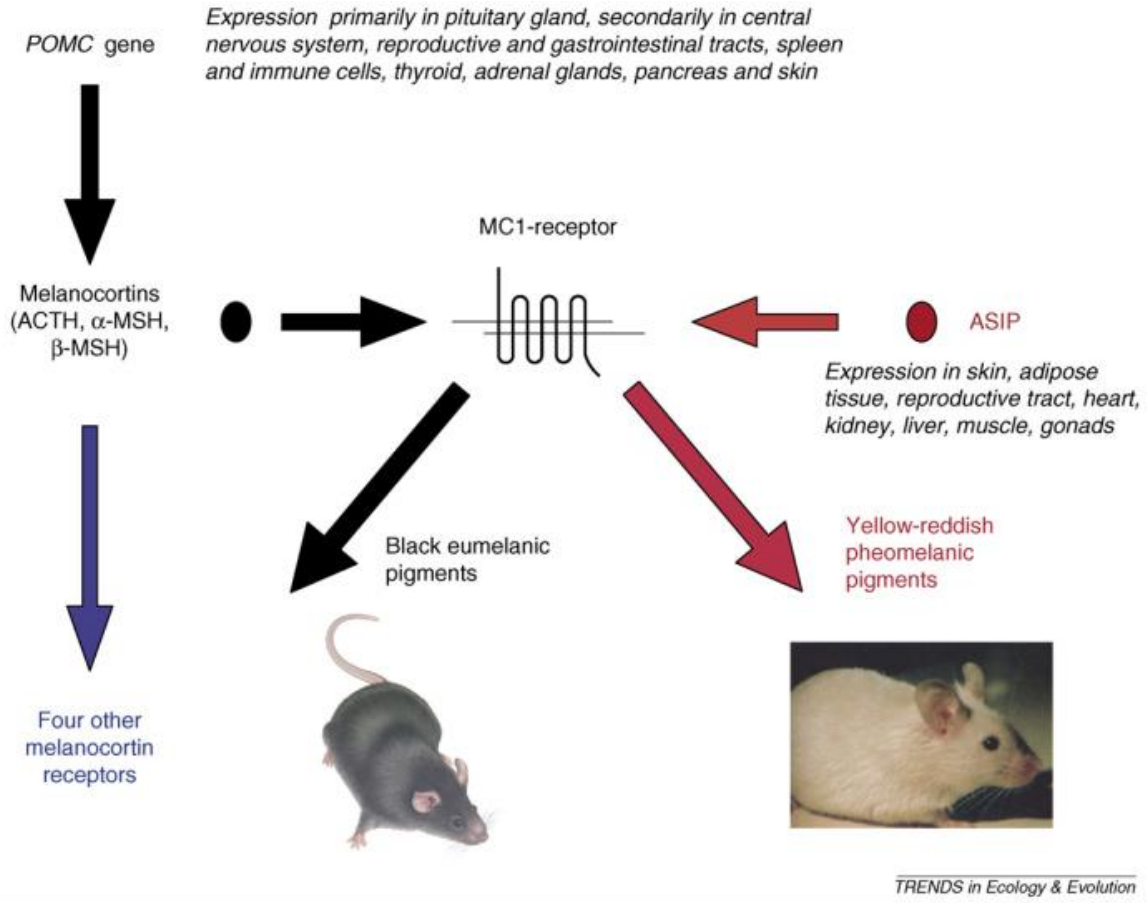
gene cx41.8 in zebrafish

```
Cx41.8    1 MADWSLLGWFLEEVQEHSTSVGKVWLTILFIFRILVLGTAAESSWGDEQEDFTCDTEQPGCENVCYDIAFPIAHIRFWVL  80
GJA5      1 MGDWSFLGNFLEEVHKHSTVVGKVWLTVLFIFRMLVLGTAAESSWGDEQADFRCDTIQPGCQNVCYDQAFPISHIRYWVL  80
cons.       M DWS LGNFLEEV. HST VGKVWLT.LFIFR.LVLGTAAESSWGDEQ DF CDT QPGC.NVCYD.AFPI.HIR.WVL

Cx41.8   81 QIVFISTPSLIYMGHAMHIVRREEKDKELDDEGAQRDGE---KYPEDDKNKED--EGGCRKVRLKGALLQTYCWSIFIR 155
GJA5     81 QIIFVSTPSLVYMGHAMHTVRMQEKRKLREAERAKEVRGSGSYEYPVAEKAELSCWEEGNGRIALQGTLLNTYVCSILIR 160
cons.       QI.FVSTPSL.YMGHAMH VR .EKR.    .   .  G     YP  .K      E G.GR. L.G.LL.TYV SILIR

Cx41.8  156 TVMEVIFIIIQYLIYGVFLSALYVCKAPPCPHPVNCYISRPTEKNVFIVFMLAVAAVSLLLSIVELYHLAWKQLRKYVHG 235
GJA5    161 TTMEVGFIVGQYFIYGIFLTTLHVCRRSPCPHPVNCYVSRPTEKNVFIVFMLAVAALSLLLSLAELYHLGWKKIRQRFV- 239
cons.       T MEV FI. QY IYG.FL..L VC.  PCPHPVNCY.SRPTEKNVFIVFMLAVAA.SLLLS. ELYHL WK..R.

Cx41.8  236 YKASKQRPWTPSTMPALSPNPSTPNRACTPPPDFNQCLTSPPSSPTLQTHSLLHPTCPPFHDRLAHQQNSAMMVTERHRG 315
GJA5    240 ------KPRQHMAKCQLSGPSVGIVQSCTPPPDFNQCLENGPGGKFFN----------PFSNNMASQQNTDNLVTEQVRG 303
cons.           .P    .  LS       ..CTPPPDFNQCL   P     .          PF   .A QQN. N.VTE. RG

Cx41.8  316 QD-YLGVNFLS--FSQTPTETPNSCASPSFLGSDFE-DKRRFSKSSGTSSRMRPDDLAV 370
GJA5    304 QEQTPGEGFIQVRYGQKP-EVPNGVSPGHRLPHGYHSDKRRLSKAS---SKARSDDLSV 358
cons.       Q.   G .F.   . Q P E PN  .    L   .  DKRR SK.S   S. R DDL.V
```

Irion et al. (2014) *eLife*

But… The GP relationship is more complex than "one gene / one trait"

→ One gene / MULTIPLE traits: Pleiotropy of "color genes"



Ducrest et al. (2008) *TREE*

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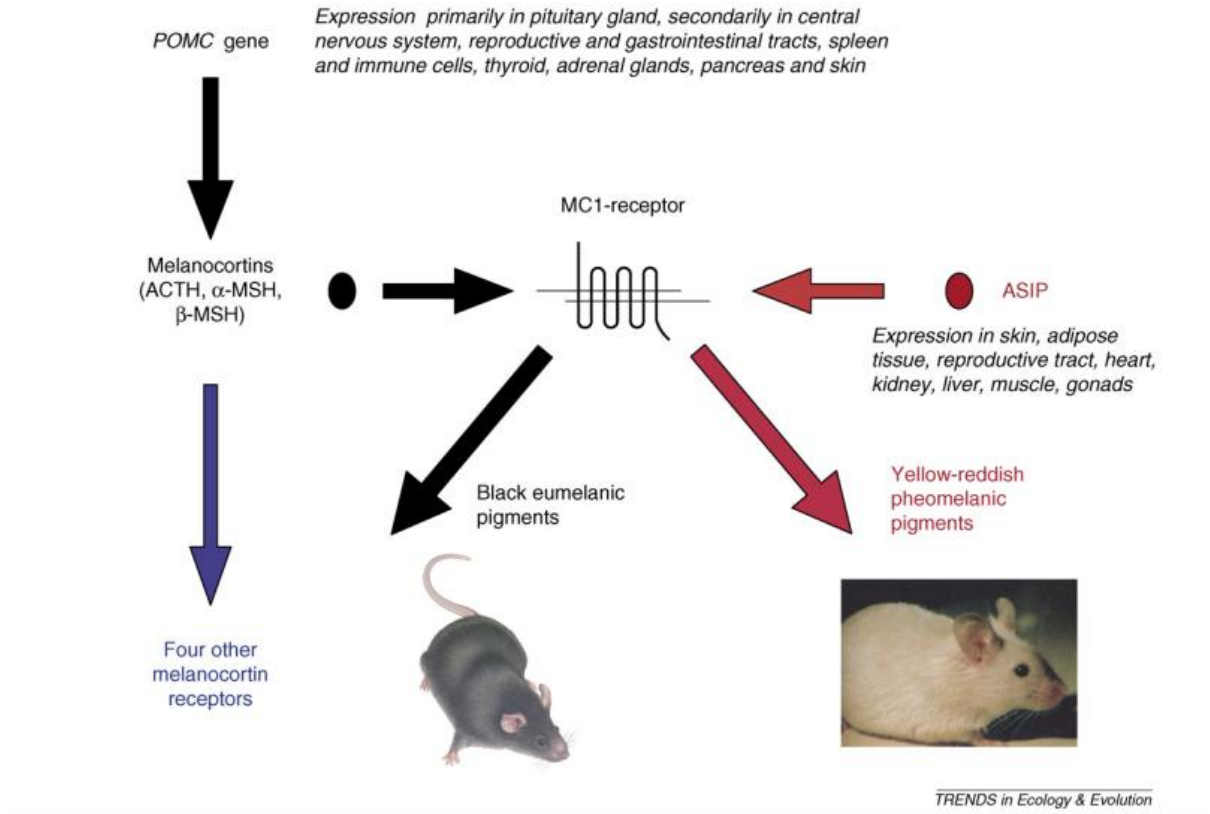
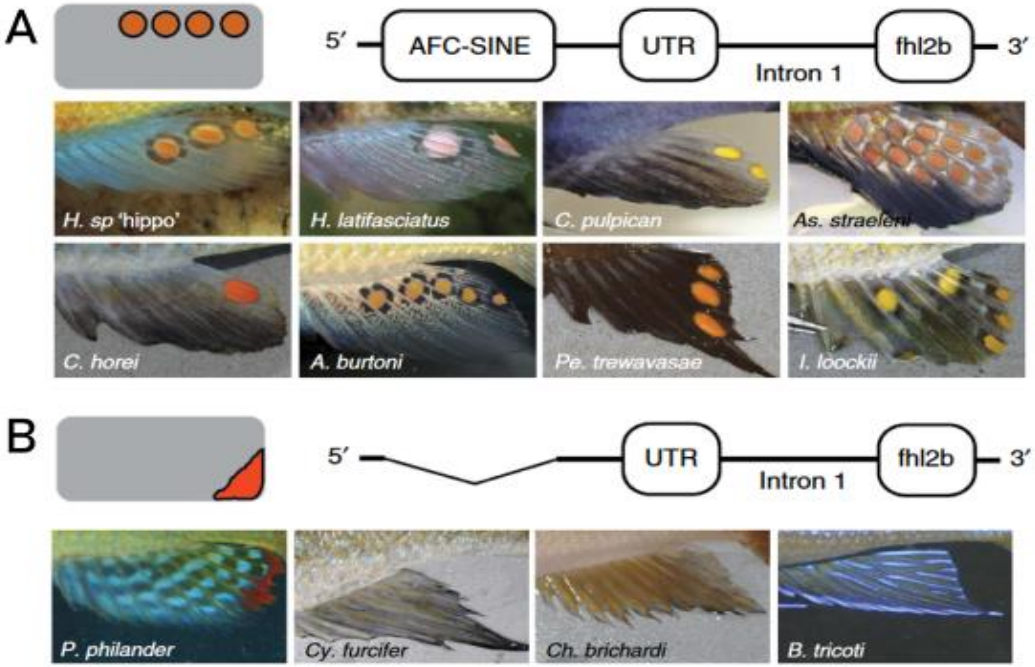


Ducrest et al. (2008) *TREE*

Coloration is sometimes due to regulatory sequences rather than "genes"

Cichlid fish

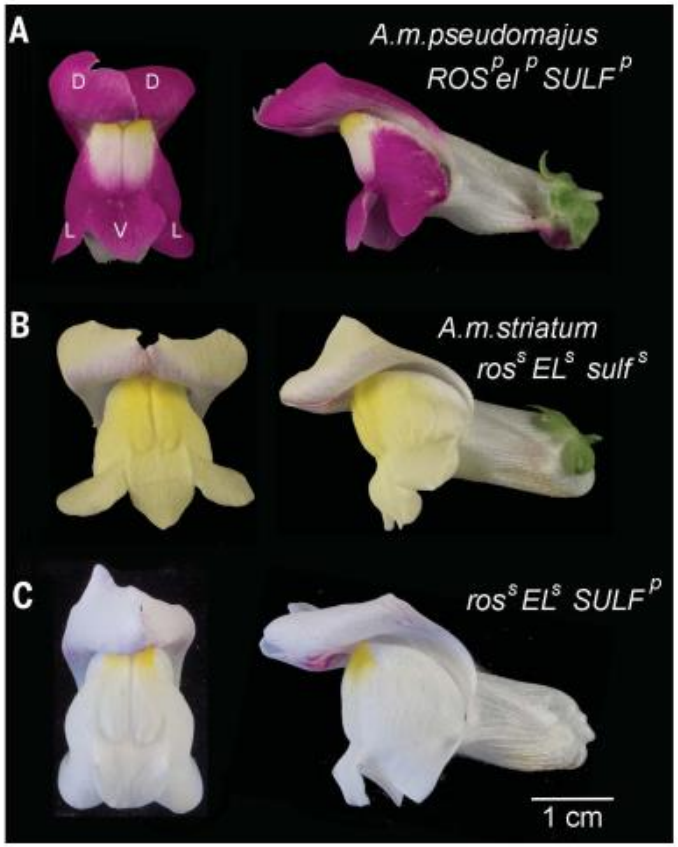
1. *Cis*-regulatory sequences



Santos et al. (2014) *Nature Comm.*

Coloration is sometimes due to regulatory sequences rather than "genes"

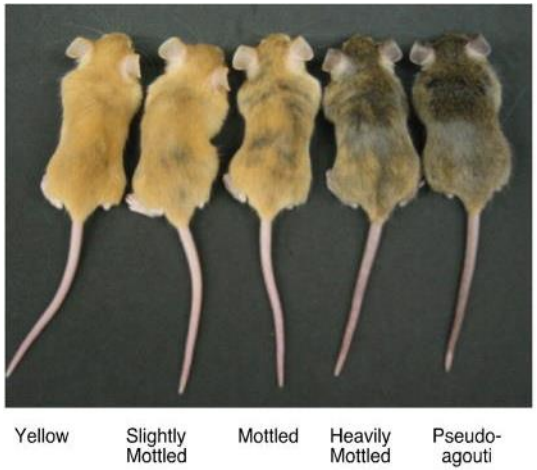
1. *Cis*-regulatory sequences
2. Non-coding RNAs



Bradley et al. (2017) *Science*

Coloration is sometimes due to regulatory sequences rather than "genes"

1. *Cis*-regulatory sequences
2. Non-coding RNAs
3. Epigenetics



"Yellow mice are hypomethylated at the transposable element upstream of the Agouti gene allowing maximal ectopic expression"

Dolinoy (2008)

Why study coloration?

→ Profitable

→ Aesthetic

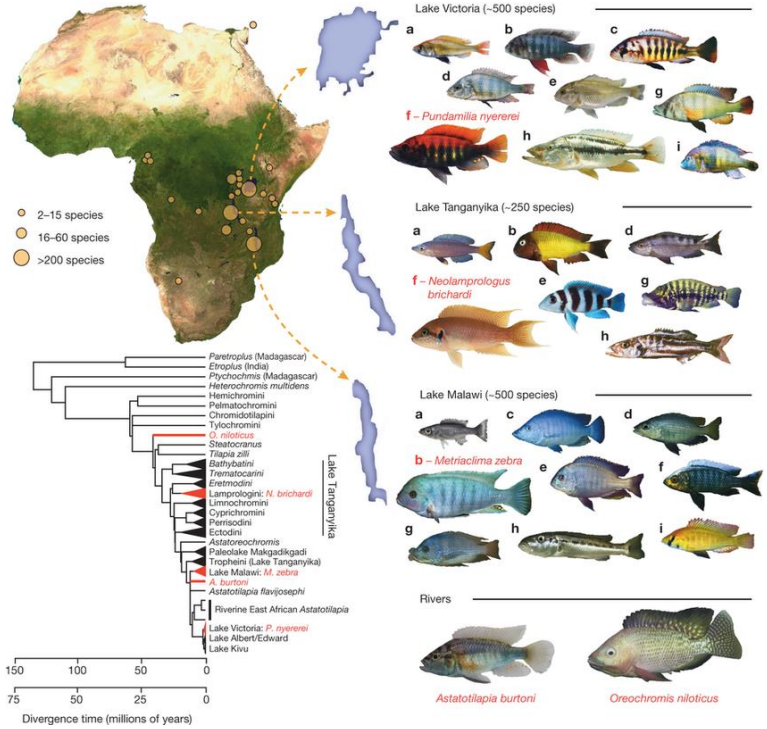
→ Convenient

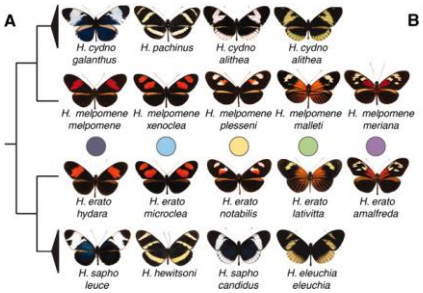
Why study coloration?

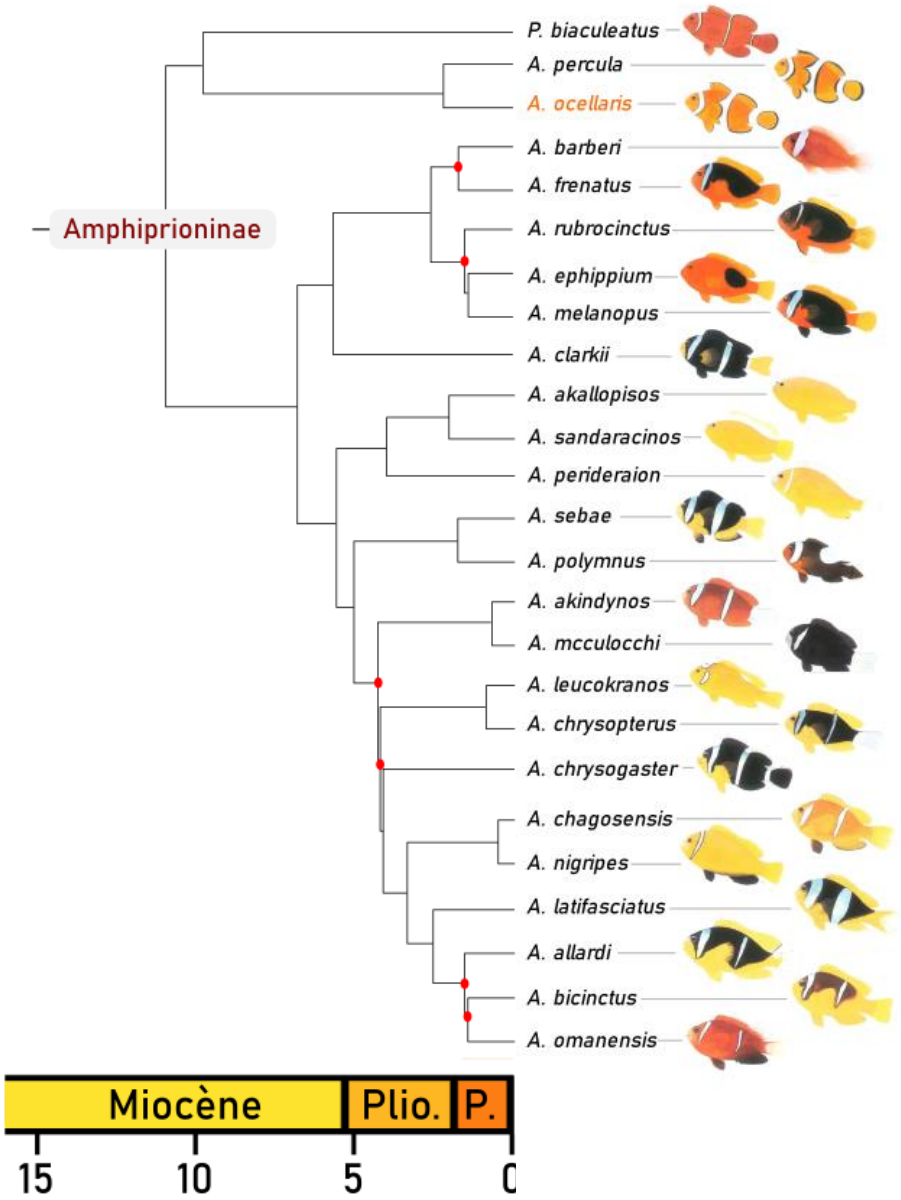
Coloration is a fast-evolving trait

Coloration is a fast-evolving trait

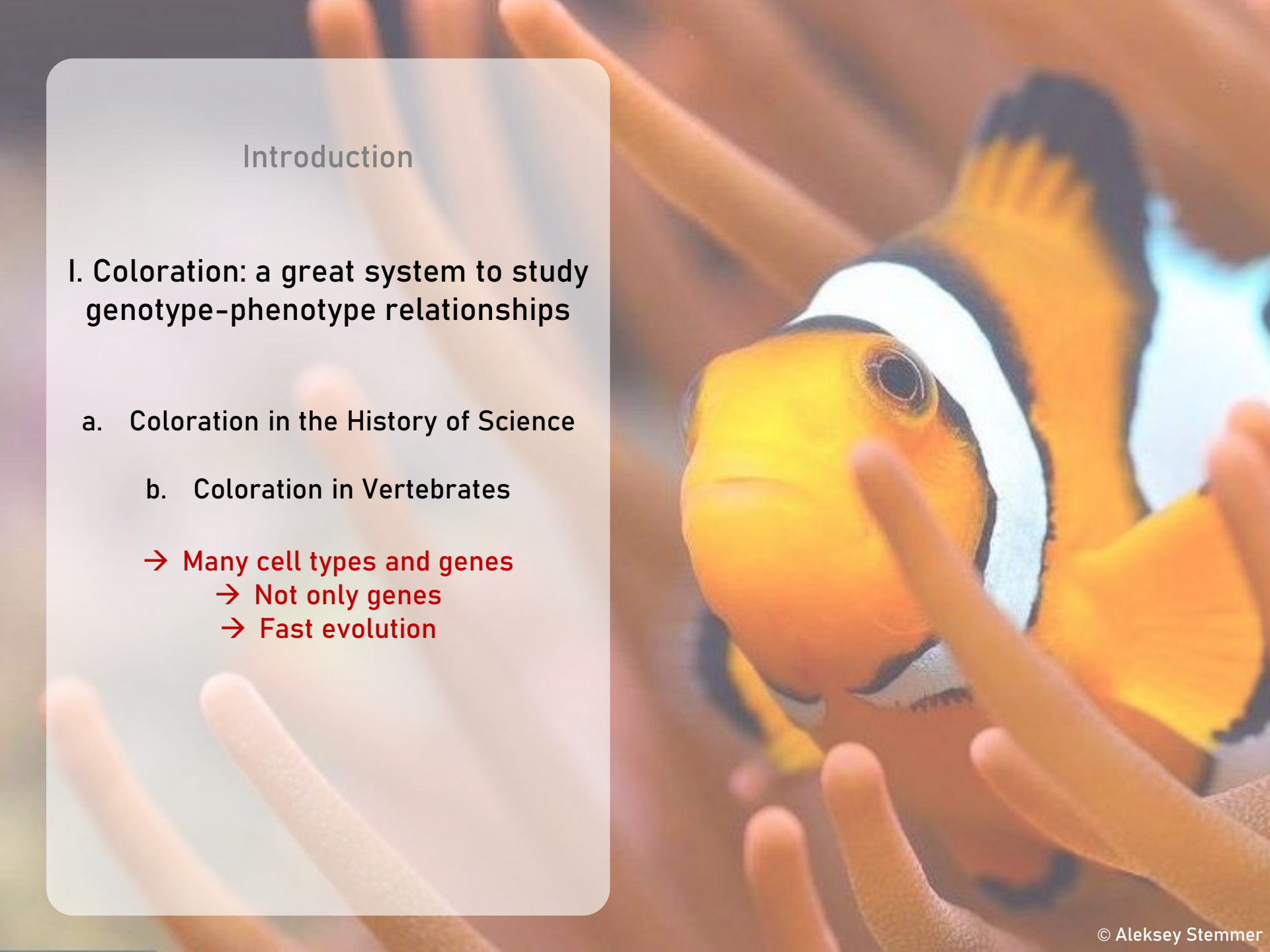
Gautier et al. (2018) *Current Biol.*







Adapted from Litsios *et al.* (2012), Litsios, Pearman *et al.* (2014) and Litsios and Salamin (2014)



Introduction

I. Coloration: a great system to study genotype-phenotype relationships

a. Coloration in the History of Science

b. Coloration in Vertebrates

→ Many cell types and genes
→ Not only genes
→ Fast evolution

Introduction

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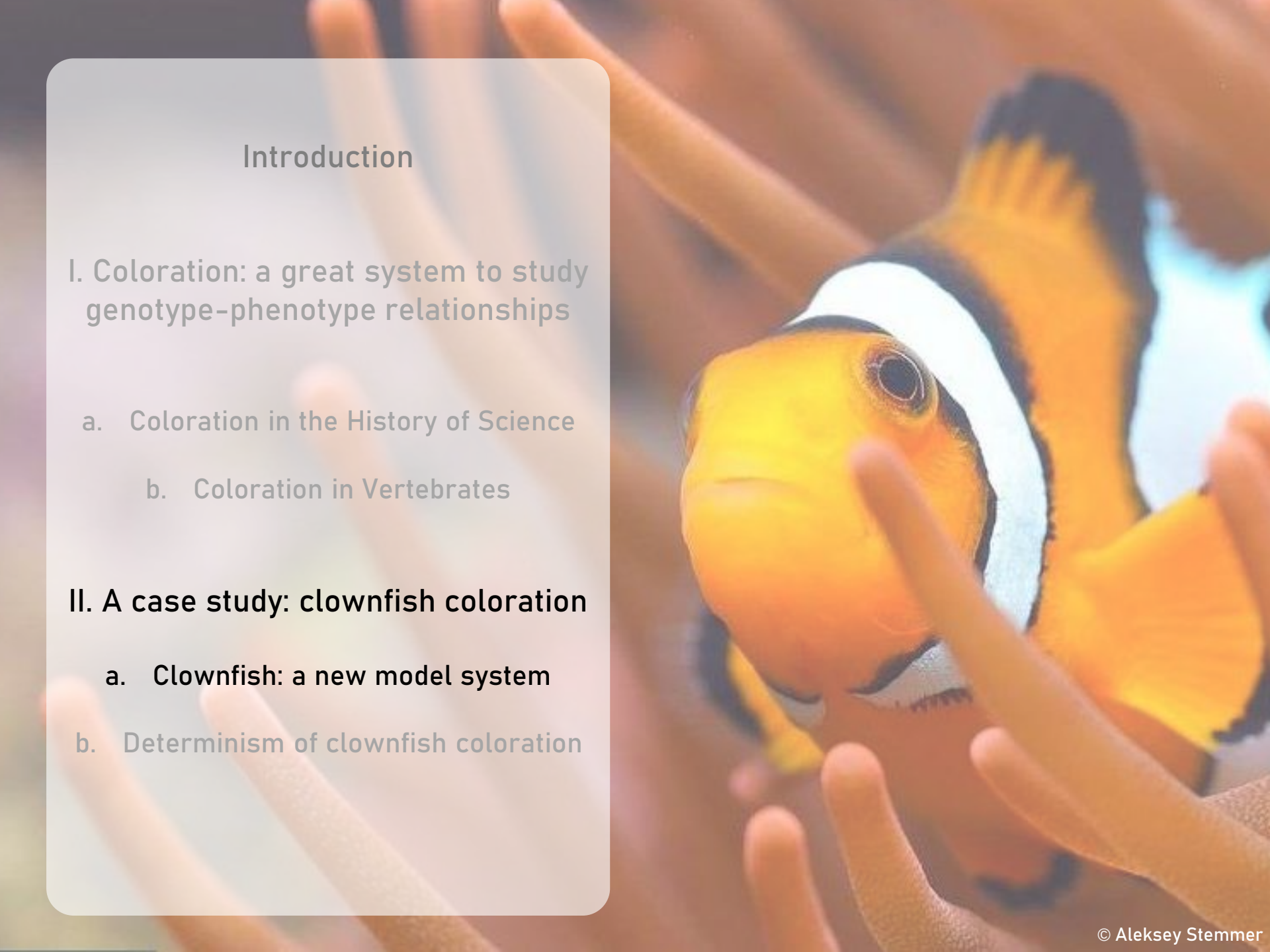
II. A case study: clownfish coloration

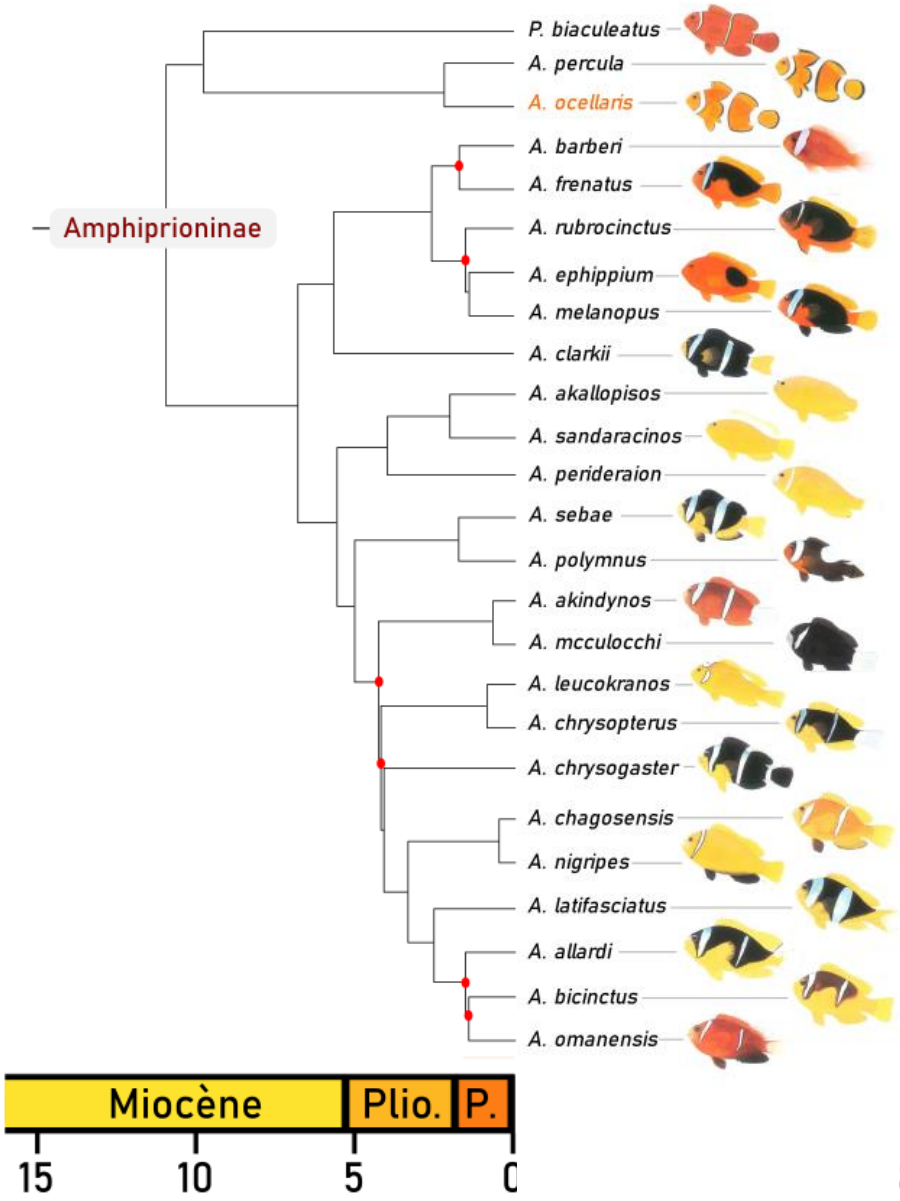
a. Clownfish: a new model system

b. Determinism of clownfish coloration



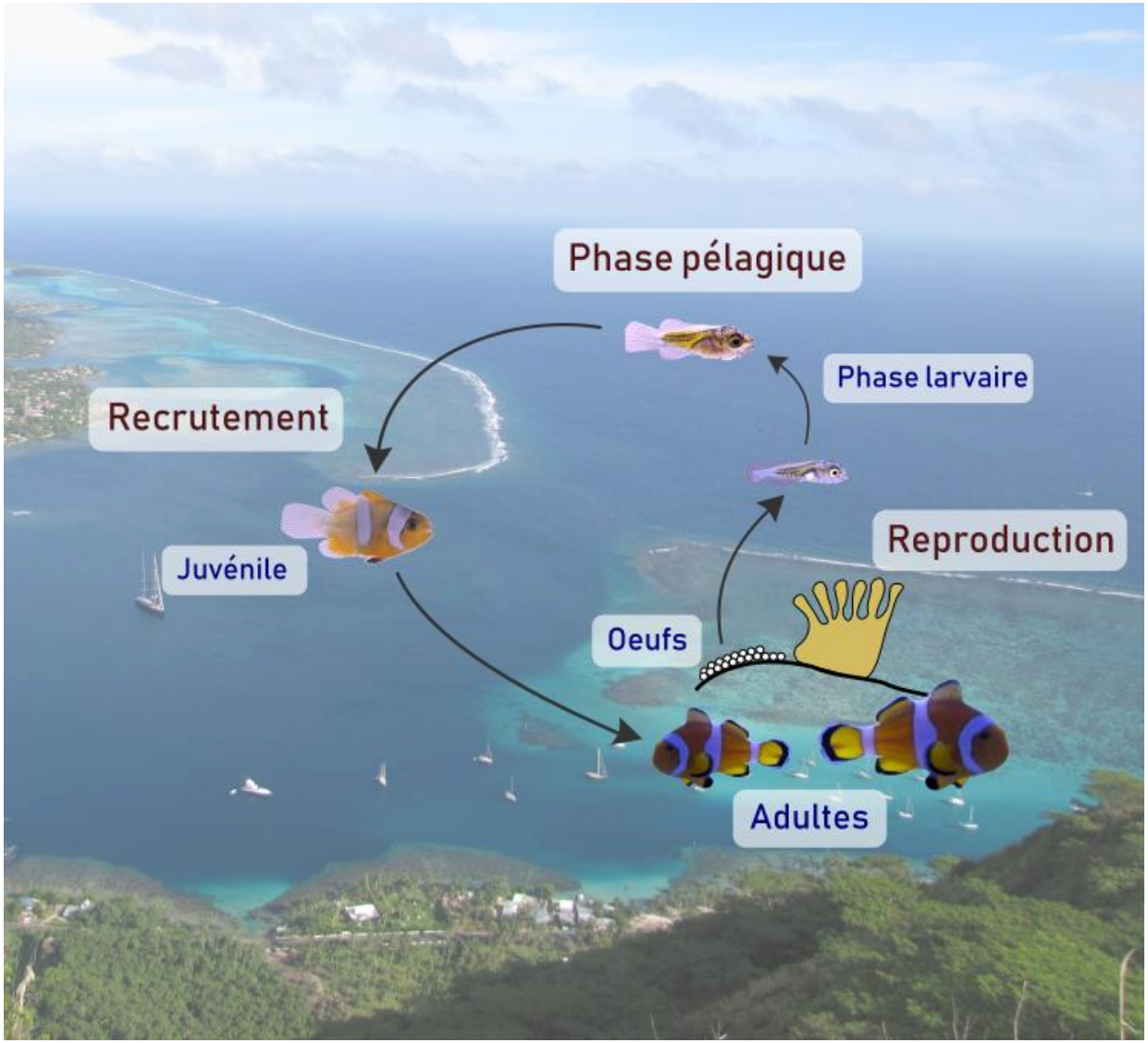

Why a new model system ?
© Aleksey Stemmer

Ecology and evolution of clownfish *Amphiprion ocellaris*

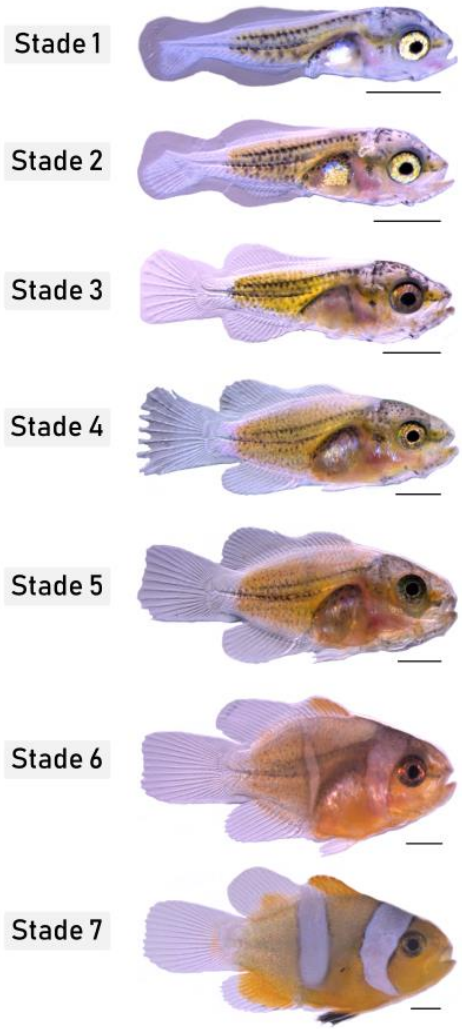


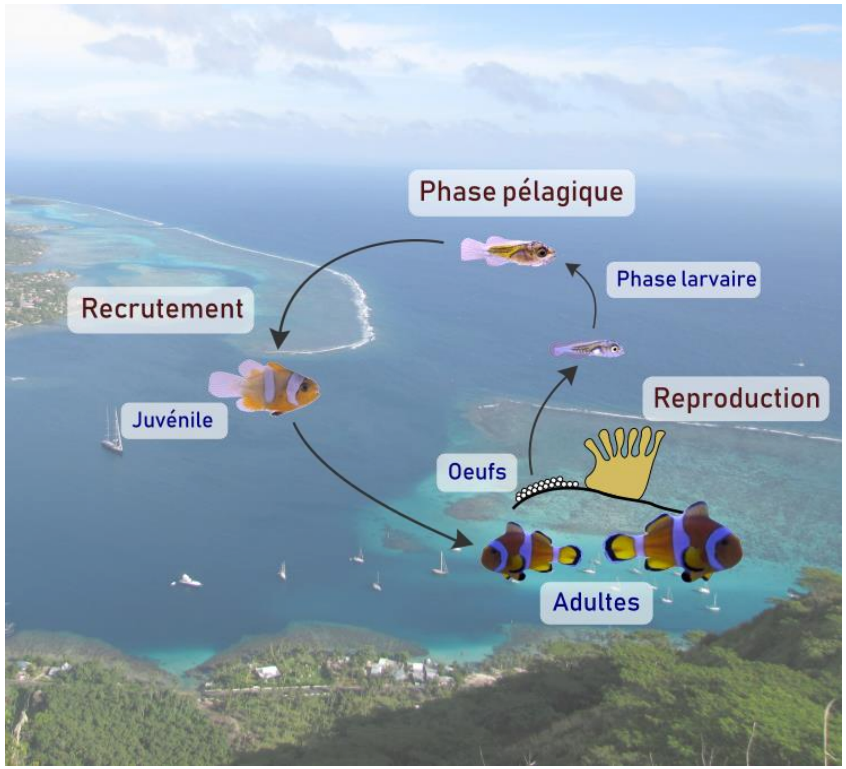
Topology adapted from Litsios *et al.* (2012), Litsios, Pearman *et al.* (2014) and Litsios and Salamin (2014)

Lifecycle of clownfish *A. ocellaris*



Pigmentary changes during *A. ocellaris* post-embryonic development





OBSERVATOIRE OCÉANOLOGIQUE de Banyuls/Mer 1882

Roux *et al.* (2019)

Introduction

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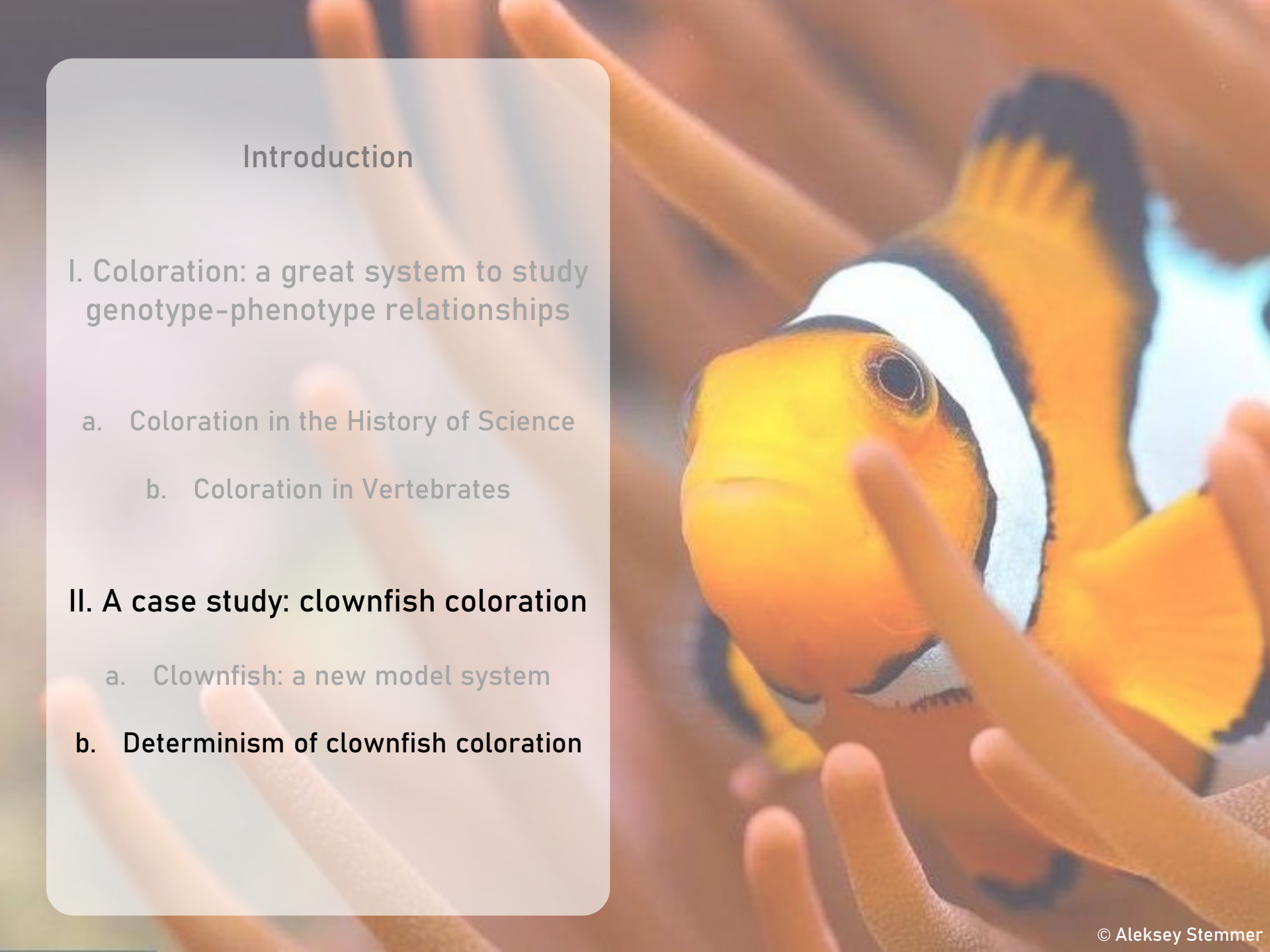
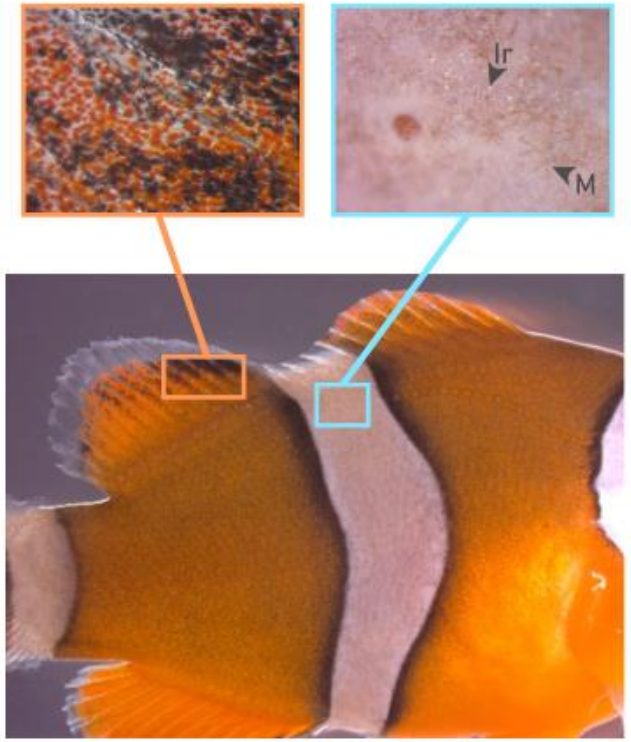
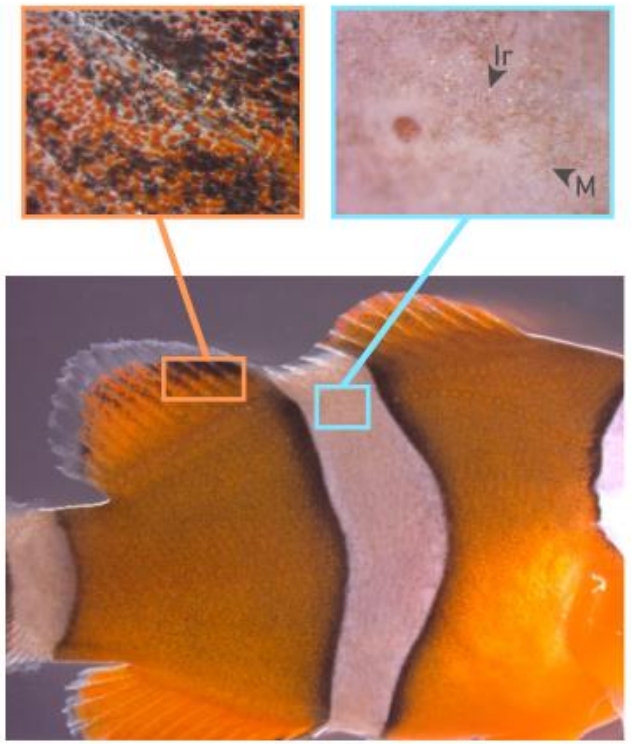


Cells present in each band in *A. ocellaris*

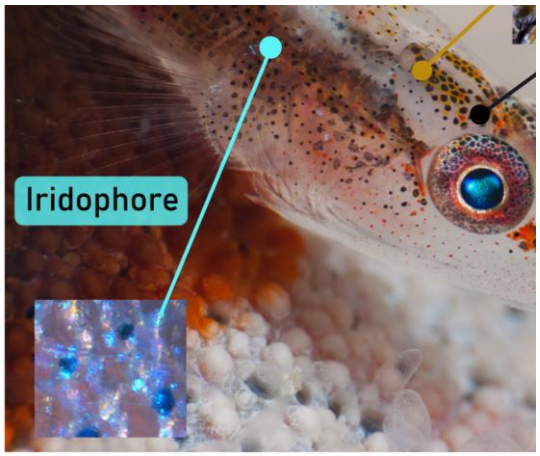


Pictures: N. Roux

Cells present in each band in *A. ocellaris*



Pictures: N. Roux



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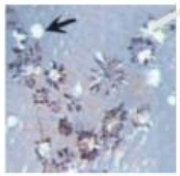
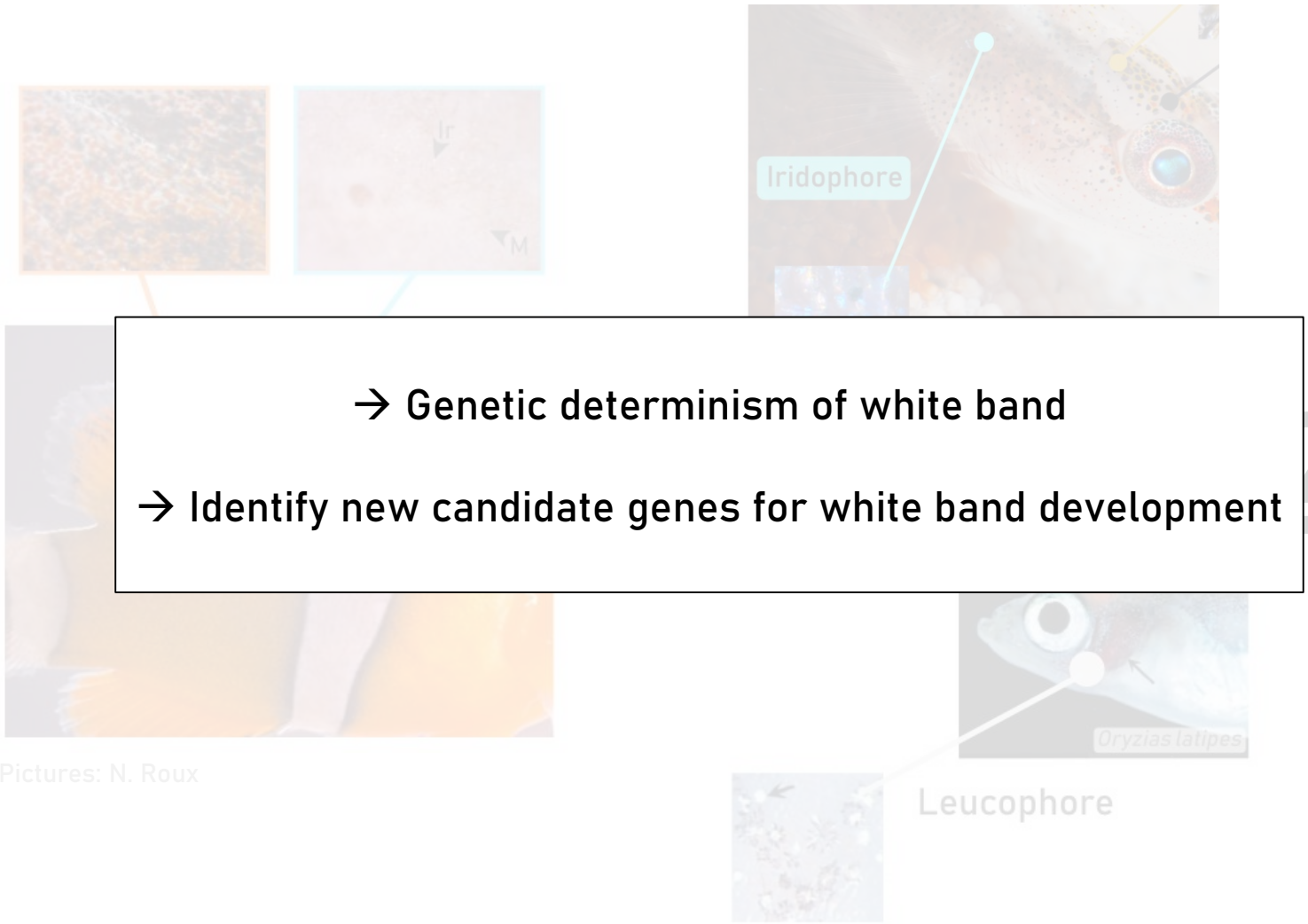


Leucophore

Cells present in each band in *A. ocellaris*

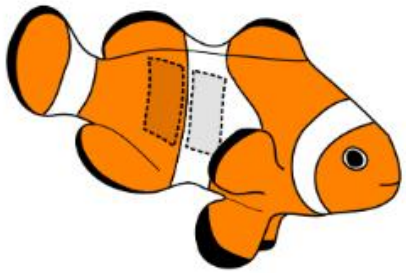


→ Genetic determinism of white band

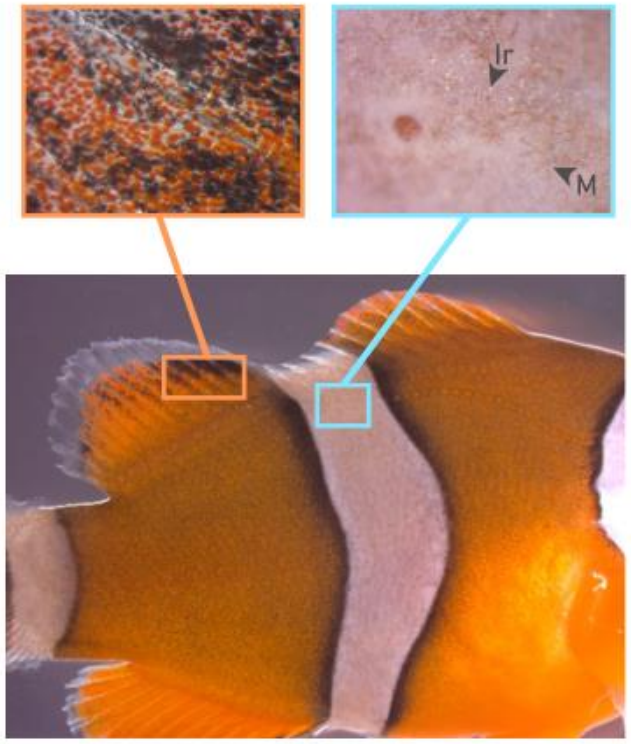
→ Identify new candidate genes for white band development

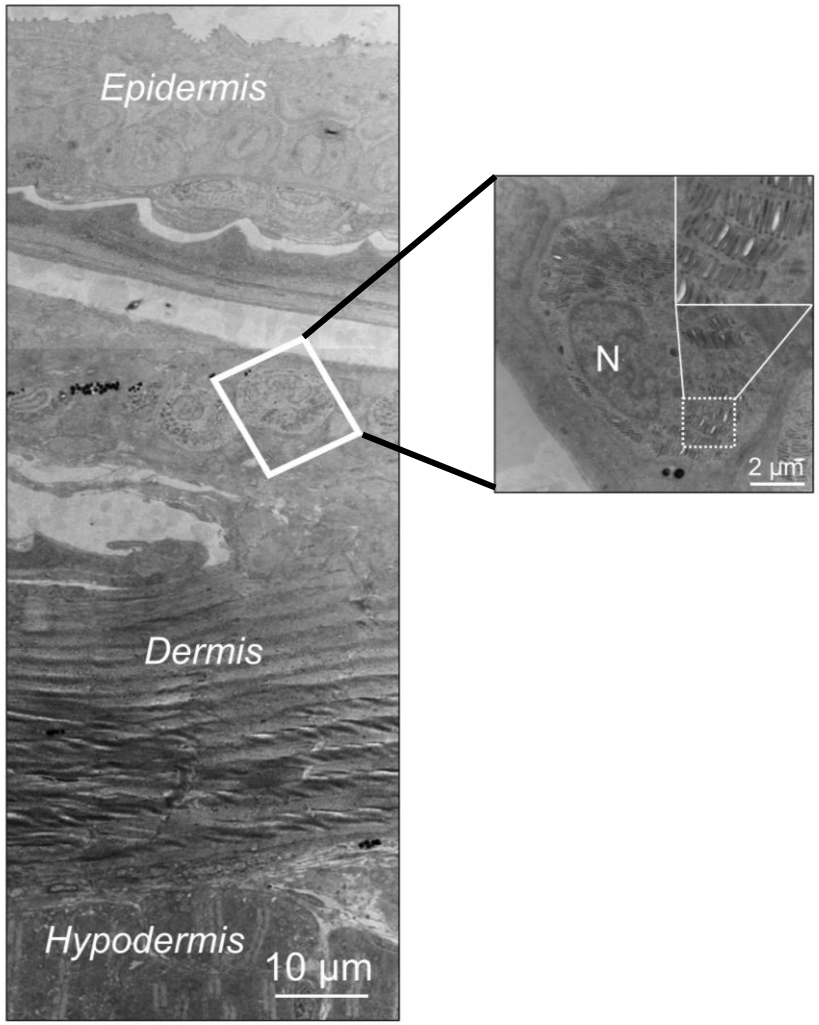
Pictures: N. Roux

Comparison white vs. orange skin using RNA-Seq



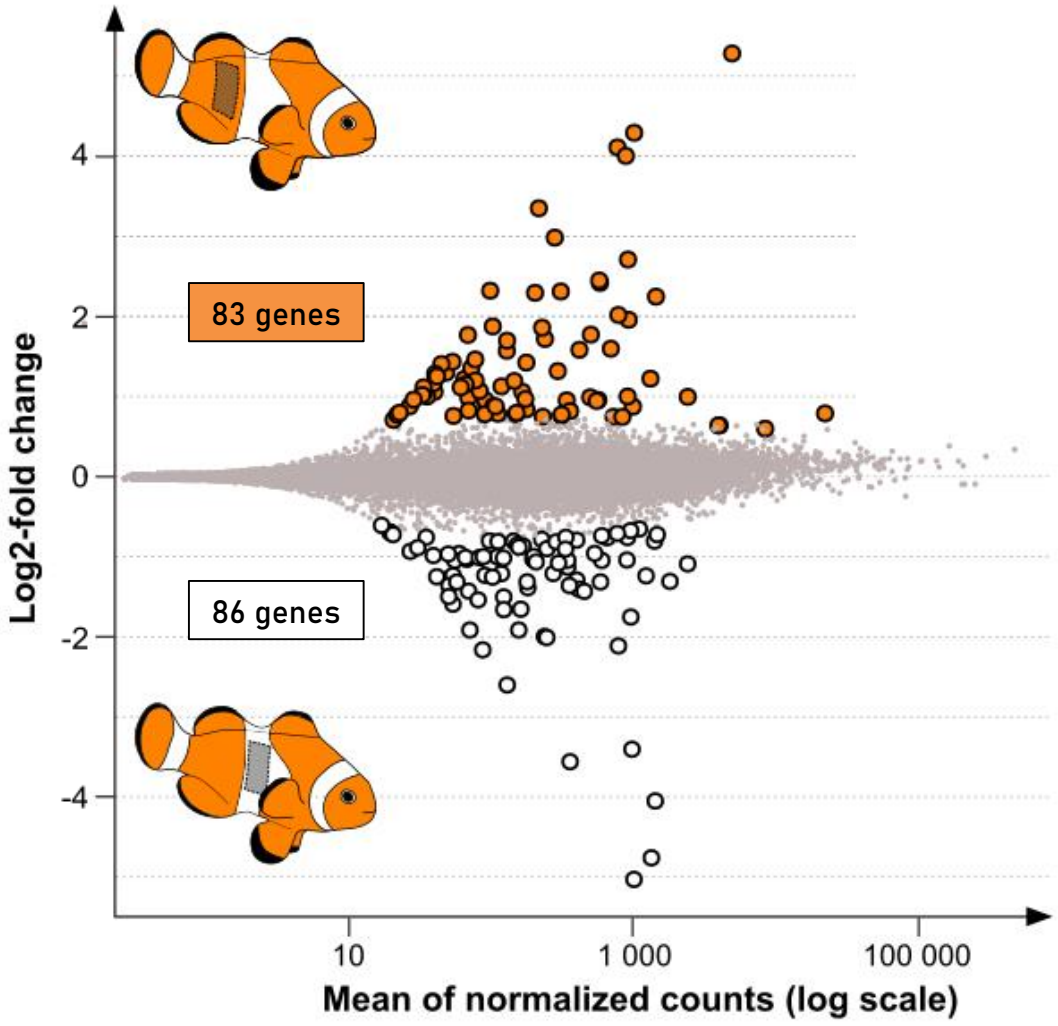
White skin of *A. ocellaris* harbors iridophores, not leucophores





Salis*, Lorin* *et al.* (2019)

RNA-Seq comparison of white vs. orange skin



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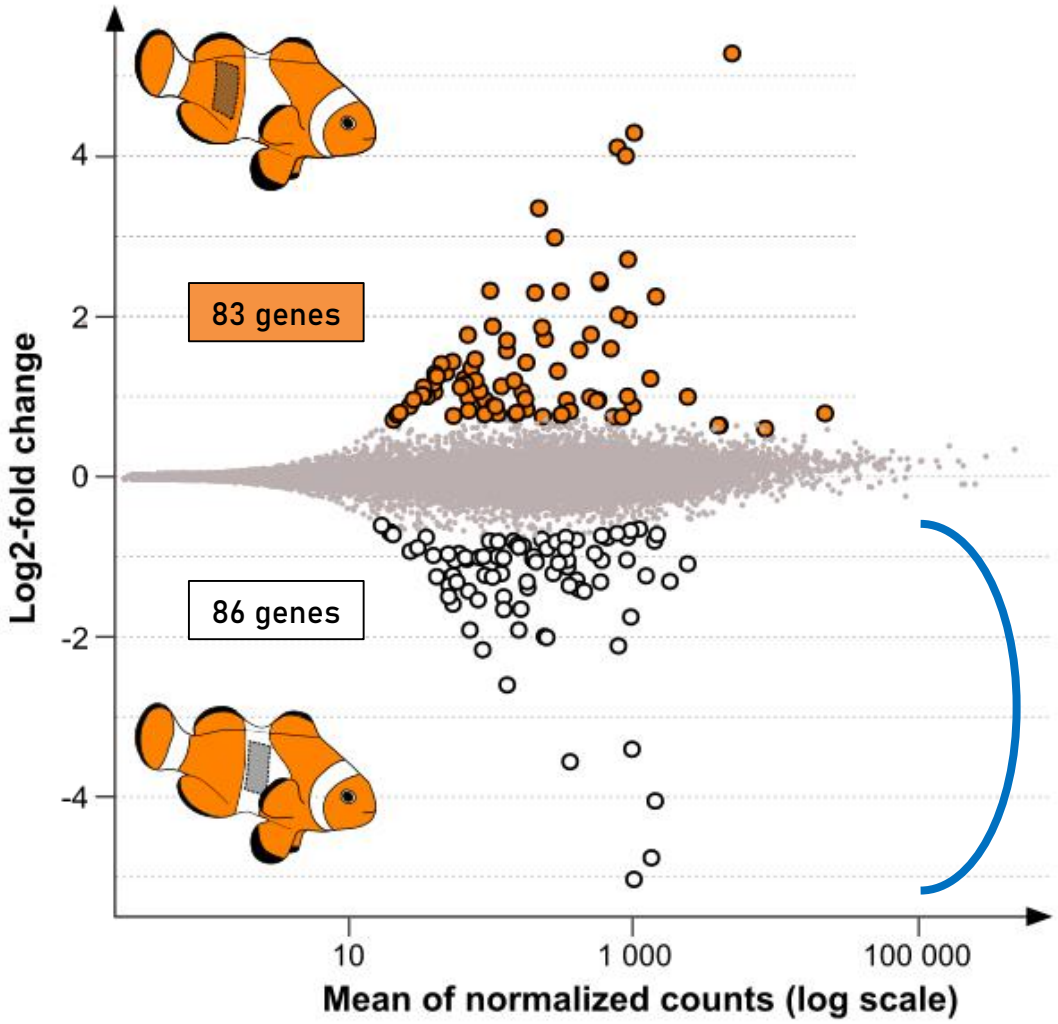
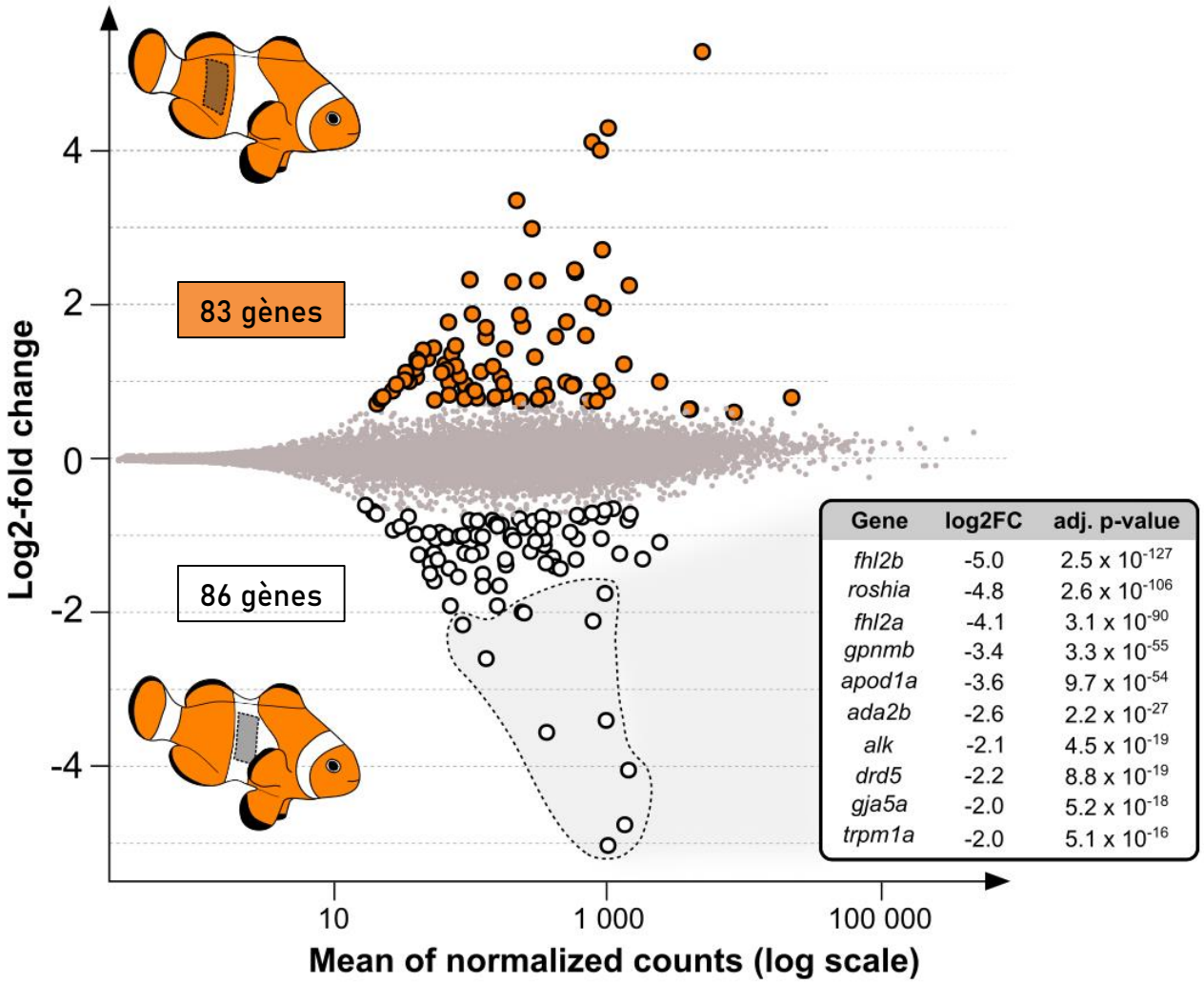


Comparable with zebrafish iridophores

Salis*, Lorin* *et al.* (2019)

10 most DEGs in white skin



Gene	log2FC	adj. p-value
fhl2b	-5.0	2.5×10^{-127}
roshia	-4.8	2.6×10^{-106}
fhl2a	-4.1	3.1×10^{-90}
gpnmb	-3.4	3.3×10^{-55}
apod1a	-3.6	9.7×10^{-54}
ada2b	-2.6	2.2×10^{-27}
alk	-2.1	4.5×10^{-19}
drd5	-2.2	8.8×10^{-19}
gja5a	-2.0	5.2×10^{-18}
trpm1a	-2.0	5.1×10^{-16}

Salis*, Lorin* *et al.* (2019)

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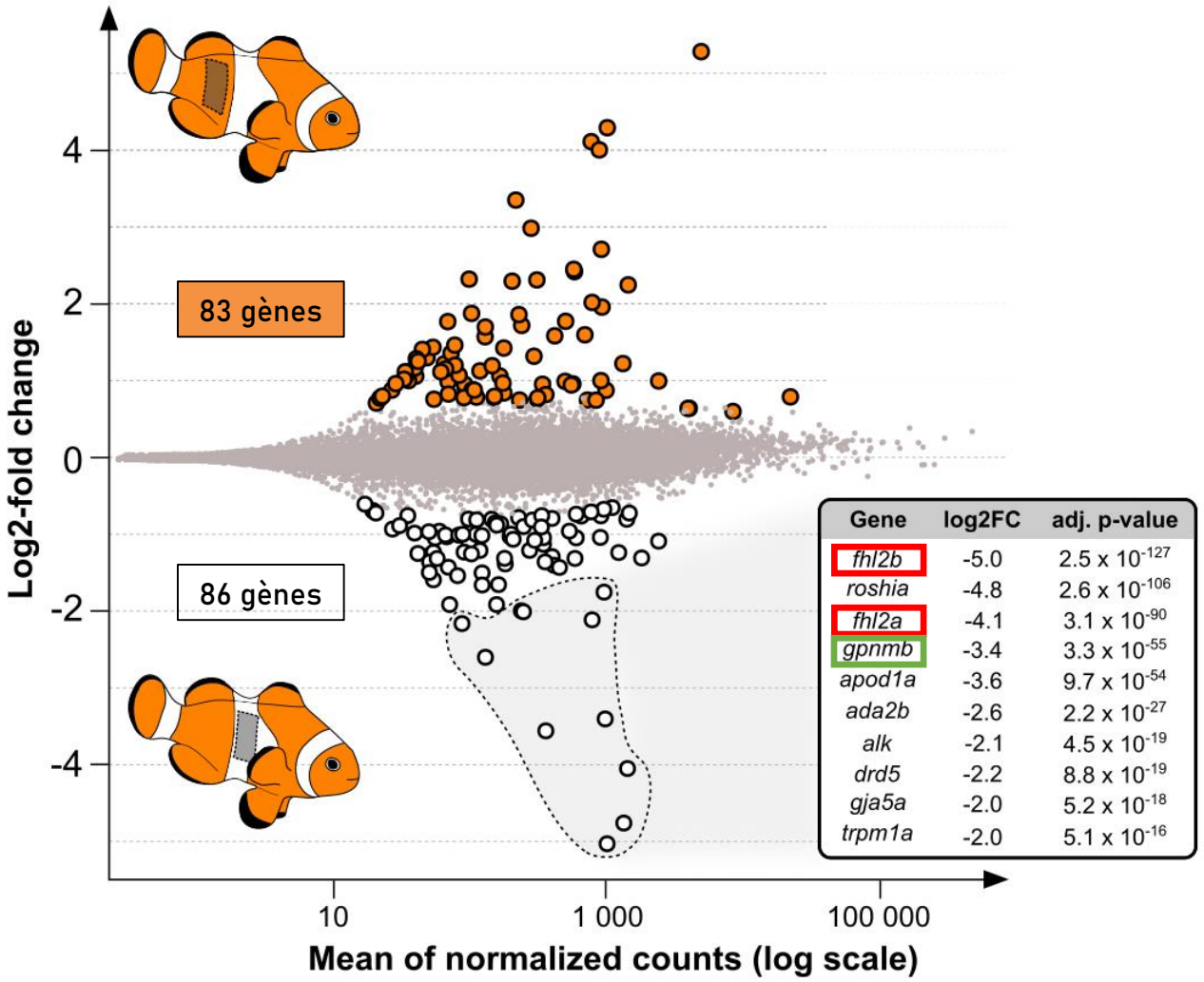

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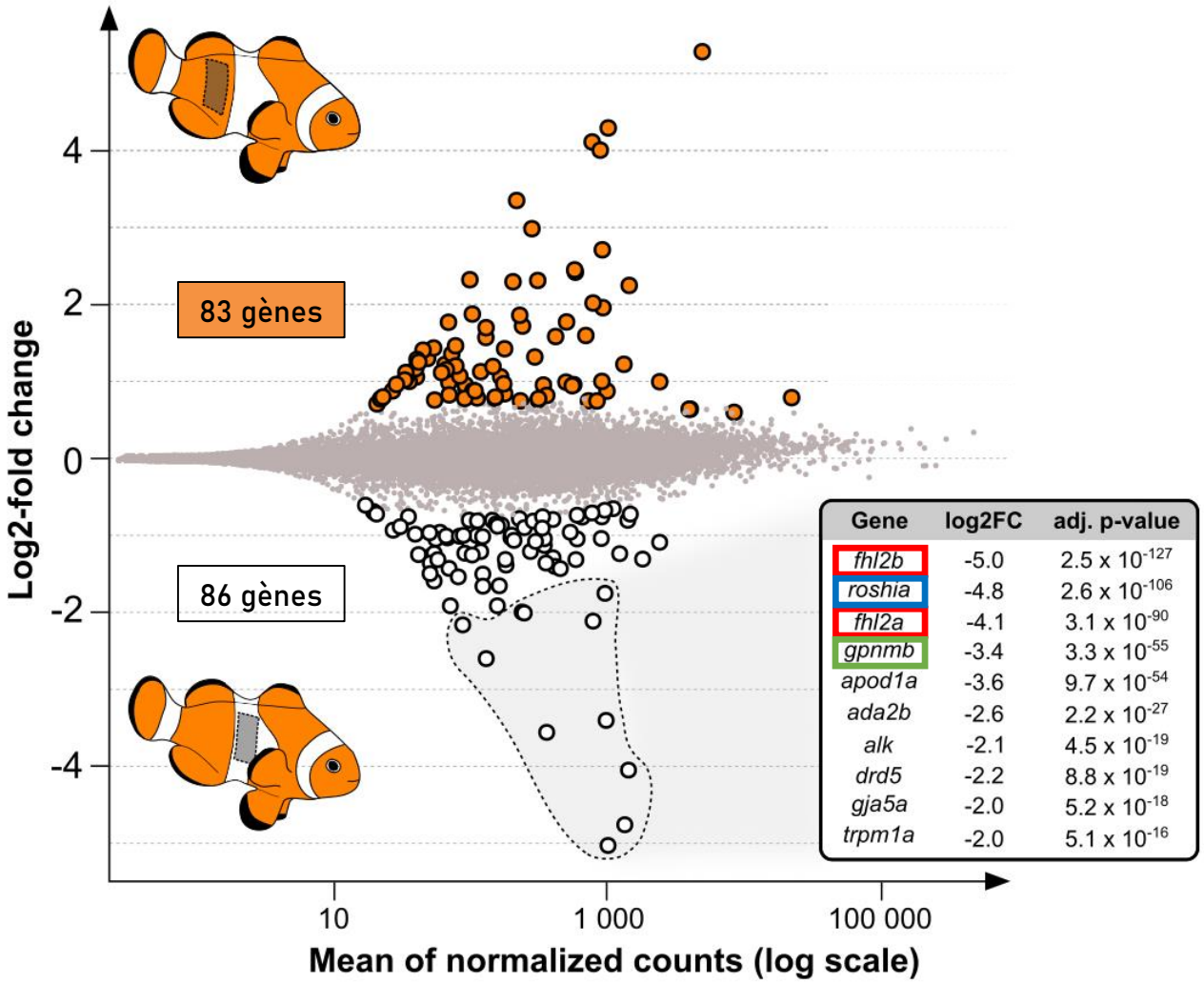
Salis*, Lorin* *et al.* (in prep.) / Santos *et al.* (2014) *Nature Comm.*

10 most DEGs in white skin



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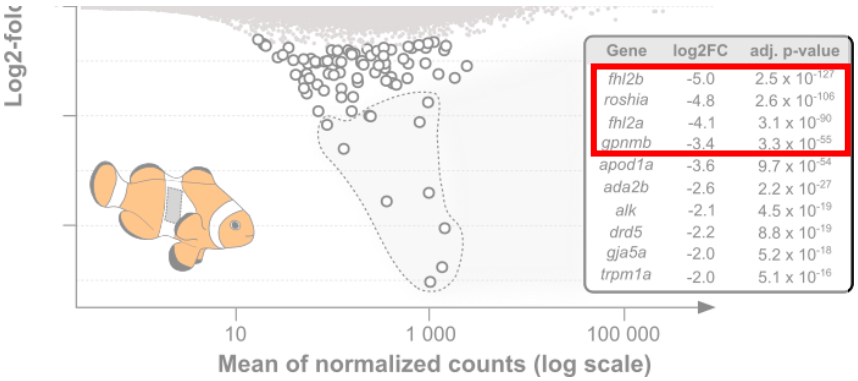
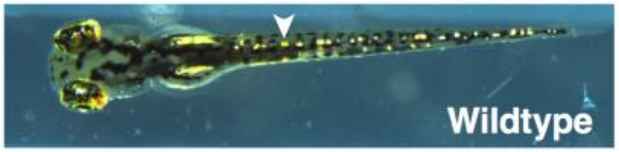
non-annotated
→ *roshi-a*

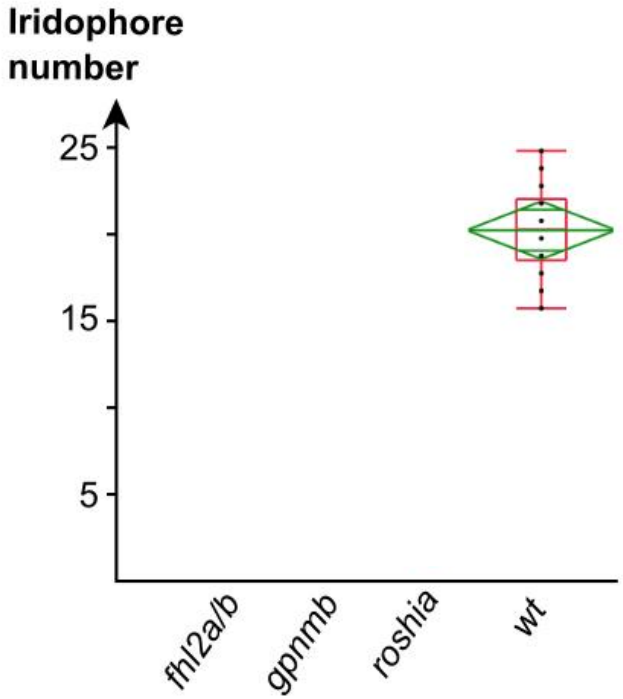
Salis*, Lorin* *et al.* (2019)

Functional validation using CRISPR-Cas9 in *D. rerio*



Gene	log2FC	adj. p-value
fhl2b	-5.0	2.5×10^{-127}
roshia	-4.8	2.6×10^{-106}
fhl2a	-4.1	3.1×10^{-90}
gpnmb	-3.4	3.3×10^{-55}
apod1a	-3.6	9.7×10^{-54}
ada2b	-2.6	2.2×10^{-27}
alk	-2.1	4.5×10^{-19}
drd5	-2.2	8.8×10^{-19}
gja5a	-2.0	5.2×10^{-18}
trpm1a	-2.0	5.1×10^{-16}





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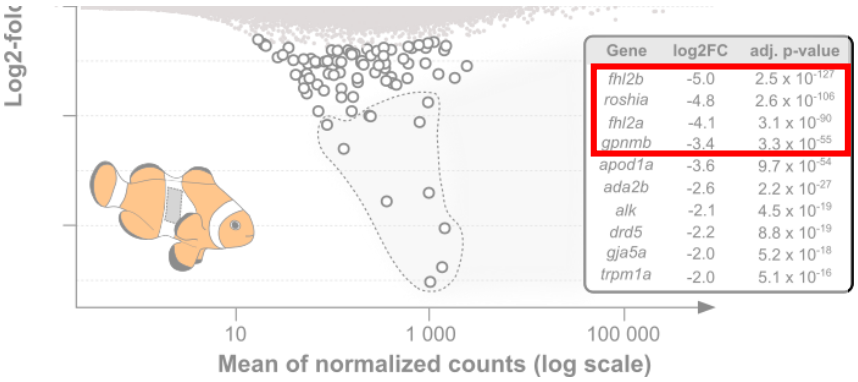

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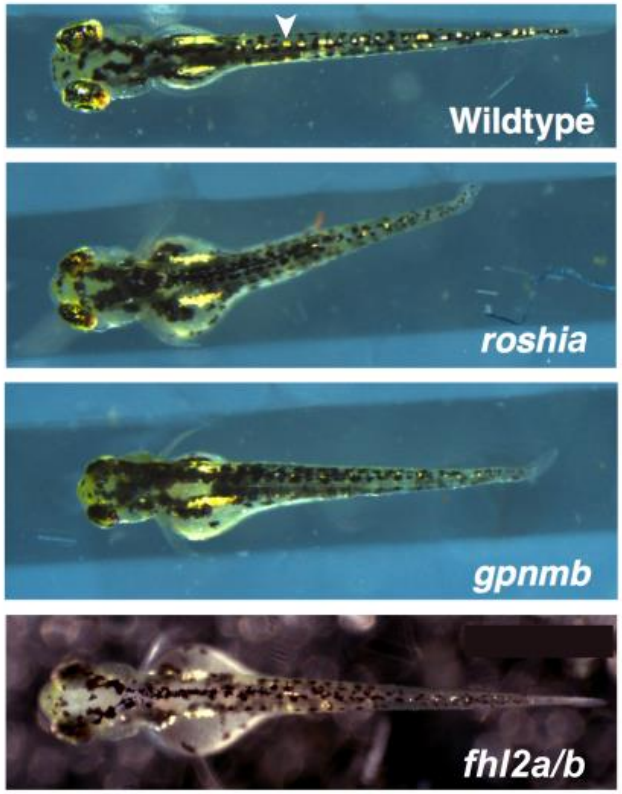
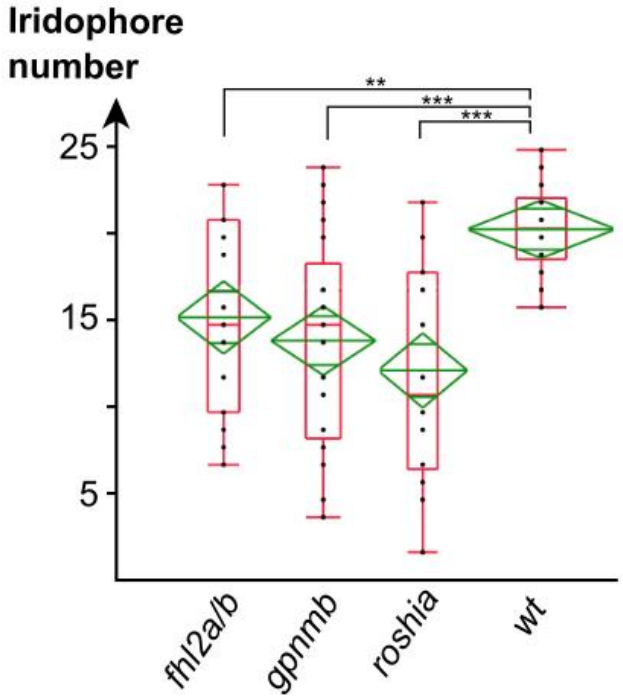
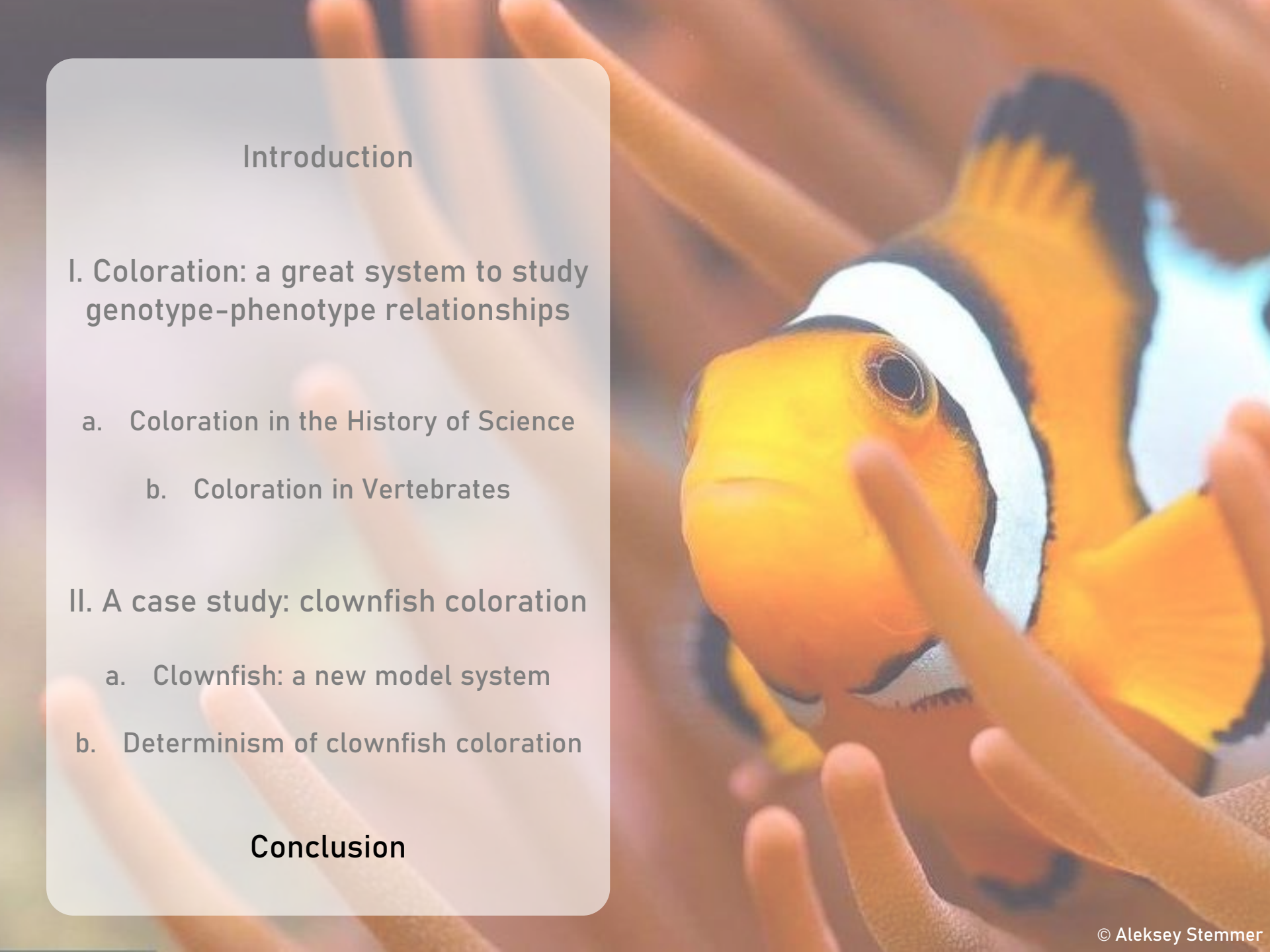




Salis*, Lorin* *et al.* (2019)



Introduction

I. Coloration: a great system to study genotype-phenotype relationships

a. Coloration in the History of Science

b. Coloration in Vertebrates

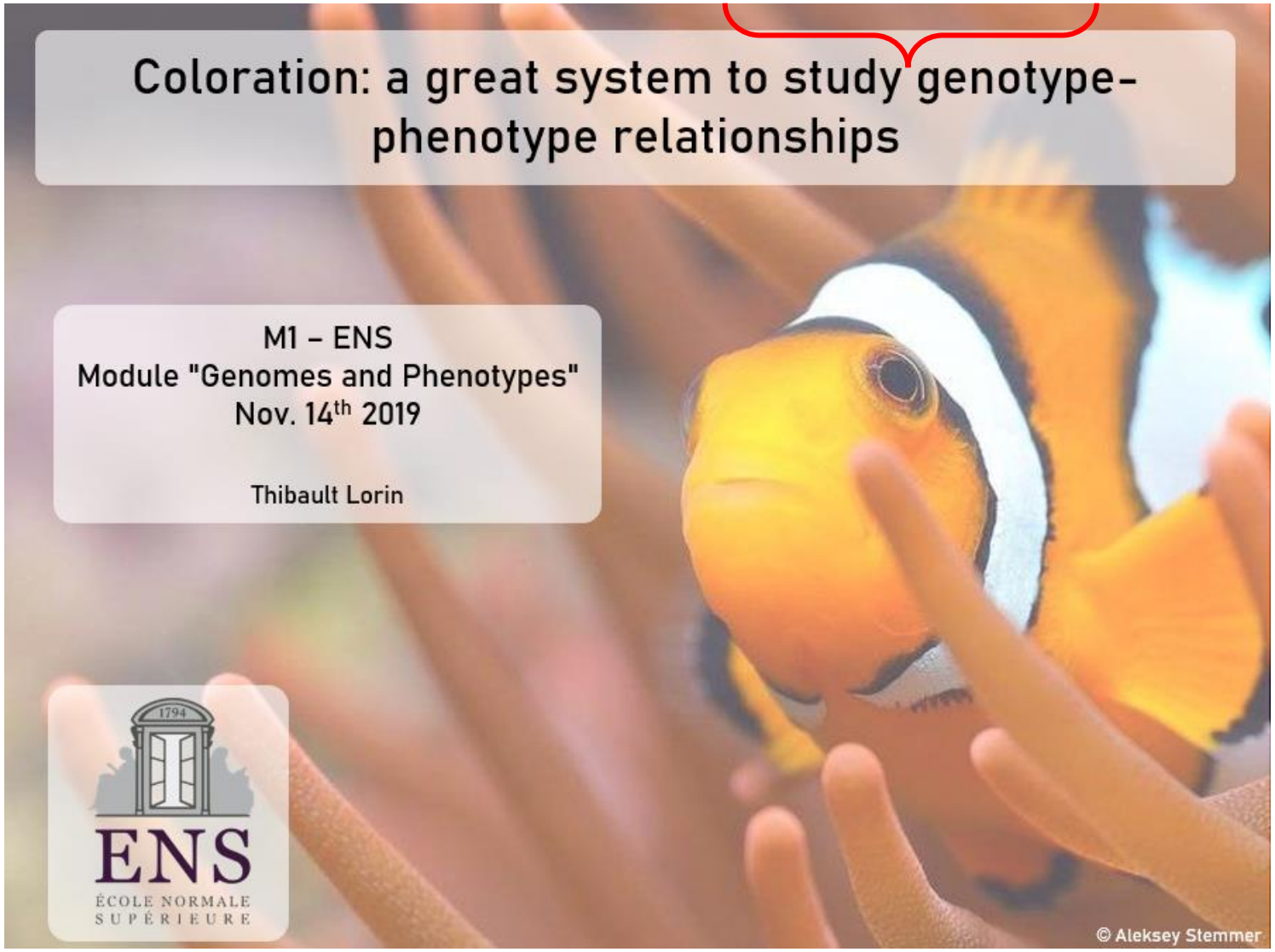
II. A case study: clownfish coloration

a. Clownfish: a new model system

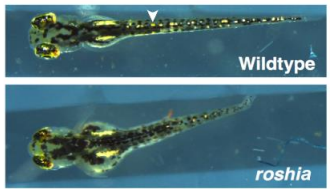
b. Determinism of clownfish coloration

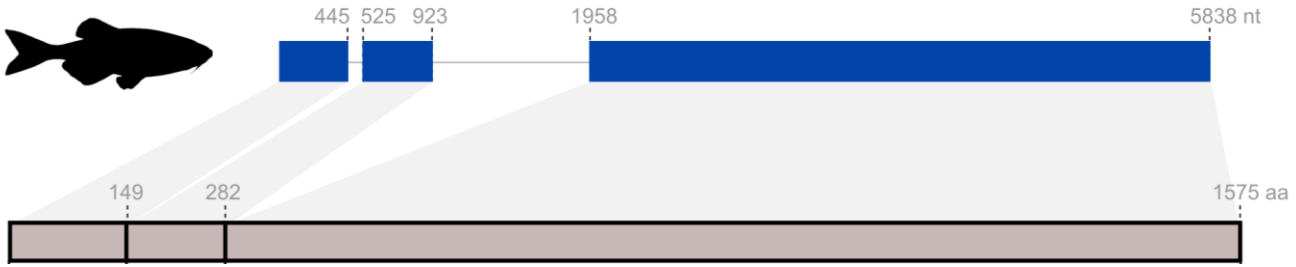
Conclusion

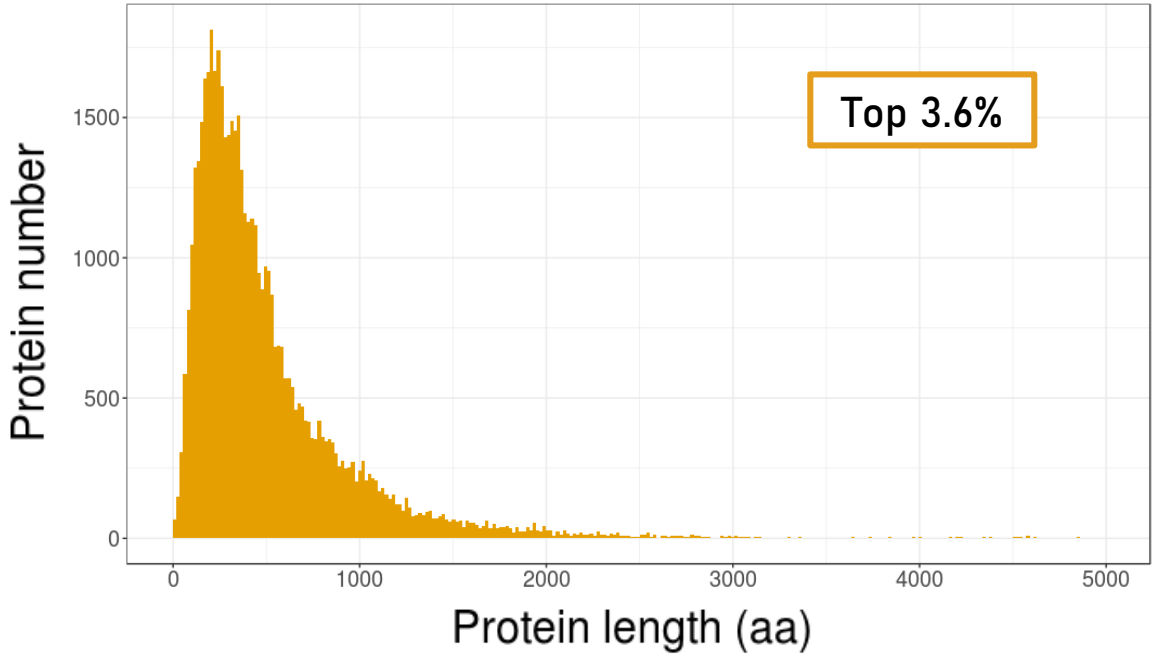
The EVOLUTION of



Structure and putative function of Roshi-a







Lorin *et al.* (in prep.)

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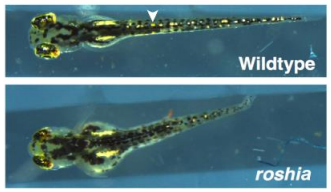

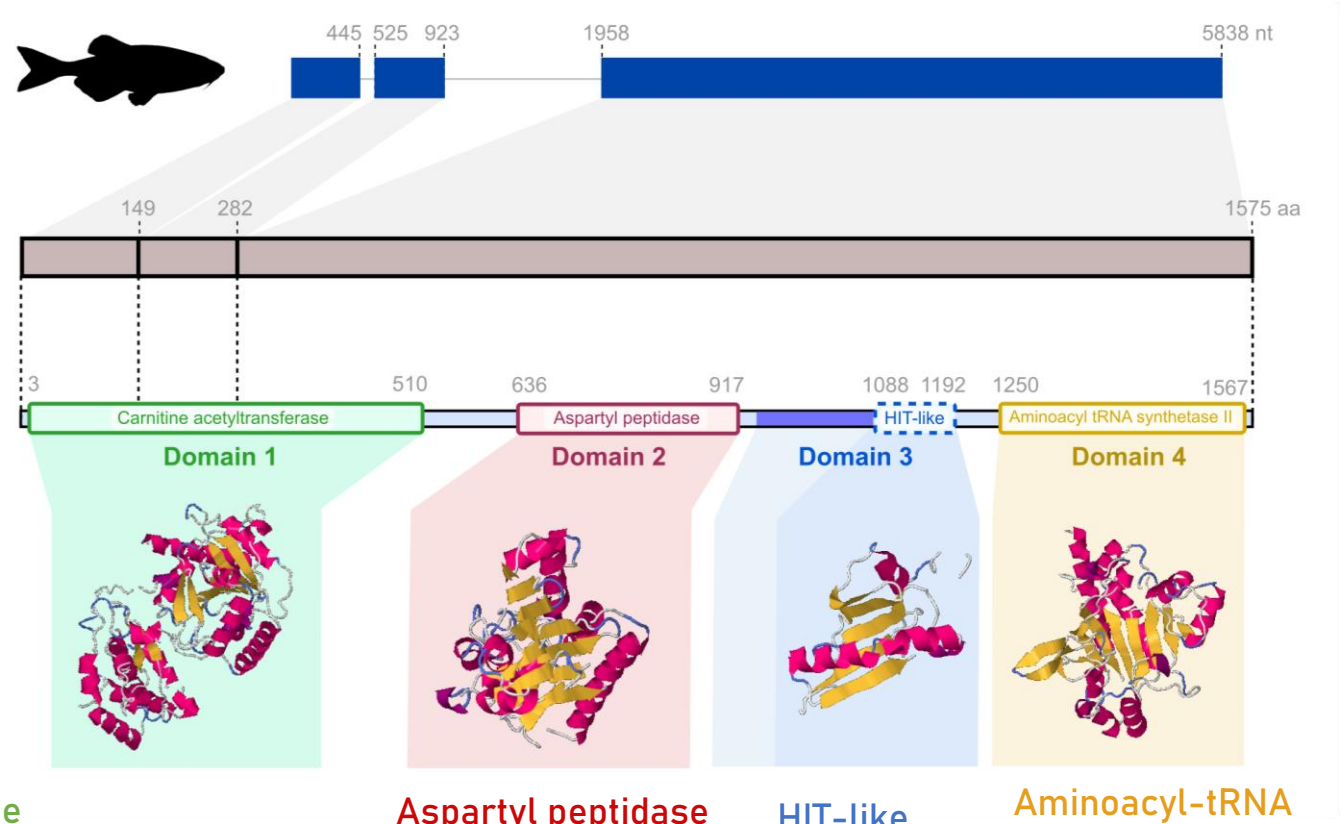

Carnitine acetyltransferase

Aspartyl peptidase

HIT-like

Aminoacyl-tRNA synthetase

Lorin *et al.* (in prep.)

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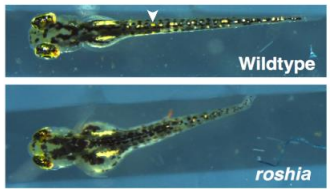
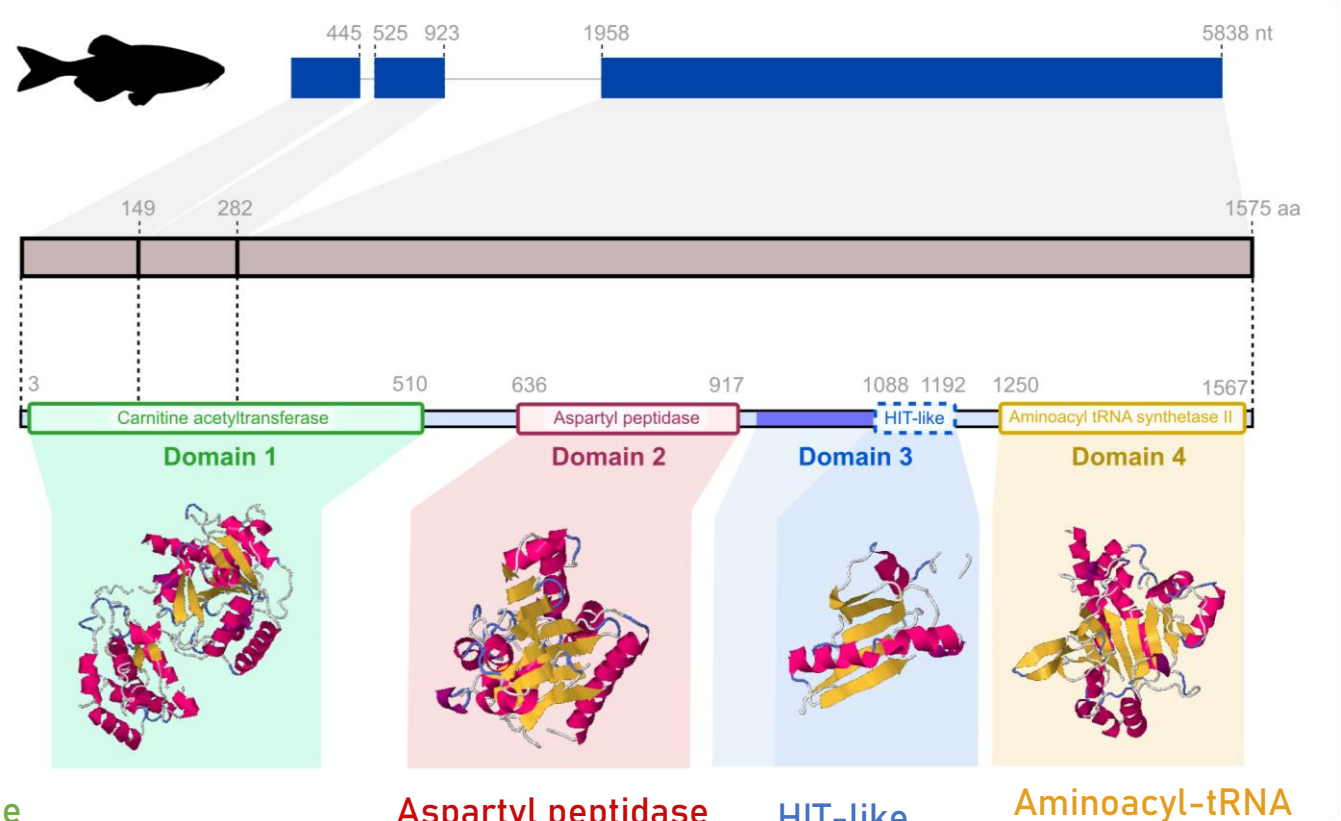


Roshi-a is a "Long Putative Multifunctional Cytosolic Enzyme"



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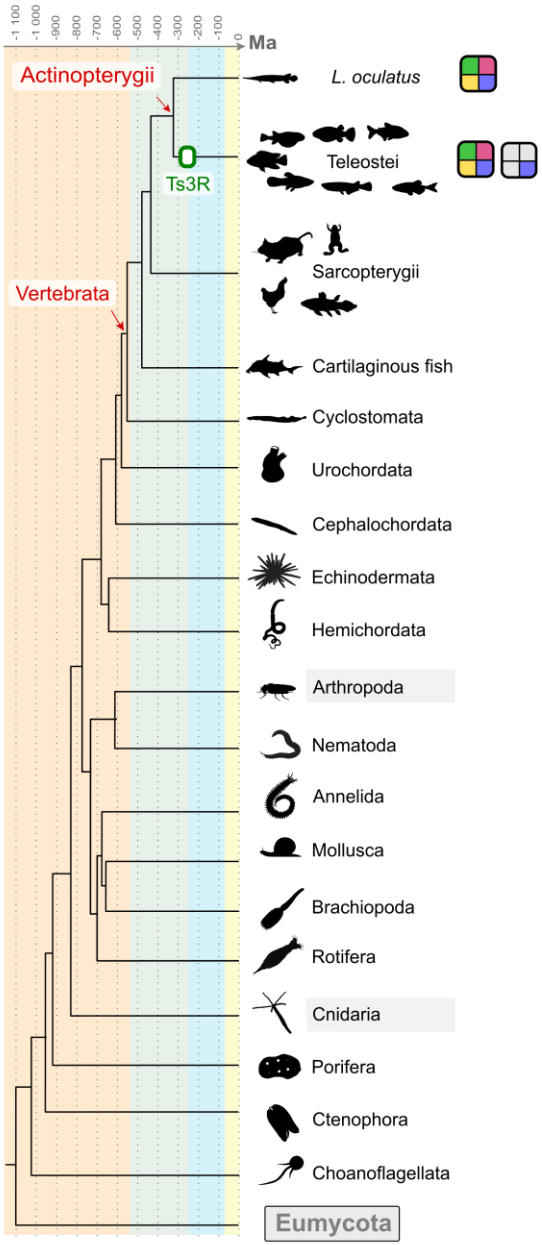
Roshi has a patchy distribution within animals



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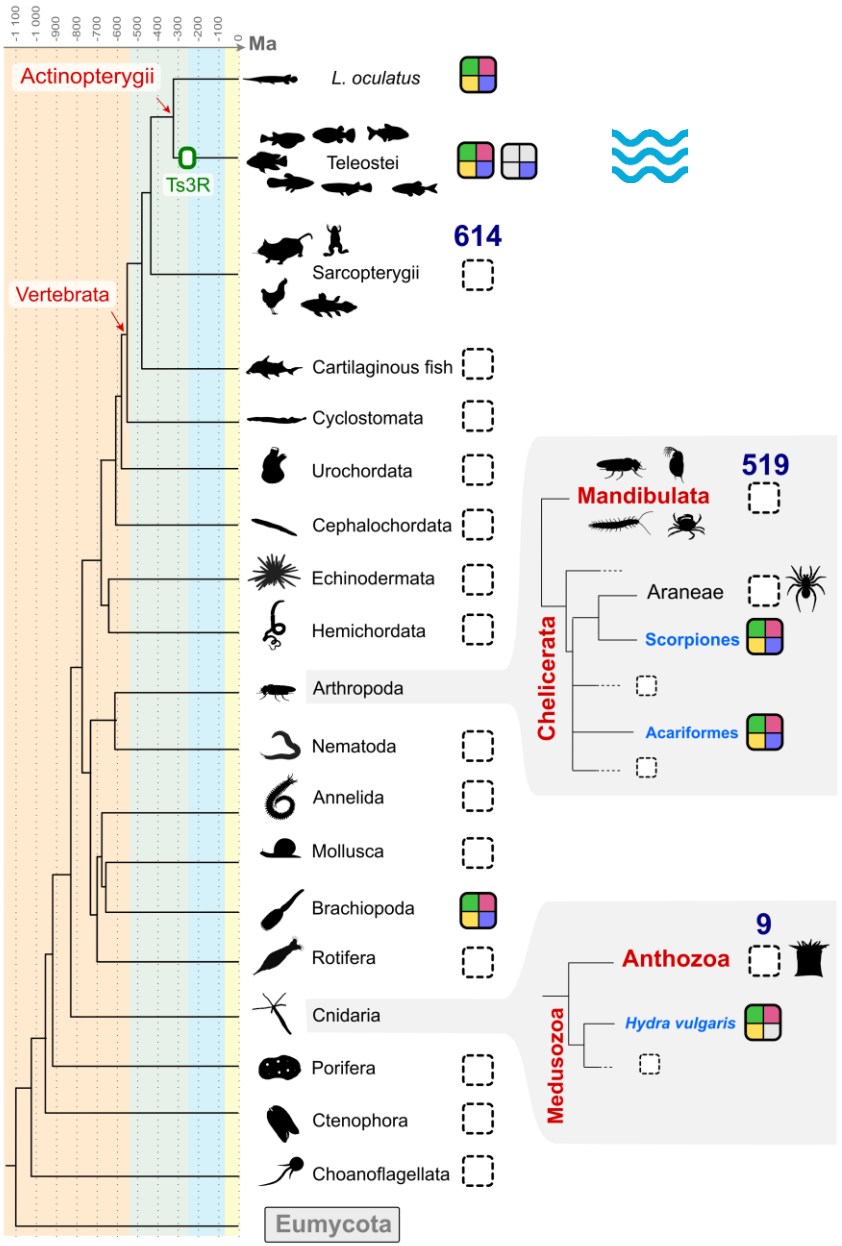

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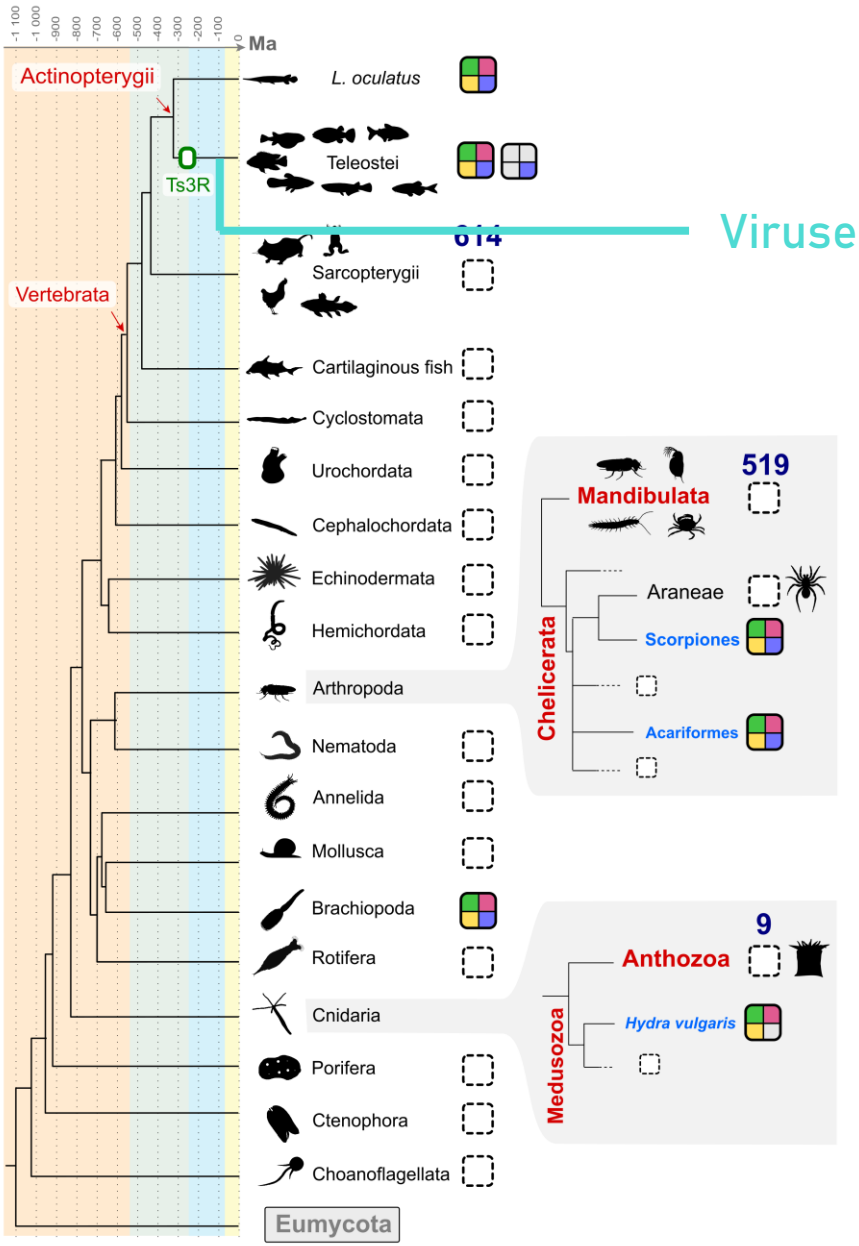
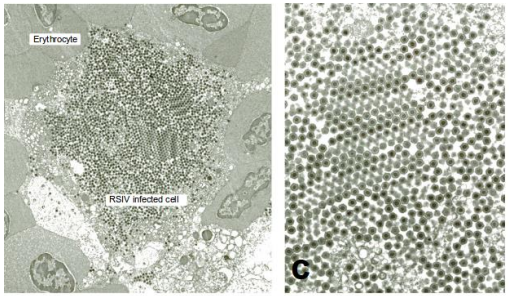
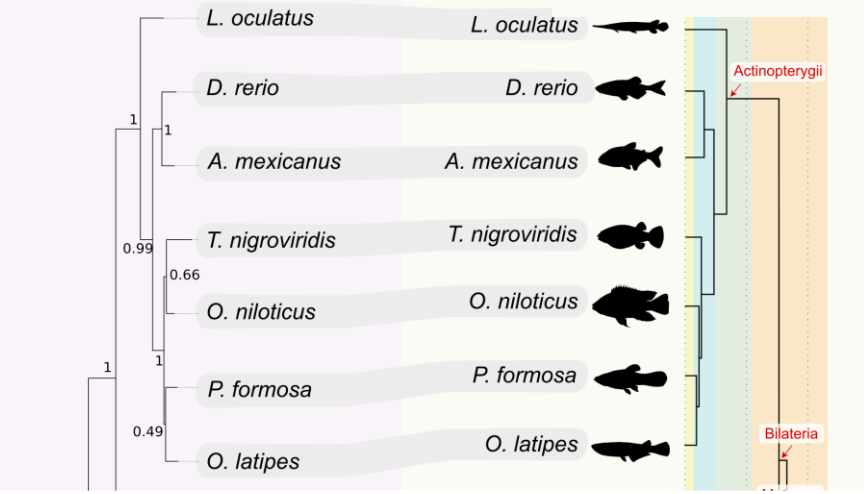


Viruses.... Iridoviruses!



Lorin *et al.* (in prep.)

roshi gene tree does not correspond to species tree



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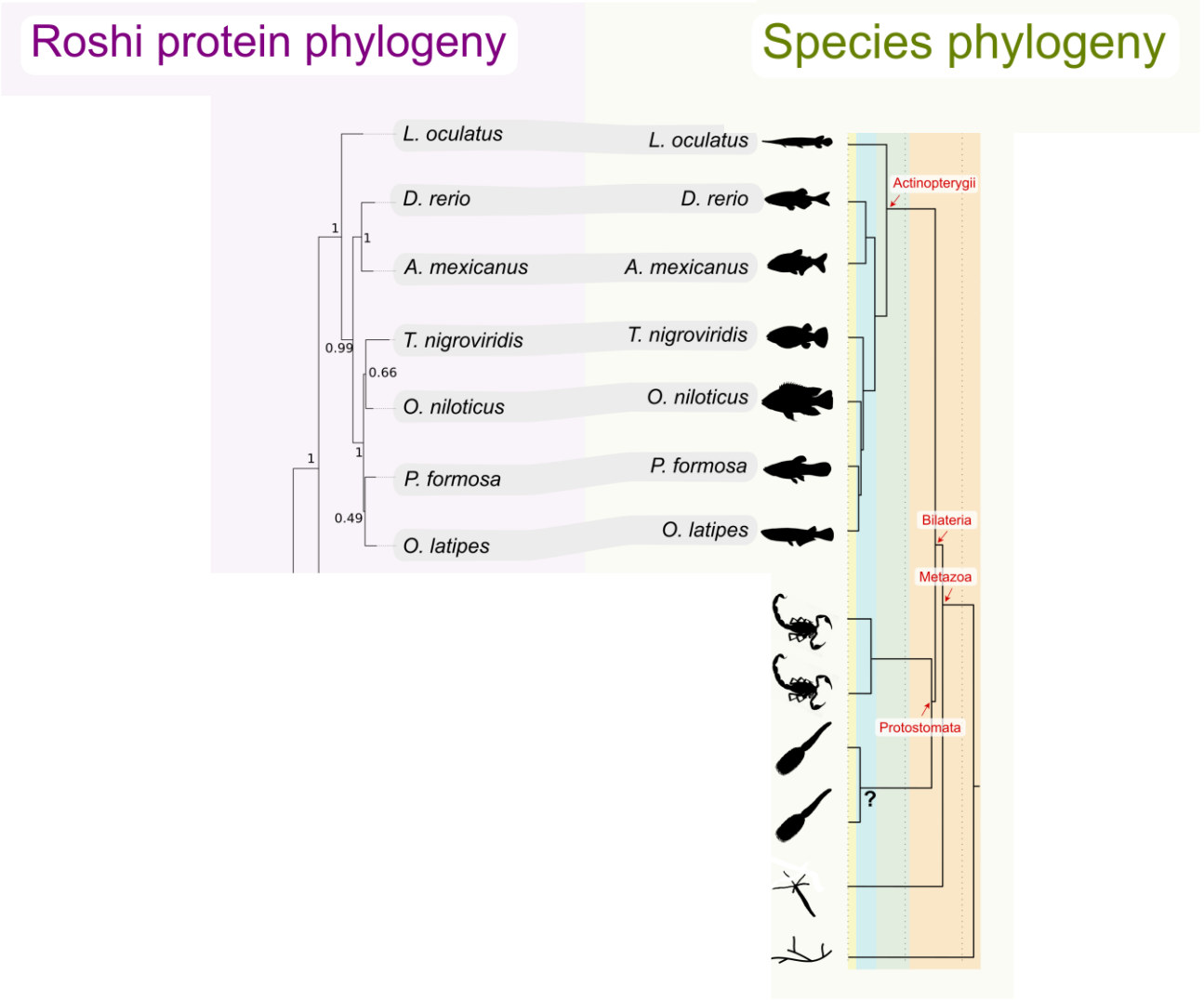

Lorin *et al.* (in prep.)

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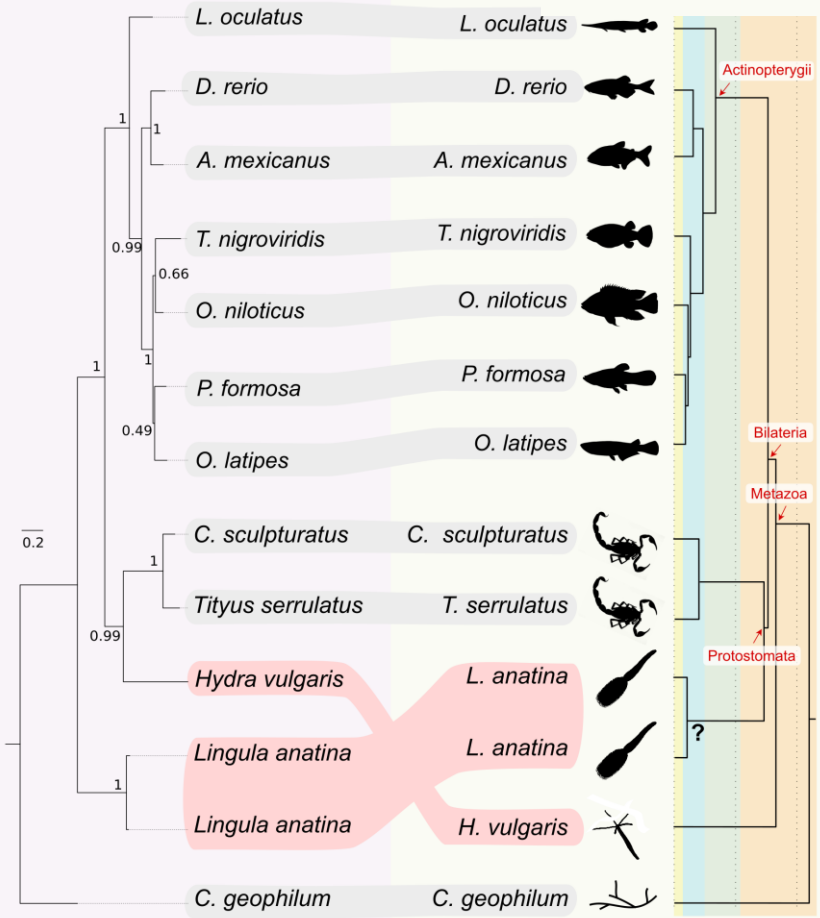
Roshi protein phylogeny

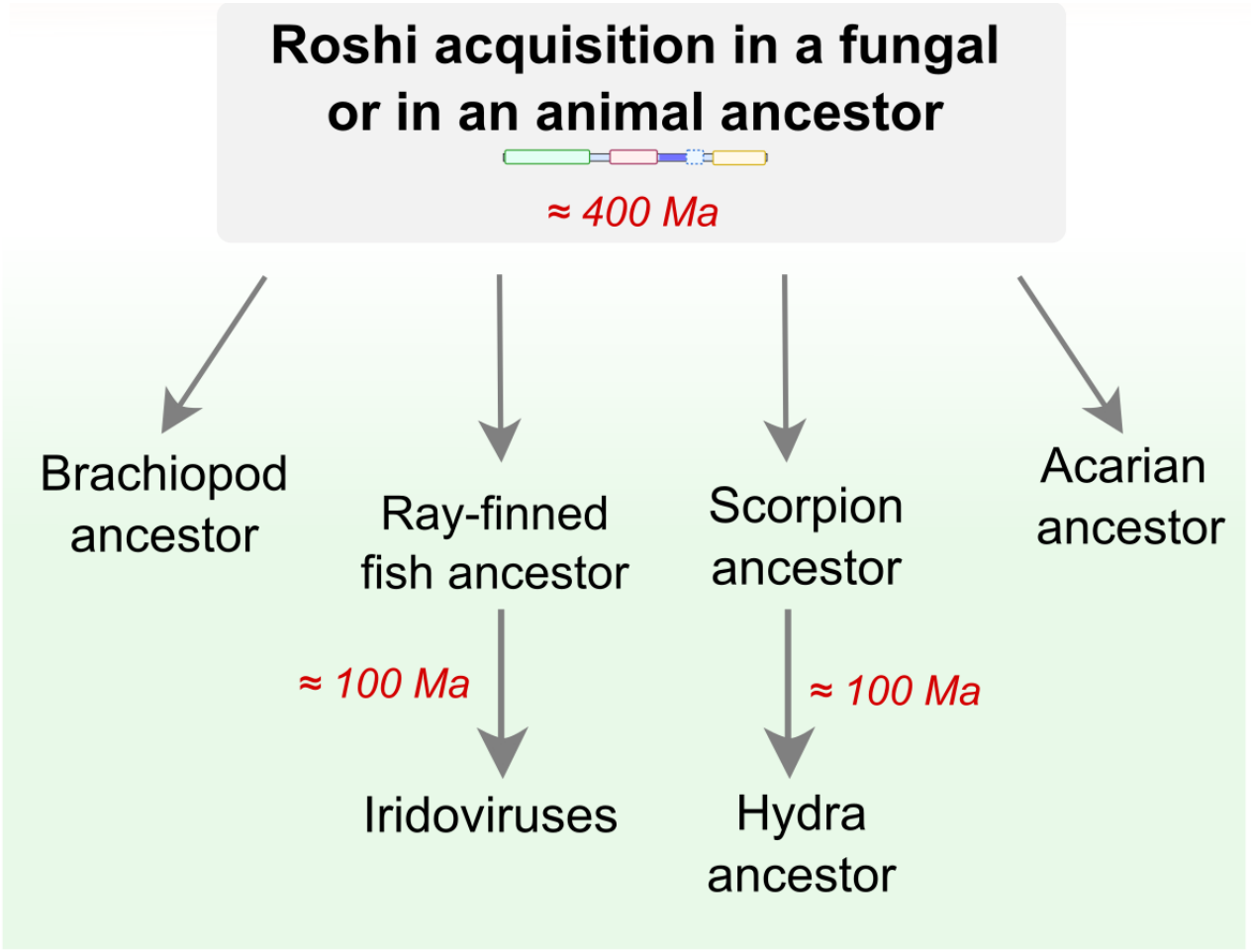
Species phylogeny



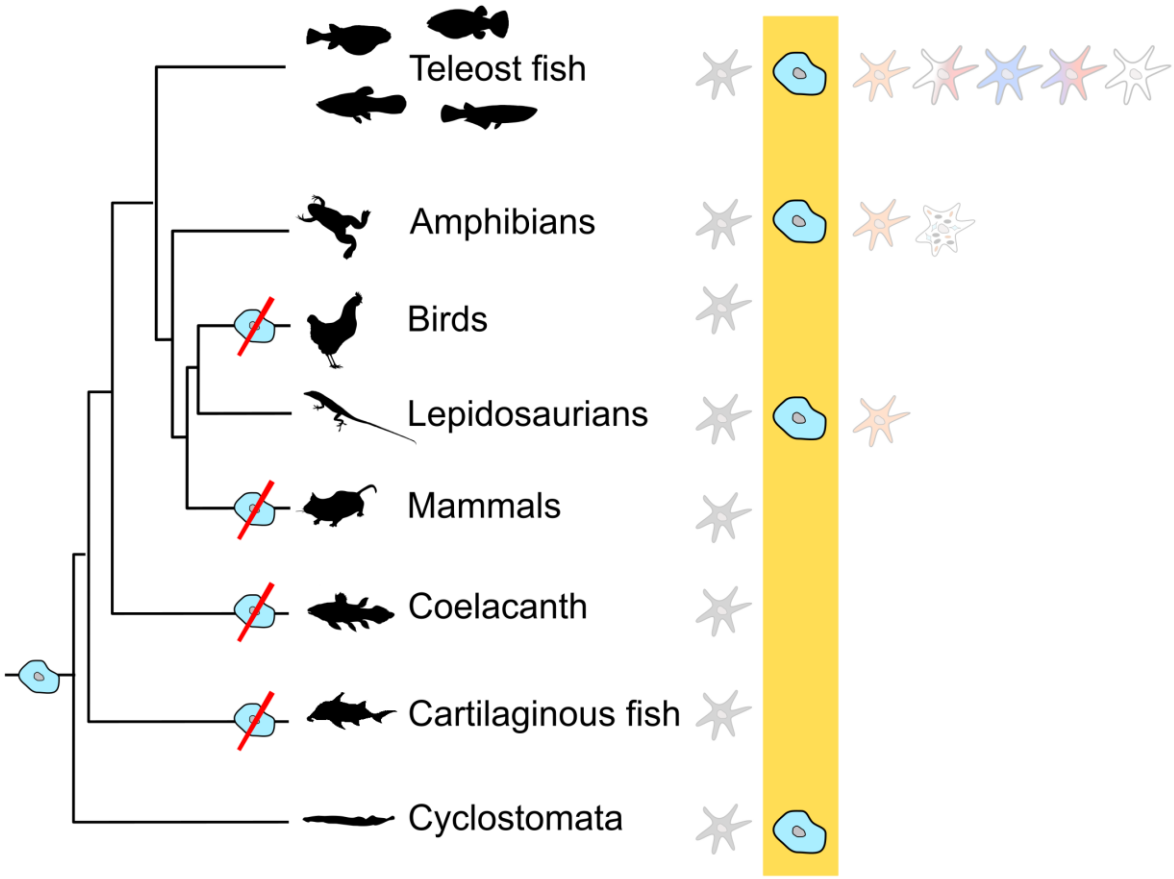
Lateral Gene Transfer ?

Lorin *et al.* (in prep.)

Hypothetical scenario for *roshi* evolution



Iridophore evolution: monophyly within vertebrates?



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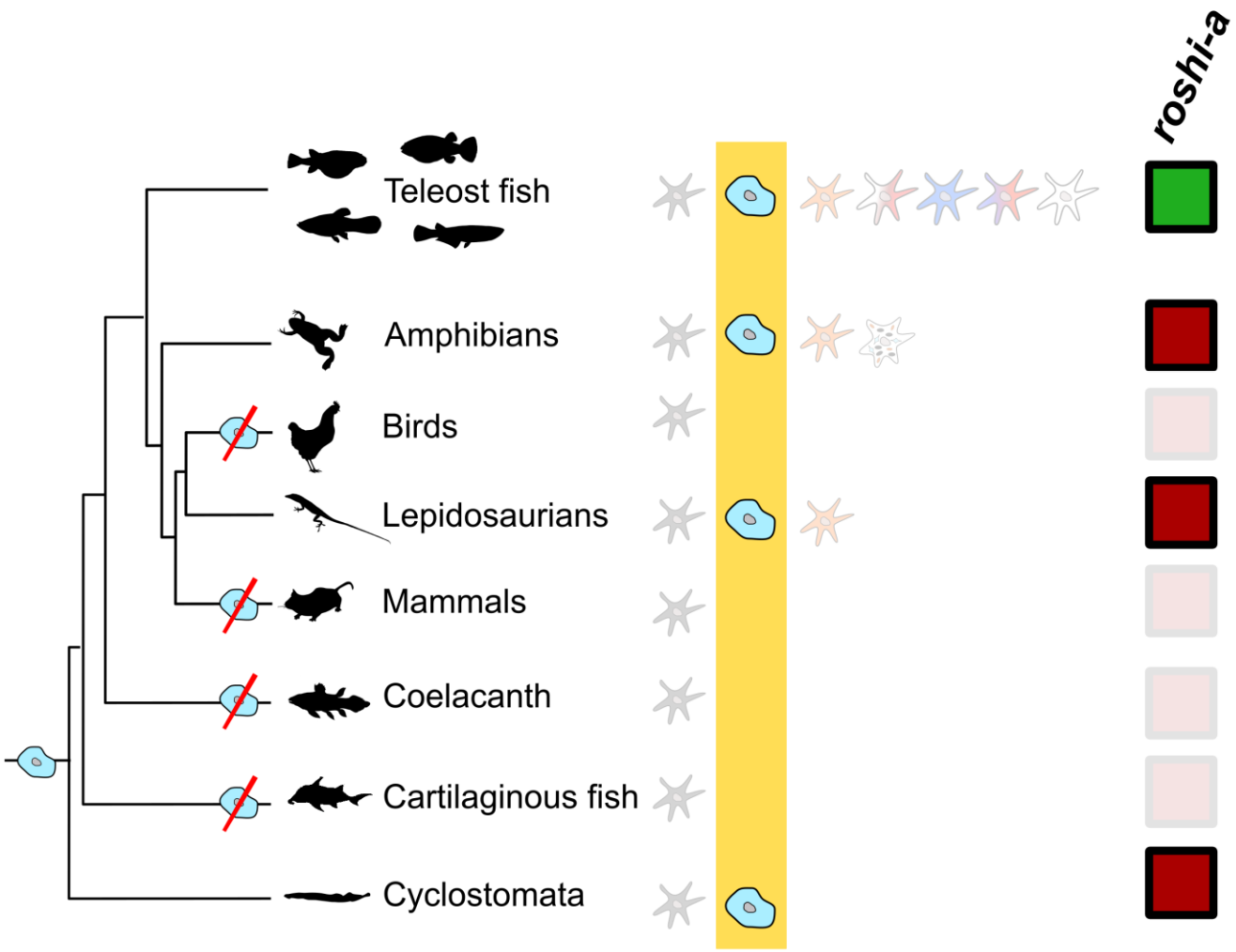
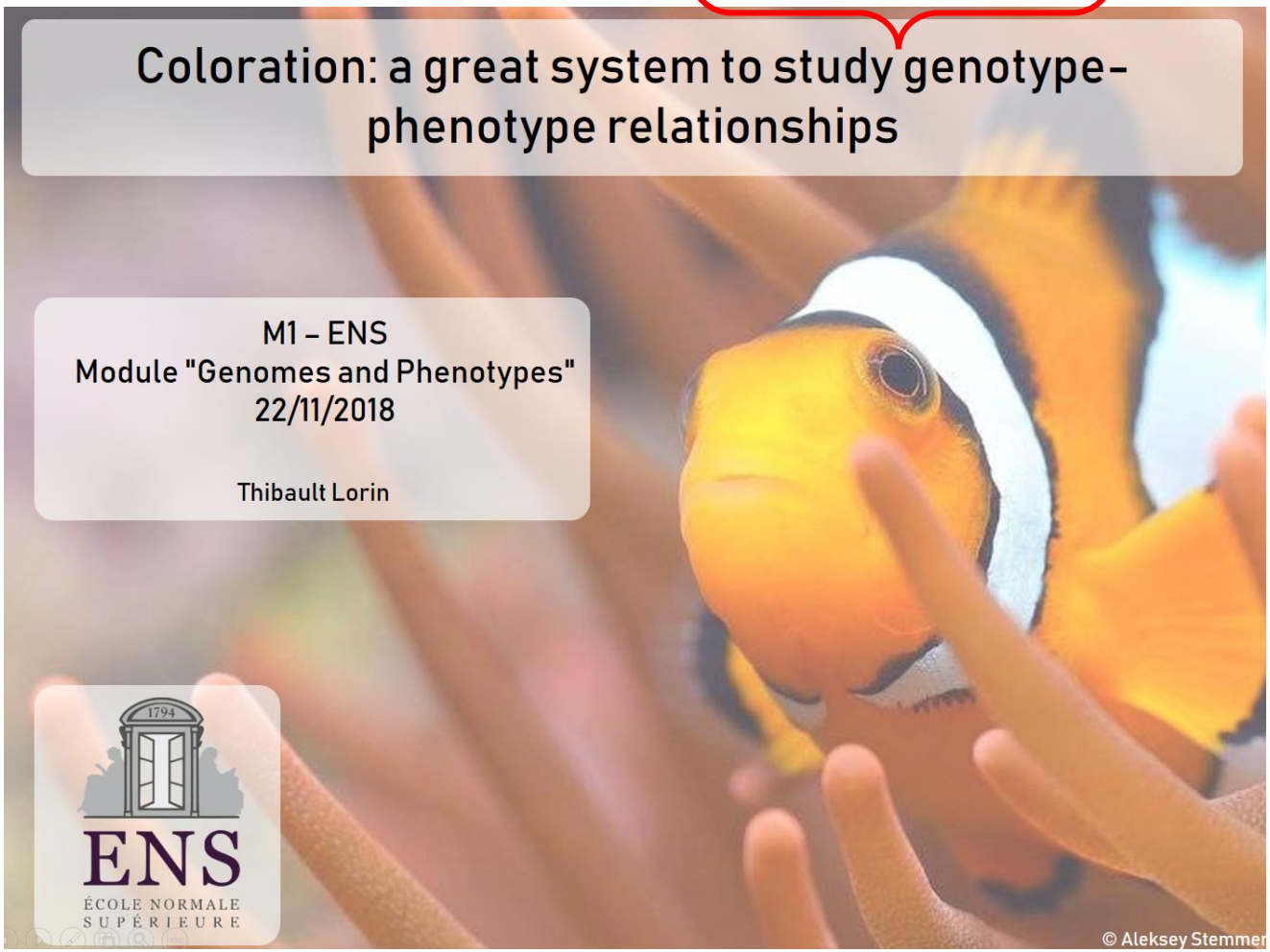
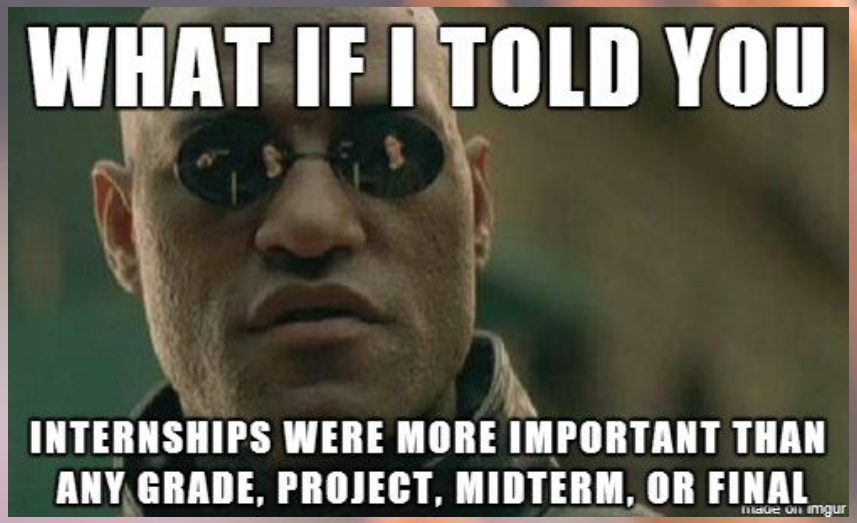


The EVOLUTION of




Thank you for your attention
© Aleksey Stemmer



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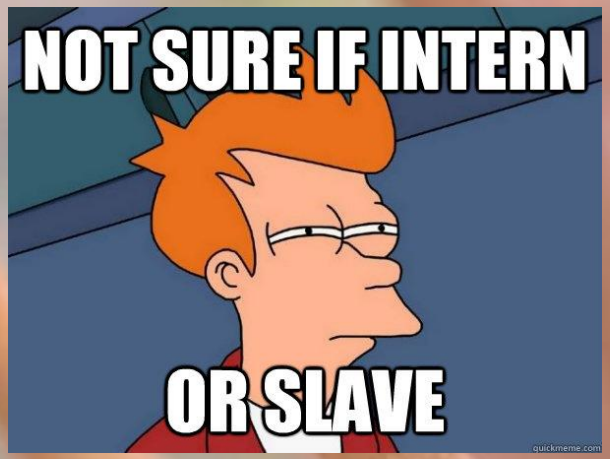

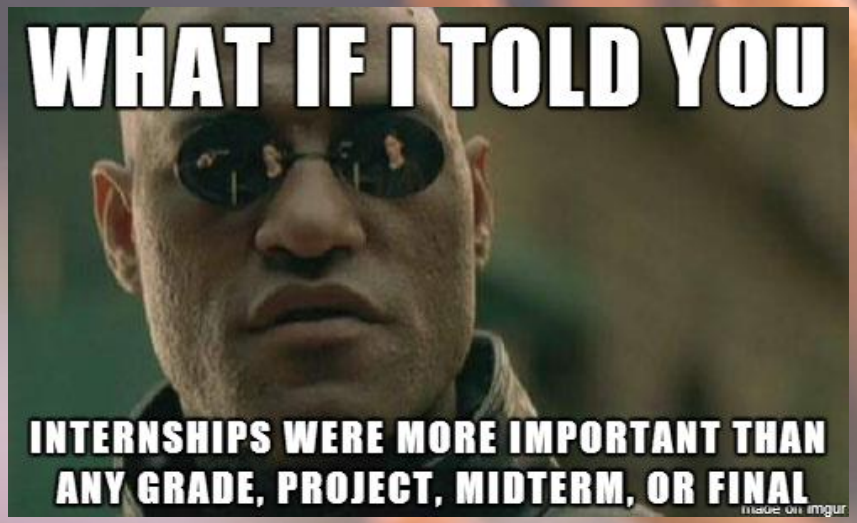

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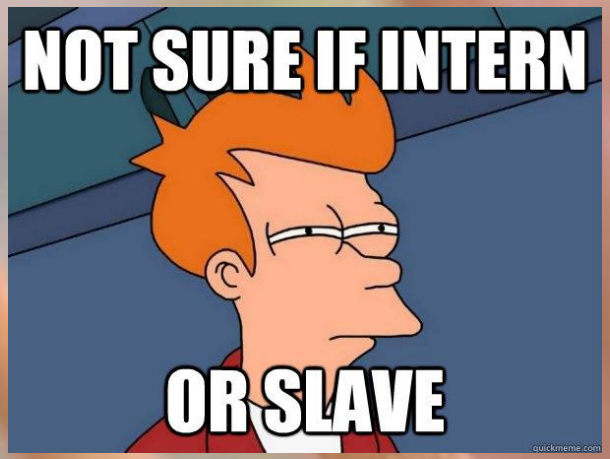
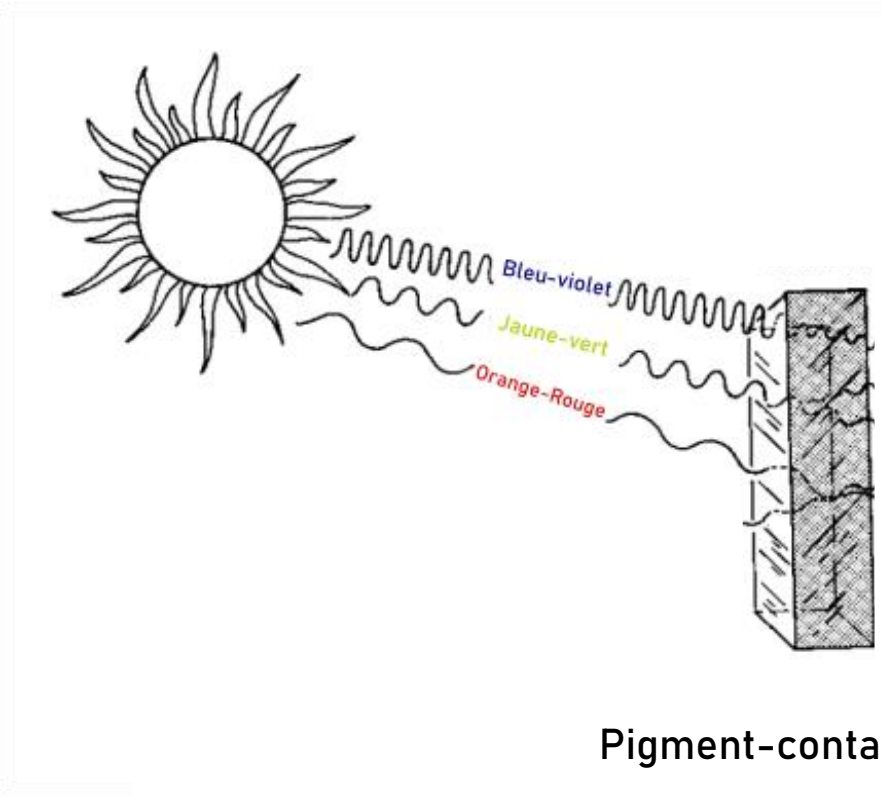
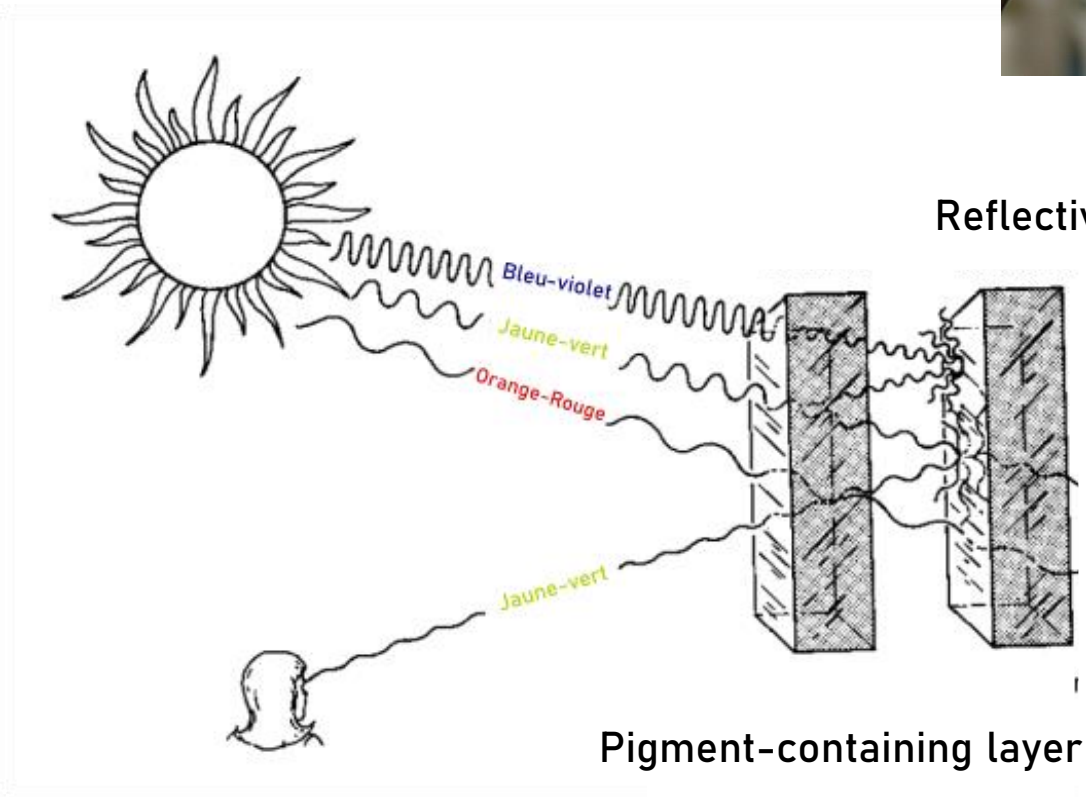


"Chemical" colors...

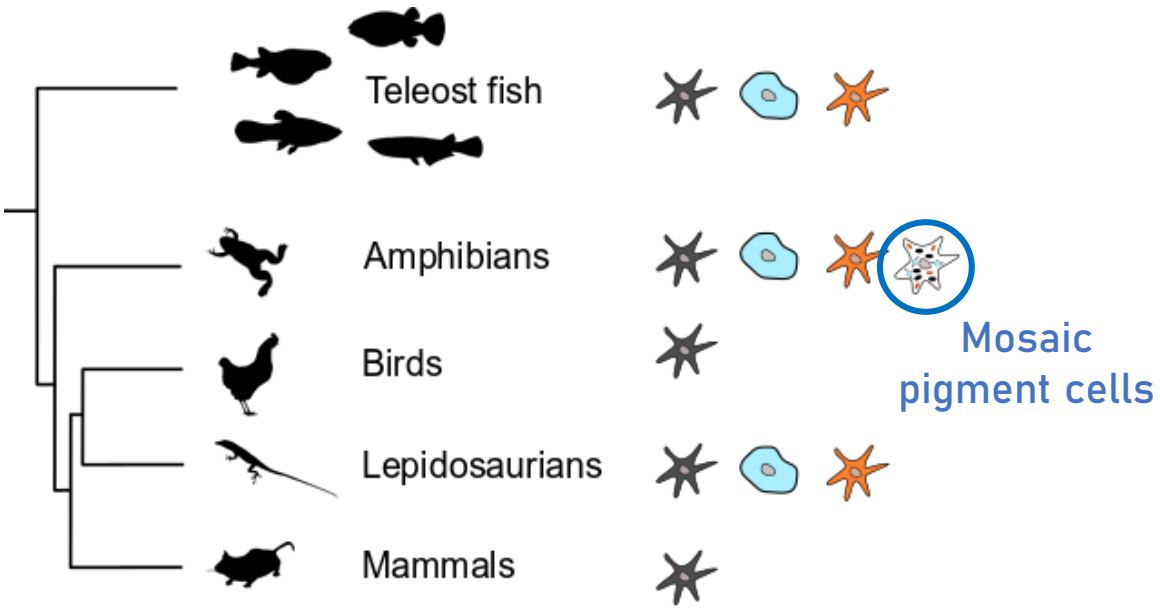


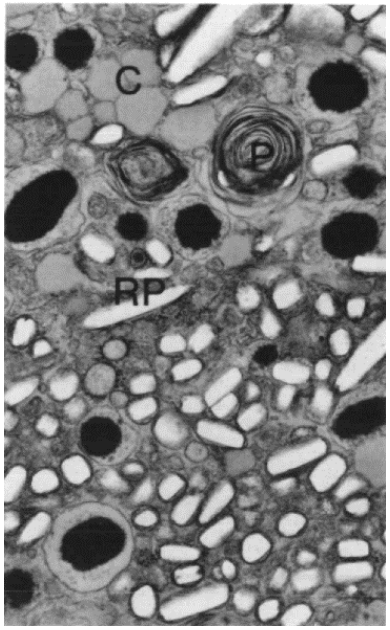
Pigment-containing layer

"Chemical" colors…. Need structural layers!

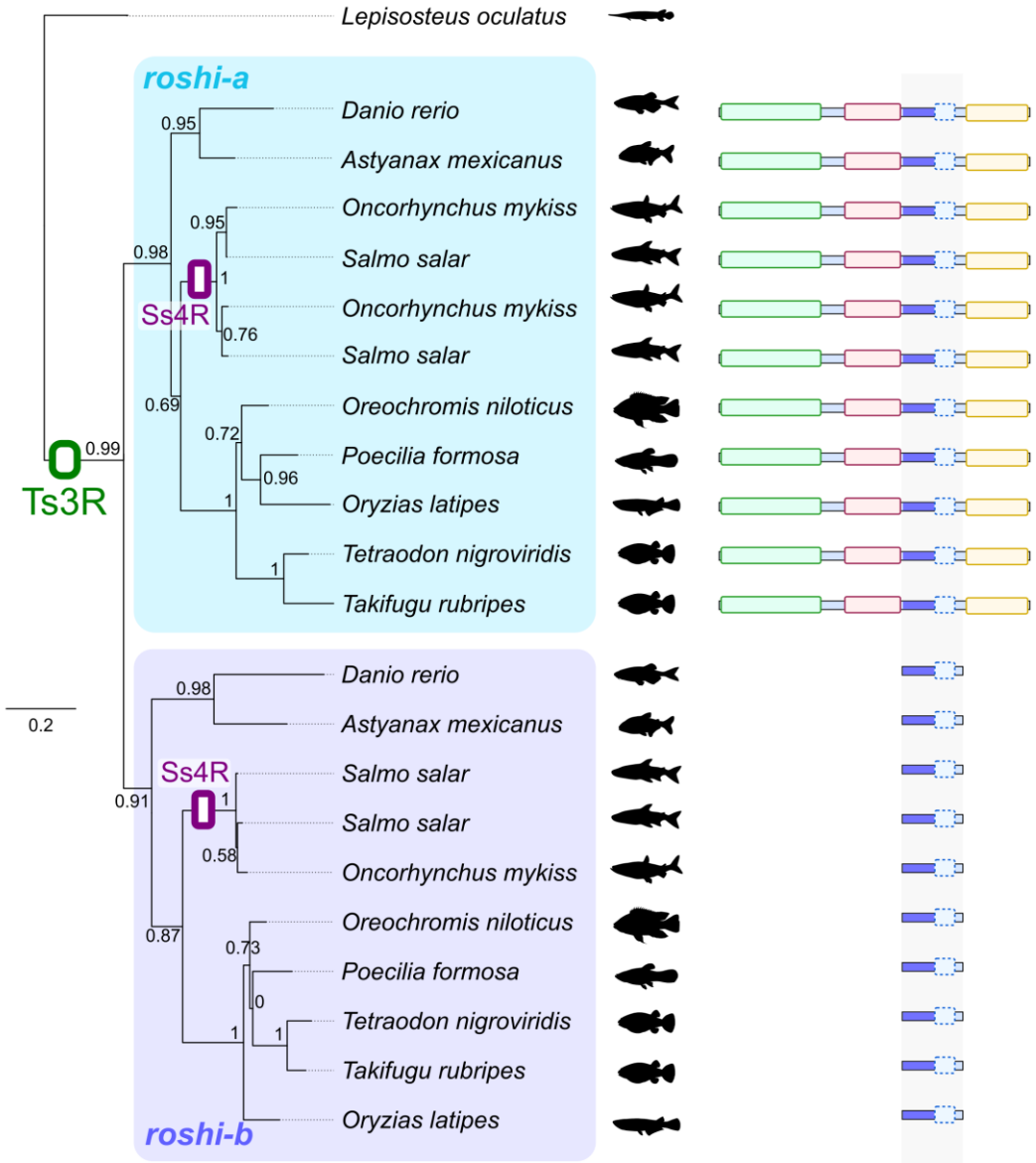


Developmental, cellular and molecular basis of pigmentation in Vertebrates



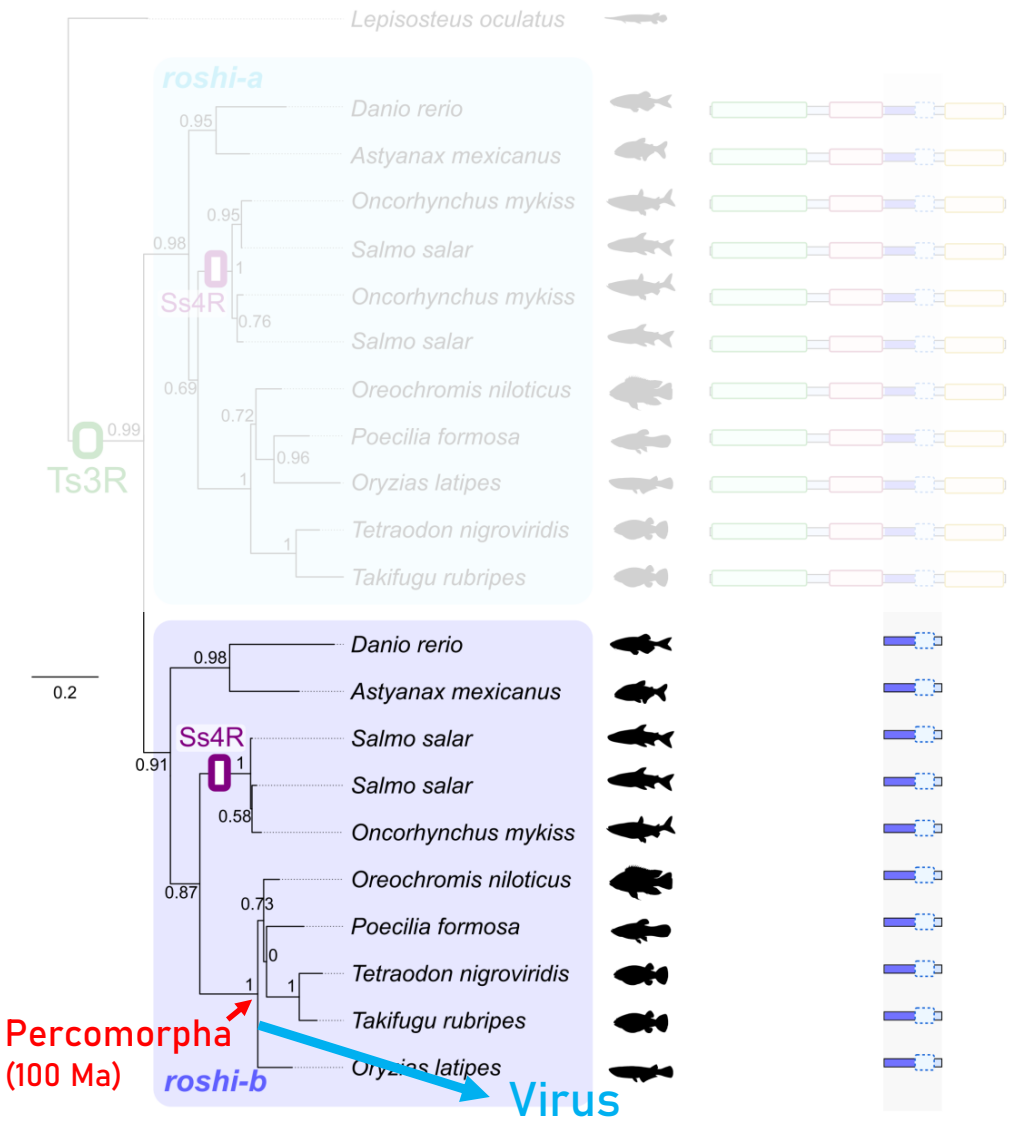


Roshi a été dupliqué et retenu après la Ts3R



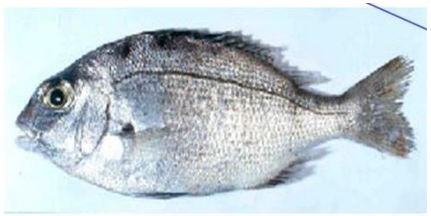
Lorin *et al.* (in prep.)

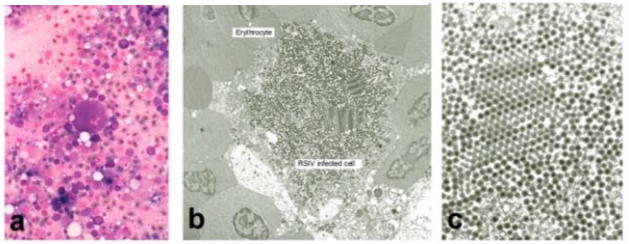
Roshi-b a été transféré à un virus de manière horizontale



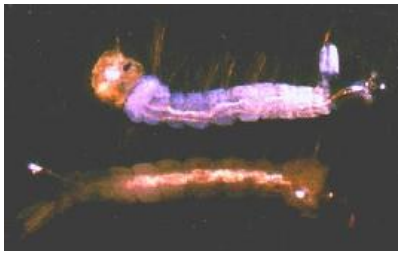
Séquences de Mégalocytivirus…

- Anémies
- Hémorragies
- Exophtalmie
- Gonflement de la rate



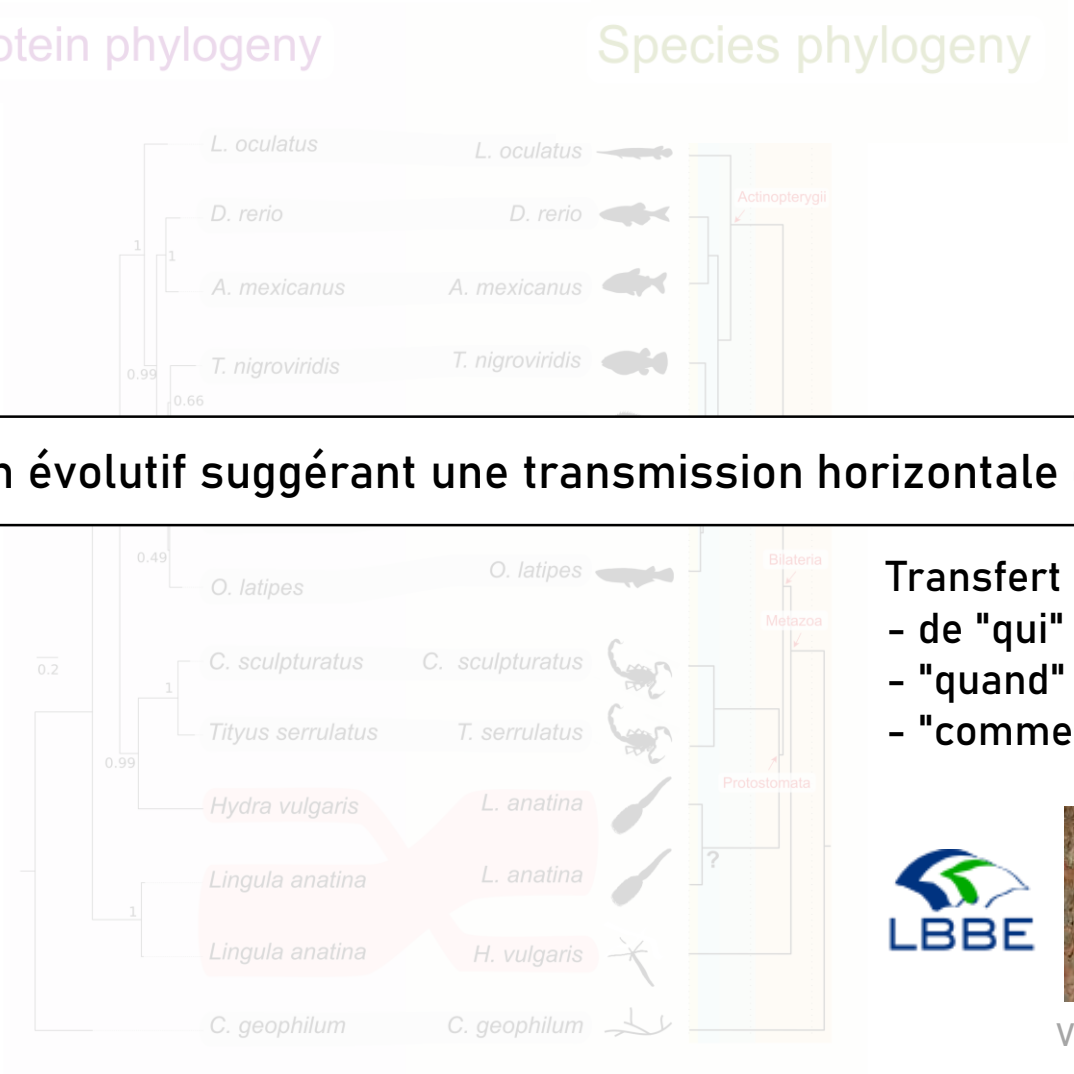


… qui sont des Iridovirus !



Kurita and Nakajima (2012) *Viruses*

La phylogénie de *roshi* ne correspond pas à la phylogénie des espèces



Patron évolutif suggérant une transmission horizontale du gène

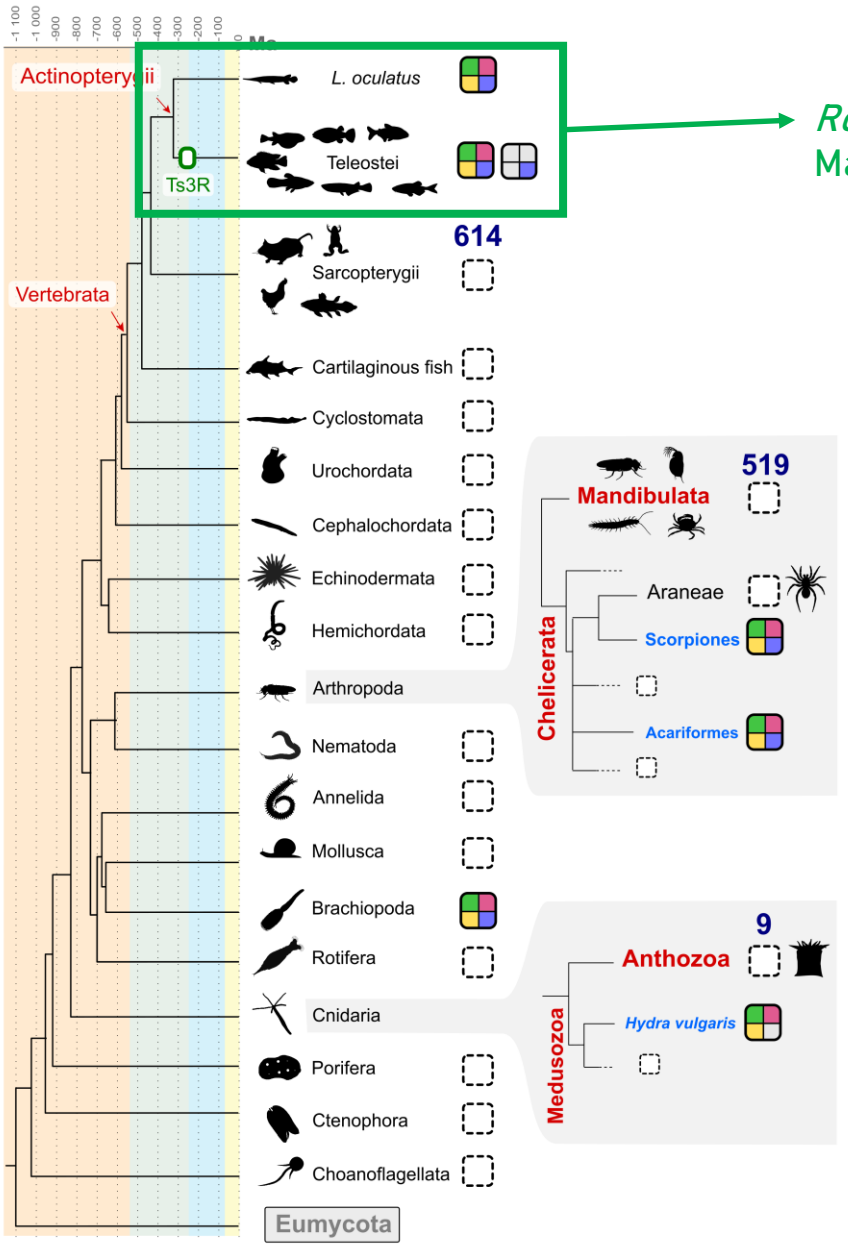
Transfert :
- de "qui" vers "qui" ?
- "quand" ?
- "comment" ?

LBBE

Vincent Daubin

Lorin *et al.* (in prep.)

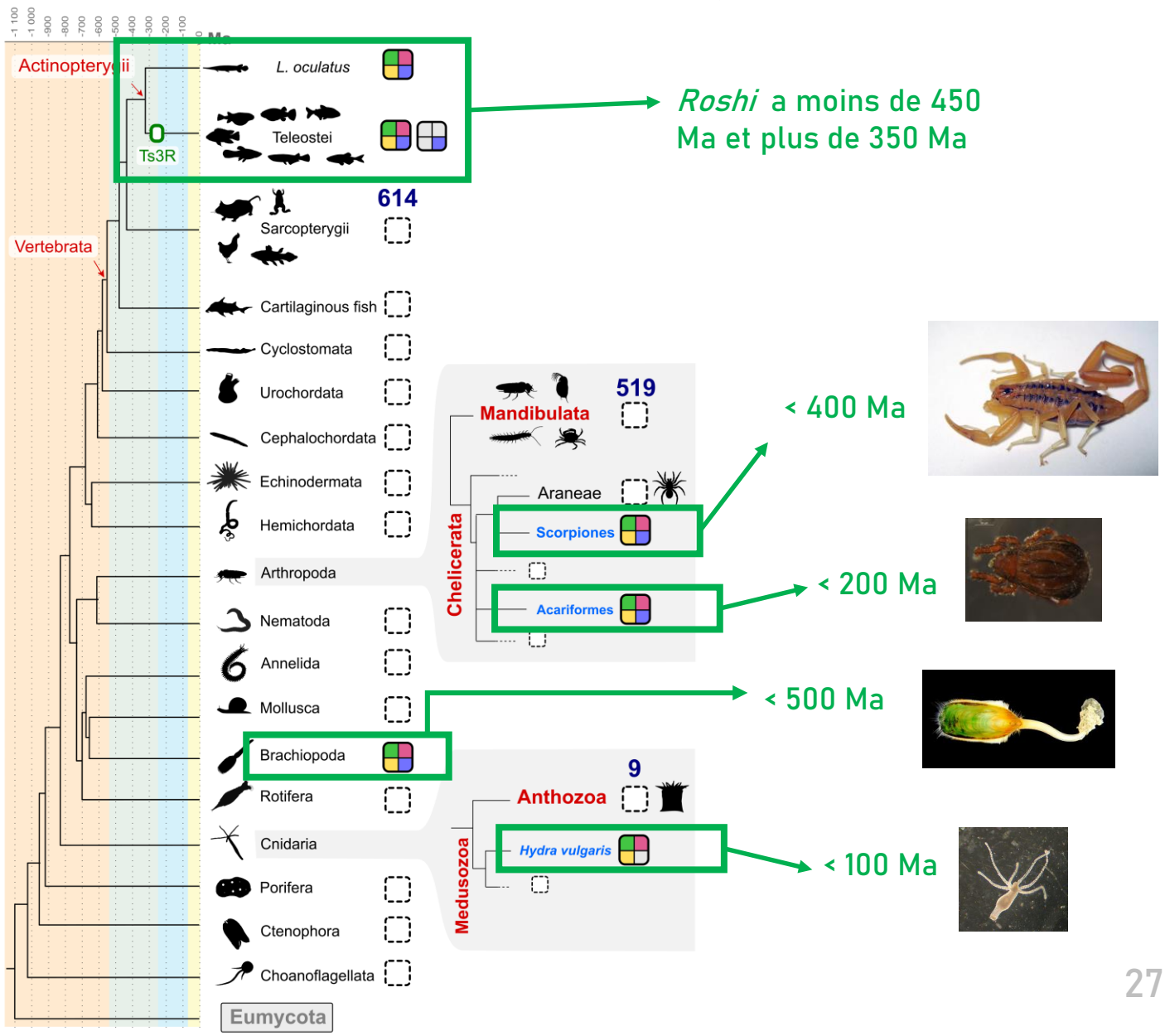
Estimation des âges de transfert de *roshi* chez les Animaux



Roshi a moins de 450 Ma et plus de 350 Ma

Lorin *et al.* (in prep.)

Estimation des âges de transfert de *roshi* chez les Animaux



Lorin *et al.* (in prep.)

More recently… "Color" is still a first-considered trait

Nature cover (1981)

Among all possible mutants used to describe the emergence of a new model system, guess which one was used?

Golden… a pigmentary mutant!

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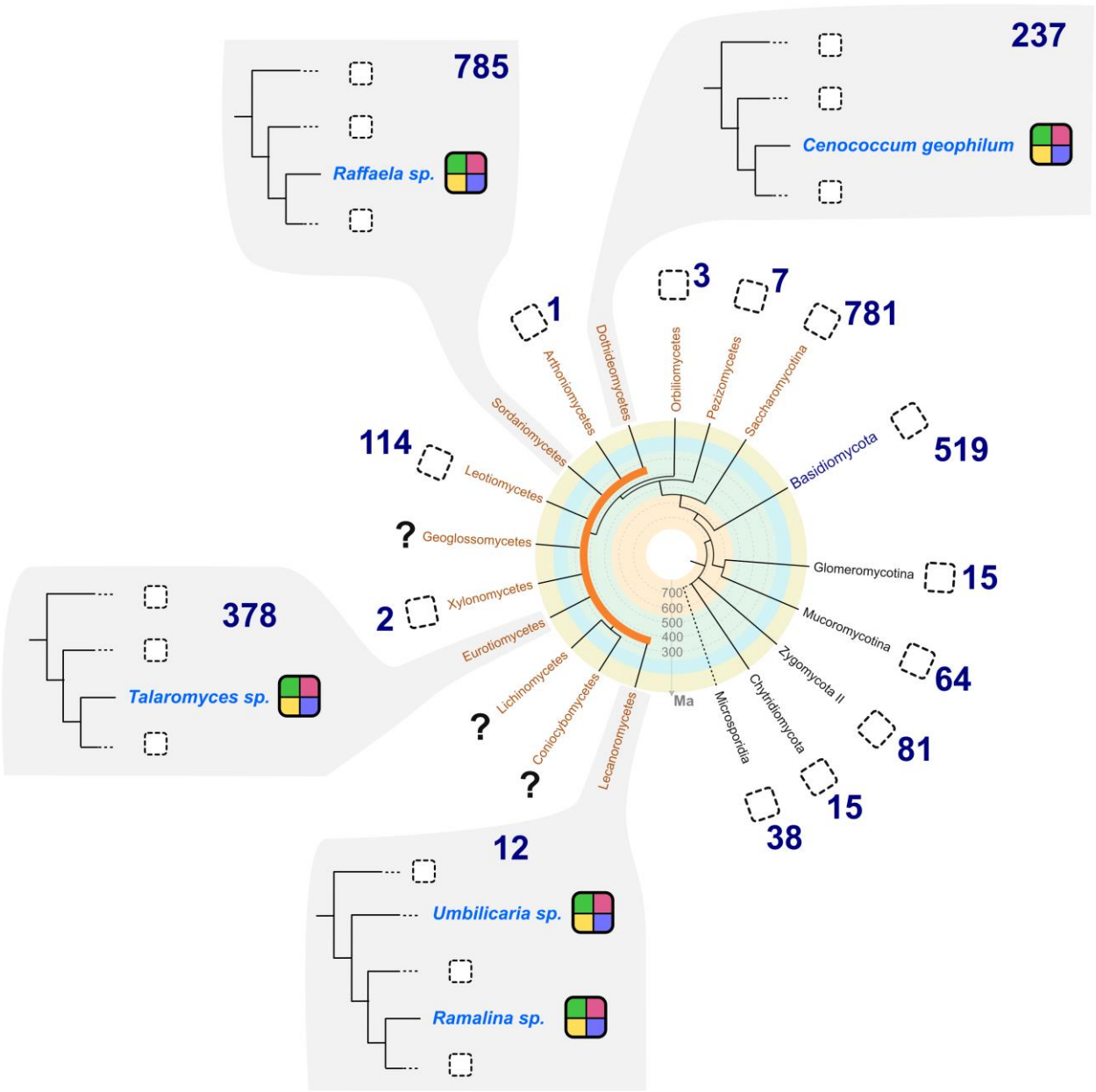
Potential biases in the choice of model systems?

Distribution de *roshi* chez les Eumycètes



Quels sont les modes de transfert envisagés pour *roshi* ?

1. Les HGT sont moins fréquents mais tout de même possibles chez les Eucaryotes

Boto (2010) *Science*
Sun *et al.* (2015) *Sci Rep*

2. Les HGT "inter-Animaux" sont rares

Gilbert *et al.* (2012) *Mol Biol Evol*
Graham *et al.* (2012) *BMC Evol Biol*
Peccoud *et al.* (2017) *PNAS*

3. Les mécanismes de transfert reposent probablement sur des vecteurs viraux

Gilbert *et al.* (2010) *Nature*
Gilbert and Cordaux (2017) *Curr Opin Virol*





Waddington *et al.* (2015) *Biol. Letters*

- ✓ a. *Roshi-b* transféré horizontalement à des Iridovirus
- ✓ b. *Roshi* présent chez des Acariens
- ✓ c. Ecologie compatible (aquatique)

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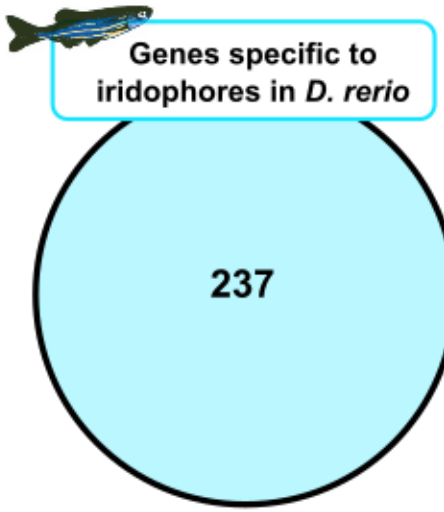
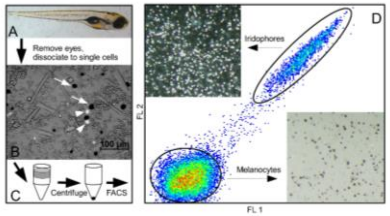
Gilbert *et al.* (2010) *Nature*
Gilbert and Cordaux (2017) *Curr Opin Virol*

4. Au sein des Champignons, les transferts horizontaux sont possibles

Fitzpatrick (2012) *FEMS Microbiol Lett*
Xie *et al.* (2008) *BMC Evol Biol*

La peau blanche a une "identité d'iridophores"





Higdon *et al.* (2013) *Plos One*

Salis*, Lorin* *et al.* (in prep.)

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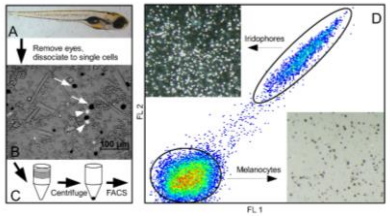
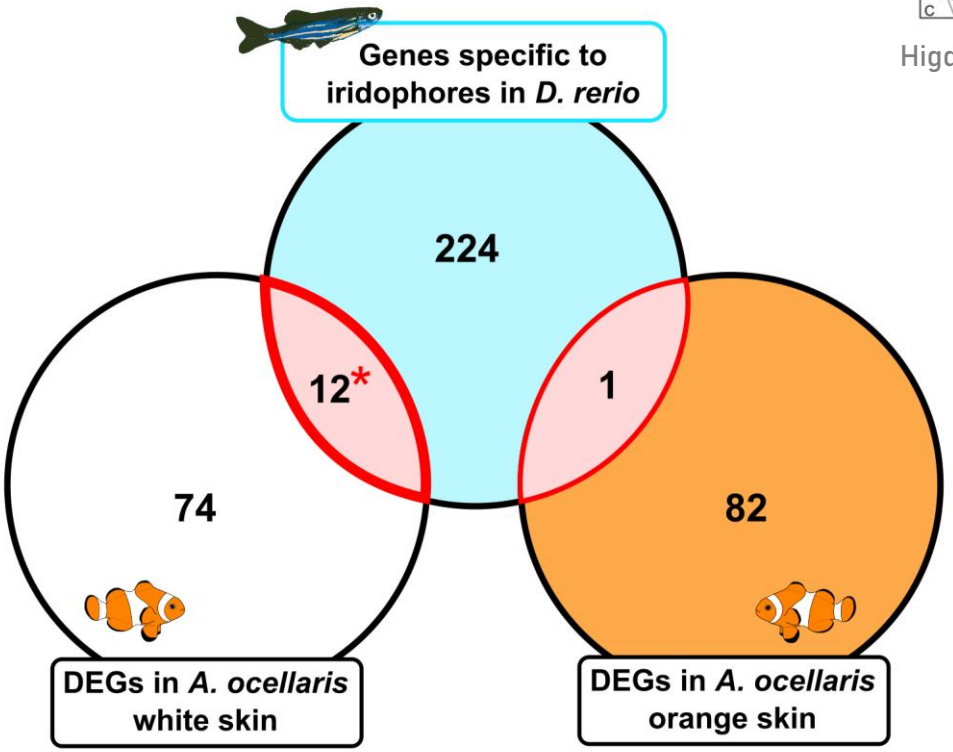
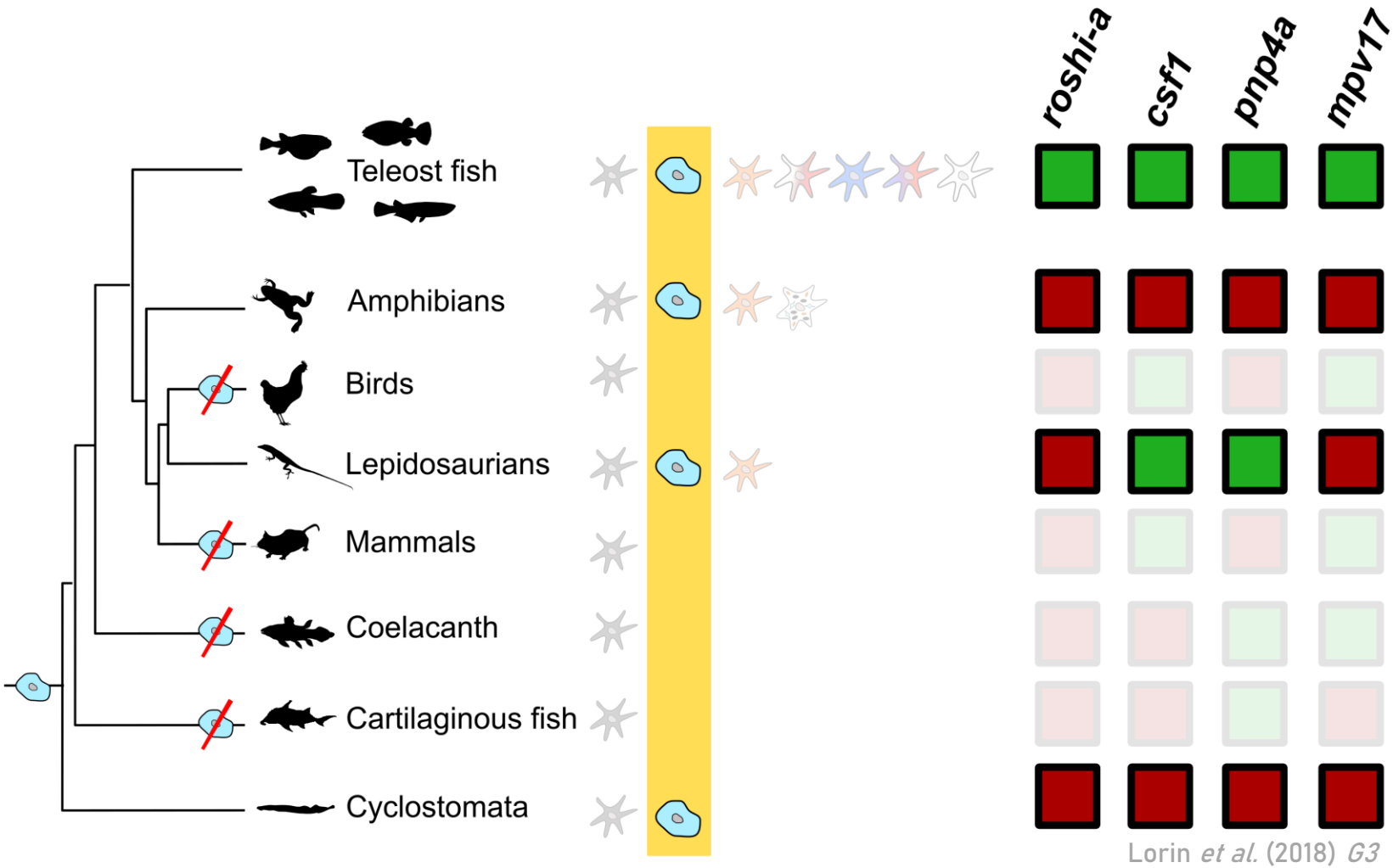


Higdon *et al.* (2013) *Plos One*



Salis*, Lorin* *et al.* (in prep.)

Roshi et d'autres gènes invitent à envisager l'évolution des iridophores chez les Vertébrés sous un nouvel angle



Lorin *et al.* (2018) *G3*

Wallace et la "coloration animale"
Une classification revisitée sur l'exemple des poissons coralliens

CAMOUFLAGE ("Protective colors")

Cryptisme

Assortiment à l'arrière-plan

Spécialisé

Hippocampus bargibenti (Randall et al. 2005)

Généraliste

Antennarius commerson (Randall et al. 2005)

Countershading

Chaetodon lunula (Hamilton et al. 1971)

Coloration trompeuse

Dascyllus aruanus (Phillips et al. 2017)

Transparence

Larve d'Acanthurus triostegus (Holzer, Besson et al. 2017)

Mascarade

Juvénile de Platax orbicularis (Randall et al. 2005)

COULEURS SEXUELLES ("Sexual colors")

Dimorphisme sexuel

Femelle (en haut) et mâle (en bas) de Poisson-perroquet

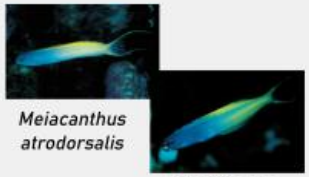
COULEURS D'AVERTISSEMENT ("Warning colors")

Organismes naturellement protégés

Aposématisme

Pterois volitans (Nelsen et al. 2014)

Mimétisme müllérien



Meiacanthus atrodorsalis

Plagiotermus laudandus (Randall et al. 2005)

Organismes non-protégés

Mimétisme batésien

Meiacanthus nigrolineatus (peu comestible, à gauche) et Ecsenius gravieri (inoffensif) (Randall et al. 2005)

COULEURS DE COMMUNICATION INTRA- OU INTERSPÉCIFIQUE ("Typical colors")

Communication intraspécifique (hors sélection sexuelle)

Compétition intrasexuelle

Chaetodon lunula (Hamilton et al. 1971)

Signaux de regroupement

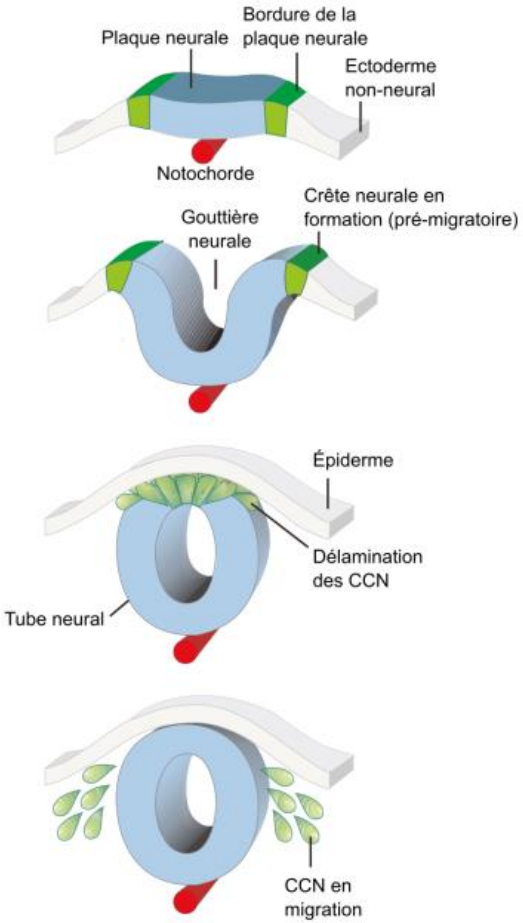
Myripristis murdjan (McRobert et al. 1998)

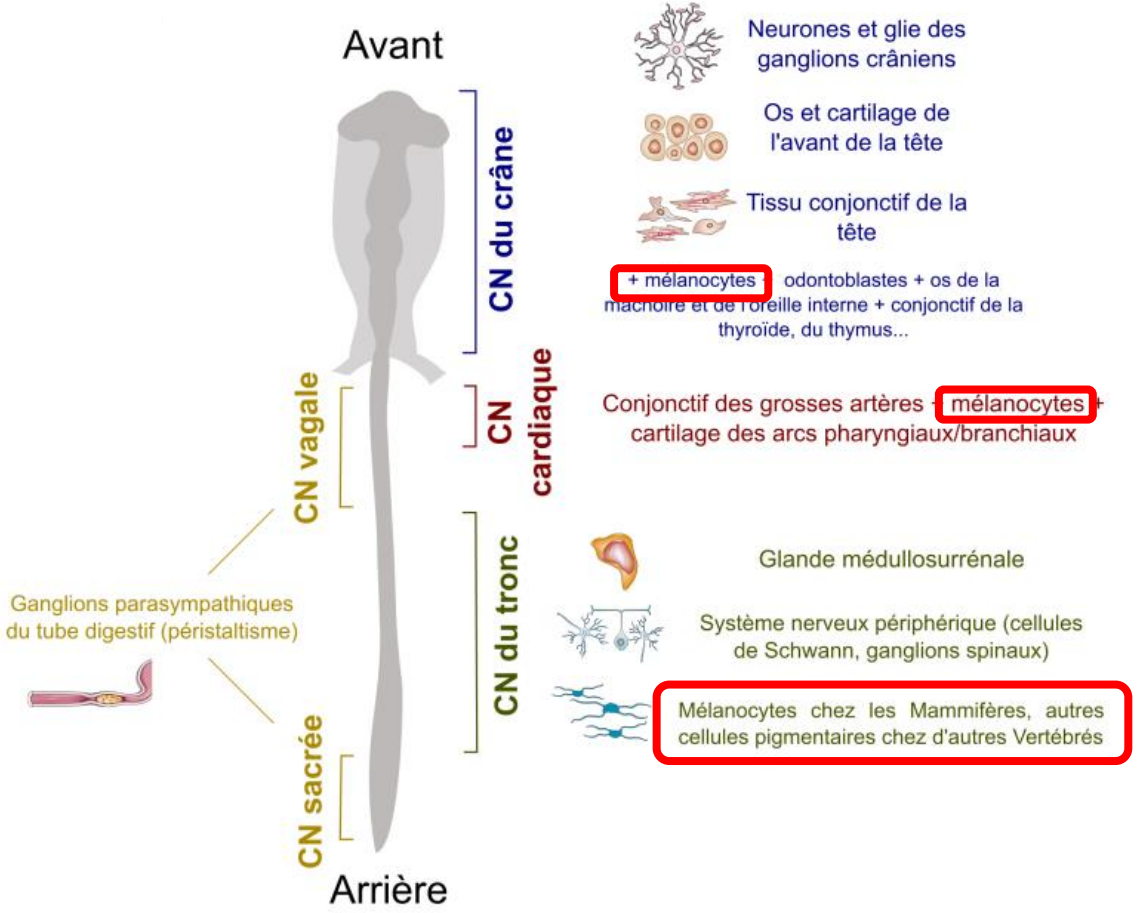
Communication interspécifique

Confusion de prédateurs

Halichoeres brownfieldi (Lönnstedt et al. 2013)

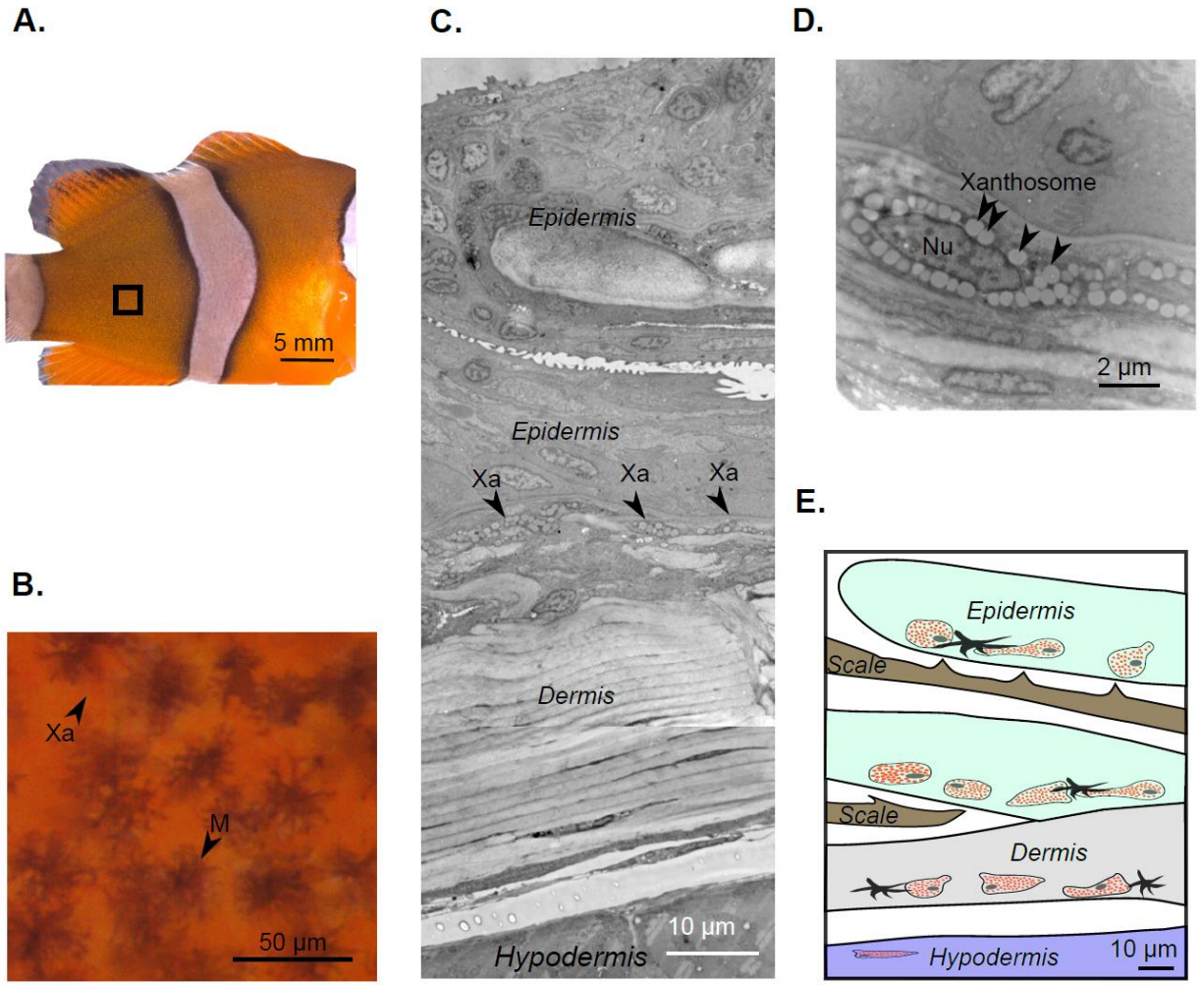
Les cellules pigmentaires proviennent de la crête neurale





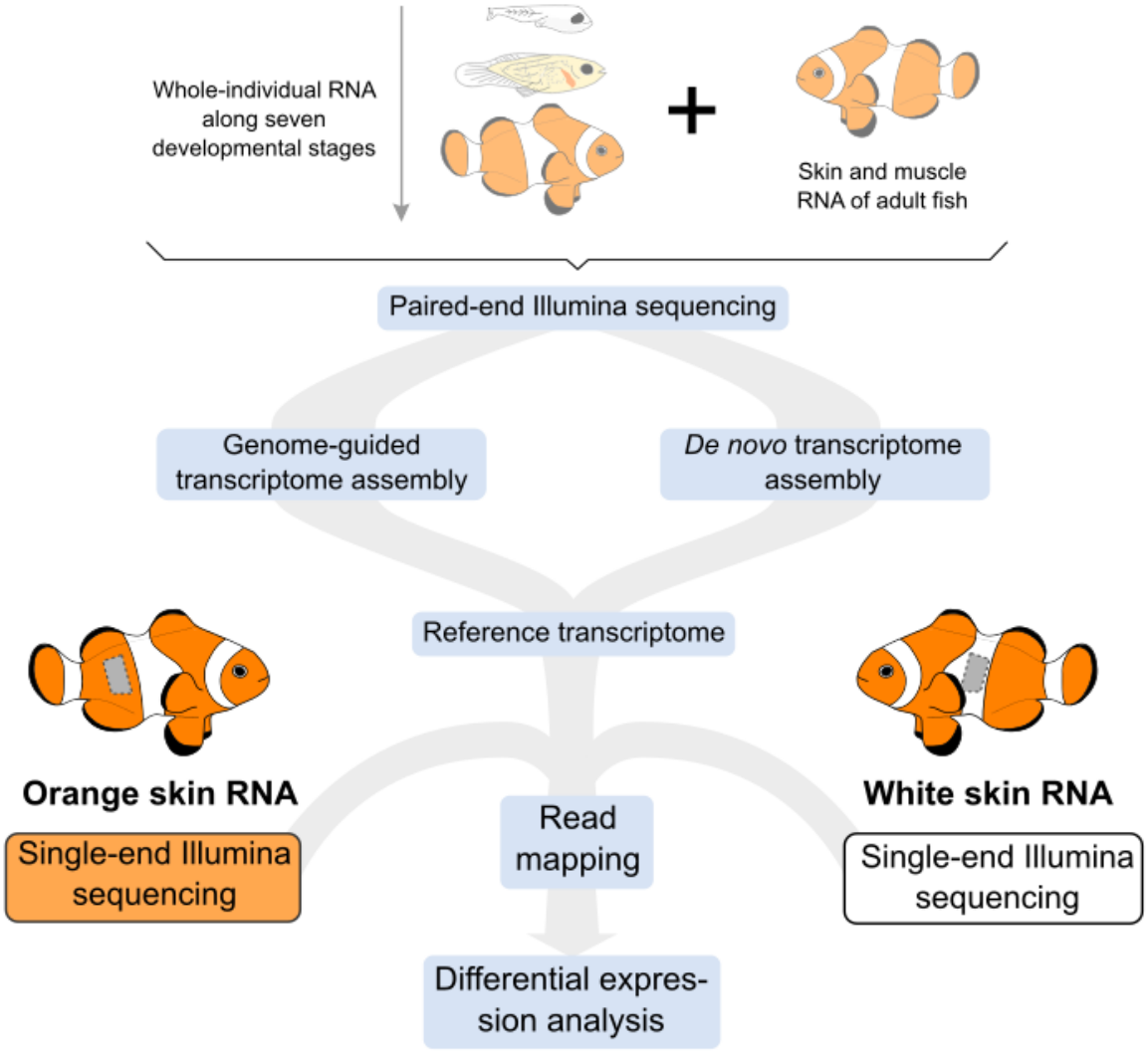
Adapté de Knecht *et al.* (2002) *Nat. Rev. Gen.* et de Simoes-Costa *et al.* (2015) *Development*

Peau orange en microscopie



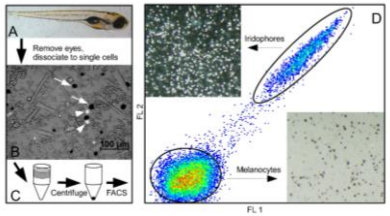
Salis*, Lorin* *et al.* (in prep.)

Pipeline utilisé pour l'analyse des différences d'expression

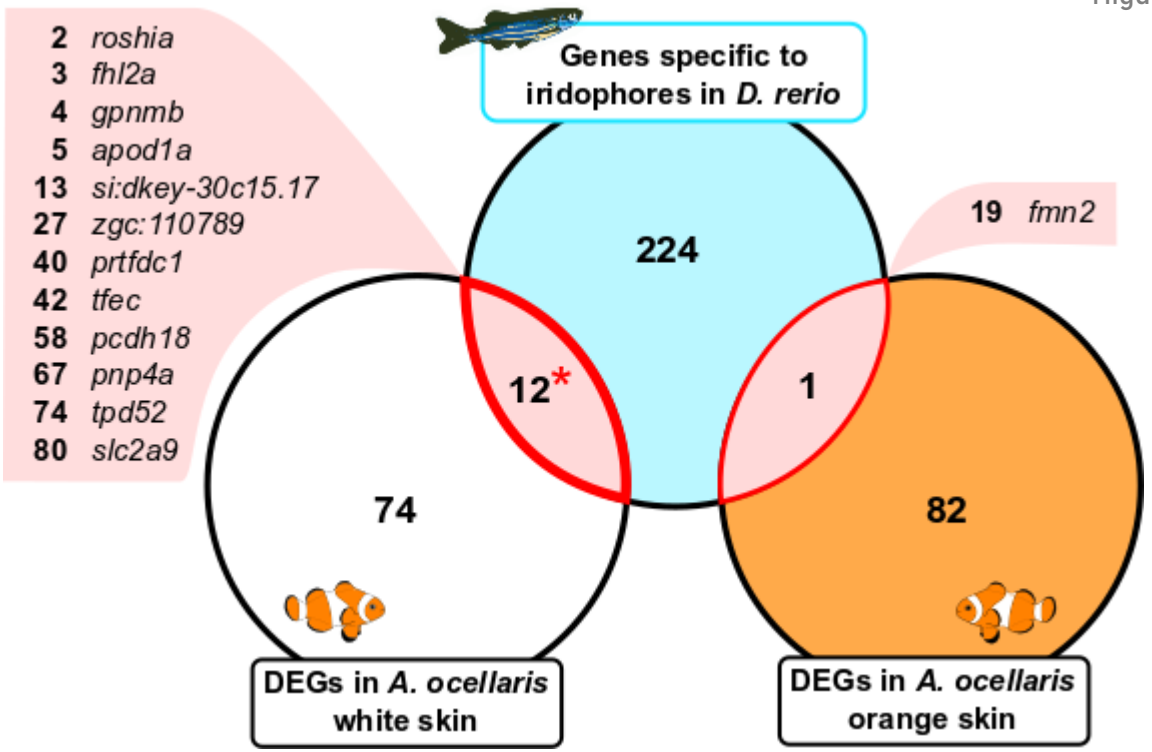


Salis*, Lorin* *et al.* (in prep.)

La peau blanche a une "identité d'iridophores"

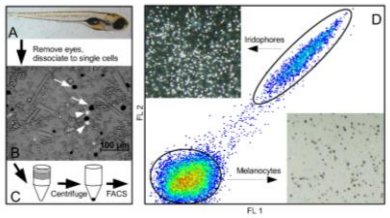


Higdon *et al.* (2013) *Plos One*

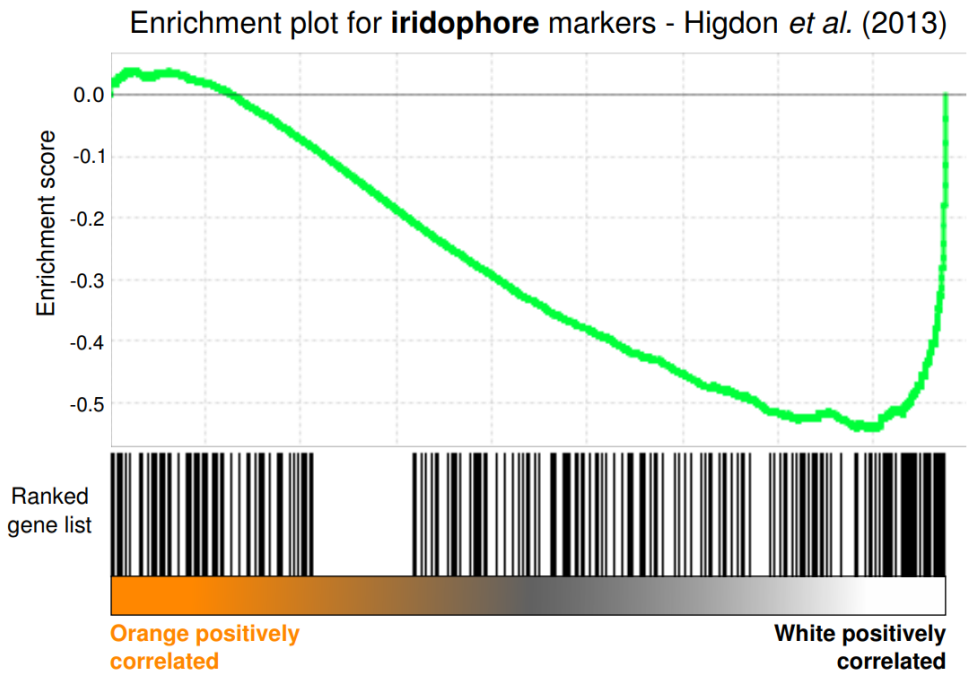


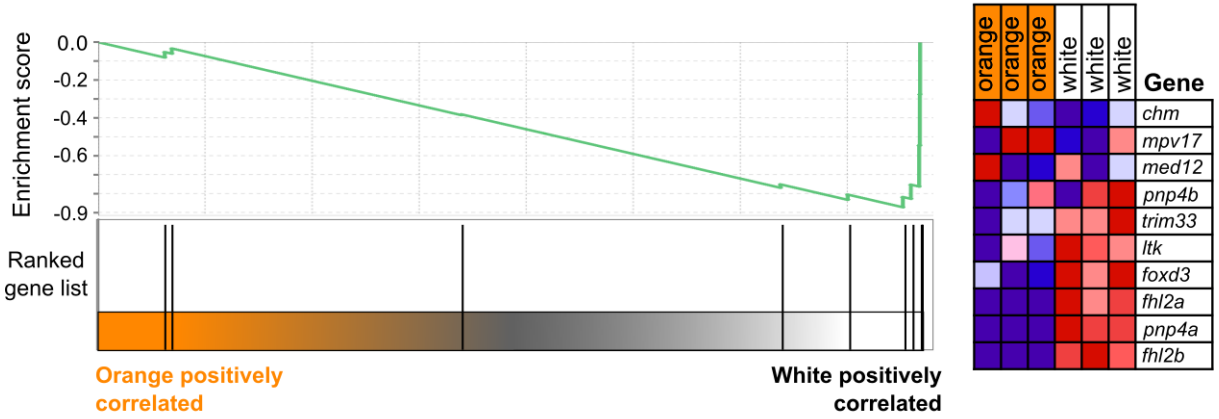
Salis*, Lorin* *et al.* (in prep.)

La peau blanche a une "identité d'iridophores"



Higdon *et al.* (2013) *Plos One*





Salis*, Lorin* *et al.* (in prep.)

Megalocytivirus (Iridoviridae)