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Integrative workshop: Avian eggshell biomineralization and innate immunity

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LE STUDIUM

CONFERENCES

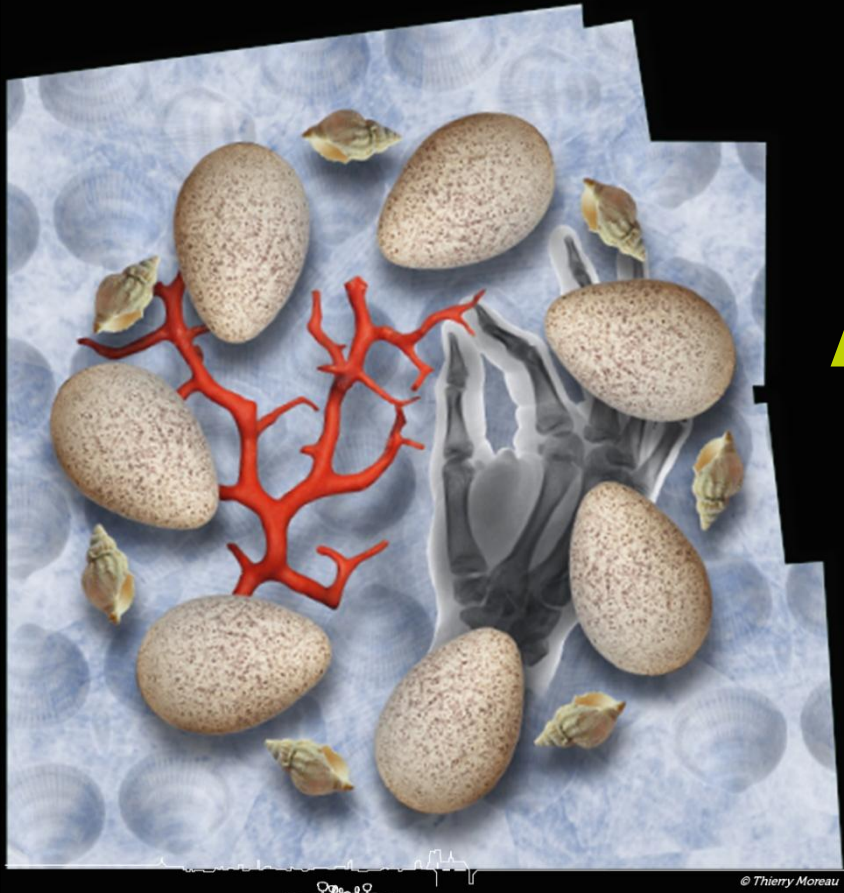
Innate immunity in a biomineralized context:
trade-offs or synergies?

Integrative workshop:

Avian eggshell biomineralization and
innate immunity

Joël GAUTRON

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The calcified avian eggshells

Physical protection

Ultrastructure and genetic variations,
Genetic traits inherited under the environmental pressure

A biomineral full of antimicrobial molecules

Distribution in the shell and roles during egg life cycle
Dual role of matrix proteins (eg ovot, lyz and OCX-32)

Shell/skeleton dialog

Molecular, vesicular and cellular mechanisms


Metabolite and immunity in biominerals

The physical protection

Ultrastructure and genetic variations,

- Strong evidences that the structural organization of avian eggshell is under genetic control
- Polymorphisms of specific shell proteins (ovalbumin, ovocleidin-116, ovocalyxin-32) partially explain variations in certain eggshell properties (i.e., eggshell thickness, crystal size, crystal orientation, eggshell mechanical properties)
- A total of 118 QTLs associated with shell strength


Toward a selection of haplotypes with higher strength quality (genomic selection, candidate gene approach) ?

ANIMAL GENETICS Immunogenetics, Molecular Genetics and Functional Genomics 

doi:10.1111/j.1365-2052.2011.02280.x

Genetic variation in eggshell crystal size and orientation is large and these traits are correlated with shell thickness and are associated with eggshell matrix protein markers

I. C. Dunn*, A. B. Rodríguez-Navarro[†], K. Mcdade[‡], M. Schmutz[§], R. Preisinger[§], D. Waddington*, P. W. Wilson* and M. M. Bain[‡]

ANIMAL GENETICS Immunogenetics, Molecular Genetics and Functional Genomics 

doi:10.1111/j.1365-2052.2010.02131.x

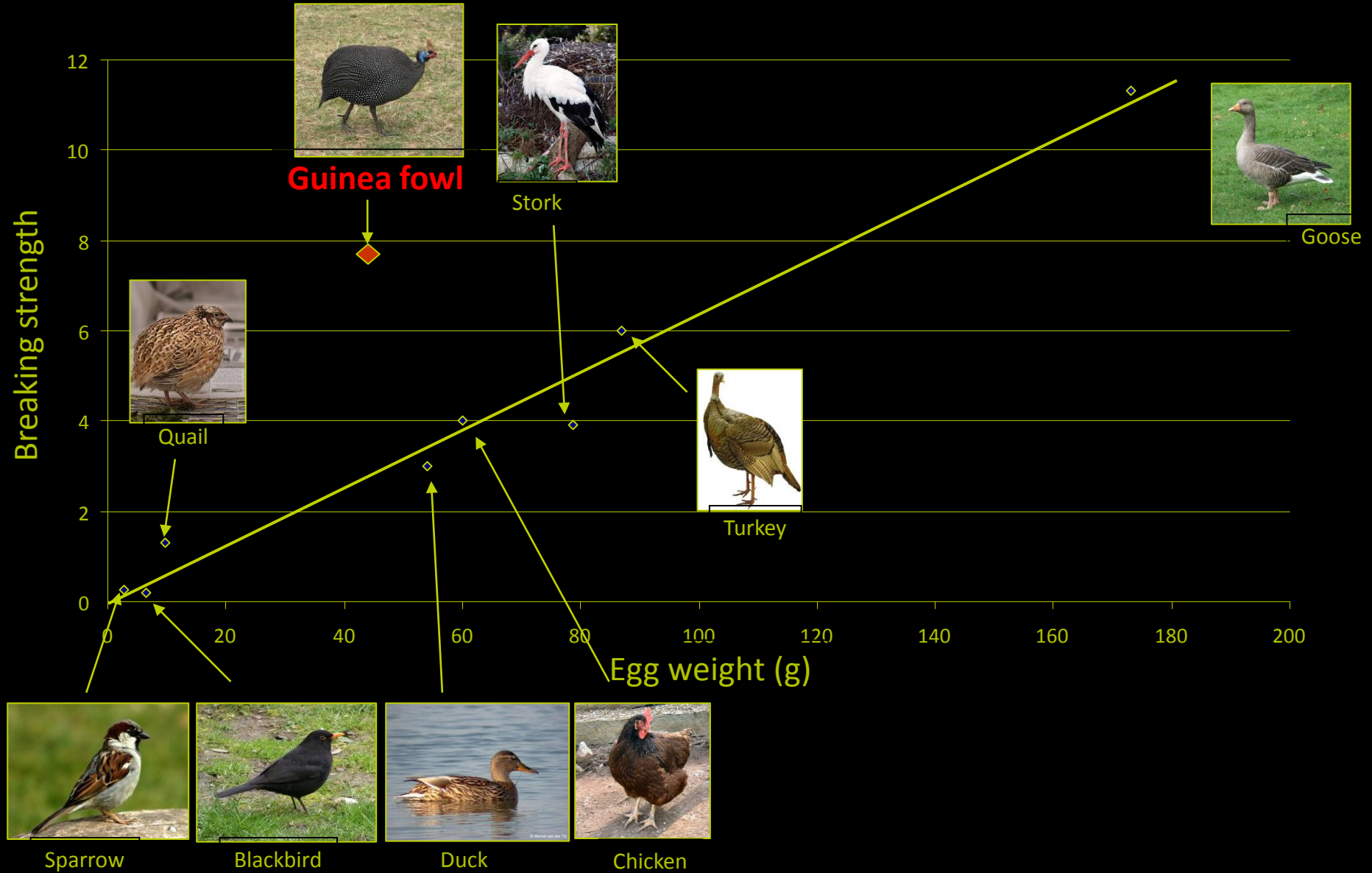
Quantitative trait loci affecting eggshell traits in an F₂ population

M. Tuiskula-Haavisto*, M. Honkatukia*, R. Preisinger[†], M. Schmutz[†], D. J. de Koning[‡], W. H. Wei[§] and J. Vilkki*

*MTT Agrifood Research Finland, Biotechnology and Food Research, 31600 Jokioinen Finland. [†]Lohmann Tierzucht GmbH Am Seedeich 9-11, PO Box 460, 27454 Cuxhaven, Germany. [‡]Genetics and Genomics, The Roslin Institute and R(D)SVS, University of Edinburgh Midlothian EH25 9PS, UK. [§]MRC Human Genetics Unit, Western General Hospital Crewe Road, Edinburgh EH4 2XU, UK

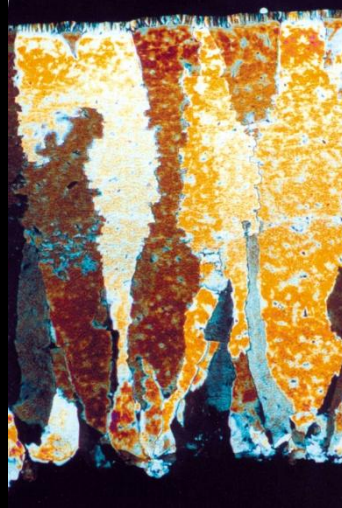
The physical protection

Genetic traits inherited under the environmental pressure



The physical protection

Genetic traits inherited under the environmental pressure



Gallus gallus



Meleagris gallopavo



Numida meleagris



Sankofa pyrenaica

The physical protection

Genetic traits inherited under the environmental pressure

JOURNAL OF Evolutionary Biology



doi:10.1111/j.1420-9101.2010.02010.x

SHORT COMMUNICATION

The evolution of host-specific variation in cuckoo eggshell strength

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†DST/NRF Centre of Excellence at the Percy FitzPatrick Institute, University of Cape Town, Rondebosch, South Africa



Behavioral Ecology Vol. 15 No. 1: 109–119
DOI: 10.1093/bhco/arg102

Phylogenetic analysis of life-history adaptations in parasitic cowbirds

Myriam E. Mermoz and Juan Francisco Ornelas

Departamento de Ecología y Comportamiento Animal, Instituto de Ecología A.C., Km 2.5 antigua carretera a Coatepec No 351, Congregación "El Haya", Xalapa, Veracruz 91070, México

Cowbirds (*Molothrus*) are obligate brood parasitic birds, that lay their eggs in nests of other bird species. The hosts provide all parental care to the parasitic eggs, chicks and fledglings.

Obligate brood parasitic birds are known for their greater eggshell thickness

- * Intraspecific competition amongst parasite birds (frequently peck and puncture of other eggs laid into the nest)
- * limit shell damage when rapid lay on elevated position
- * Prevent damage from attempts by hosts to pierce-eject parasitic eggs

Increased thickness, but also variability in shell microstructure → Increased eggshell mechanical properties.

The physical protection

Genetic traits inherited under the environmental pressure

Eggshell cuticles containing vaterite nanospheres have been noted (but not studied) on eggshells of six species including the double-crested cormorant (*Phalacrocorax auritus*), emperor penguin (*Aptenodytes forsteri*), great frigatebird (*Fregata minor*), hamerkop (*Scopus umbreta*) and smooth-billed ani (*Crotophaga ani*) (Mikhailov, 1997). The majority of these species incubate eggs in wet environments, where microbial abundance is likely high (D'alba et al., 2014)



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Available online at www.sciencedirect.com



Comparative Biochemistry and Physiology, Part B 149 (2008) 640–649



www.elsevier.com/locate/cbpb

Antimicrobial activity of the Anseriform outer eggshell and cuticle

Olivier Wellman-Labadie, Jaroslav Picman, Maxwell T. Hincke *

Department of Biology, University of Ottawa, 30 Marie Curie, Ottawa, Ontario, Canada K1N 6N5

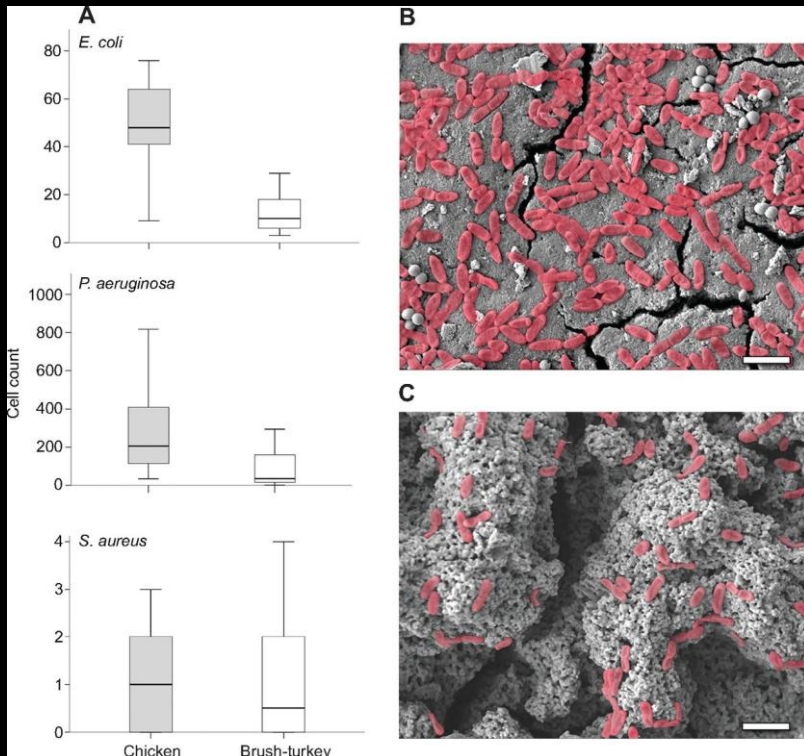
Received 28 October 2007; received in revised form 4 January 2008; accepted 4 January 2008

Available online 12 January 2008

... the presence of more potent antimicrobial proteins in the eggshells of cavity-nesting versus open cup-nesting Anseriform species

The physical protection

Genetic traits inherited under the environmental pressure



© 2014. Published by The Company of Biologists Ltd | The Journal of Experimental Biology (2014) 217, 1116-1121 doi:10.1242/jeb.098343



RESEARCH ARTICLE

Antimicrobial properties of a nanostructured eggshell from a compost-nesting bird

Liliana D'Alba^{1,*}, Darryl N. Jones², Hope T. Badawy³, Chad M. Eliason¹ and Matthew D. Shawkey¹

“The presence of nanoscale spheres composed of calcium phosphate, renders the eggs hydrophobic, decreases bacterial attachment and is most likely the major component preventing trans-shell penetration

This modified surface also appears to limit bacterial adhesion...”

A biomineral full of antimicrobial molecules

Anti-microbial activity observed in eggshell extracts (Mine et al. 2003)



Identification of antimicrobial proteins into the shell

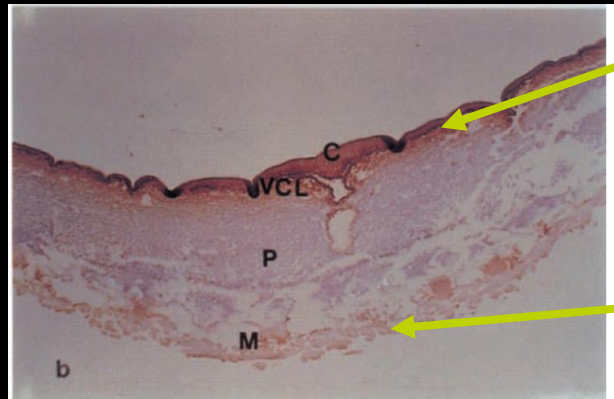
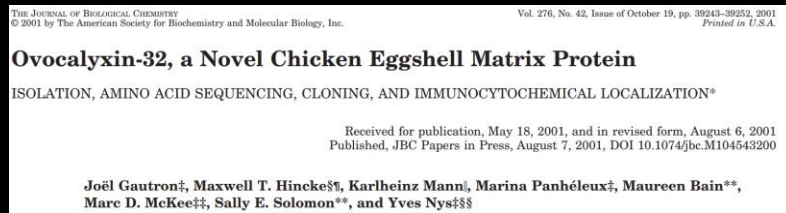
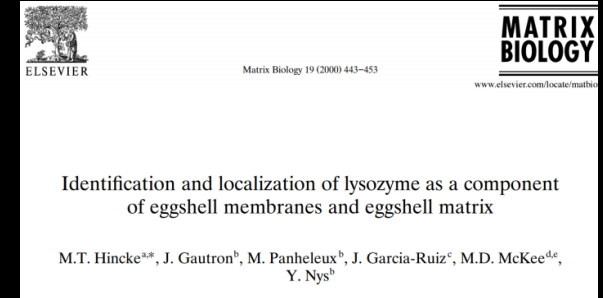


FIG. 2. Immunohistochemistry to localize the 32-kDa protein in eggshell matrix. Shell was decalcified/fixated and paraffin-embedded in a conventional way ("Formalin-ethanol-Paraffin"). Sections were stained with

Highly concentrated in the cuticle
→ to avoid bacterial penetration during eggshell formation?

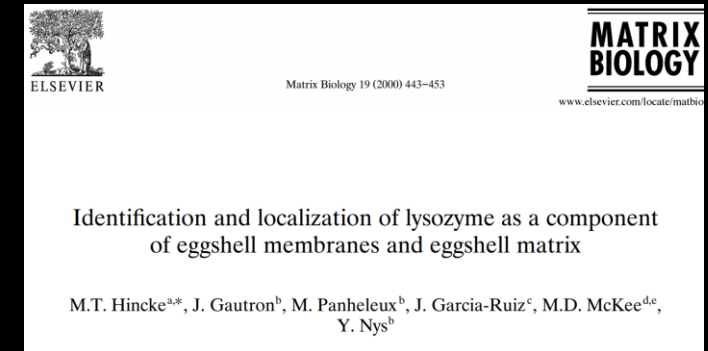
Highly concentrated in the lower part of the shell (membranes and mammillary layers)
→ to protect the developing embryo when shell components are made soluble?

A biomineral full of antimicrobial molecules

Anti-microbial activity observed in eggshell extracts (Mine et al. 2003)



Identification of antimicrobial proteins into the shell



Multi purpose roles

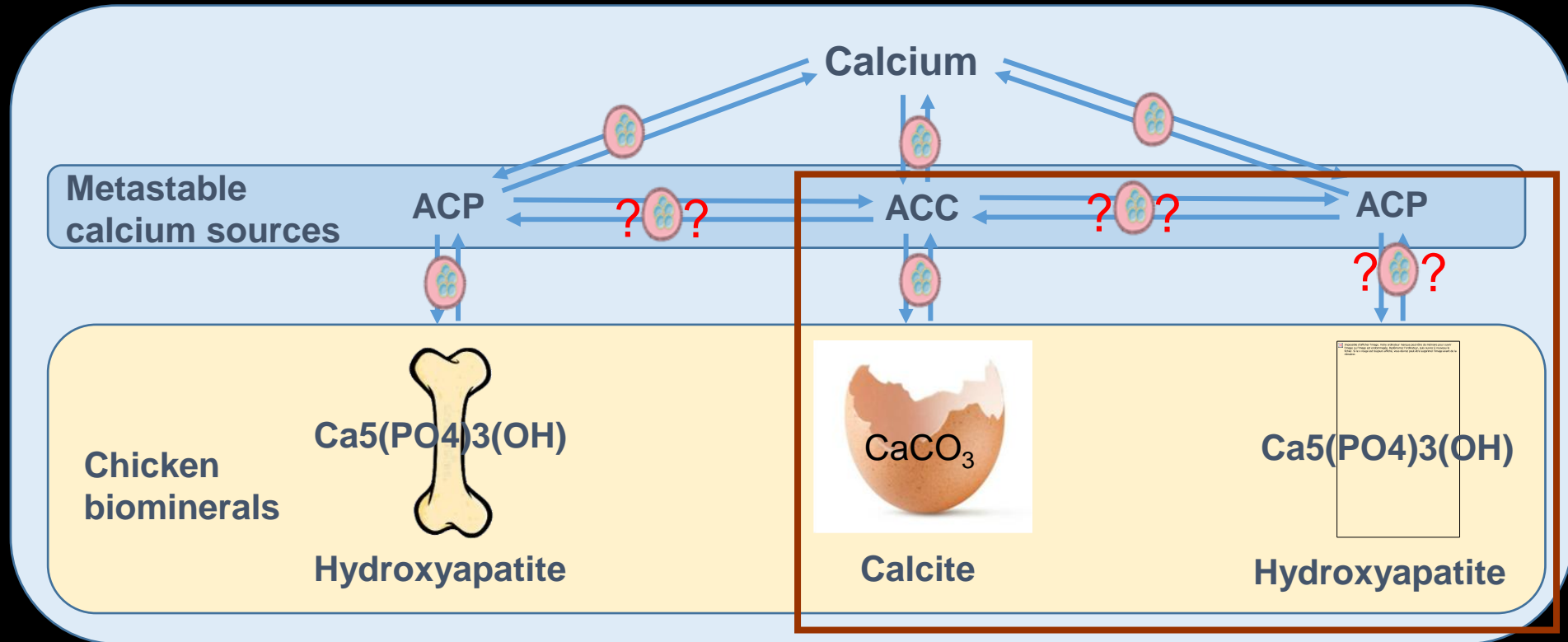
Biomineralization
Ultrastructure and
mechanical properties

Antimicrobials 1
In soluble form during shell
formation (keep the egg free of
pathogens)

Antimicrobials 2
Solubilisation during chicken
embryo development and
skeleton formation

Shell/skeleton dialog

Molecular, vesicular and cellular mechanisms



Role of CAM to solubilize the shell
CAM and osteoblasts ?
CAM and immune cells ?

Metabolite and immunity in biominerals

Fish and Shellfish Immunology 106 (2020) 645–655

Contents lists available at [ScienceDirect](#)

Fish and Shellfish Immunology

journal homepage: www.elsevier.com/locate/fsi

Full length article

Immune-responsive gene 1 (IRG1) and dimethyl itaconate are involved in the mussel immune response

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Metabolomics (2019) 15:97
<https://doi.org/10.1007/s11306-019-1556-8>

ORIGINAL ARTICLE



Targeted metabolomics to investigate antimicrobial activity of itaconic acid in marine molluscs

Thao Van Nguyen¹ · Andrea C. Alfaro¹ 

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SCIENTIFIC REPORTS

OPEN

Itaconic acid inhibits growth of a pathogenic marine *Vibrio* strain: A metabolomics approach

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Thao Van Nguyen¹, Andrea C. Alfaro², Tim Young¹, Saras Green², Erica Zarate²
& Fabrice Merien³