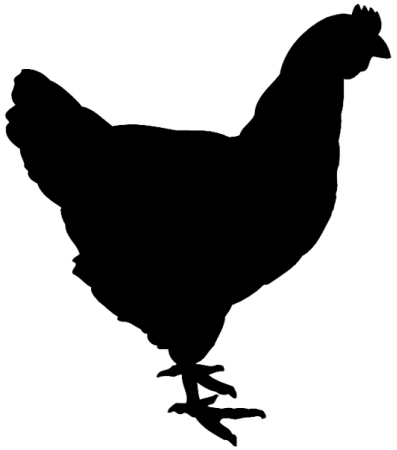
Avances recientes en la formación y calidad de la cáscara de los huevos

Joël Gautron



science for people, life & earth

Avances recientes en la formación y calidad de la cáscara de los huevos

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université de TOURS

UNIVERSIDAD DE GRANADA

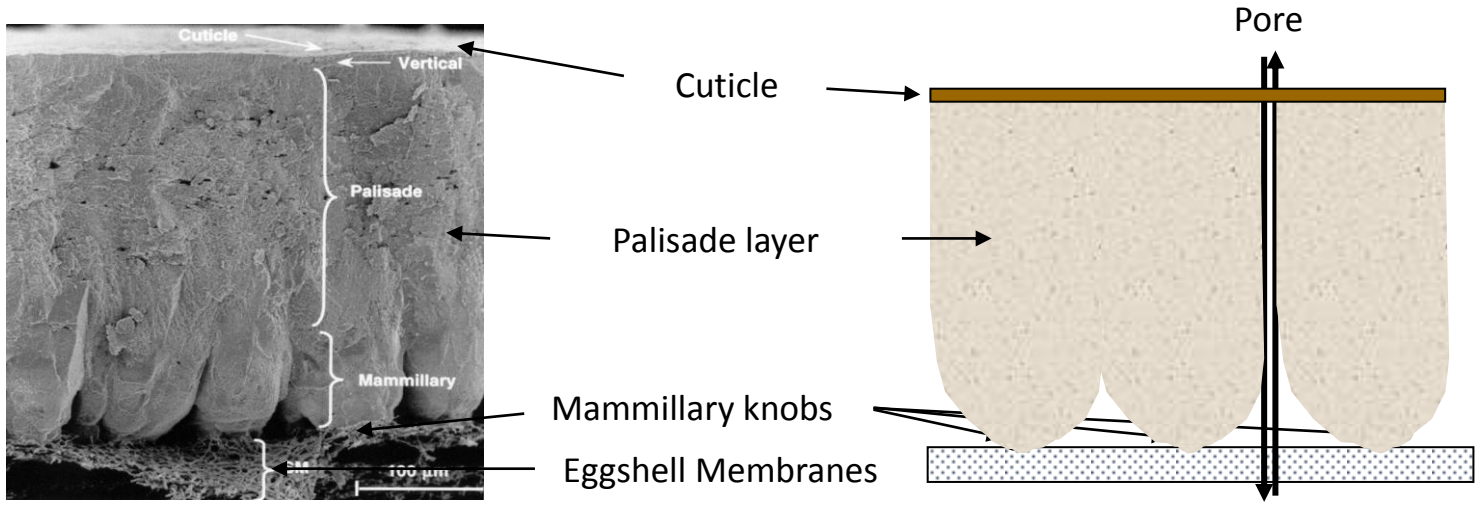
uOttawa

Défenses de l'œuf DOVE Valorisation Evolution

UMRBOA Biologie des Oiseaux & Aviculture

La cáscara: una barrera física contra la penetración bacteriana

- ✓ Eggshell biomineralization in uterus (fast process)
- ✓ 5-6 g of mineral (calcium carbonate) are deposited within a 20 h period



- 95 % of minéral (calcium carbonate)
- 3,5 % organic matter (proteins and complex sugar)
- 1,5 % water

La formación de la cáscara del huevo

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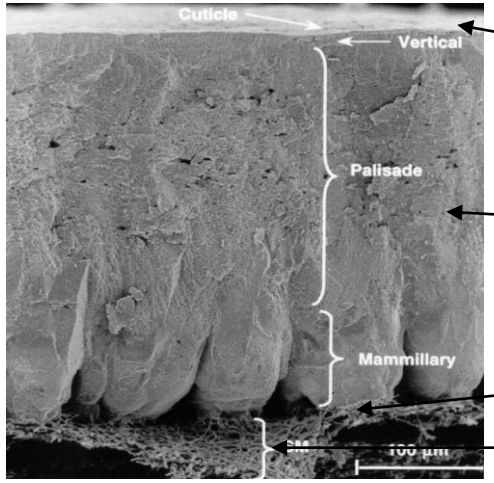
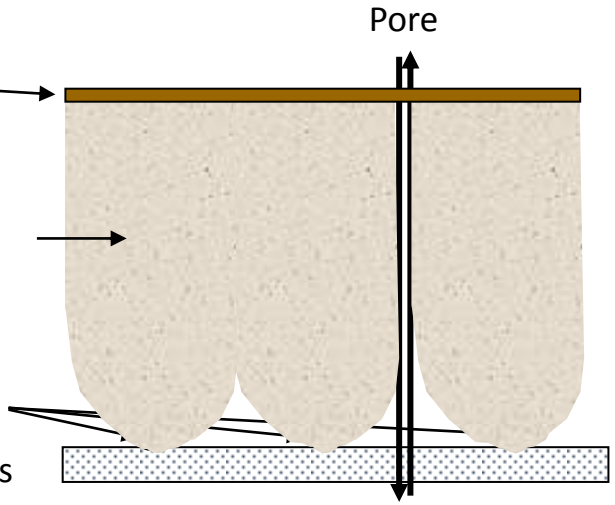
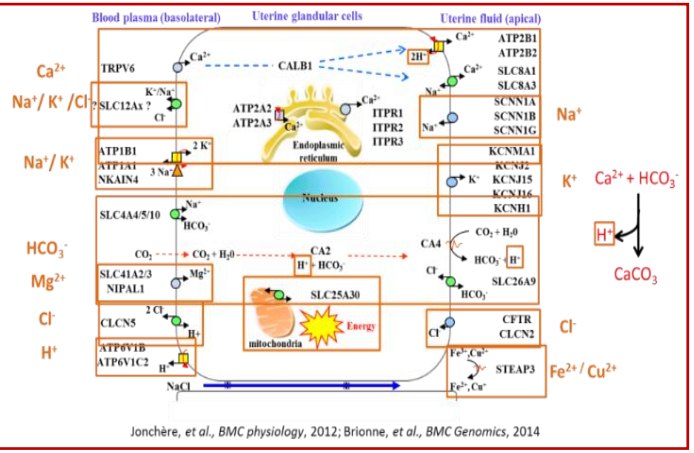


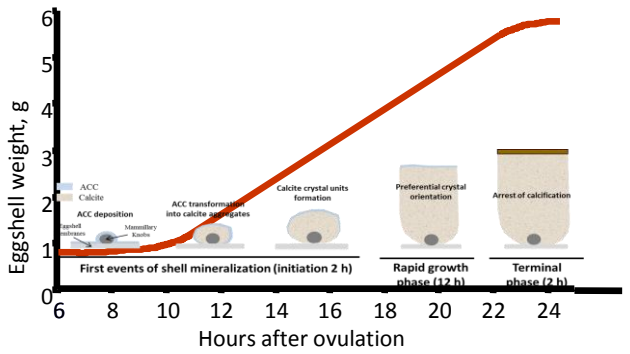


-I- Mineral supply



Jonchère, *et al., BMC physiology*, 2012; Brionne, *et al., BMC Genomics*, 2014

-II- Biomineralization



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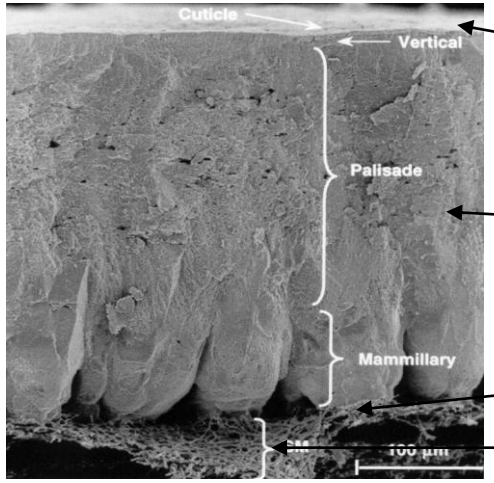
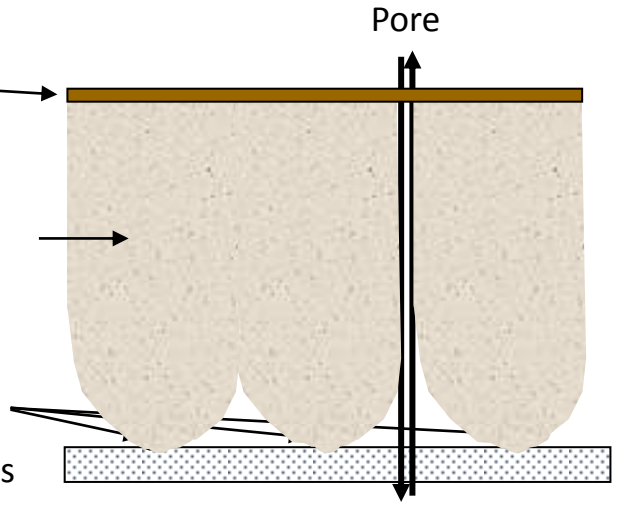


Cuticle

Palisade layer

Mammillary knobs

Eggshell Membranes



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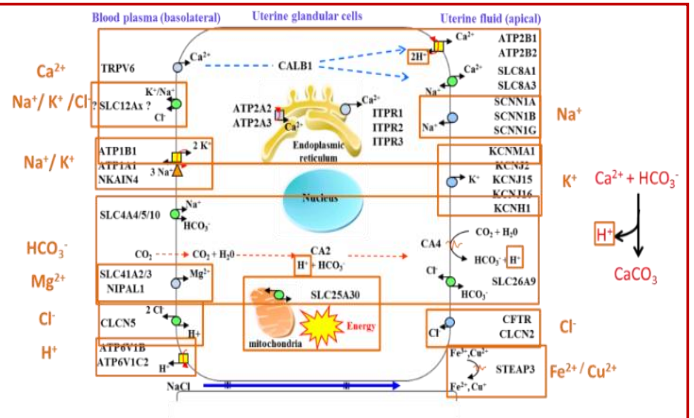

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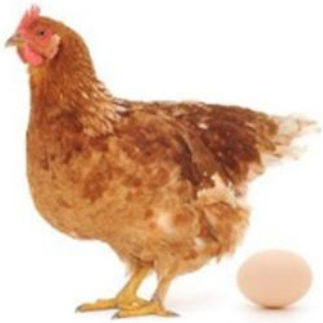
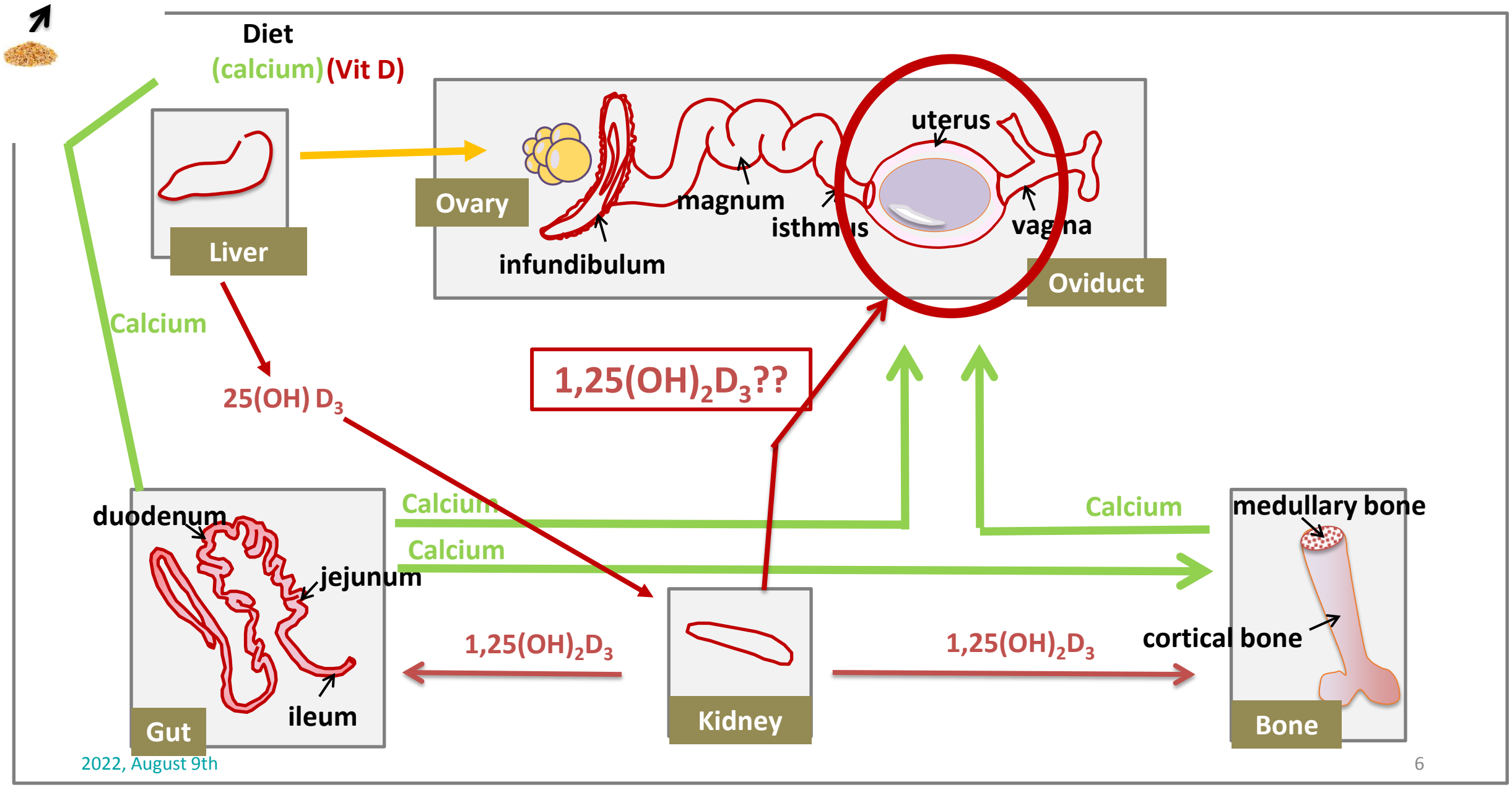
Desincronización entre la ingesta y las necesidades de calcio

Diet
(calcium)



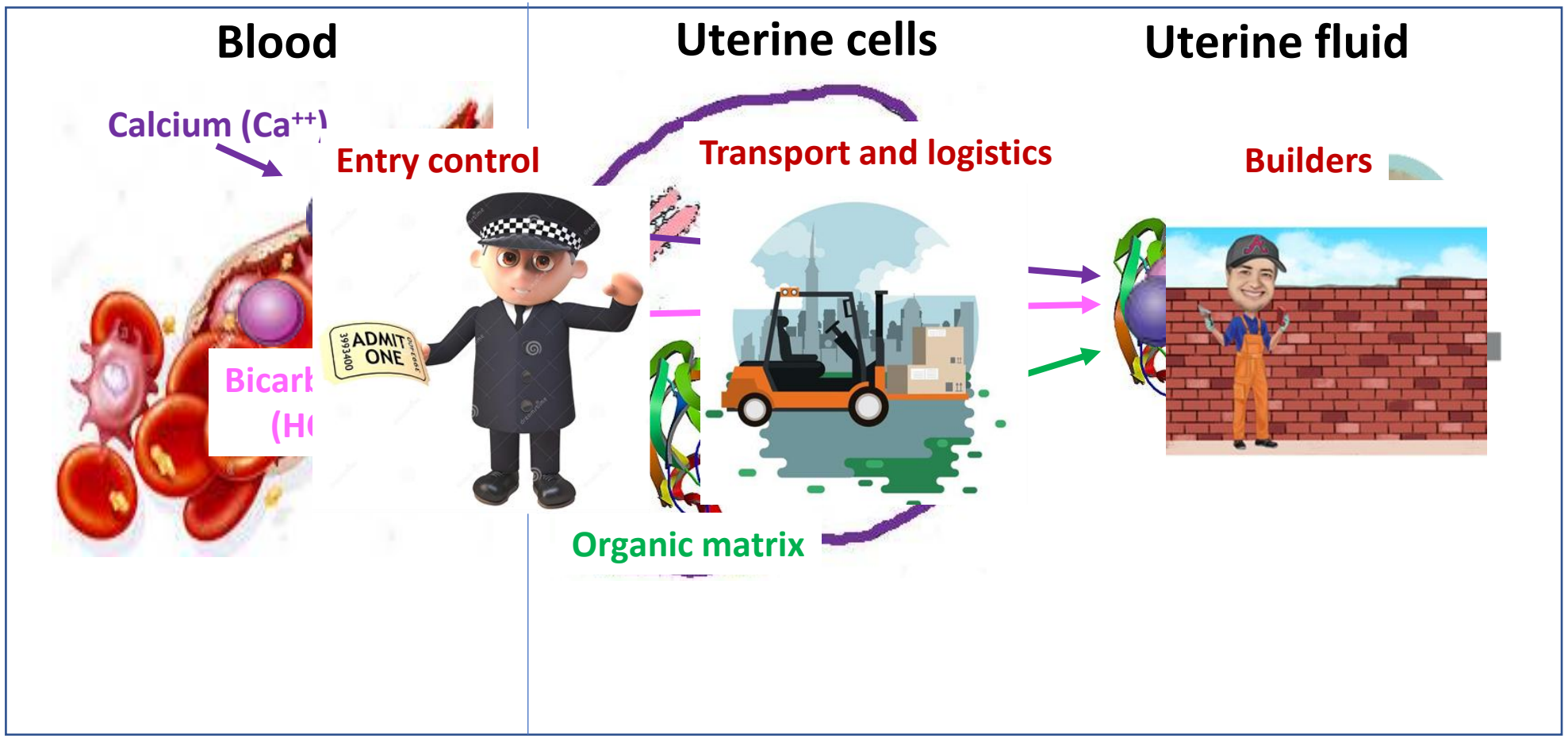
Need for shell calcification	0	--+	+++	+++	+++	+++
Availability of calcium	+++	+++	0	0	0	0

Regulación del metabolismo del calcio en gallinas ponedoras



Regulation of shell calcification

$Ca^{++} + HCO_3^- \rightarrow CaCO_3 + H^+ + \text{Organic matrix} \rightarrow \text{Shell}$



Regulación del metabolismo del calcio en gallinas ponedoras

3 Potential pathways

Transcellular

- *Carbonic Anhydrase 2*
- *Carbonic Anhydarse 4*
- *SLC4A4-A5-A10*
- *SLC26A9*
- *TRPV2-3*
- *Calbindin-1*
- *ATPA2/3*
- *ITPR1/2/3*
- *ATP2B1-B2*
- *SLC8A1-A3*

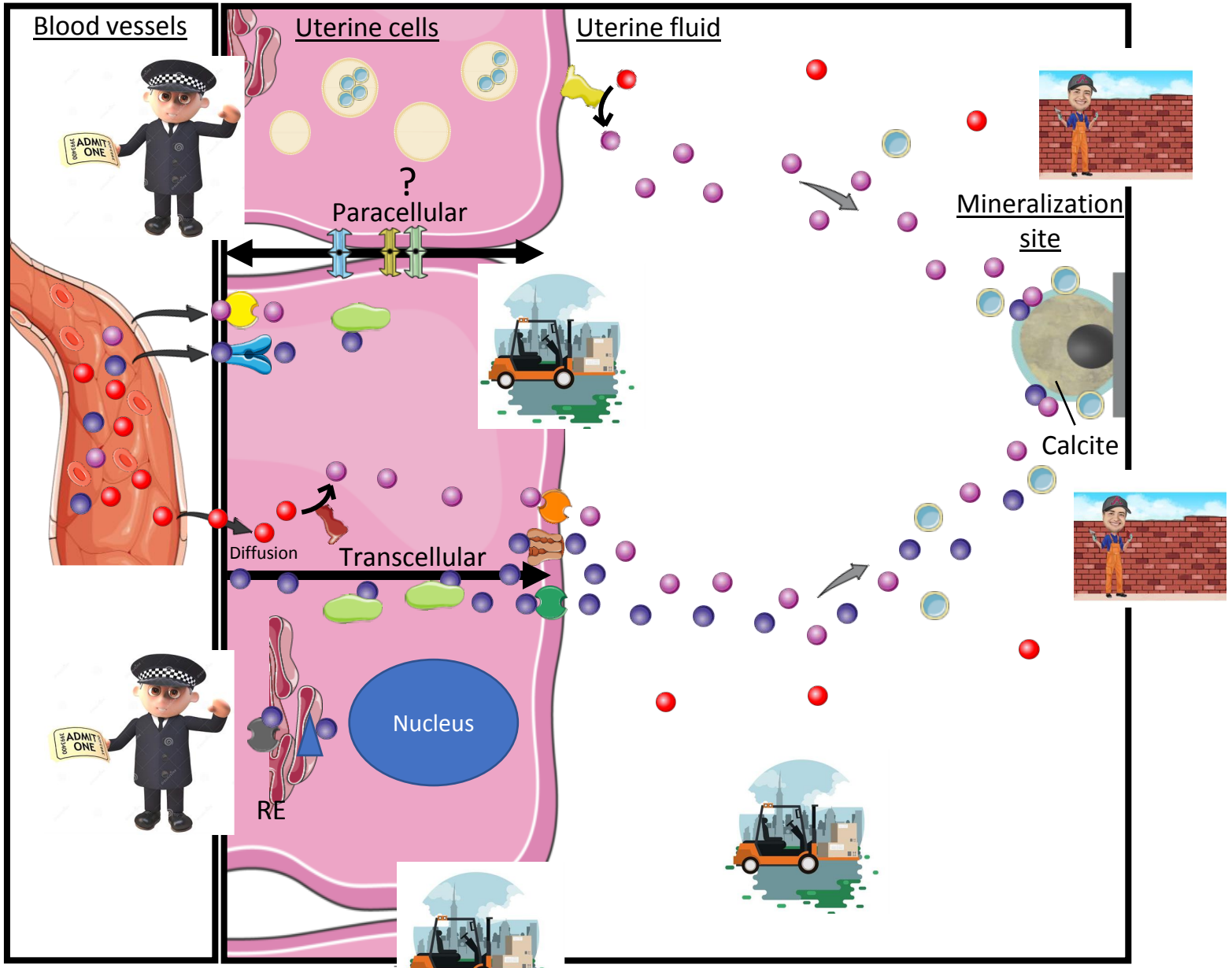
Vesicular

- Extra and intra cellular vesicles
- *Annexines*
- *EDIL3/MFGE8*

Paracellular ?

- *Claudins*
- *JAM*
- *Occludin/TJP*

- HCO_3^-
- Ca^{2+}
- CO_2
- ACC



Adapted from L..Stapane-D-17/12/19

Hodges et Lörcher 1967; Jonchère *et al.*, 2012; Brionne *et al.*, 2014; Nys et Le Roy, 2018

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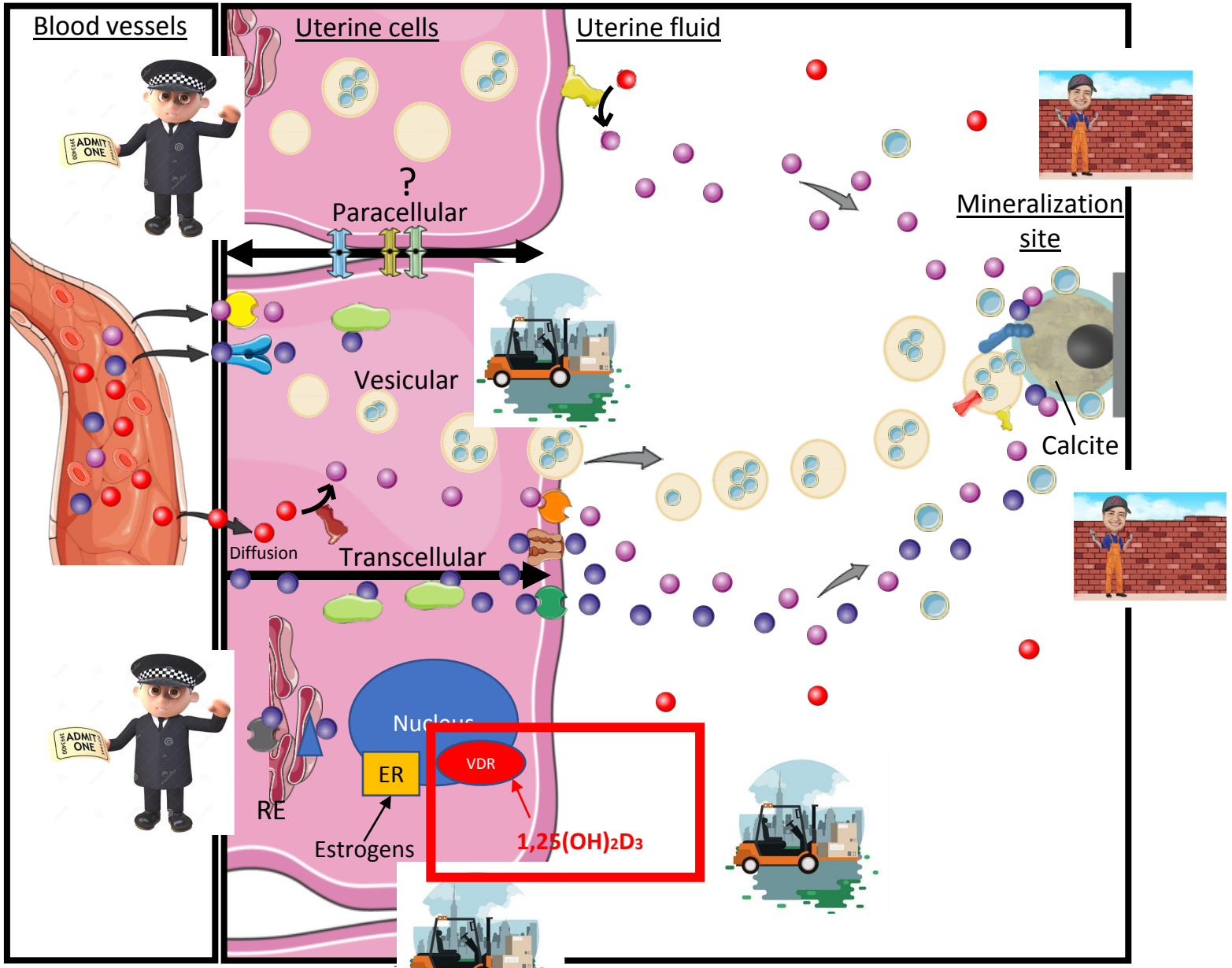

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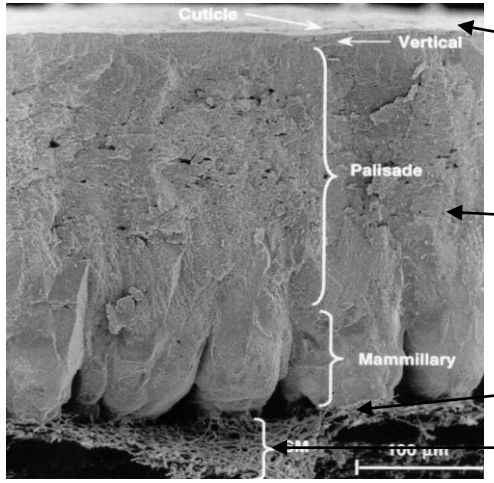

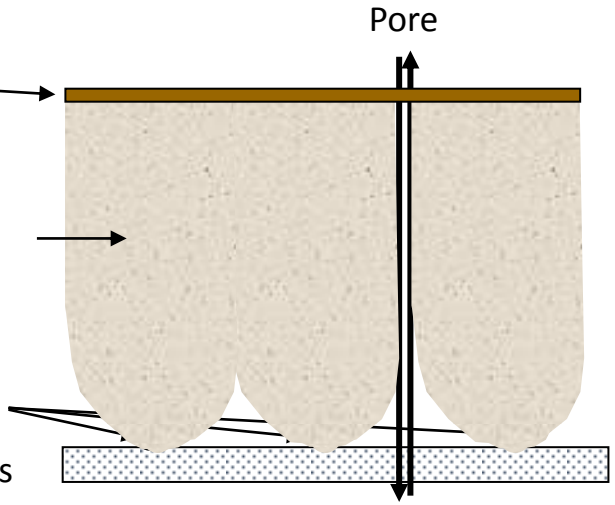

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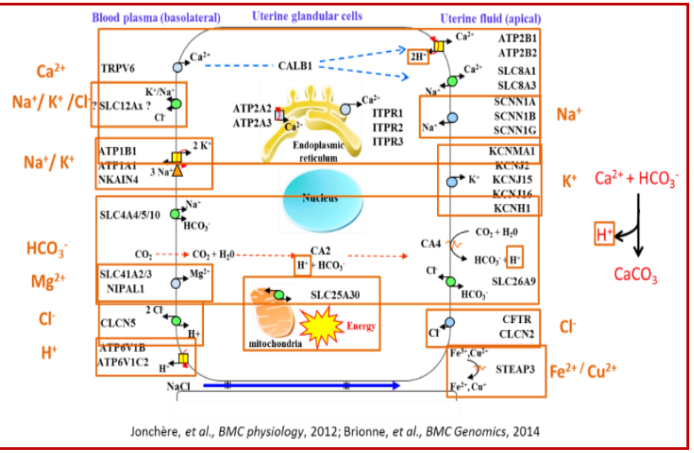

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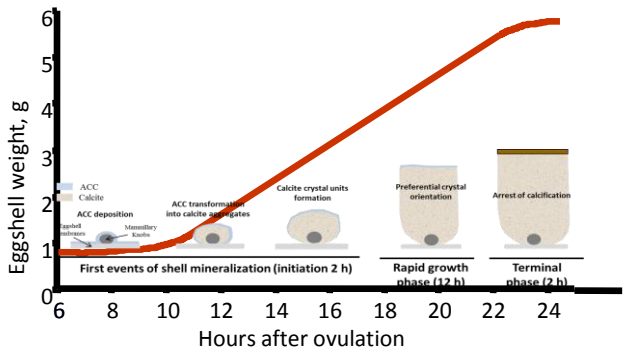

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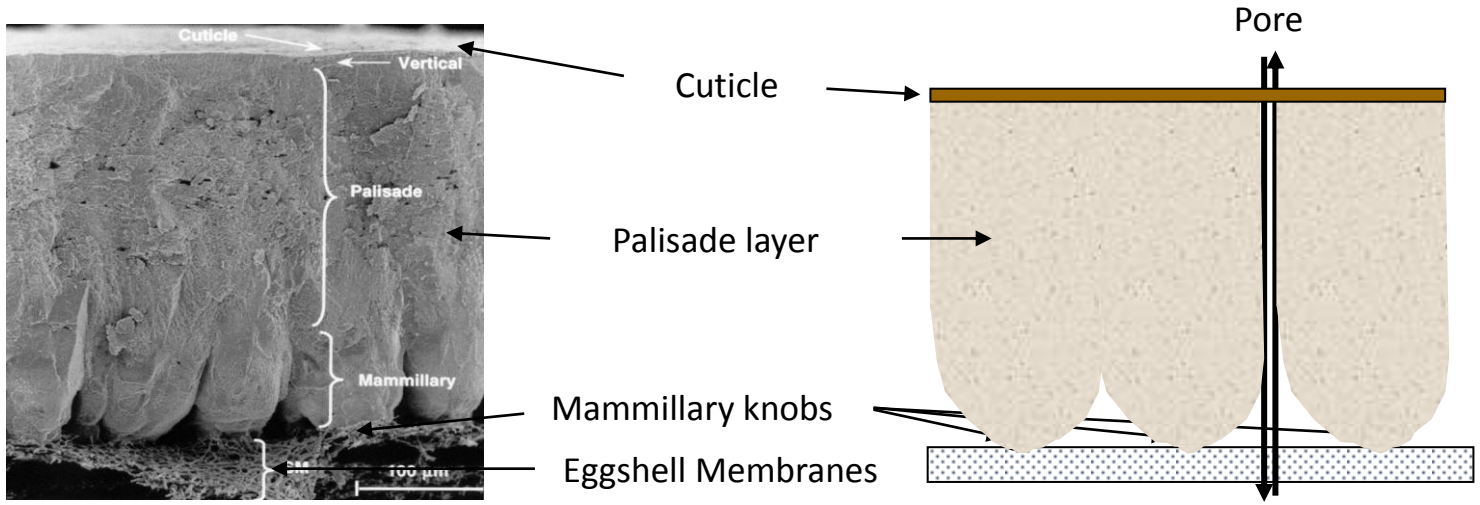

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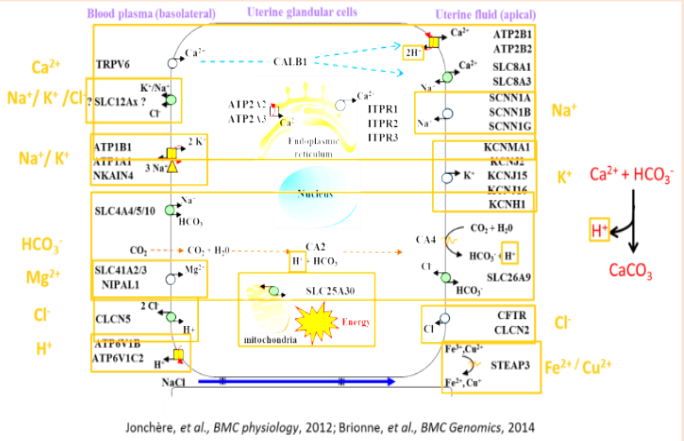

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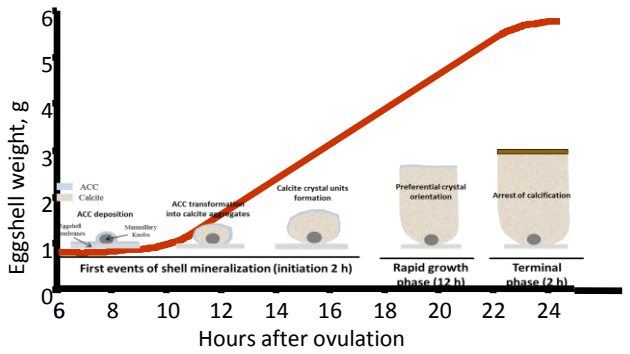
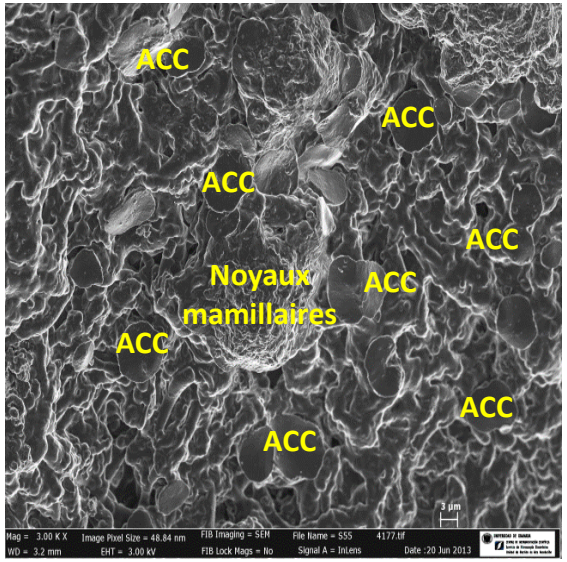
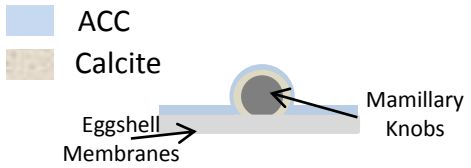


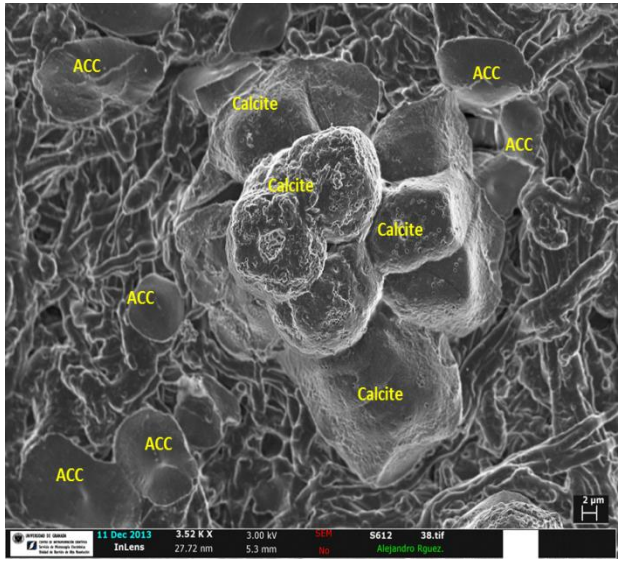
Biomineralización de la cáscara de huevo



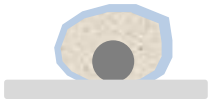
First events of nucléation



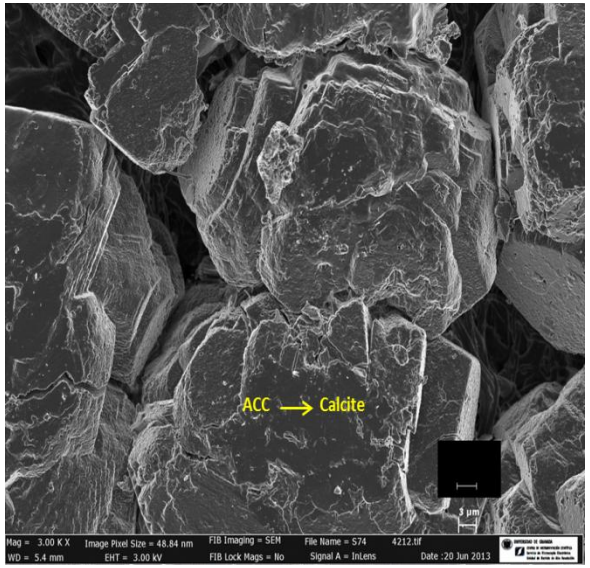
Time 1 (5-6 h Post ovulation):
Amorphous calcium carbonate (ACC) particles nucleate on the whole eggshell membranes.
Form massive deposits



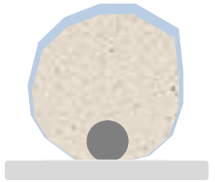
Calcite formation



Time 2 (6-7 h post ovulation):
Interface-coupled dissolution precipation process
Direct transformation of ACC into calcite aggregates on mammillary knobs



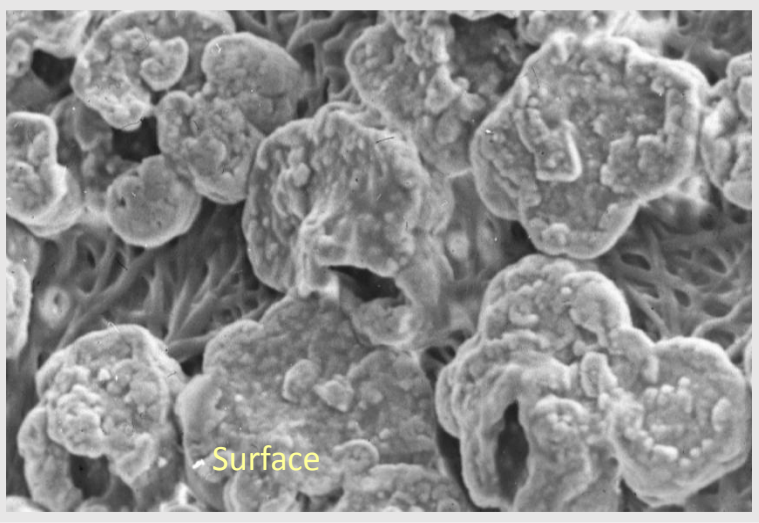
Larger calcite crystal units deposition

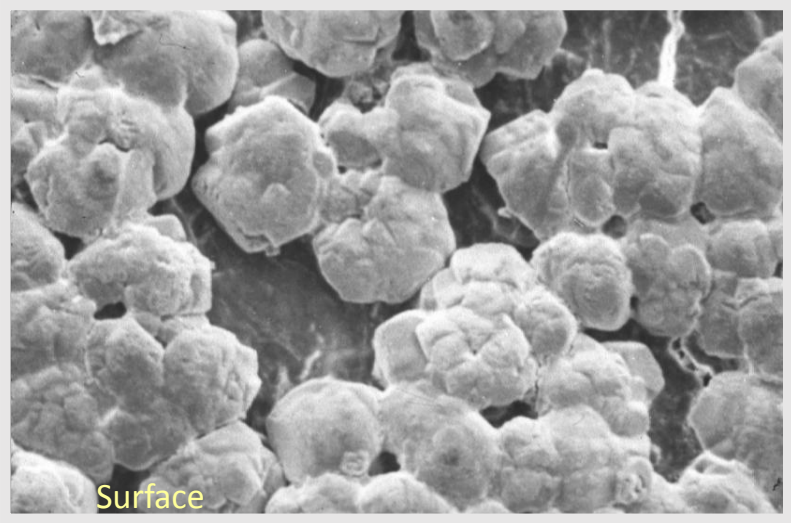


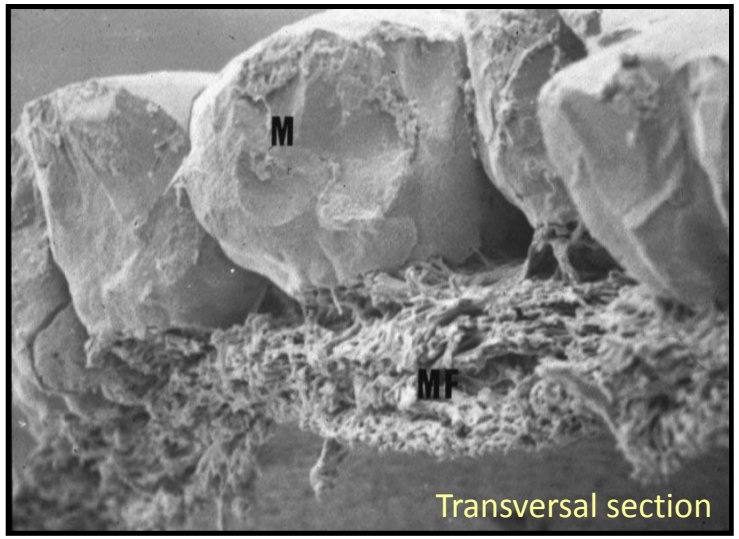
Time 3 (>7h post ovulation):
Additional cristallisation events on calcite template

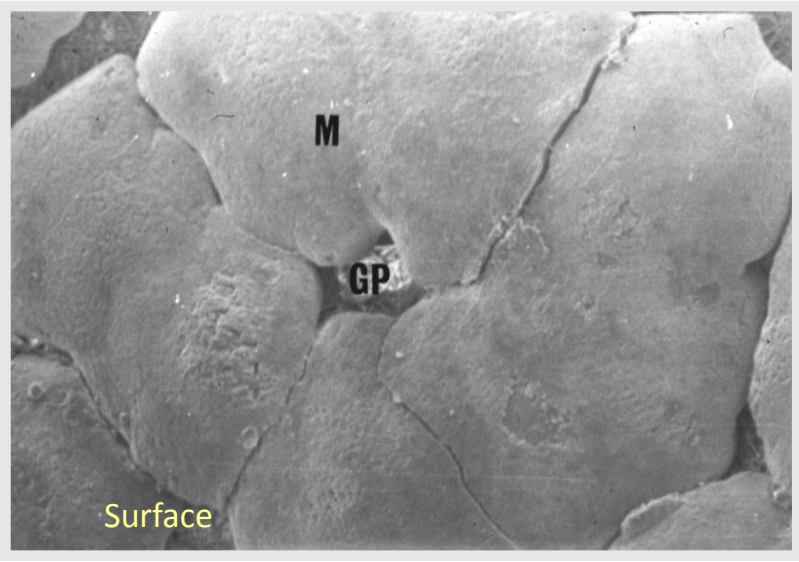
Rodriguez-Navarro et al., Journal of structural Biology, 2015

Biomineralización de la cáscara de huevo



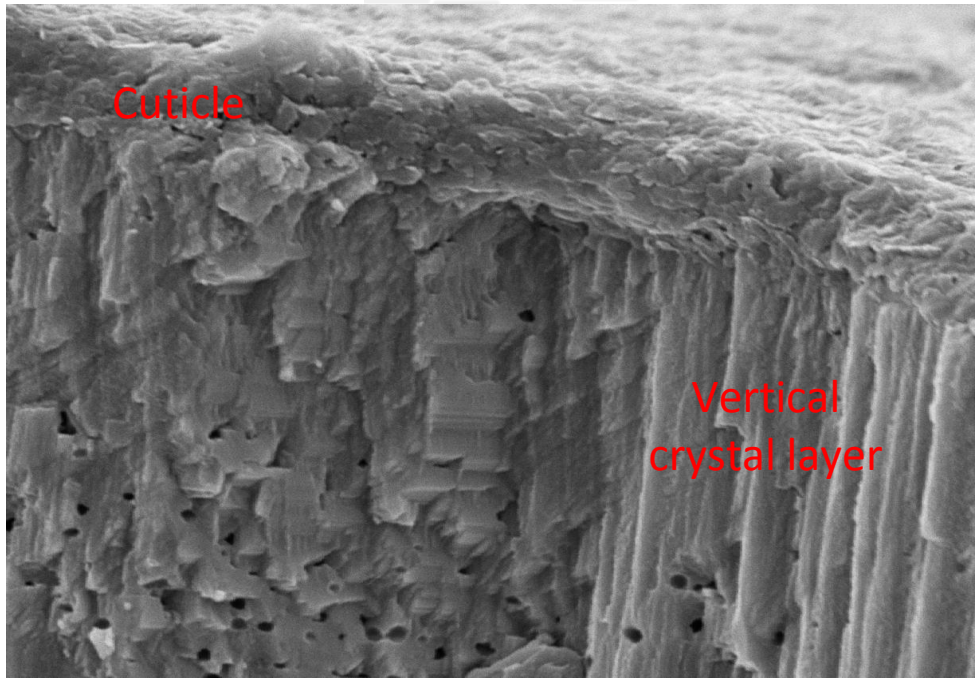


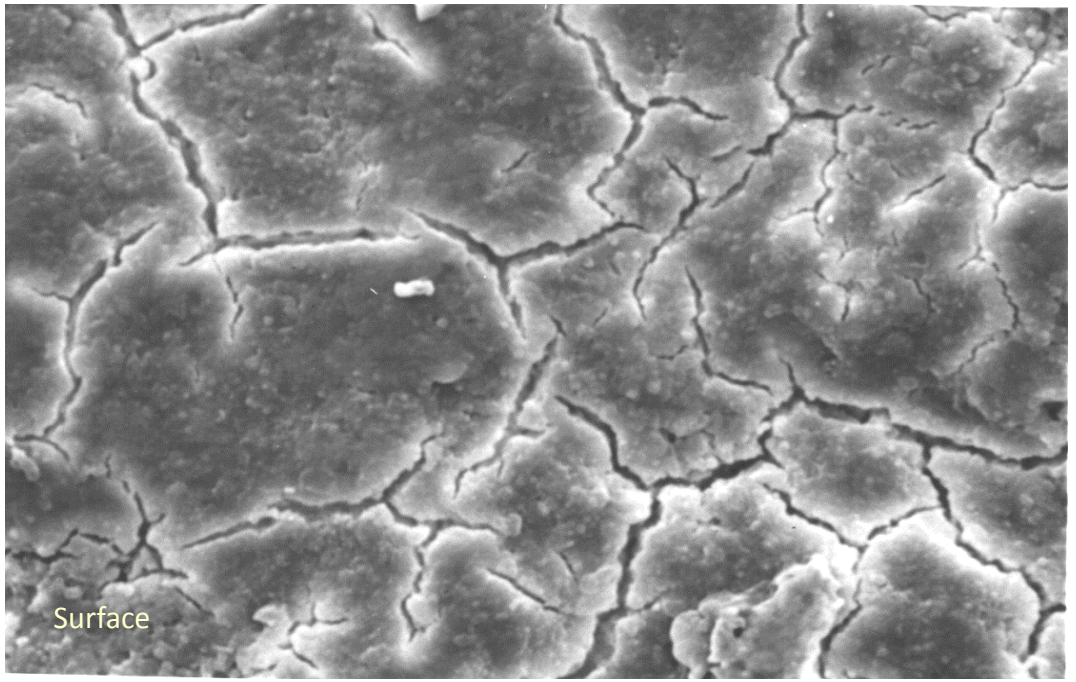




Time 4 (7-10h post ovulation):
Calcite deposition and fusion of adjacent cônes

Biomineralización de la cáscara de huevo

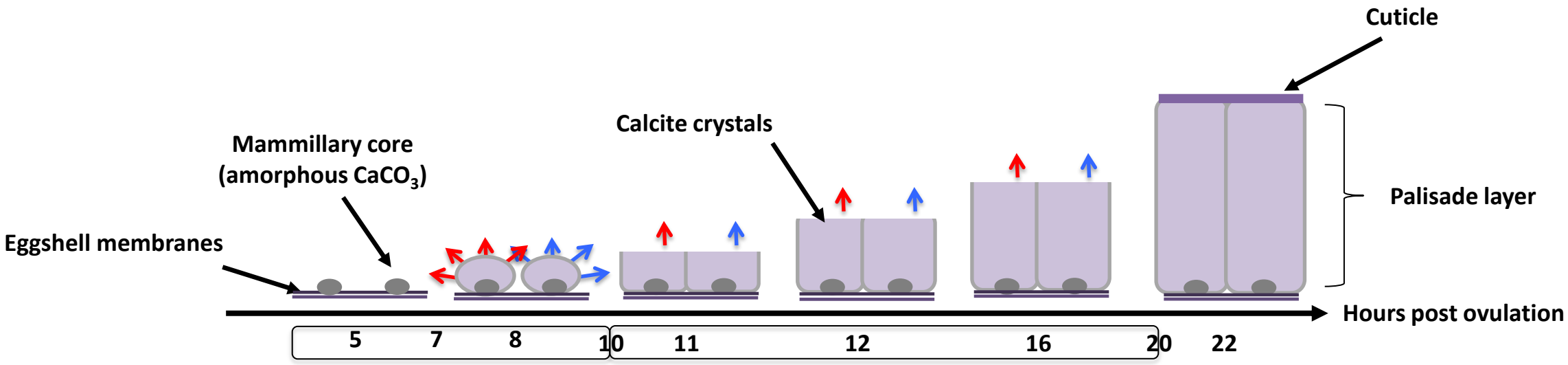




Time 5 (11 to Oviposition):

- Generation of a compact layer (palisade layer)
- Deposition of a thin layer of vertical structure
- Cuticle deposition
- Oviposition, drying and cracking of cuticle

Biomineralización de la cáscara y propiedades mecánicas



95 % of calcium carbonate (calcite) ← Interaction → 3.5 % organic matrix (proteins, proteoglycans)

Quantity → **Mechanical properties** ← Ultrastructure

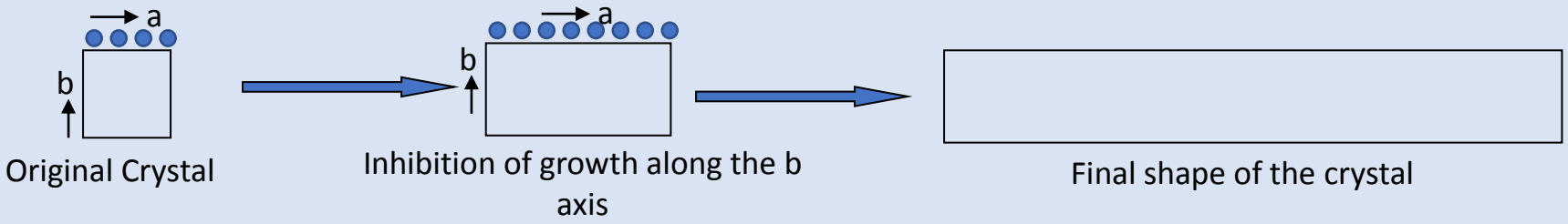
Biomineralización de la cáscara y propiedades mecánicas

3.5 % organic matrix → **About 900 proteins in the shell**

(Gautron et al., 2019)

Stabilize the amorphous calcium carbonate (ACC), controls polymorphs, morphology and size of crystals

Theoretical example for understanding

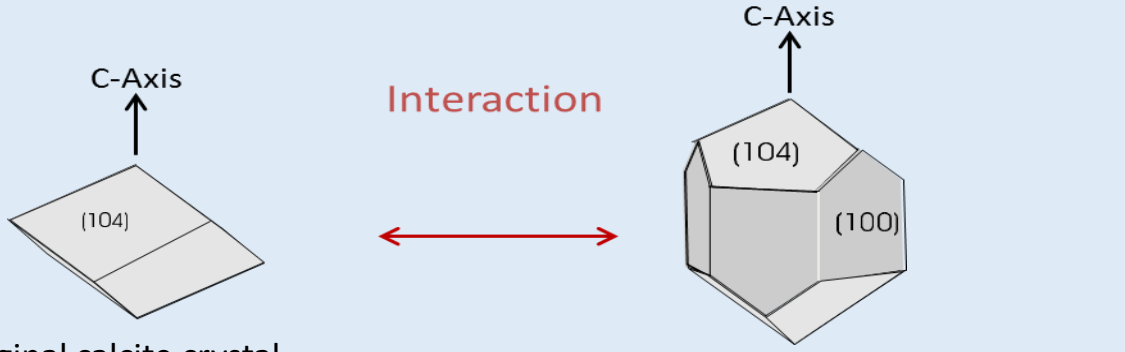


Original Crystal

Inhibition of growth along the b axis

Final shape of the crystal

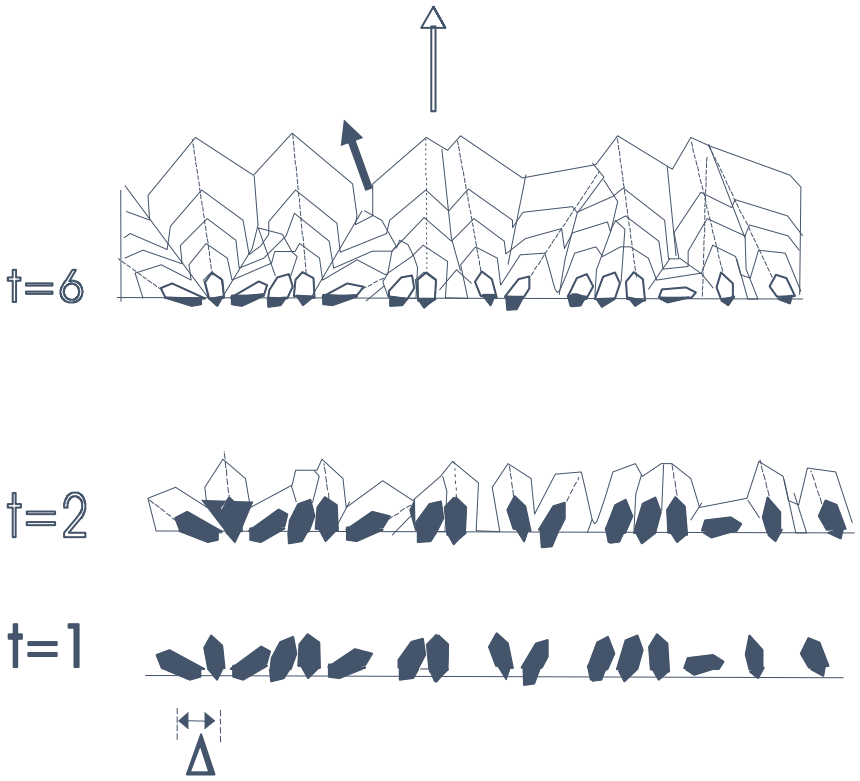
The real life of chickens: Calcite crystals in eggshell

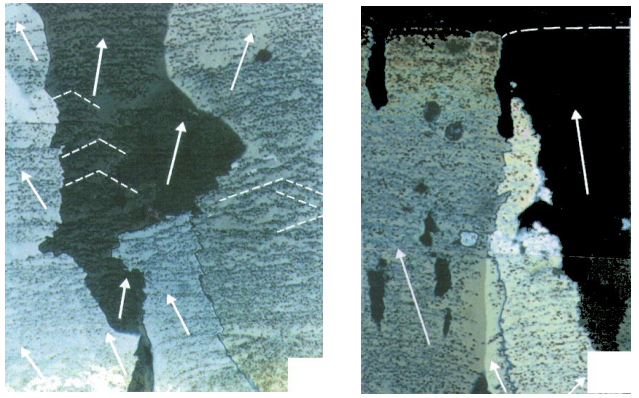


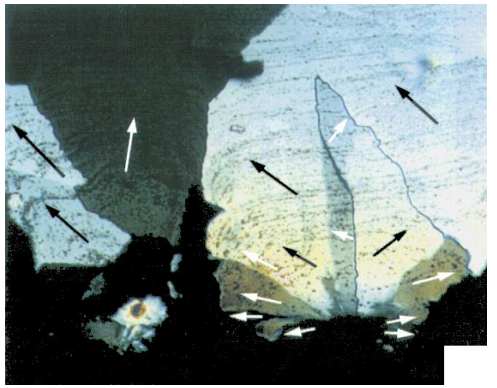
Original calcite crystal

Shape of the chicken calcite crystal

Biomineralización de la cáscara y propiedades mecánicas







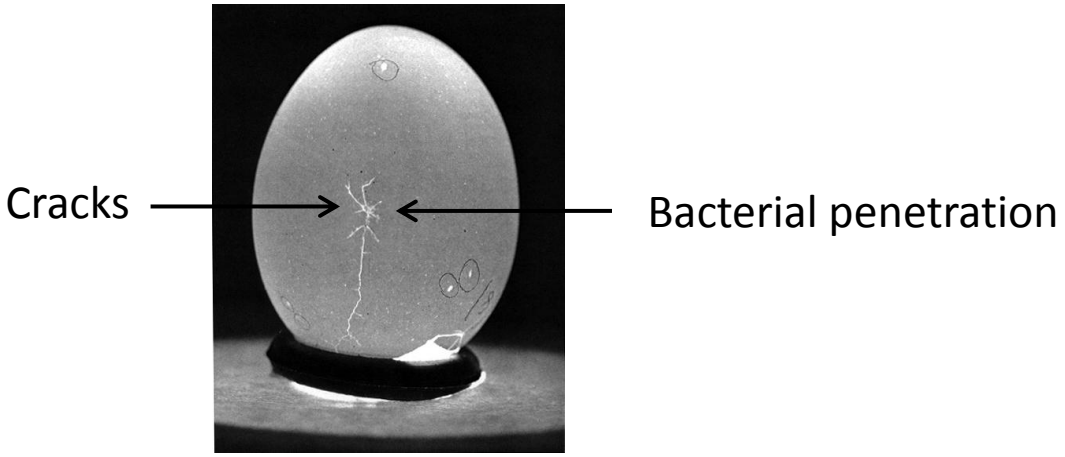
Rodriguez-Navarro 2003

Establishment of the ultrastructure and a preferred crystal orientation perpendicular to the surface → **Eggshell mechanical properties**

Mejorar la calidad de la cáscara del huevo

Natural envelope to ensure physical defence of egg

- *Protects the developing embryo*
- *Ensures that table eggs remains free of pathogens*

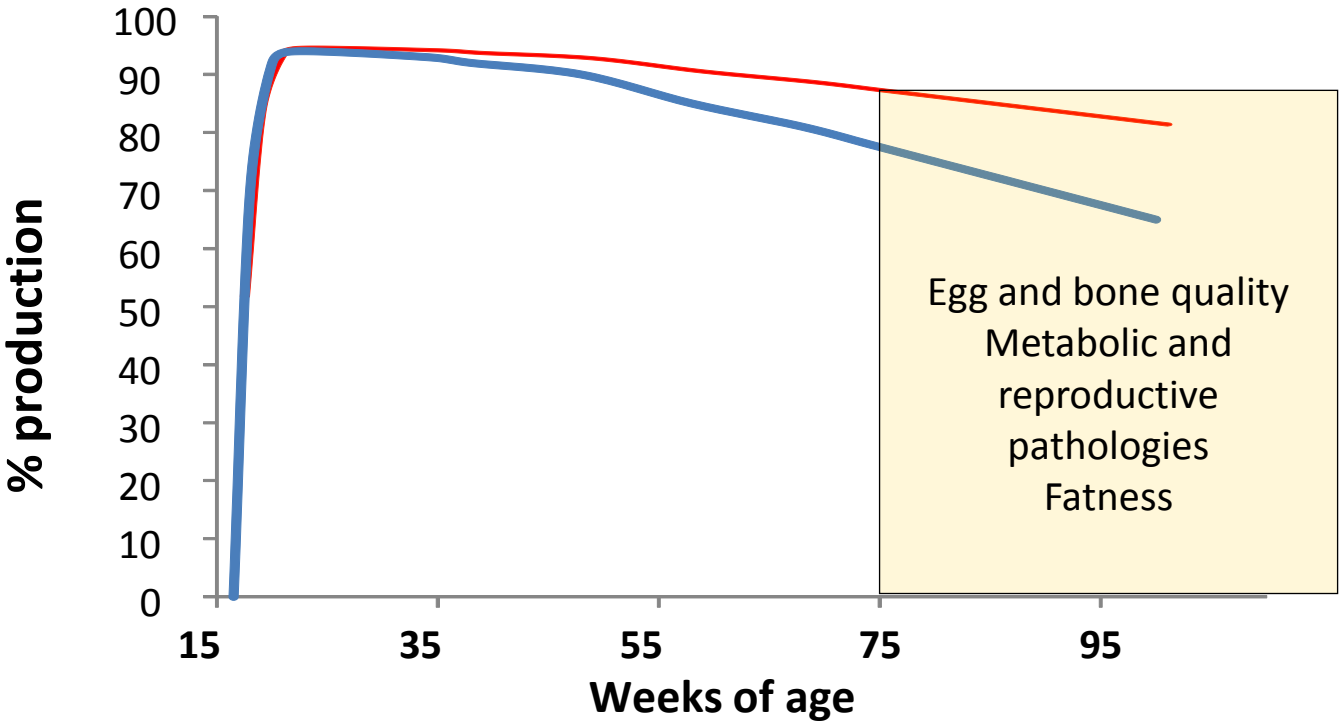


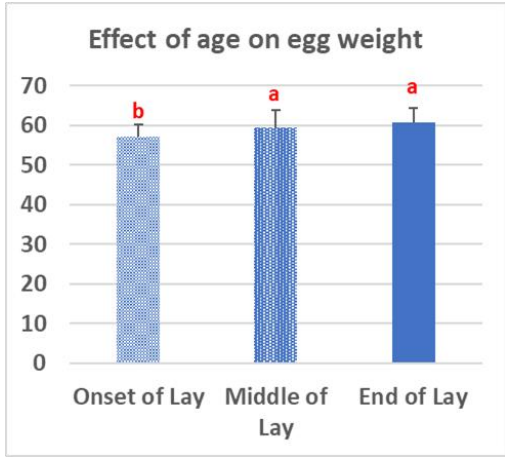
Shell quality depends on Numerous factors

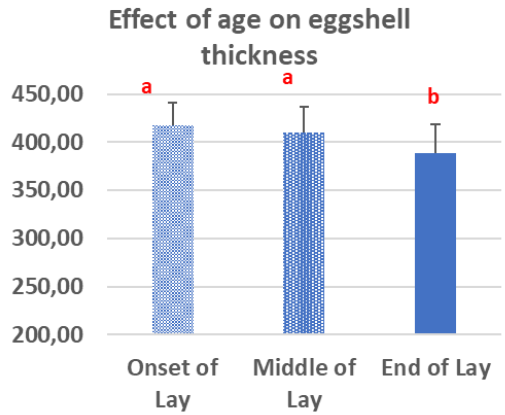
- **Genetic**
- **Hen physiology (age, mold)**
- **Environment of hens (lighting programs, temperature)**
- **Nutrition and management of hens**
- **“Insult”: rearing system, egg transport, egg sorting…**

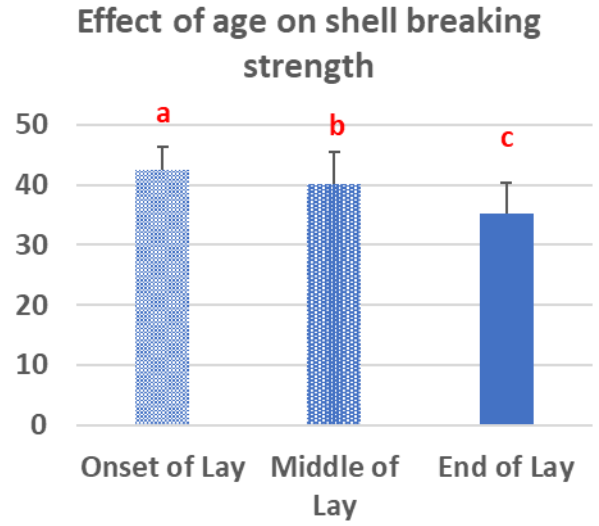
Genetic, optimal nutrition limit but do not eliminate breakage, notably for elderly birds

Extension of the Laying Period



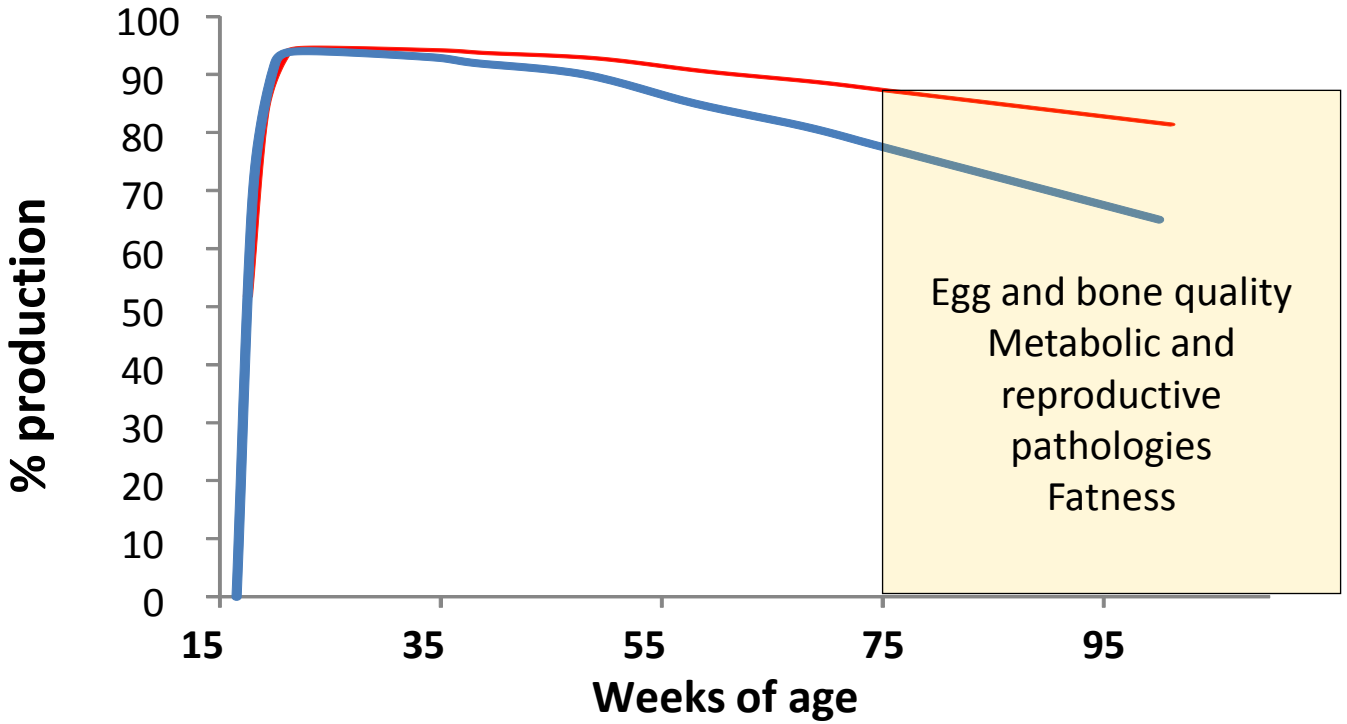






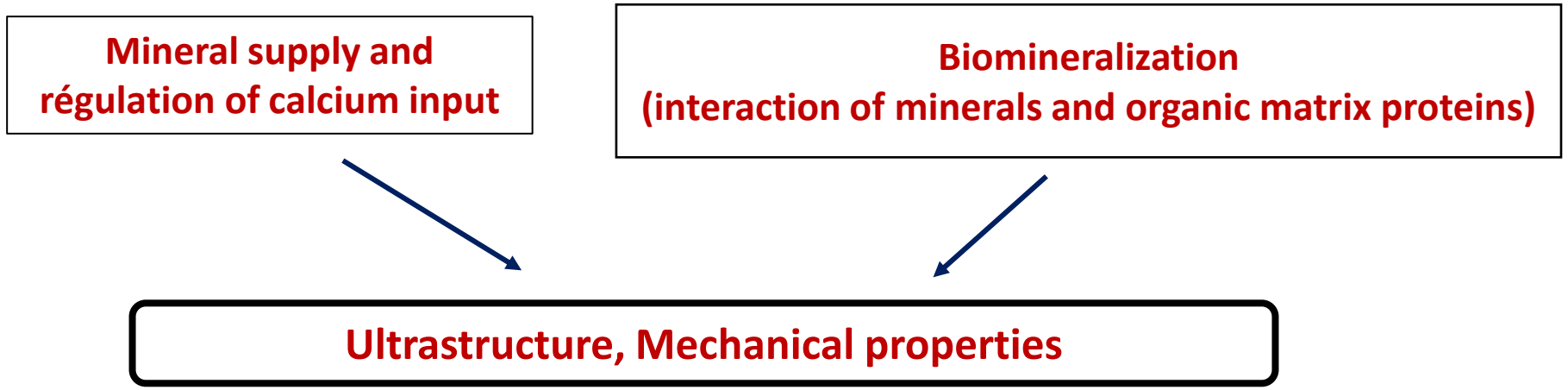
Weekly decreased in egg quality between 70 and 90 weeks of age estimated to be quite linear: - 0.4 haught unit, - 0,02% for egg shell, + 0,05 cm2 egg surface (European data, 2015, practical conditions)

Extension of the Laying Period



The current genetic strategy is to improve persistency in lay and to extend the laying cycle of existing flocks (500 eggs in 100 weeks of age)

Mejorar la calidad de la cáscara del huevo



✓Quantity (Mass) **About 60 %**

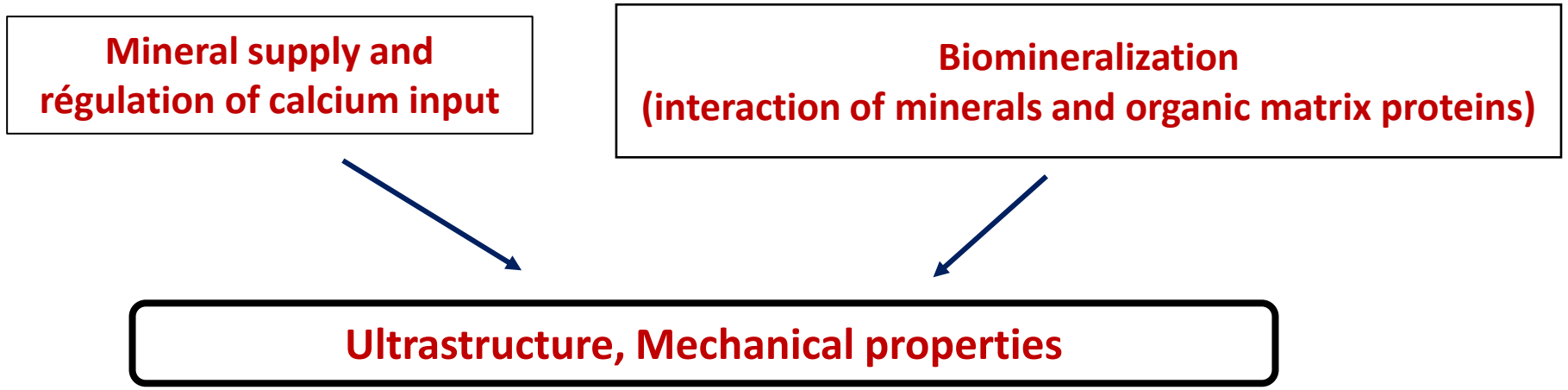
✓Control of the mineralisation process (fabric) **About 40%**

Mass or fabric ?

☞ Mass : nutrition, genetic, environment, lightning programs

☞ fabric : shell ultrastructure and crystalline arrangement

Mejorar la calidad de la cáscara del huevo



✓Quantity (Mass) About 60 %

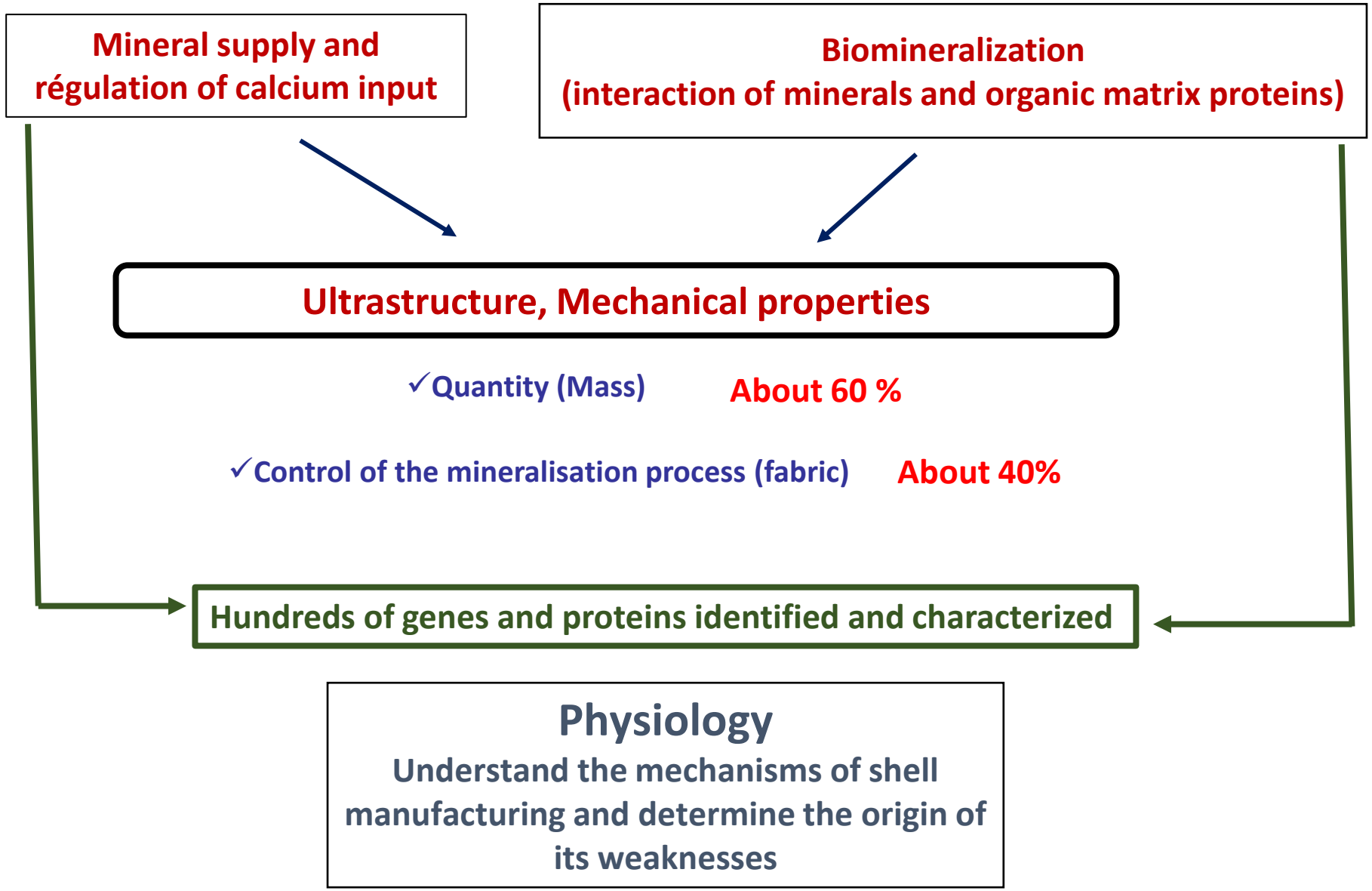
✓Control of the mineralisation process (fabric) About 40%

Mass or fabric ?

☞ Mass : nutrition, form and quantity of vitamin D, trace elements (Mn, Zn…)

☞ fabric : eggshell matrix proteins and biomineralization

Mejorar la calidad de la cáscara del huevo



And now ? How to improve shell quality ?

- Mapping genes coding matrix proteins and mineral regulation to detect polymorphisms and haplotype related to

Physiology

Understand the mechanisms of shell manufacturing and determine the origin of its weaknesses

Genetics

Classical and genomic selection

Recent Developments and Future Prospects :

- ✓ Genomic selection (precision, taking into account the male effect)
- ✓ Taking into account scientific advances in the knowledge of mechanisms
  - ✓ Candidate gene approach

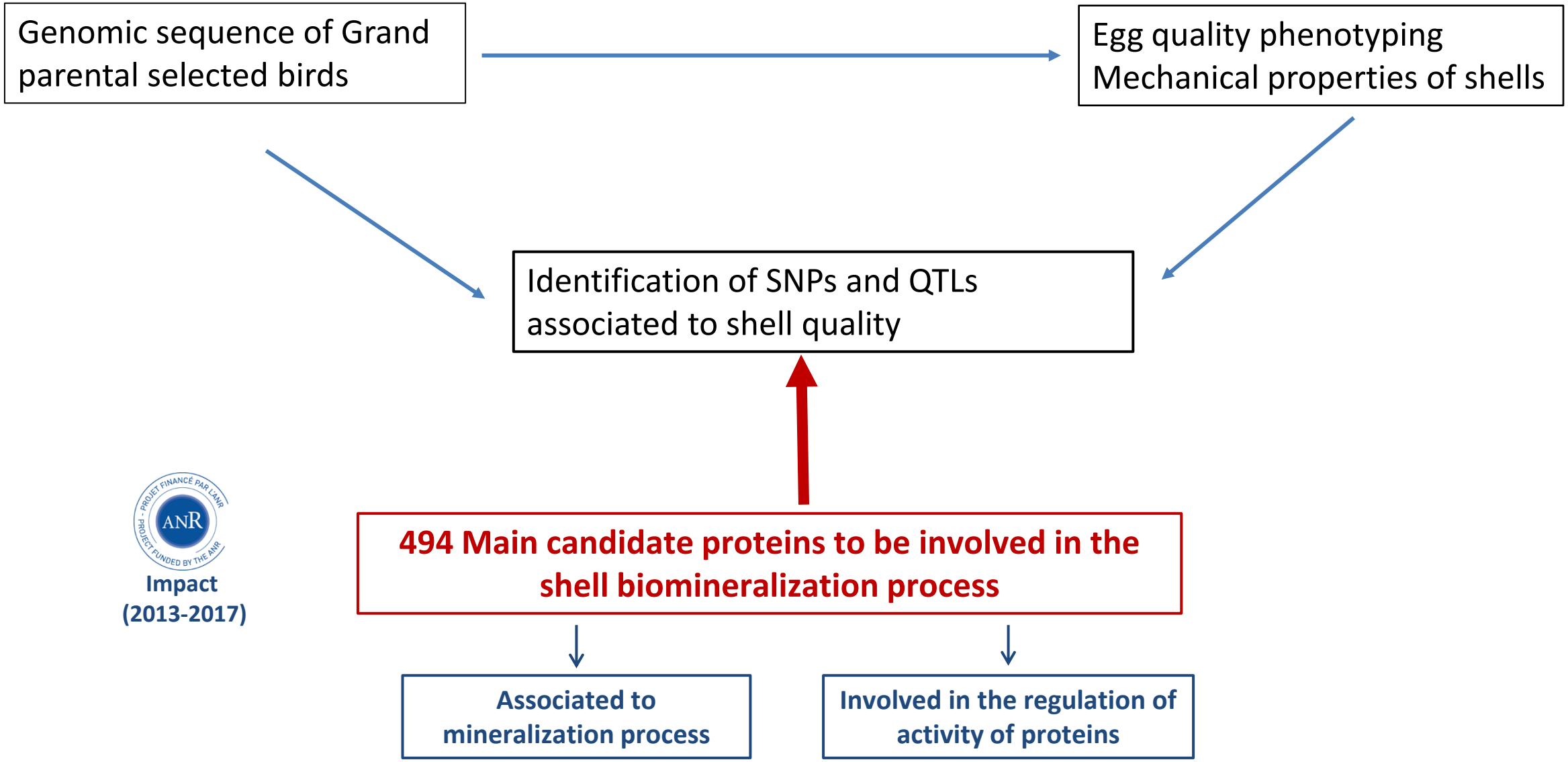
Candidate Genes of eggshell calicification in laying hens (CACAO)

Défenses de l'œuf
DOVE
Valorisation Evolution

Eggshell Calcification Polymorphism Candidates (POLCACAO)

Combine physiology, genetics and precise nutrition

Selección genómica a partir de datos sobre los genes y las proteínas que intervienen en la homeostasis de la gallina

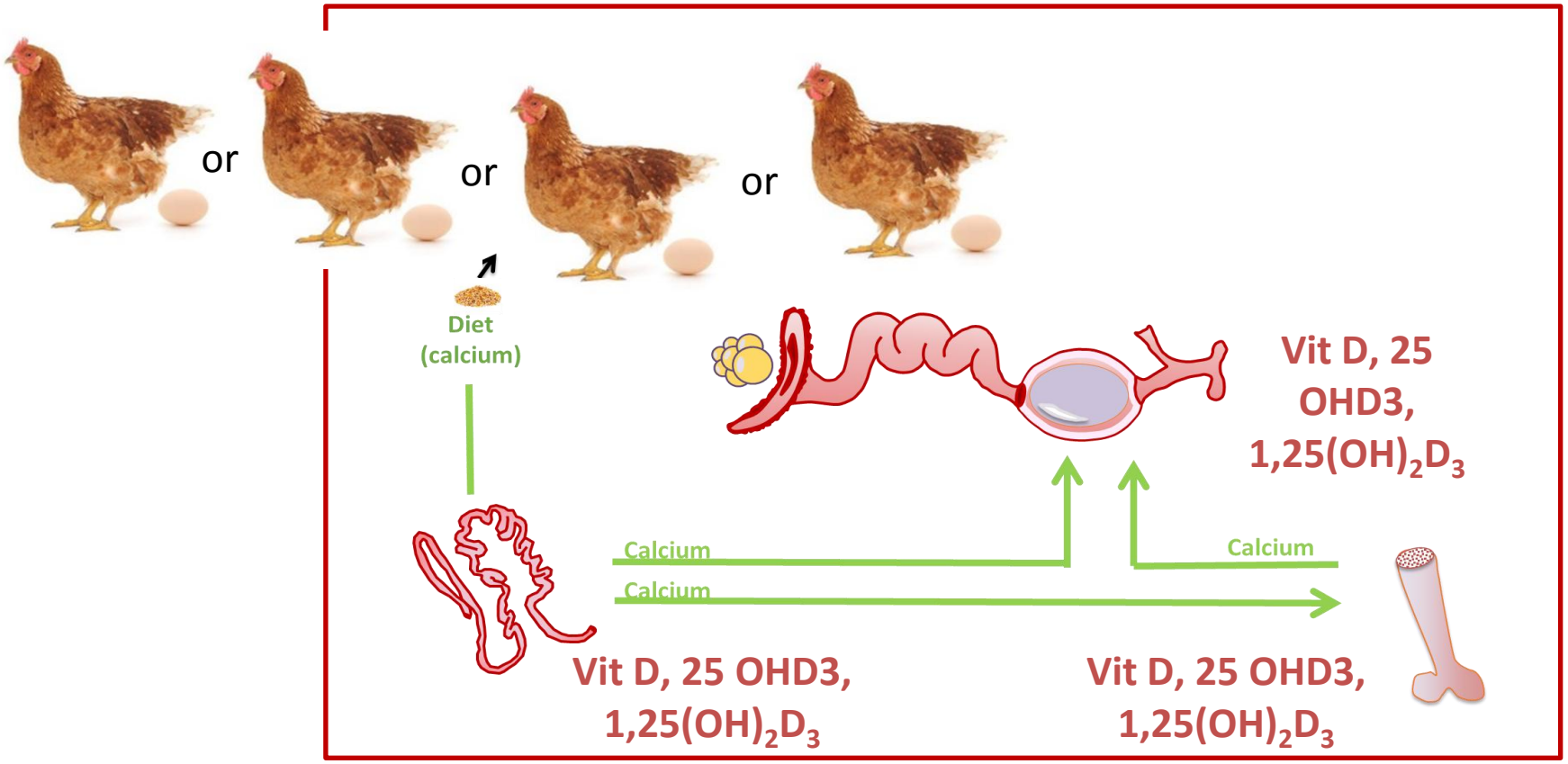


PROJET FINANCÉ PAR L'ANR · PROJECT FUNDED BY THE ANR

Impact (2013-2017)

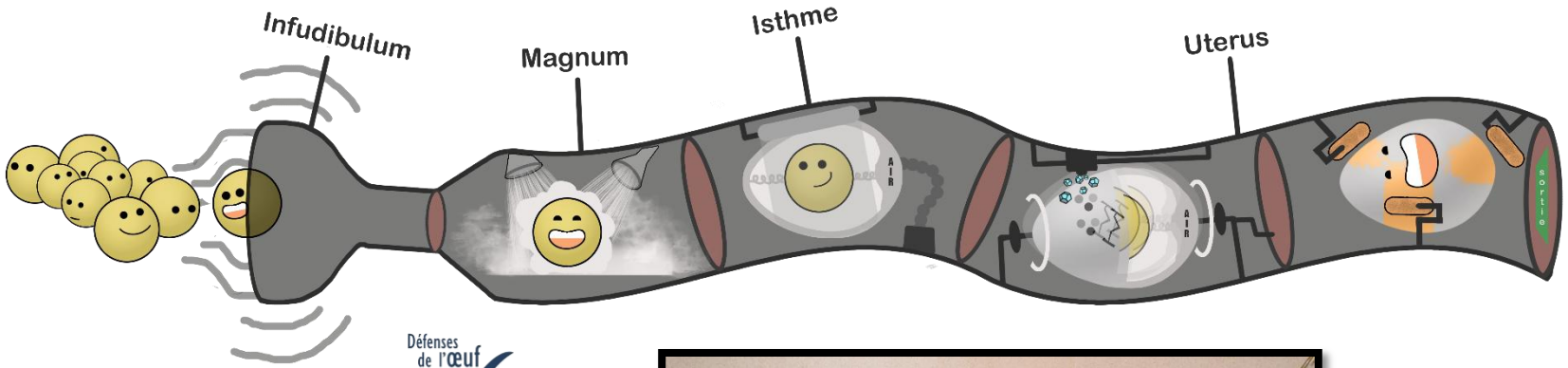
Y ahora cómo mejorar la solidez de las cáscaras de huevo

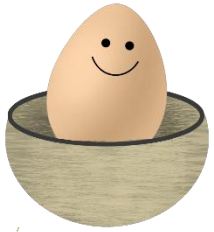
Selección genómica a partir de datos sobre los genes y las proteínas que intervienen en la homeostasis de la gallina



Nutrición cálcica de precisión en cuanto al momento, la forma del calcio aportado y la edad de los animales

Thank you for your attention





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