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Societal impact of biomineralization in chicken eggshells

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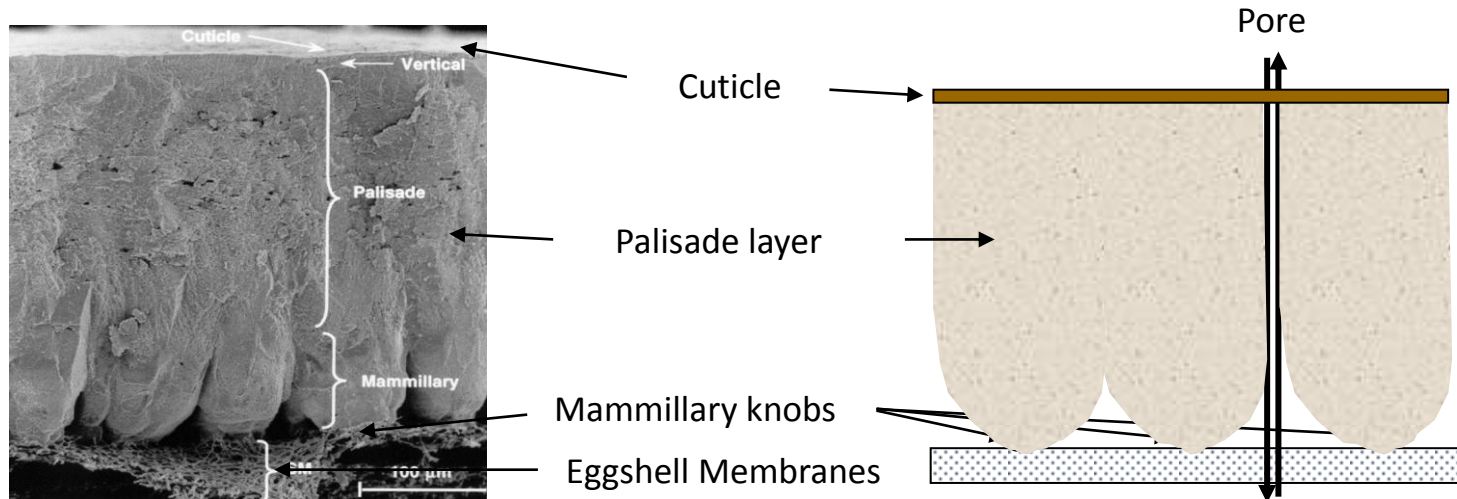
Societal impact of biomineralization in chicken eggshells

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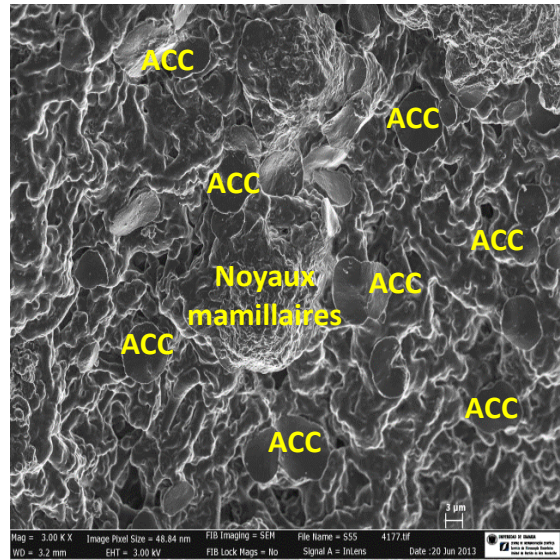
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The chicken eggshell formation

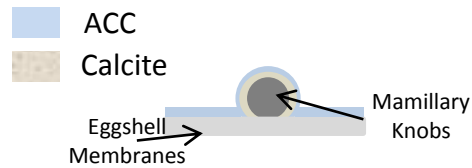
- ✓ Eggshell biomineralization in uterus (fast process)
- ✓ 5-6 g of mineral (calcium carbonate) are deposited within a 20 h period



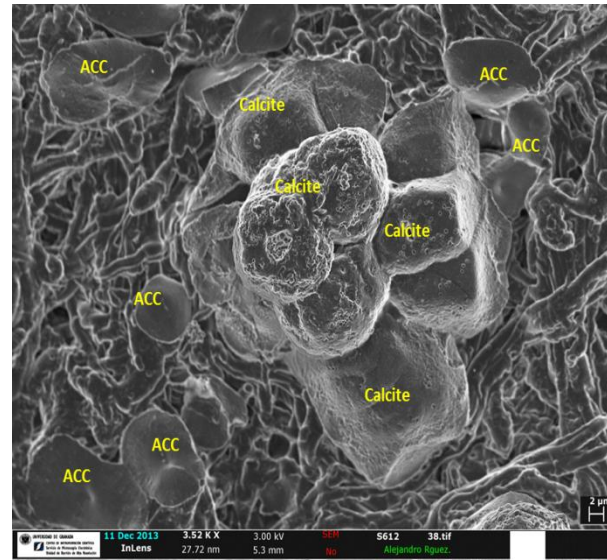
Eggshell biomineralization



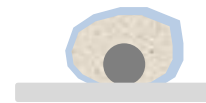
First events of nucléation



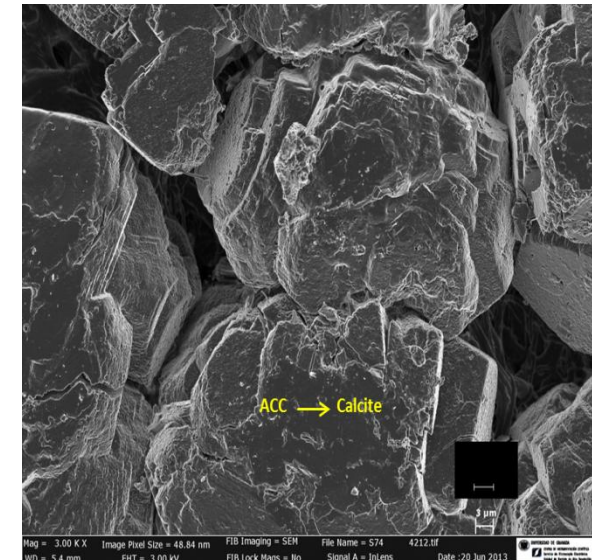
Time 1 (5-6 h Post ovulation):
ACC particles nucleate on the whole eggshell membranes.
Form massive deposits



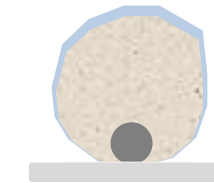
Calcite formation



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

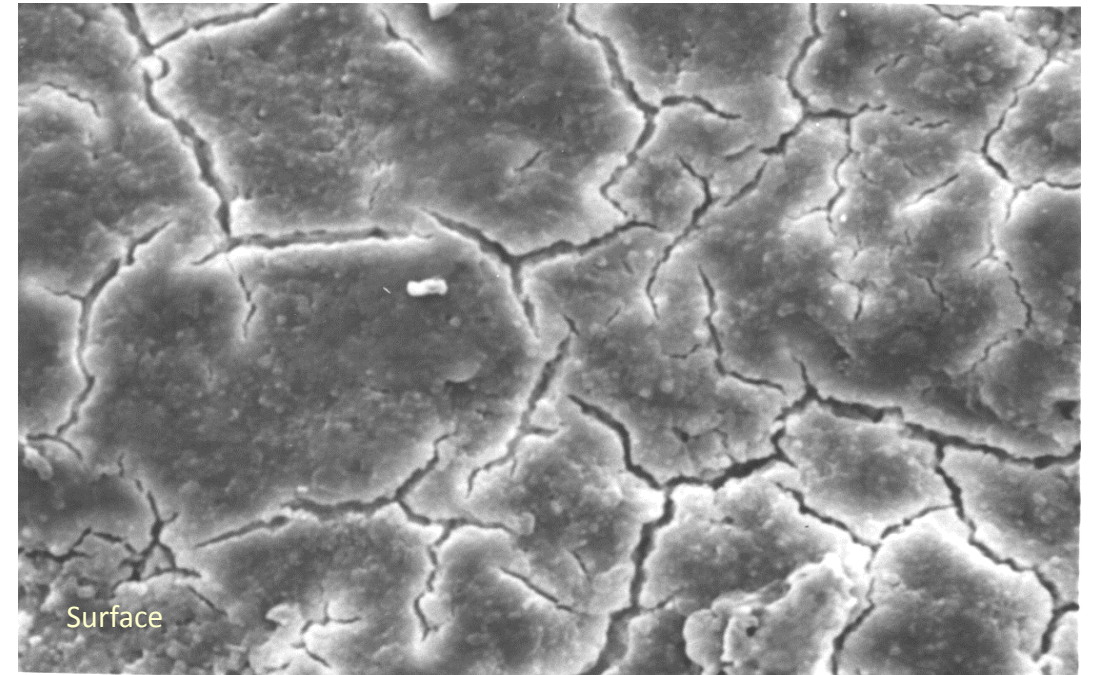
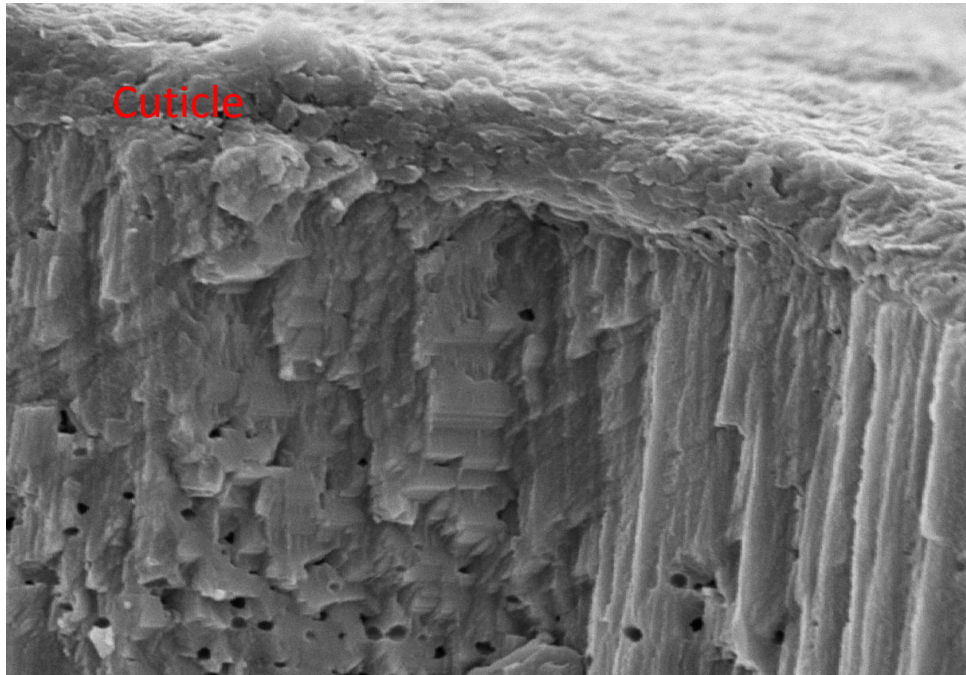


Larger calcite crystal units deposition



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

Avian eggshell biomineralization



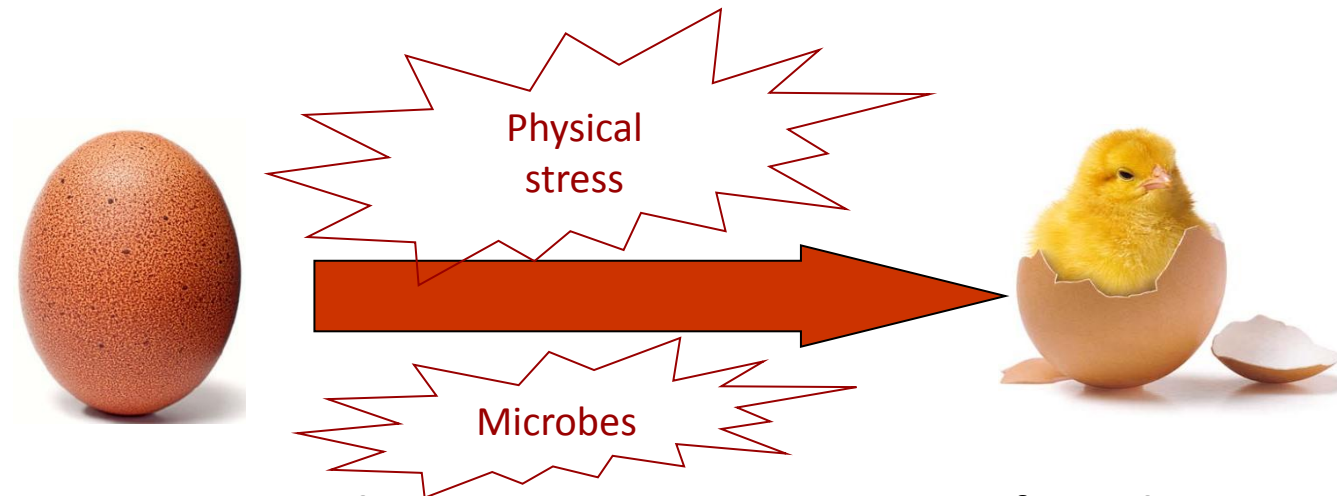
Time 5 (11 to Oviposition):

- Formation of palisade layer. Generation of a compact layer with crystals all oriented perpendicular to the surface
- Deposition of a thin layer of vertical structure
- Cuticle deposition
- Oviposition, drying and cracking of cuticle

Socio-economic context

Eggs

An autonomous close chamber to allow the embryo development



Must contains the entire components necessary for embryo

- Well-balanced nutritious ingredients
- Lot of compound (> 1000) with a broad range of biological activities
- Protective systems (natural defenses)

Physical defense (Mainly shell)

Chemical defense (Proteins with antimicrobial activities)



Table eggs

A basic ingredient for human food

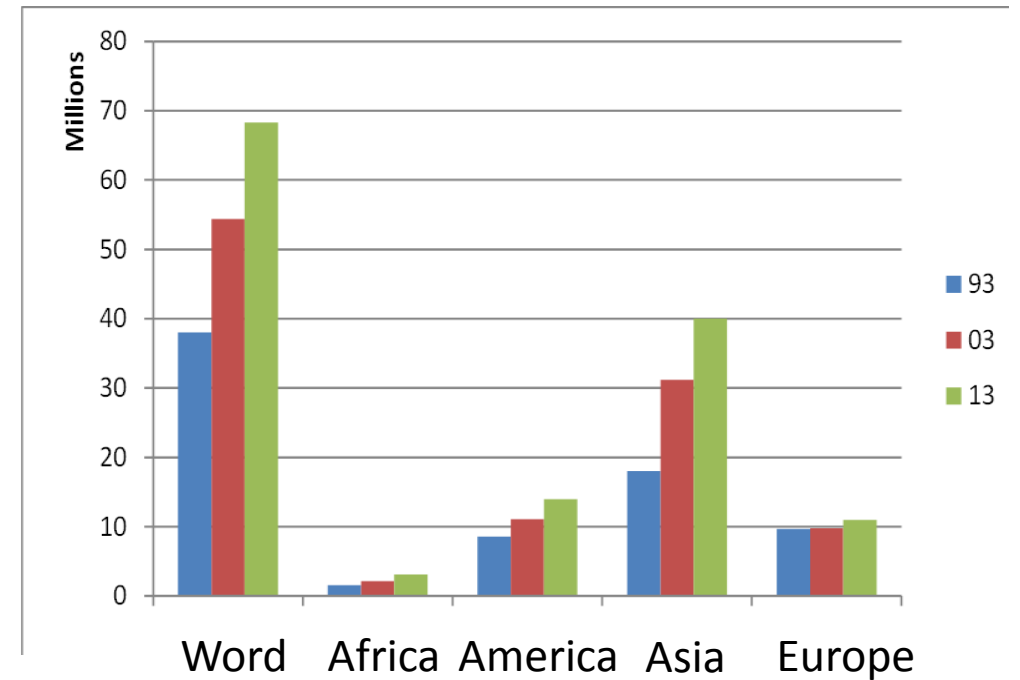
Socio-economic context

Table eggs

A basic ingredient for human food



- ▶ 68.2 MT of egg produced each year in the world > 1200 billions eggs each year
- ▶ 14,7 billions eggs in France each year
- ▶ The cheapest animal food of high nutritional quality
- ▶ No religious prohibition

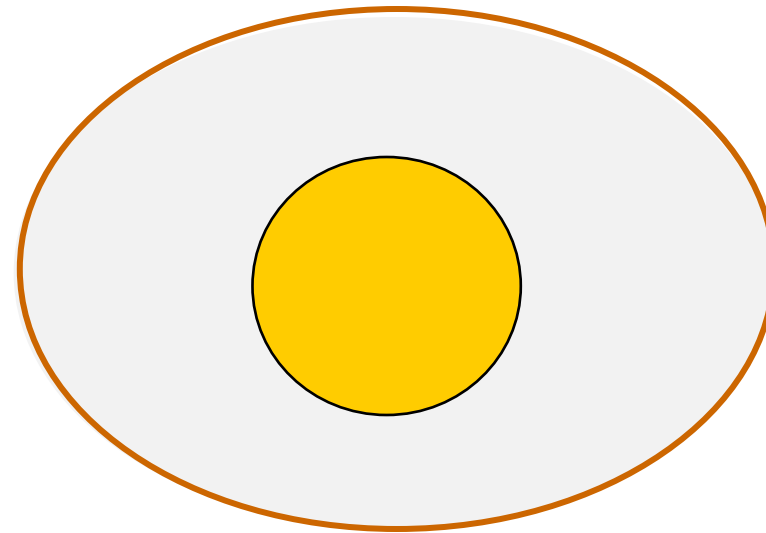


Eggshell in the socio-economic context of the egg

Eggshell is the only non-consumable part of an egg.....

Mineral eggshell

- *Ensure the physical protection*
- *Avoid bacterial penetration*
- *Ensure a thermic protection*
- *Allow gaz exchanges*
- *Calcium source for embryo*



... but its quality is crucial for the marketing of the egg

Socio-economic context

Economic issues

Downgraded eggs due to deteriorated egg quality

poor internal qualities leading to white/yellow separation problems

Dirty, cracked or broken shells

Hatchability of the chick

Shell allows gas exchanges during embryo development

Health issues

Risks of toxi-infections for the consumer (Salmonellosis)

Eggshell as a physical barrier

SHELL QUALITY

Shell mechanical properties

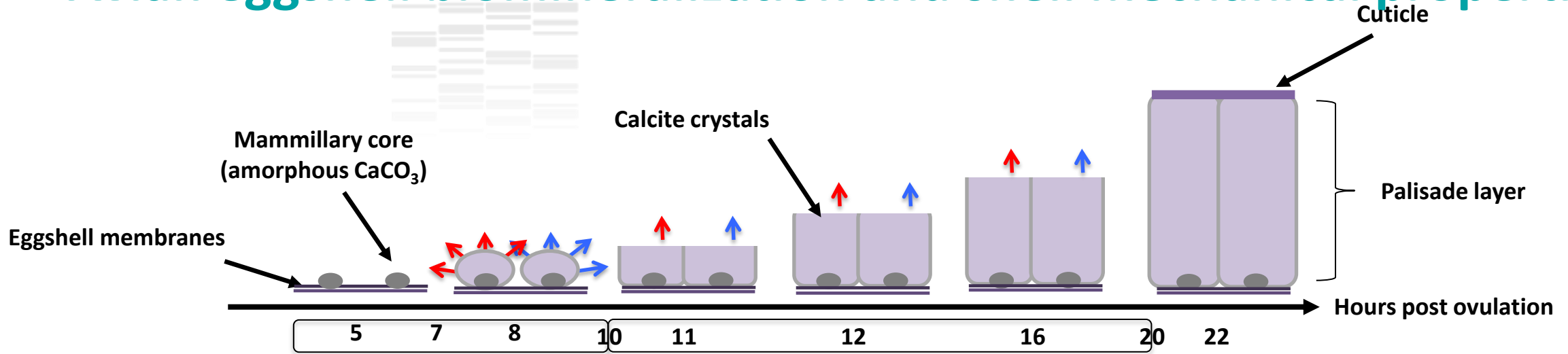
Ethical issues

Housing systems and societal demand

Consumer demand for non cage and free-range systems → Lower shell quality

Long life cycle (shell quality decreases with age of birds)

Avian eggshell biomineralization and shell mechanical properties



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

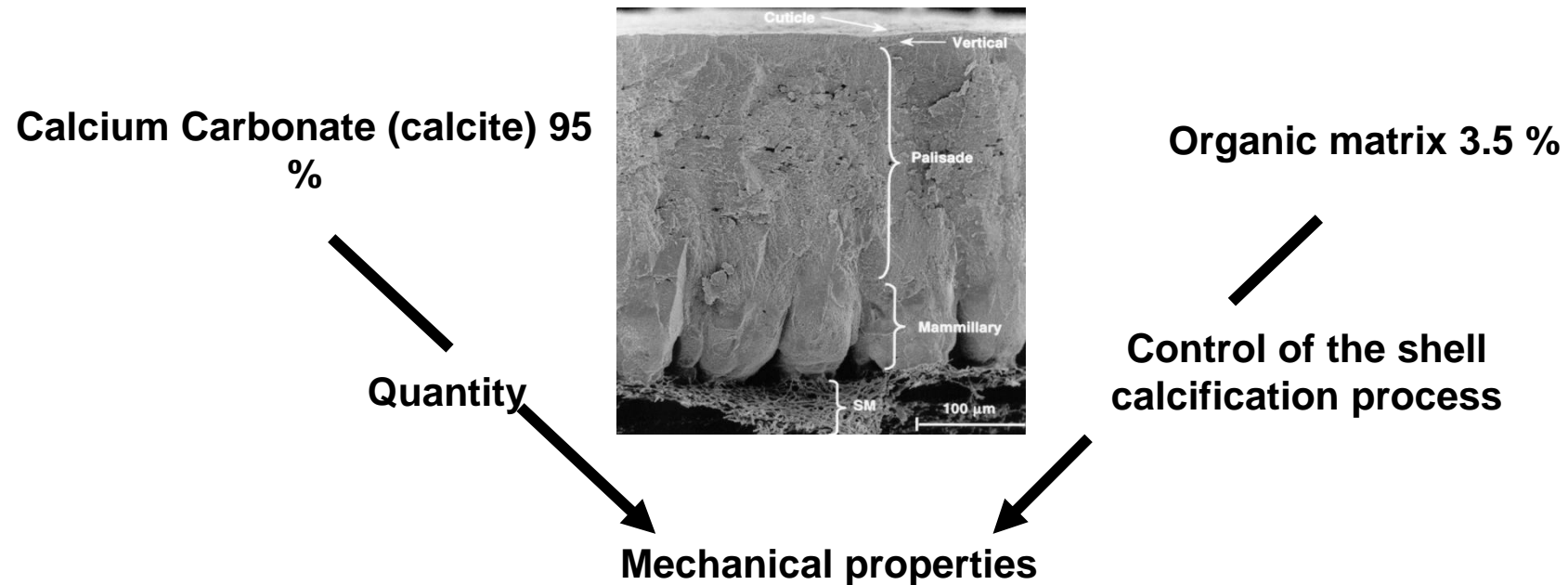
Role of organic matrix proteins at pivotal events

- ✓ *Stabilization of amorphous calcium carbonate (ACC)*
- ✓ *Polymorphs, morphology and size of crystals*

Ultrastructure, Mechanical properties

Societal impact of avian eggshell biomineralization

Maintain and improve shell quality

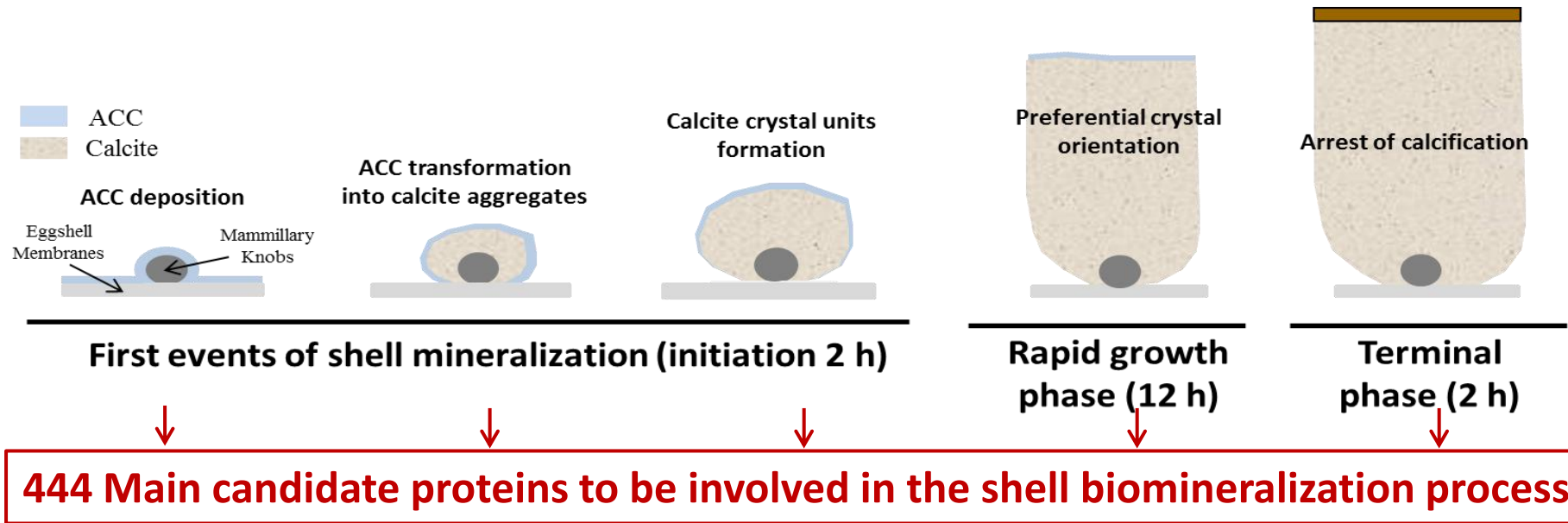


Mass or fabric ?

☞ Mass: nutrition, génétic, environemment, lighting programs

☞ fabric : Regulation of shell matrix proteins and genetic selection

Eggshell biomineralization



Predicted functional activities of the identified matrix proteins ?

(Marie et al., 2014, 2015a,b)

Classification in 3 different groups according to their potential functions

Associated to mineralization process

Involved in the regulation of activity of proteins

Antimicrobial and other proteins



Impact (2013-2017)

INRAE

And now ? How to improve shell quality ?



Physiology

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

Genetics

Classical and genomic selection

Recent Developments and Future Prospects :

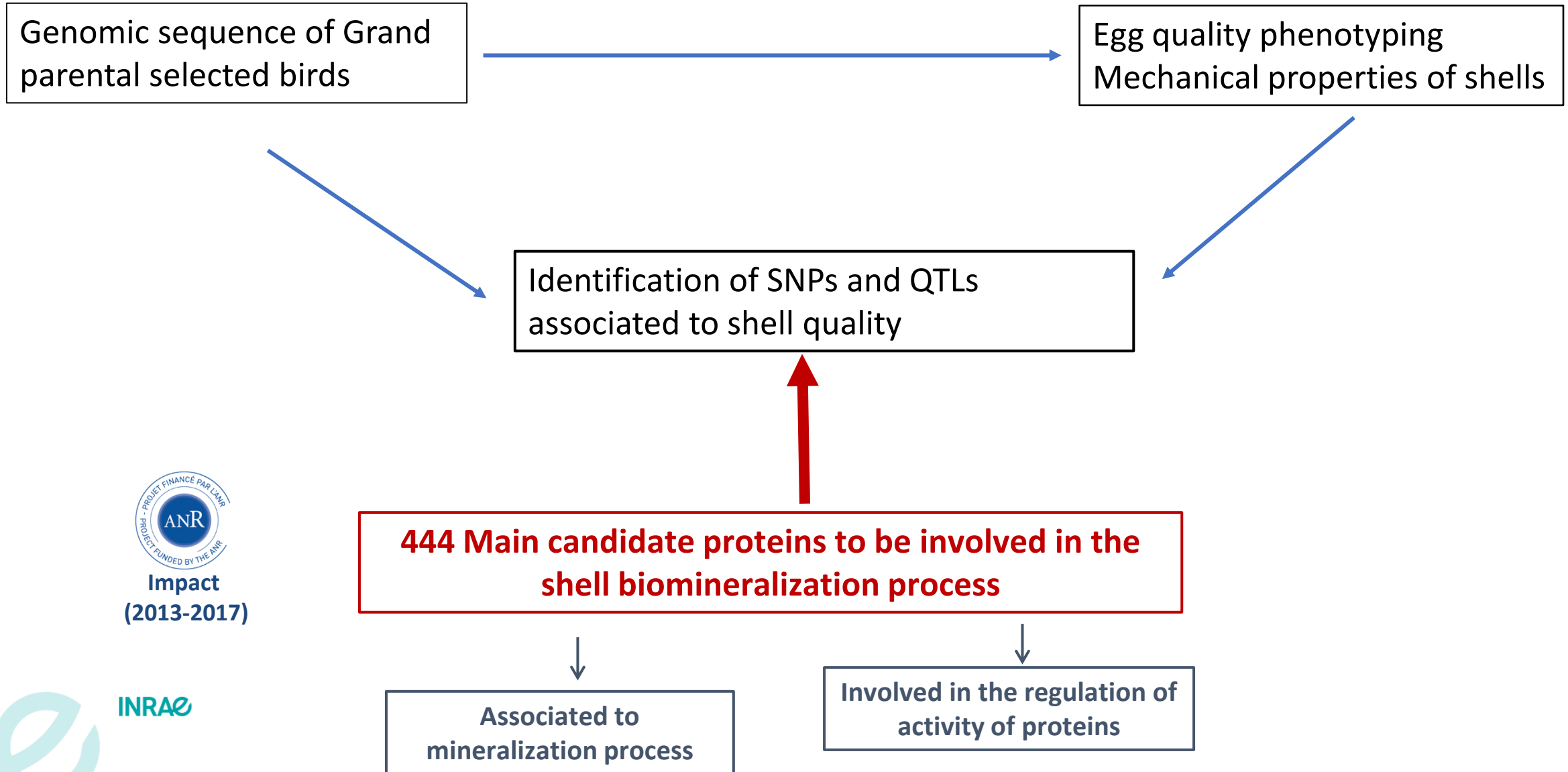
- ✓ Genomic selection to taking into account scientific advances in the knowledge of mechanisms
 - Candidate gene approach



Candidate Genes of eggshell calcification in laying hens (CACAO)

Eggshell Calcification Polymorphism Candidates (POLCACAO)

Using recent advances in genetics and genomics to improve eggshell strength

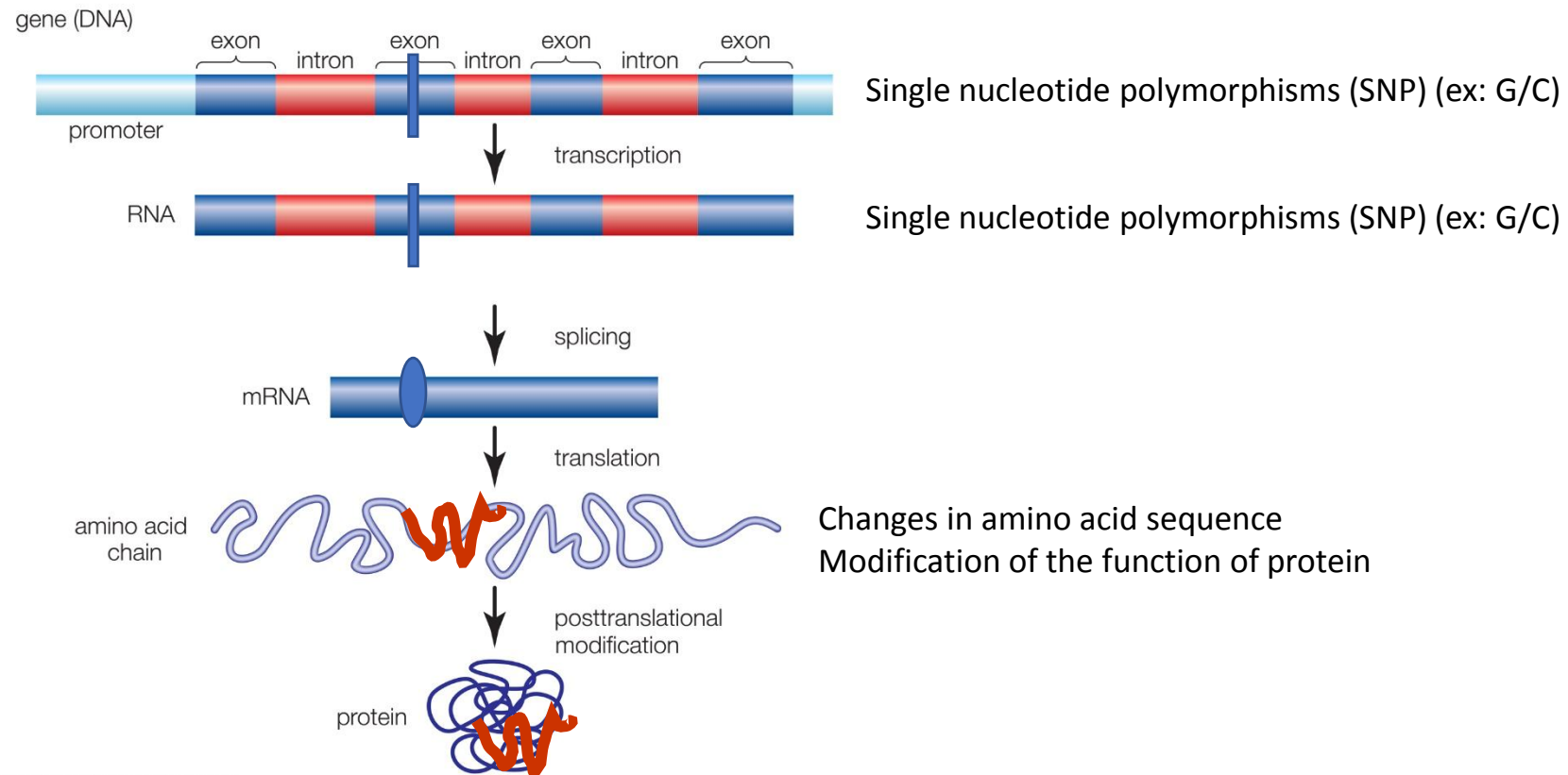


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Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection

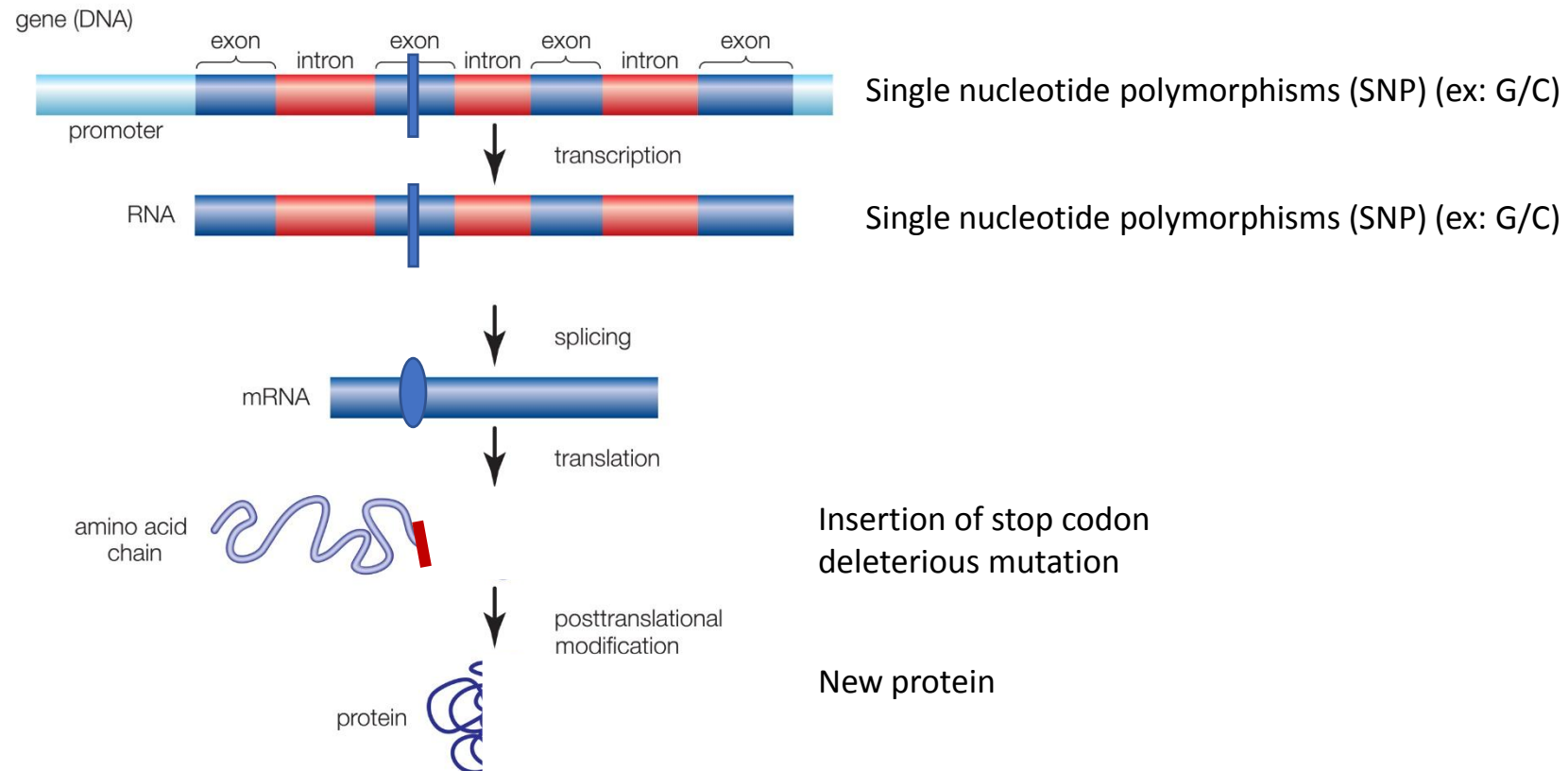


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Polymorphism usable in genetic selection

Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection

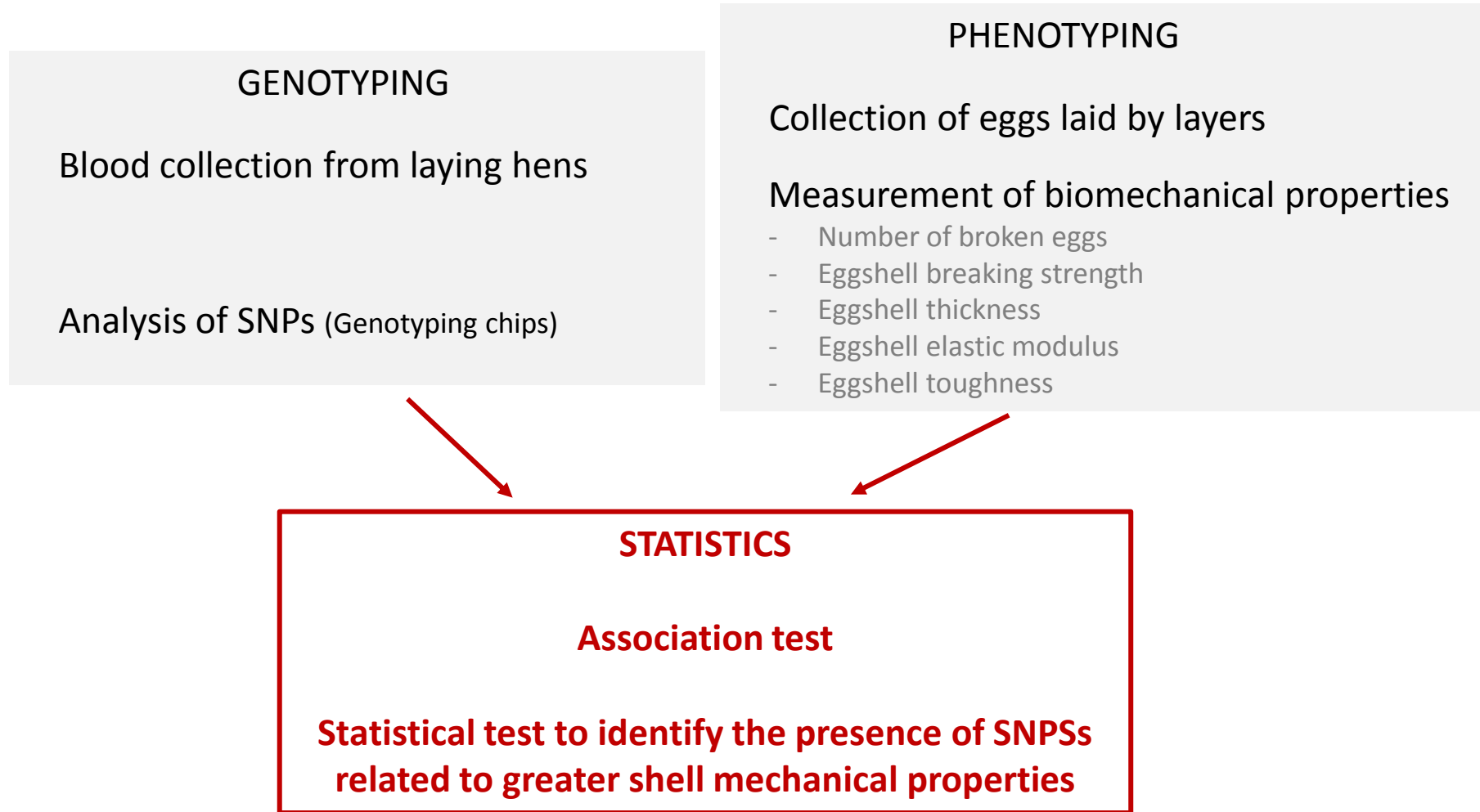


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Polymorphism usable in genetic selection

Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection



Conclusions- Take home messages

- Biom mineralization mechanisms in birds' eggs determine the mechanical properties of the shell
- The societal and socio-economic challenges of this mineralization process are important
 - Economic, health and ethical issues
- Using the information on eggshell biom mineralisation, genetic improvement can be achieved
- This component involves many actors in the egg sector:
 - ✓ Egg producers
 - ✓ Genetic selection companies
 - ✓ Nutritionists and formulators
 - ✓ Decision-makers (political, economic, food industry, supermarket sales)