



Societal impact of biomineralization in chicken eggshells

Joël Gautron

► To cite this version:

Joël Gautron. Societal impact of biomineralization in chicken eggshells. Summer school of biomineralization, ECTS, Jul 2021, Valbone, France. hal-03663456

HAL Id: hal-03663456
<https://hal.inrae.fr/hal-03663456>

Submitted on 10 May 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



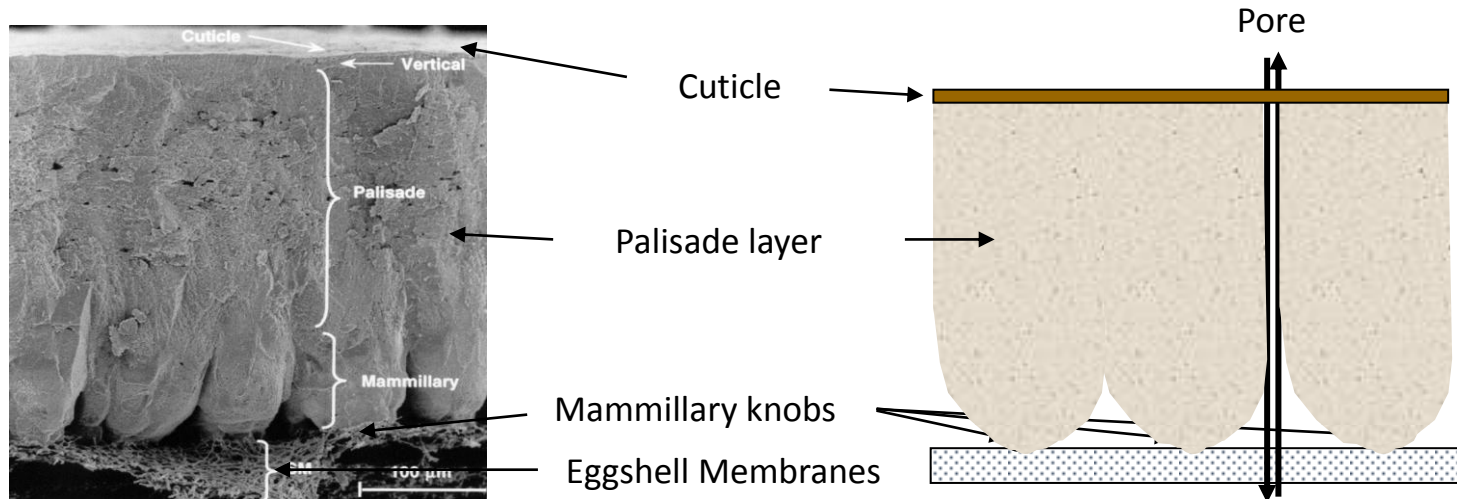
Societal impact of biomineralization in chicken eggshells

Joël GAUTRON
Joel.gautron@inrae.fr

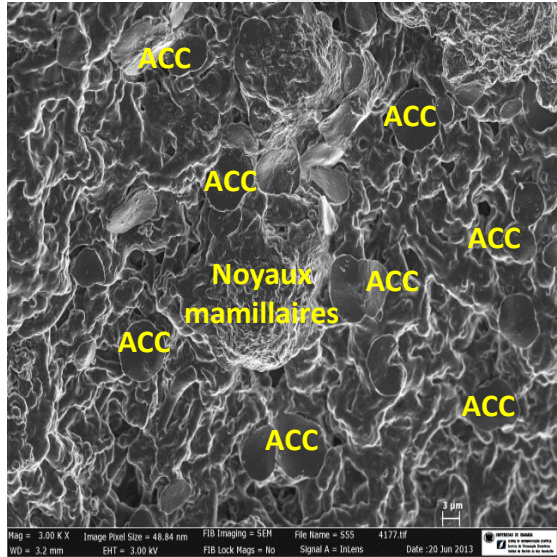
Directeur de recherche
Research Director
UMR BOA
(33) 2 47 42 75 40

The chicken eggshell formation

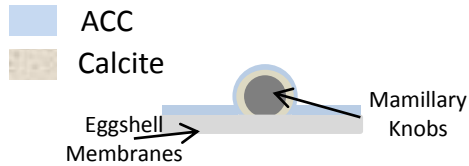
- ✓ Eggshell biomineralization in uterus (fast process)
- ✓ 5-6 g of mineral (calcium carbonate) are deposited within a 20 h period



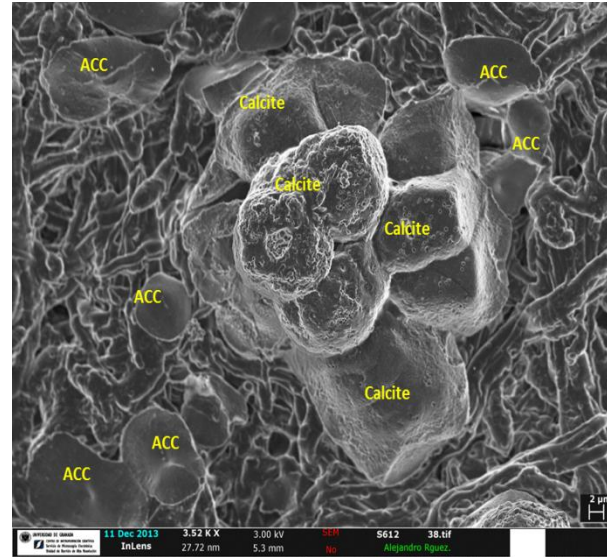
Eggshell biomineralization



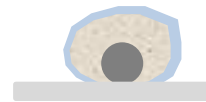
First events of nucléation



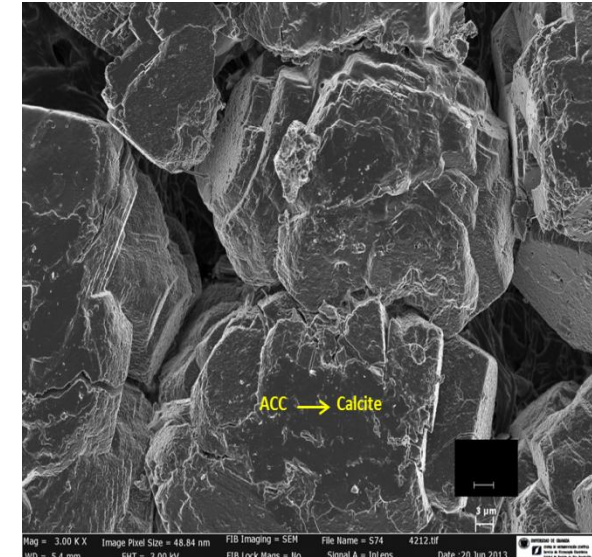
Time 1 (5-6 h Post ovulation):
ACC particles nucleate on the whole eggshell membranes.
Form massive deposits



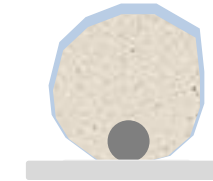
Calcite formation



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

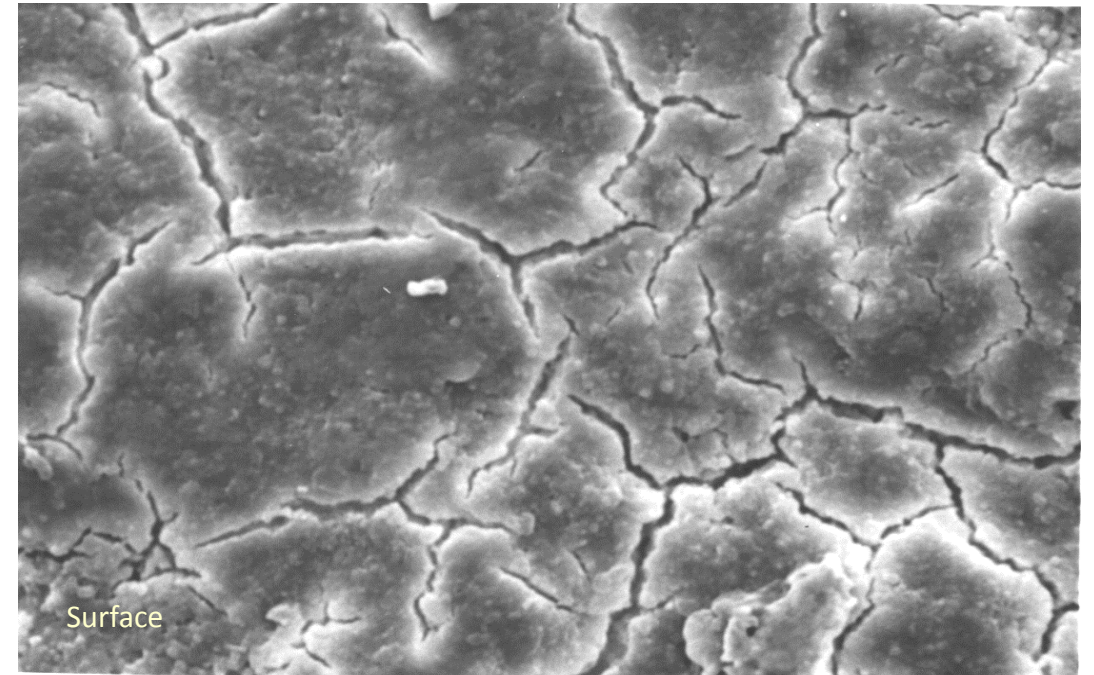
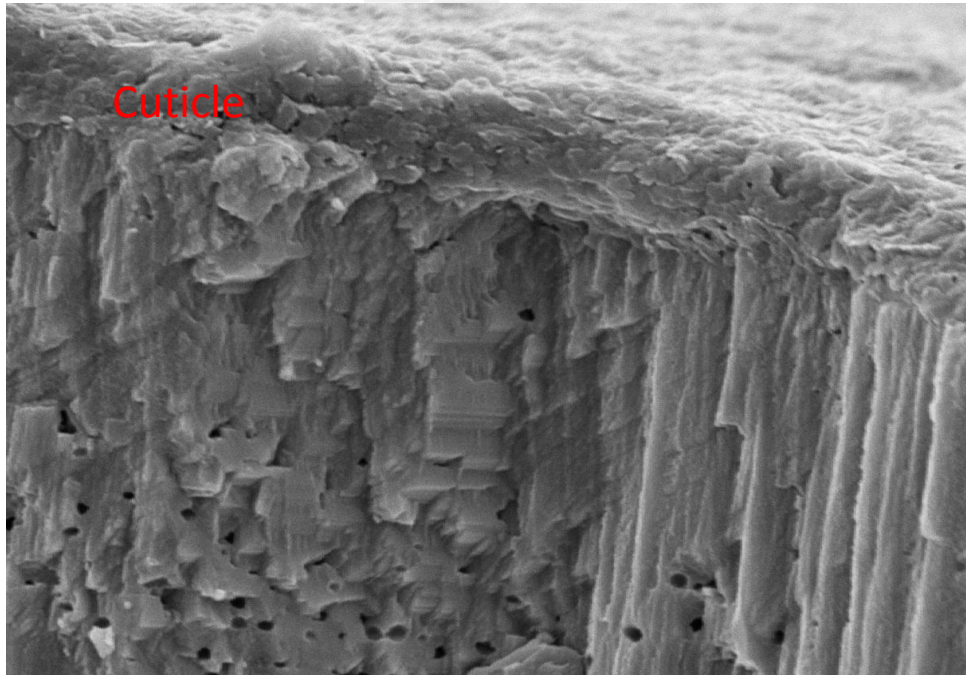


Larger calcite crystal units deposition



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

Avian eggshell biomineralization



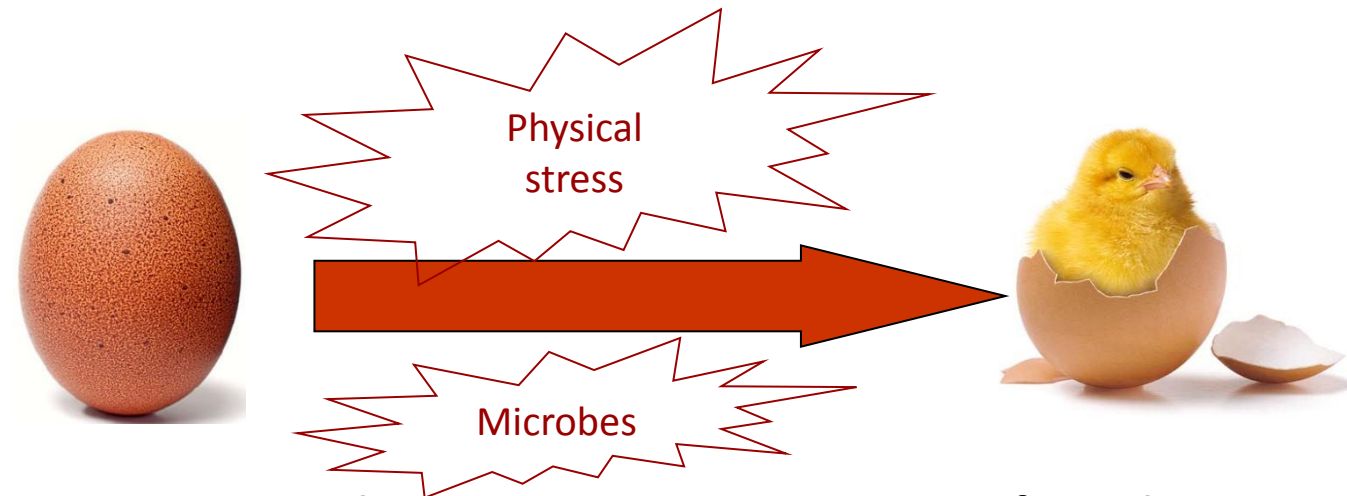
Time 5 (11 to Oviposition):

- 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

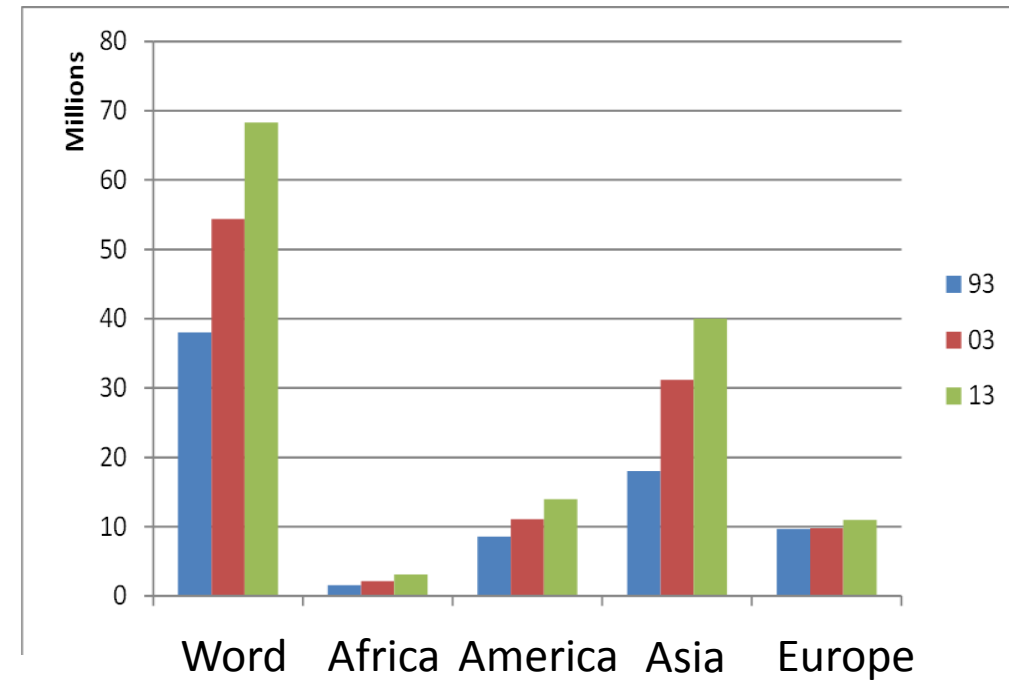
Socio-economic context

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

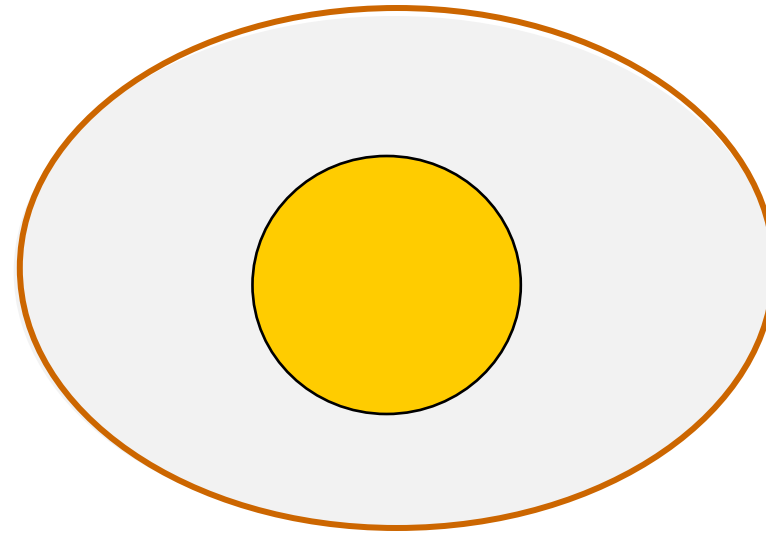


Eggshell in the socio-economic context of the egg

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

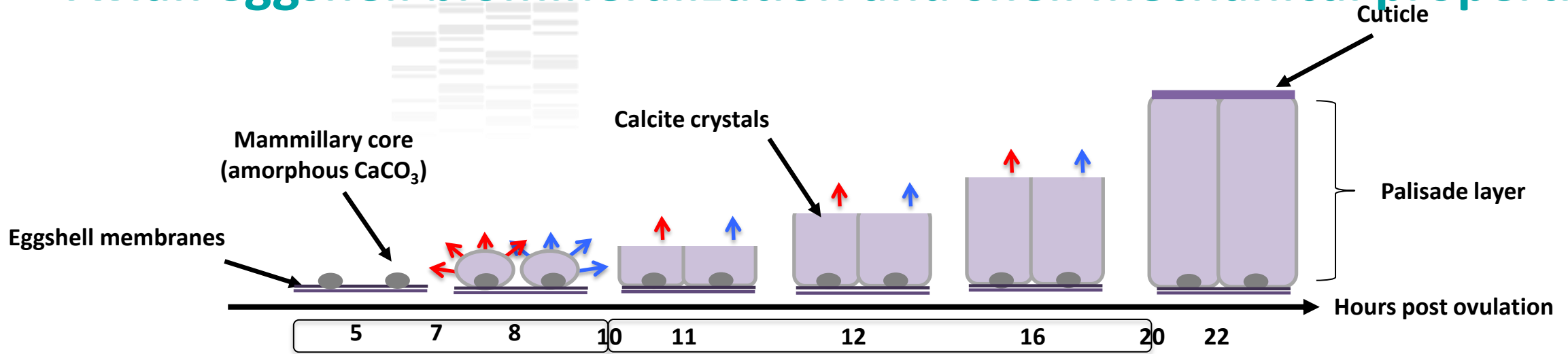
Ethical issues

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)

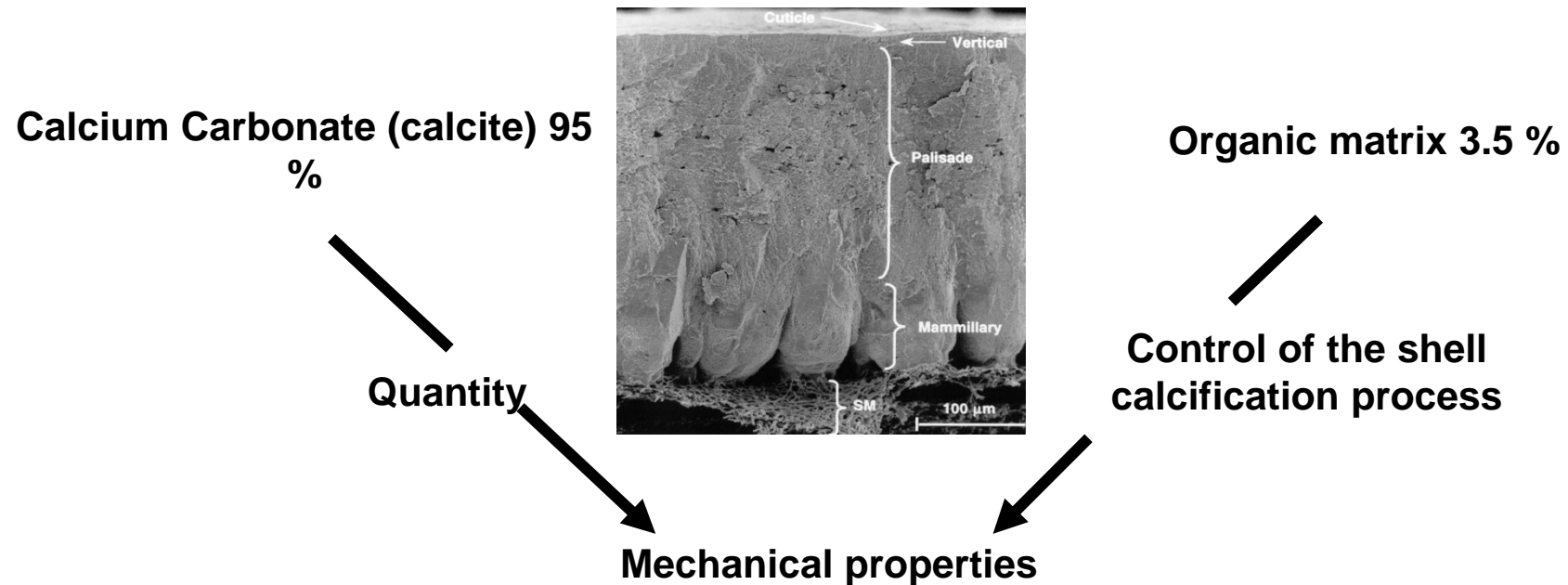
Role of organic matrix proteins at pivotal events

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

Ultrastructure, Mechanical properties

Societal impact of avian eggshell biomineralization

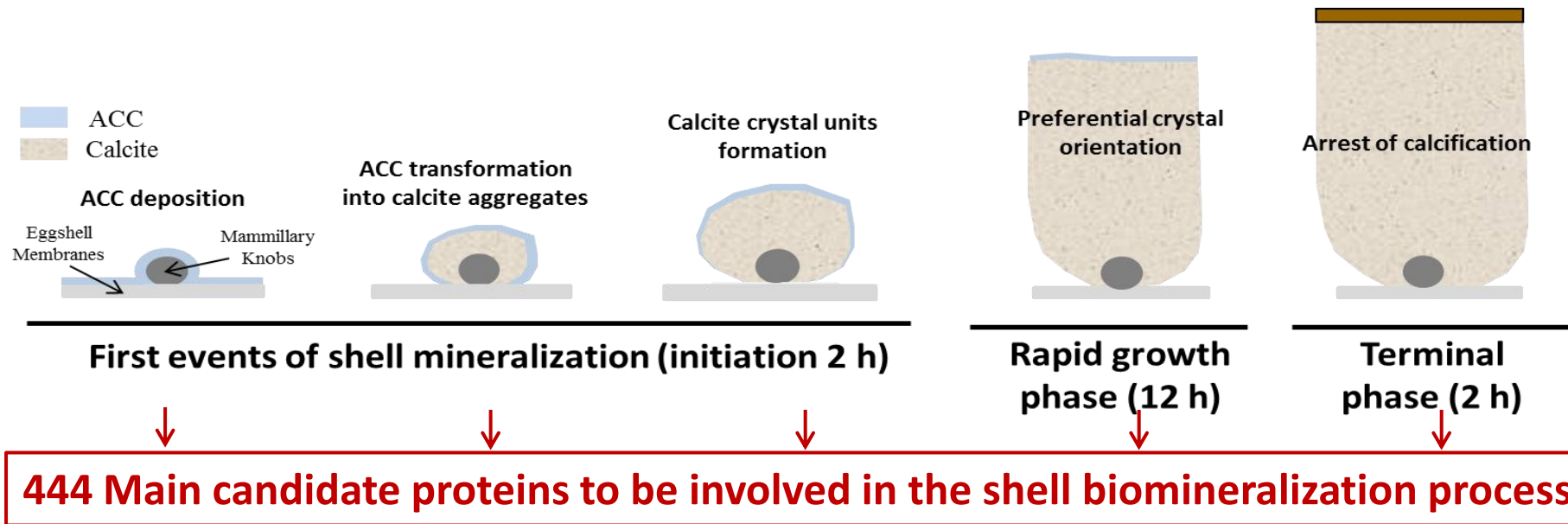
Maintain and improve shell quality



Mass or fabric ?

- ☞ Mass: nutrition, génétique, environnement, 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

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 :

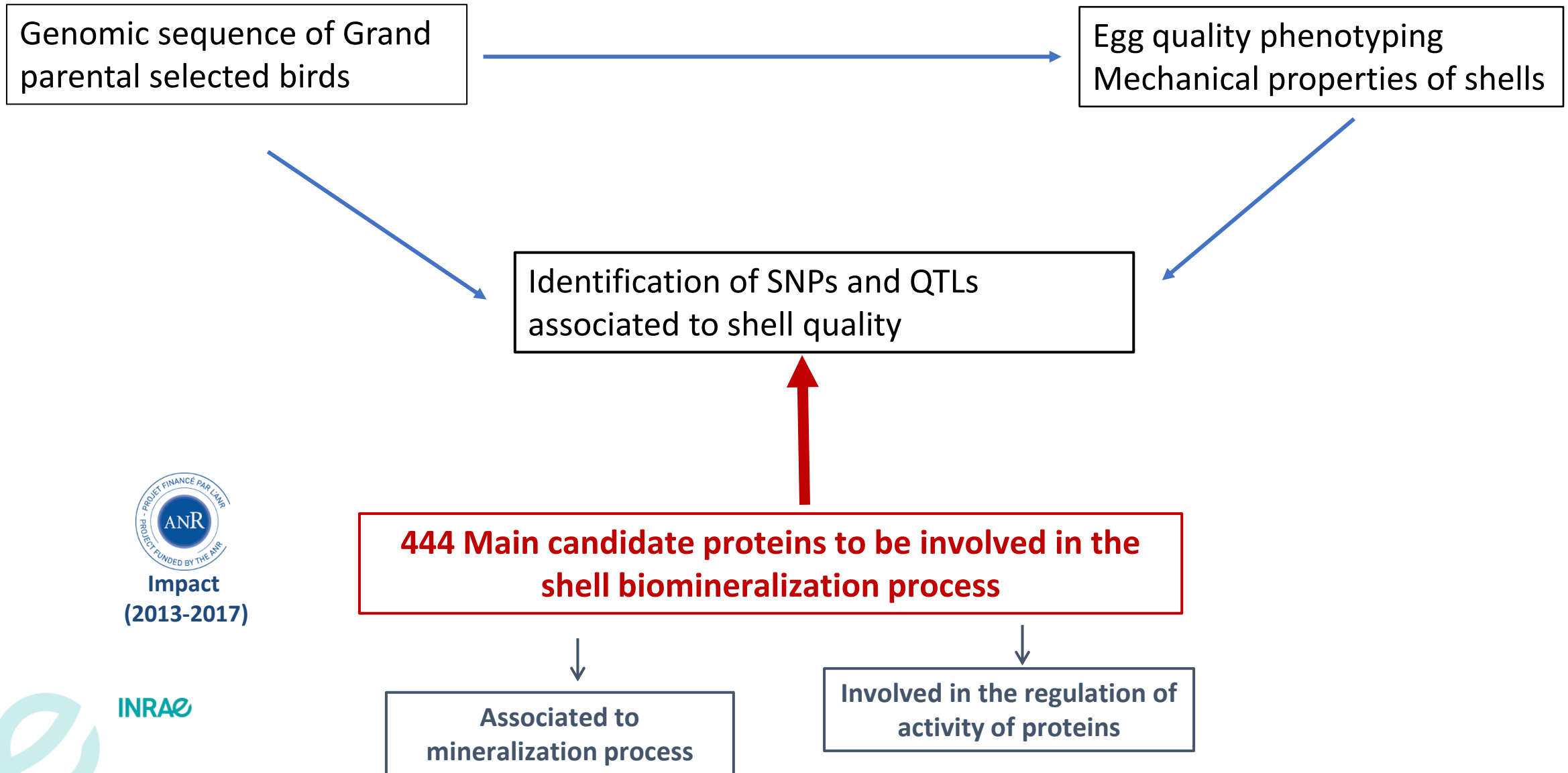
- ✓ Genomic selection to taking into account scientific advances in the knowledge of mechanisms
 - Candidate gene approach



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

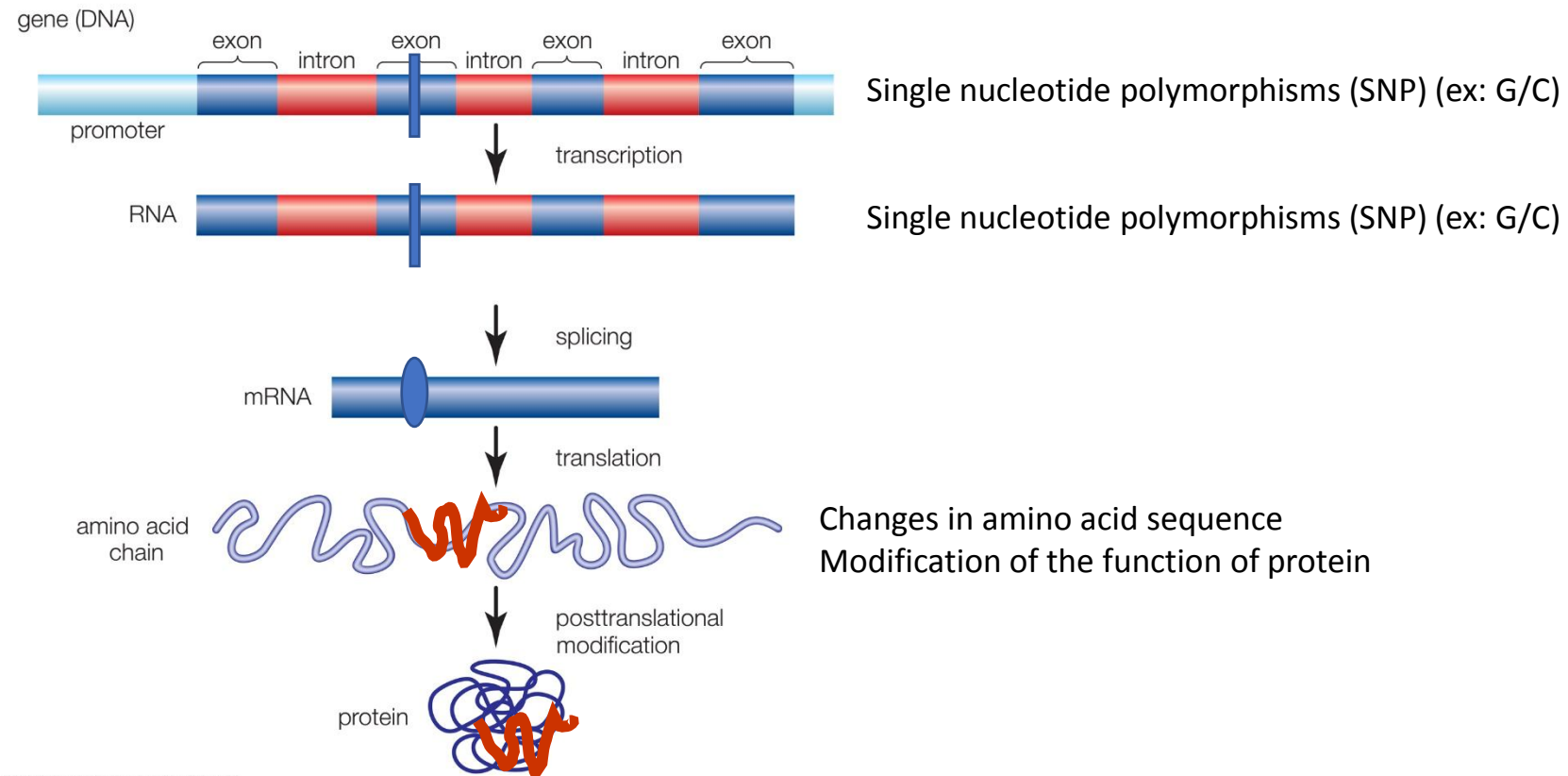


Impact
(2013-2017)

INRAE

Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection

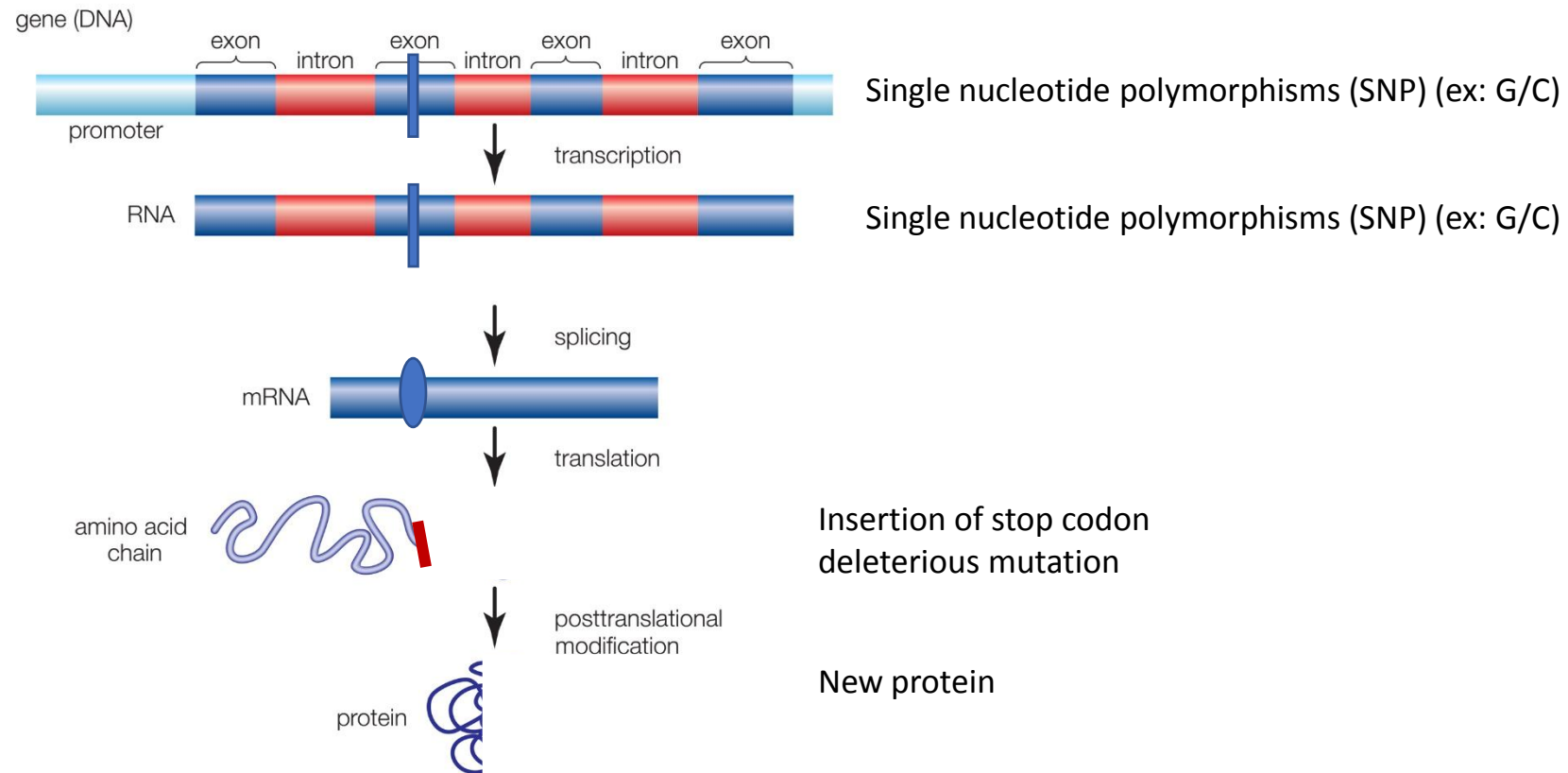


© 2013 Encyclopædia Britannica, Inc.

Polymorphism usable in genetic selection

Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection

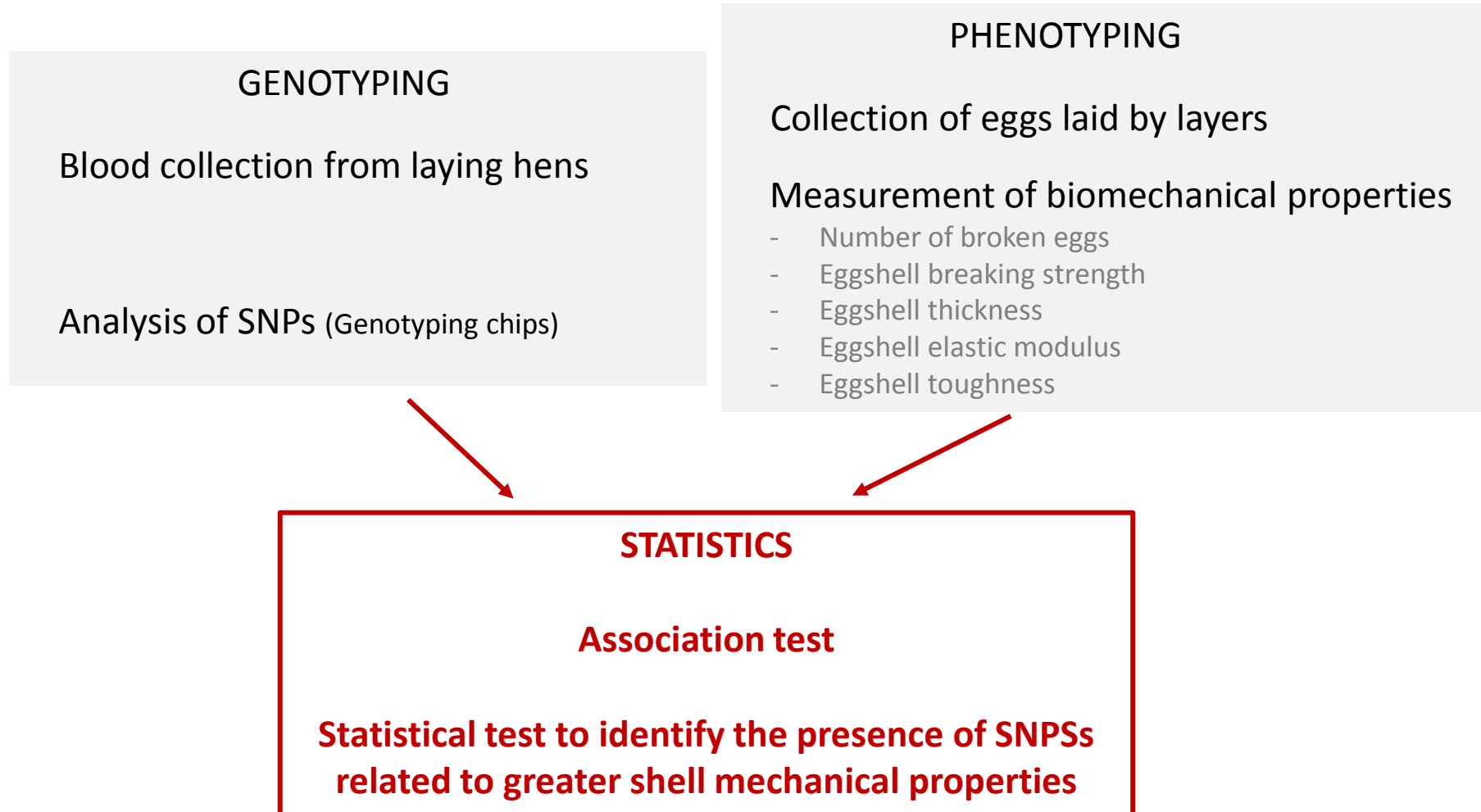


© 2013 Encyclopædia Britannica, Inc.

Polymorphism usable in genetic selection

Using recent advances in genetics and genomics to improve eggshell strength

Marker-assisted genomic selection



Conclusions- Take home messages

- Biomineralization 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 biomineralisation, 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)