Genomics and resilience

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ACADÉMIE d'AGRICULTURE de FRANCE
AGRICULTURE ■ ALIMENTATION ■ ENVIRONNEMENT

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Genomics and resilience

Basic biological concepts

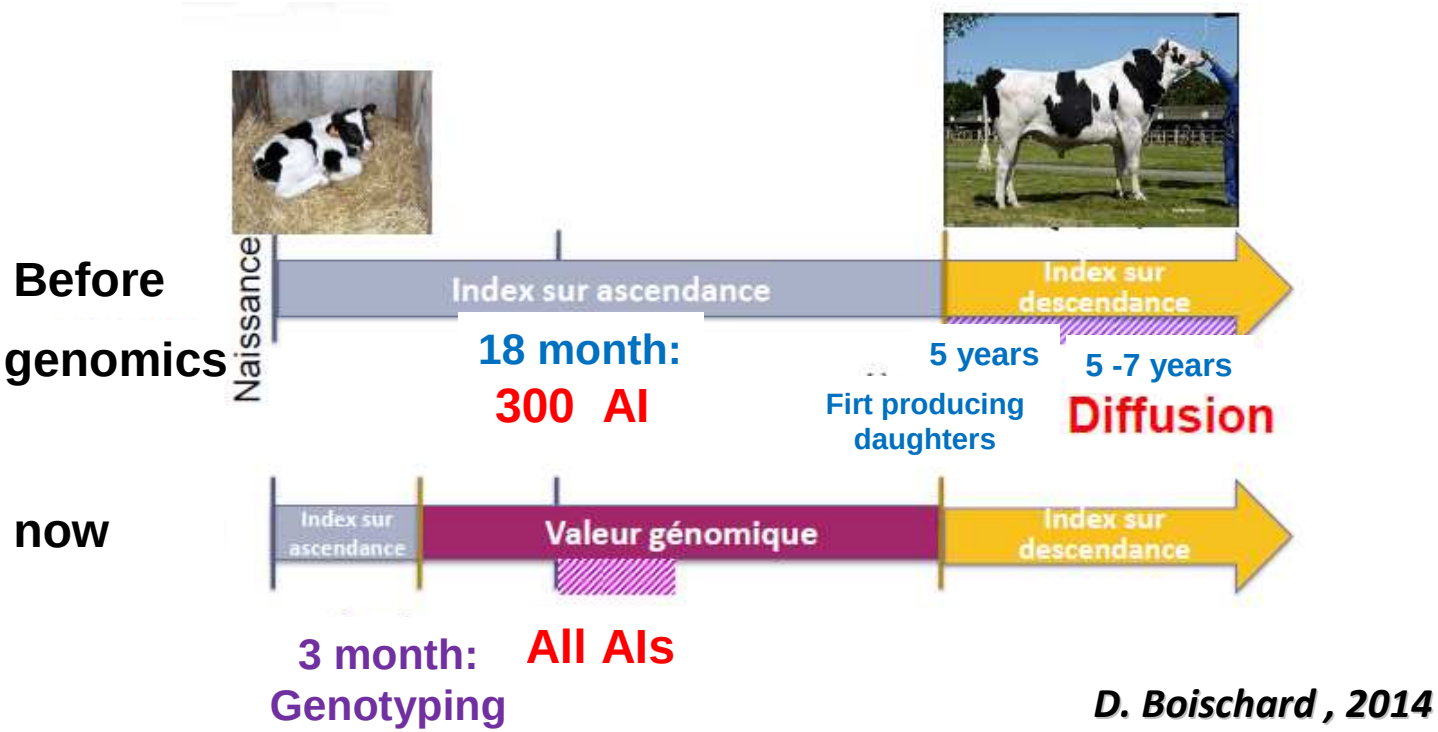
coherency

their application to plant and animal farming systems

The running question of my presentatio:n

Is the horizon of genomics in livestock not becoming narrowed because of the success of selection in cattle?

Genomics allows the selection of animals using the information generated from high density maps of molecular markers identified all over the genome. It offers a reliable mean to improve functional traits and allows the identification of candidate animal for selection before the recording of their own performances.



D. Boischard , 2014

Genomic selection from a reference population

made from bulls evaluated from progeny test

dairy cattle: 40 traits R_2 = 0.5-0.9

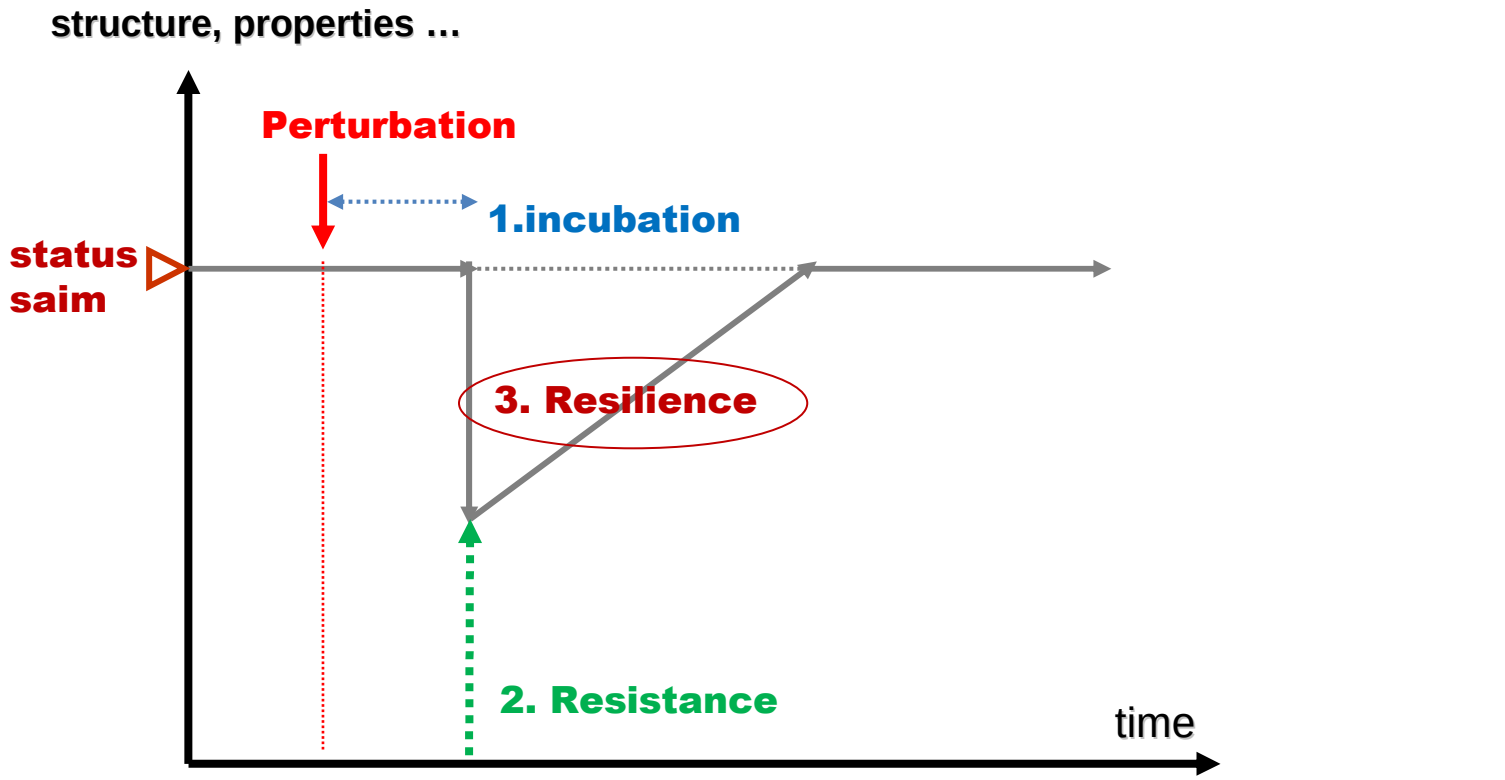
the size of the population matters in genetic selection

Montbeliard
670 000 cows
150 bulls tested per year

Holstein
2 500 000 cows
650 bulls tested per year

High efficiency with in-house farming

Resilience refers to the ability of living organisms to adapt to stresses induced by changes in their environment. It deserves increasing attention including because of global climate change.



Adapted from Sauvant 2005
Sauvant and Martin 2010,

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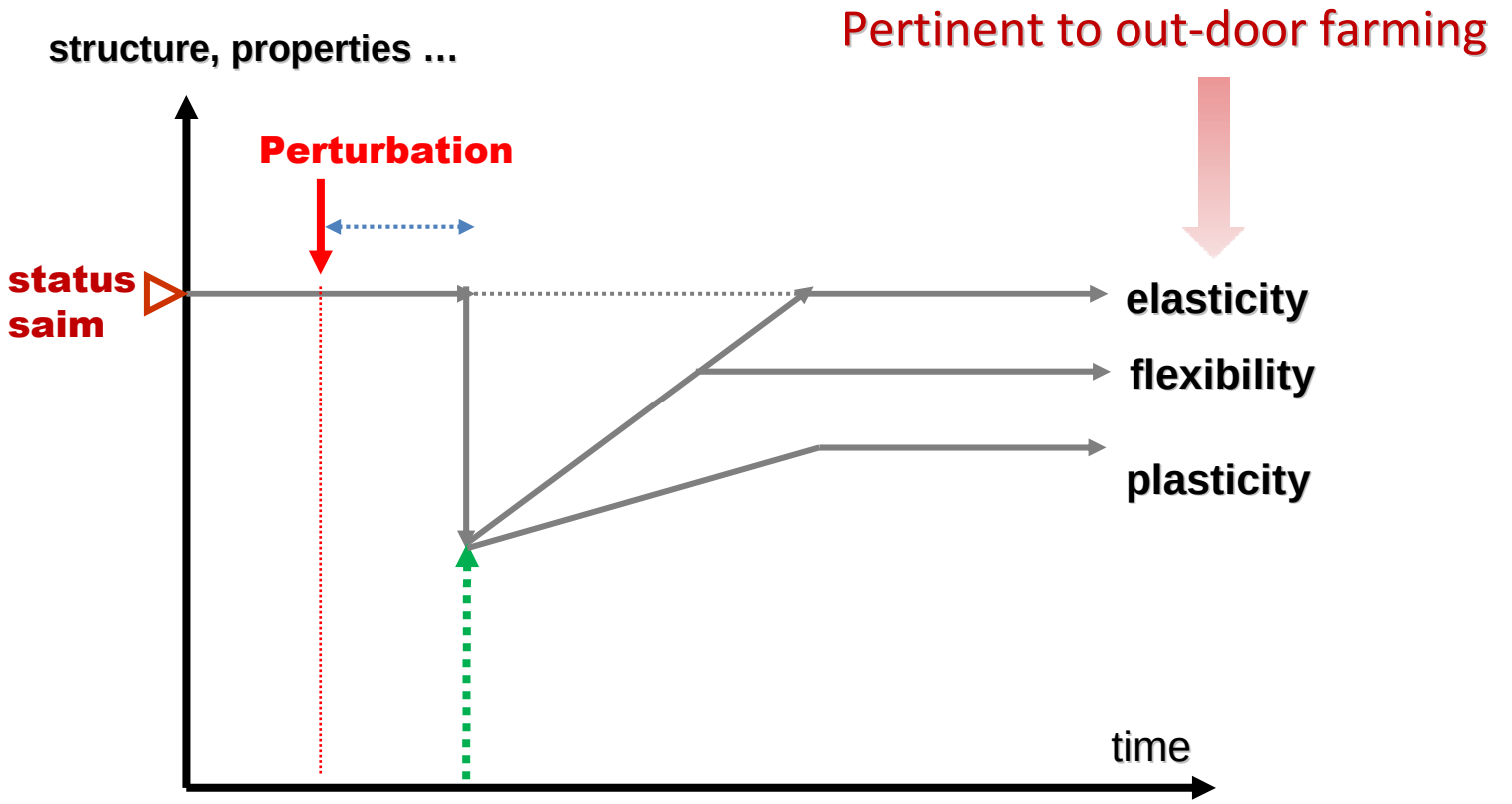

Adapted from Sauvant 2005
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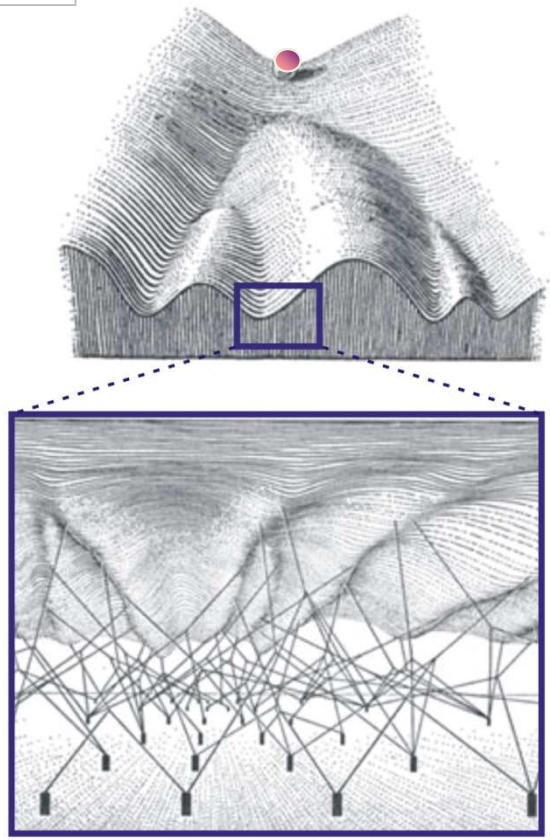
the adaptation to environment also matters

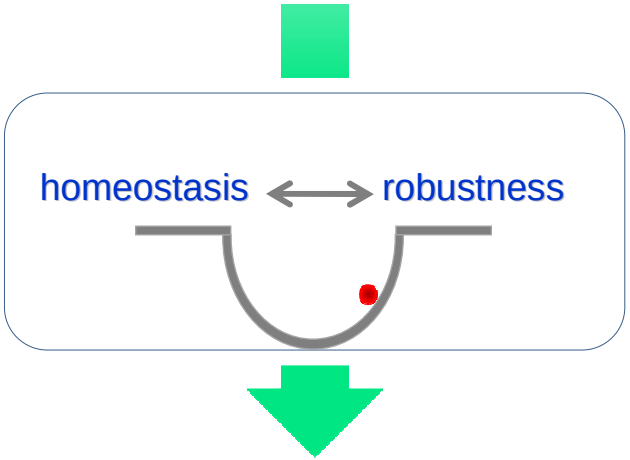
C. Wadington, Nature 1959



Waddington CH, 1940

genetic canalisation:
Buffers allelic mutations effects

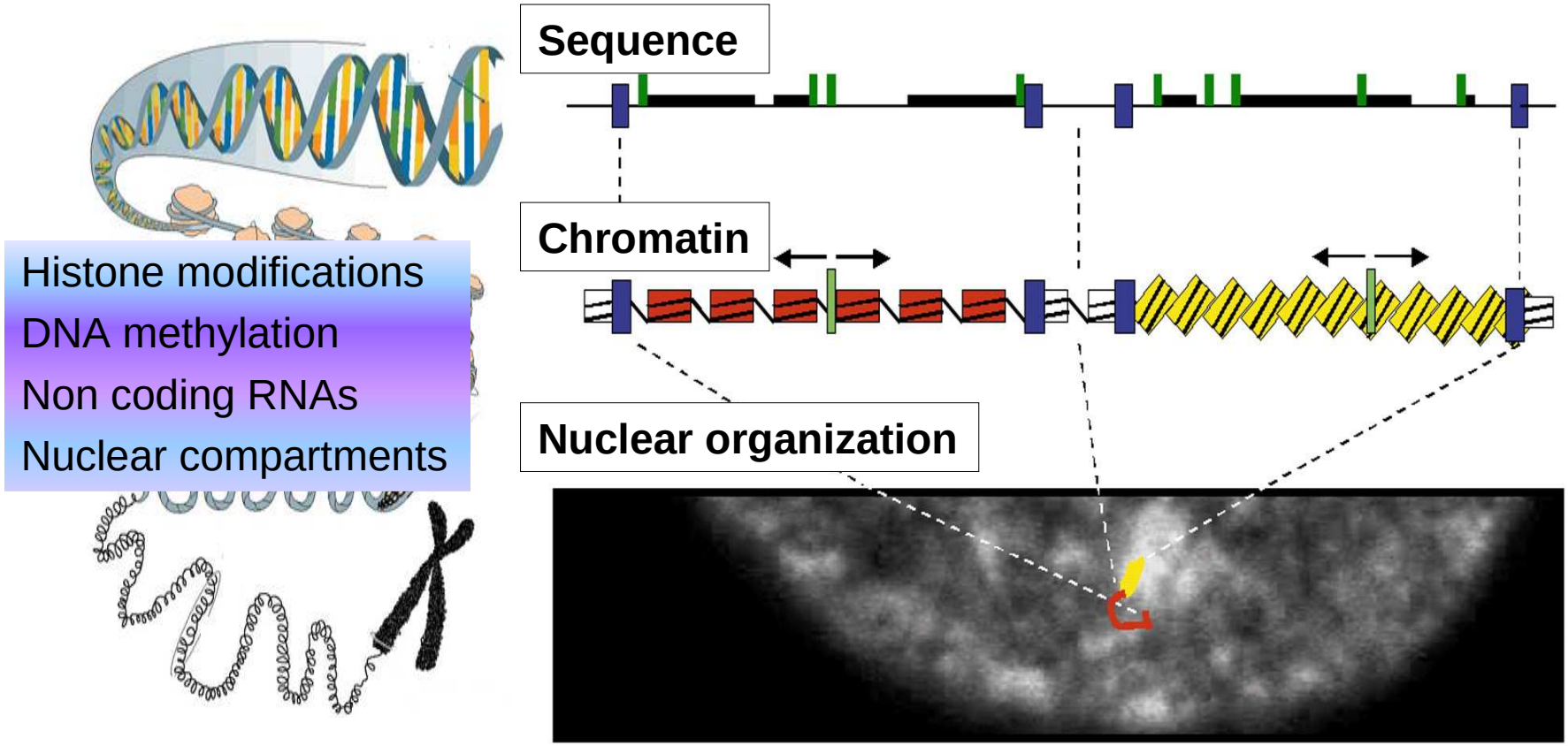
environnemental canalisation
Buffers environnemental effects



phenotypes

Between genotype and phenotype

3 levels of genes regulation…

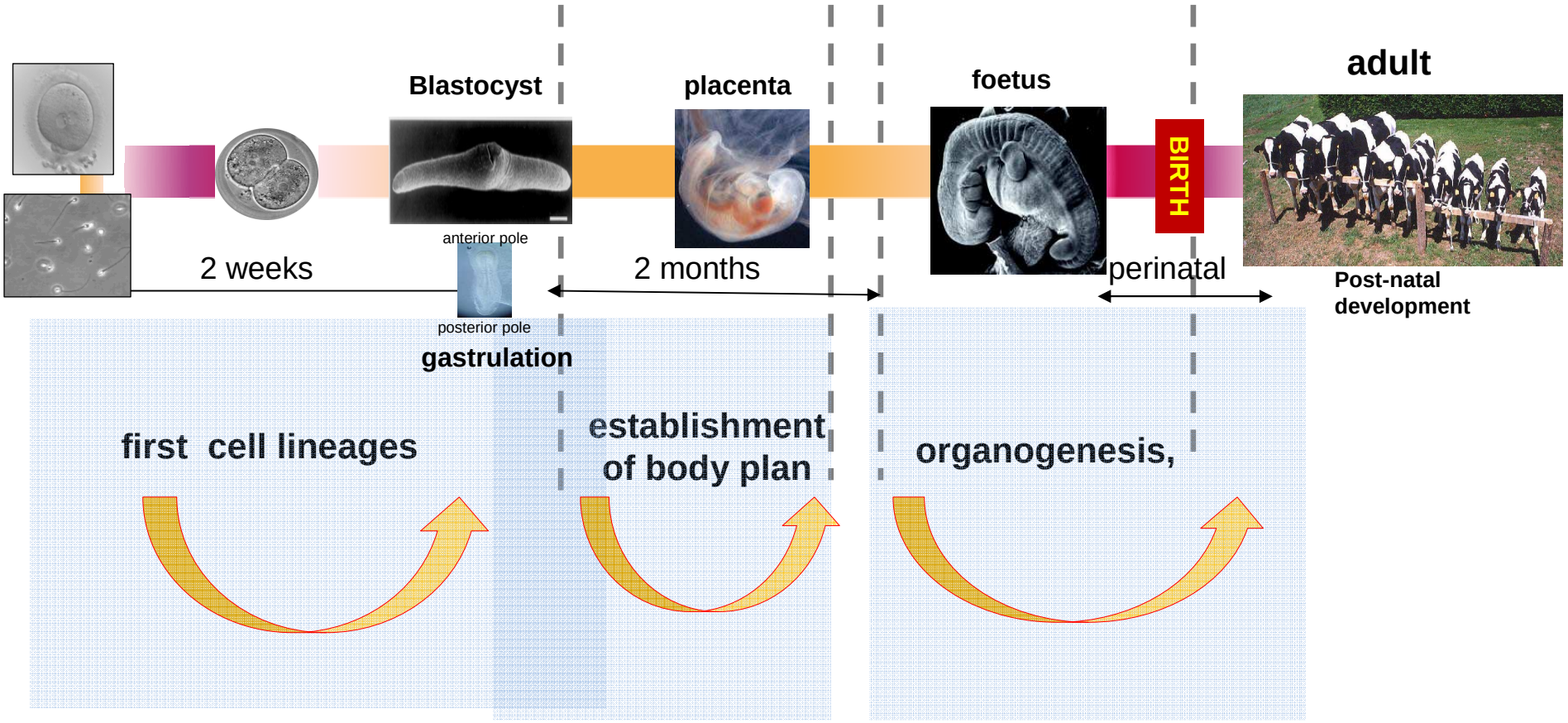


van Driel, R. *et al.*, 2003 Journal of Cell Science

…controlled by epigenetic information

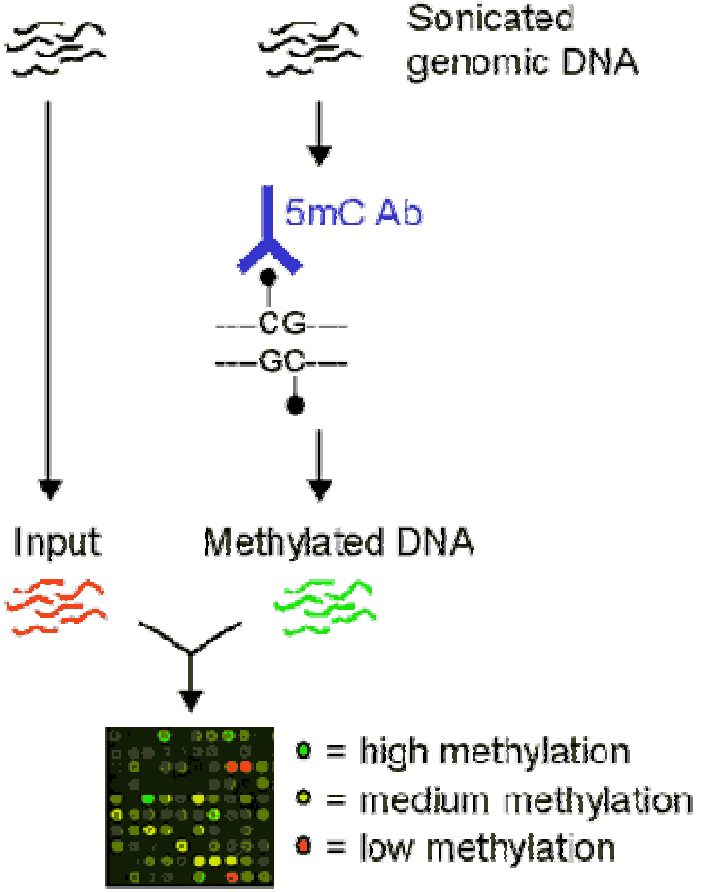
Epigenetics: the perpetuation of gene expression and function across cell divisions without changes in DNA sequence.

waves of epigenetic reprogramming shape transcriptomic patterns during both embryonic, foetal and post natal periods

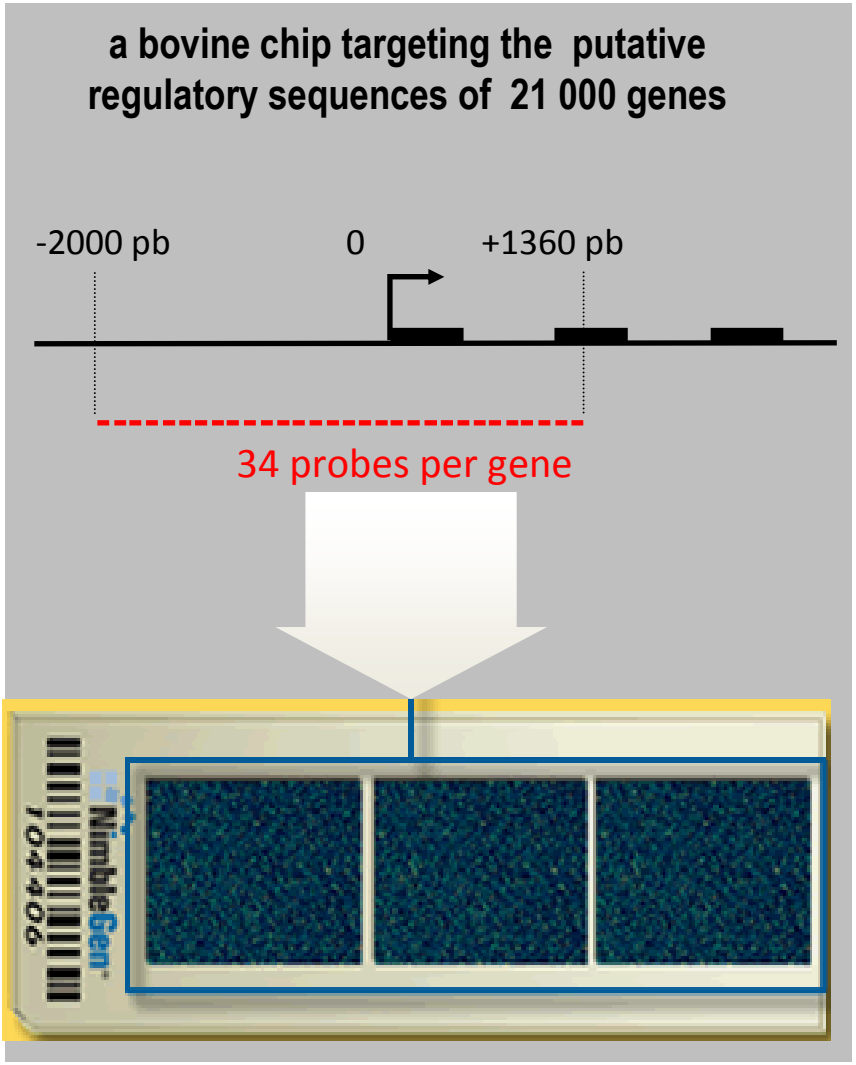


Resilience and epigenetic changes can be analysed using highthroughput molecular and genomic tools

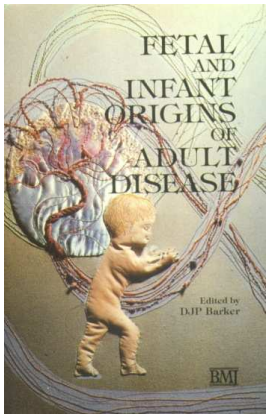
ex: MeDIP/Chip



From : http://www.epigenome-noe.net/researchtools/protocol.php?protid=33



a wide range of environmental conditions during embryonic development and early life determines susceptibility to disease during adult life

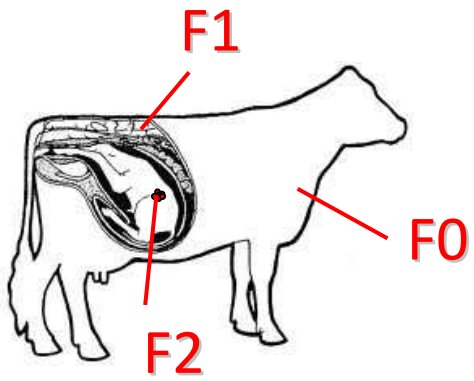


Bygren LO et al. *BMC Genetics 2014* ***15***:*12*
Change in paternal grandmothers´ early food supply influenced cardiovascular mortality of the female grandchildren

DOHaD"developmental origins of health and disease,"

www.perspectivesinmedicine.org

Human and bovine; both with a 9 month pregnancy period



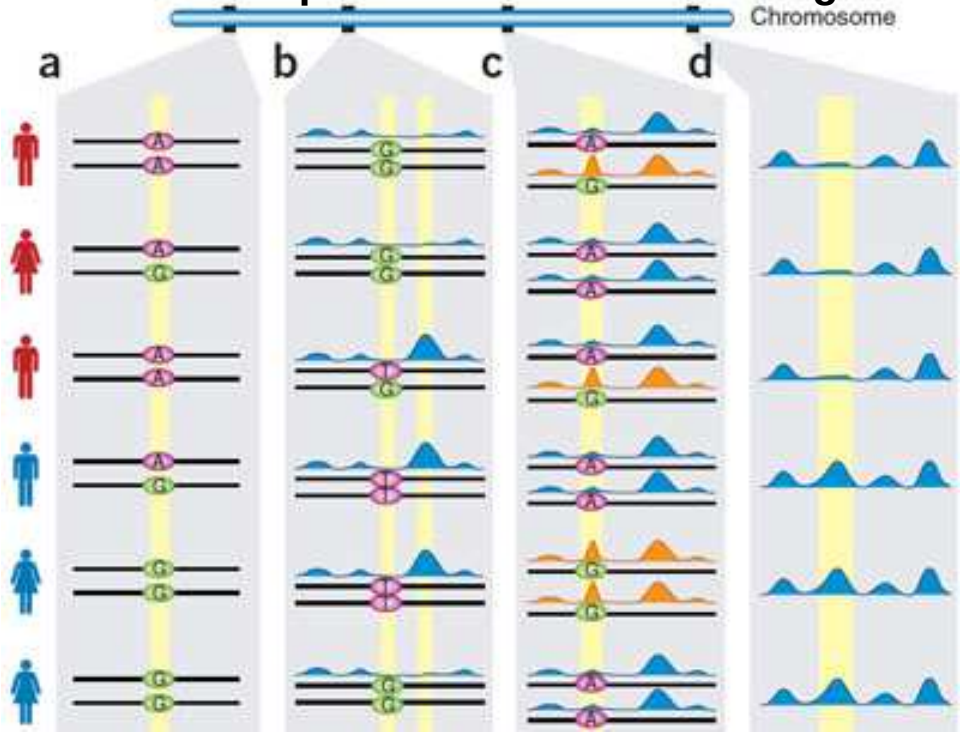
Parental environment

- Diet
- Metabolism
- infections
- climate

In human medicine

Epigenetic information is already embedded in the prediction of traits from GWAS..

ex: interpreting non coding genetic variation in complex human traits at a single locus



Involves the use of reference epigenome maps of primary and cultured cells

Ward and Kellis, 2012, Nat.Botech.

a- Genetic association with an organismal trait (**GWAs**)

b- Genetic association with a molecular trait (**eQTL**)

c- Genetic association with allelic activity (**ASE**)

d-molecular biomarker for physiological traits (**EpiWAs**)

In bovine

The use of wide scale collected epigenetic data is emerging

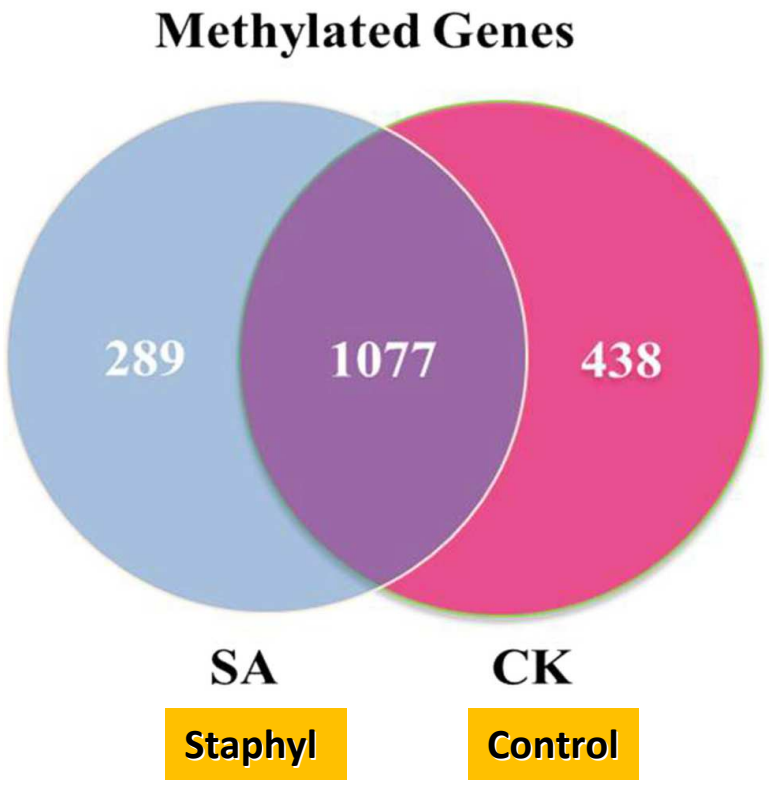
ex: susceptibility to bovine mastitis infection detectable from epigenetic markers

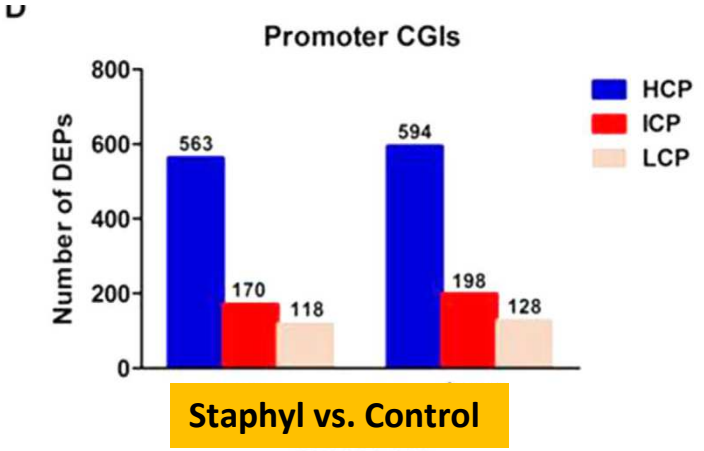
Song et al. 2016

Nature scientific Reports,

DOI: 10.1038/srep29390

Combined analysis of DNA methylome and transcriptome reveal novel candidate genes with susceptibility to bovine *Staphylococcus aureus* subclinical mastitis





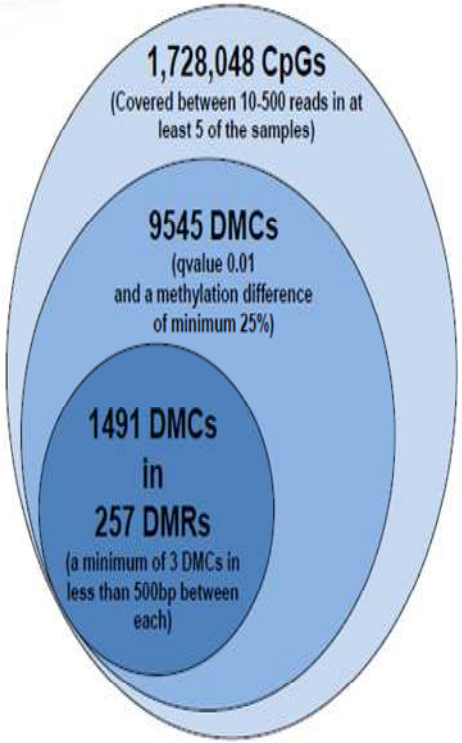
Number of differentially methylated enrichment peaks (DEPs) of the promoter CGI regions

HCP high CpG density promoter

LCP Low CpG density promoter

SeQuaMol
Qualité Moléculaire de la semence

differential methylome



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JP Perrier
Eli Sellem
C.Ledanvic
L Schibler
H Jammes

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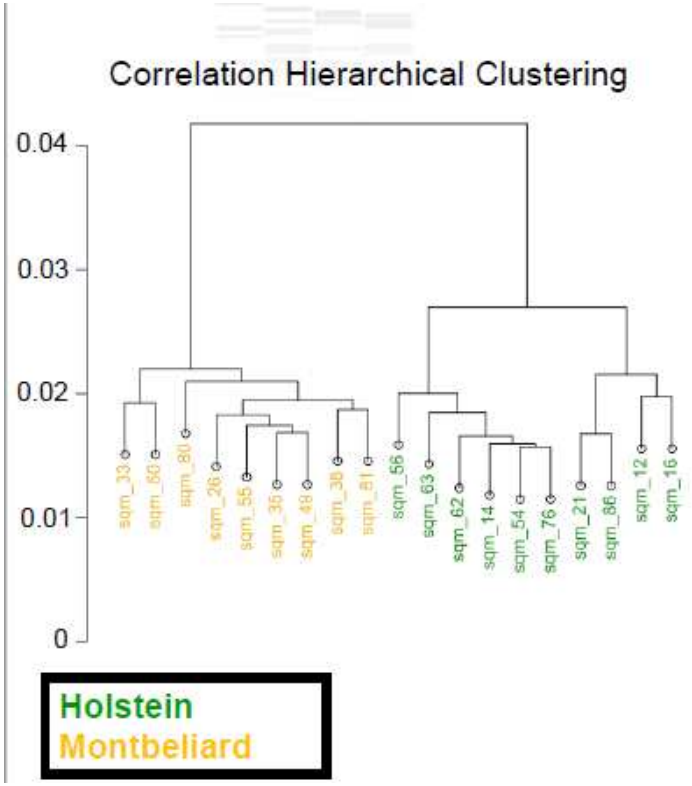
differential methylome



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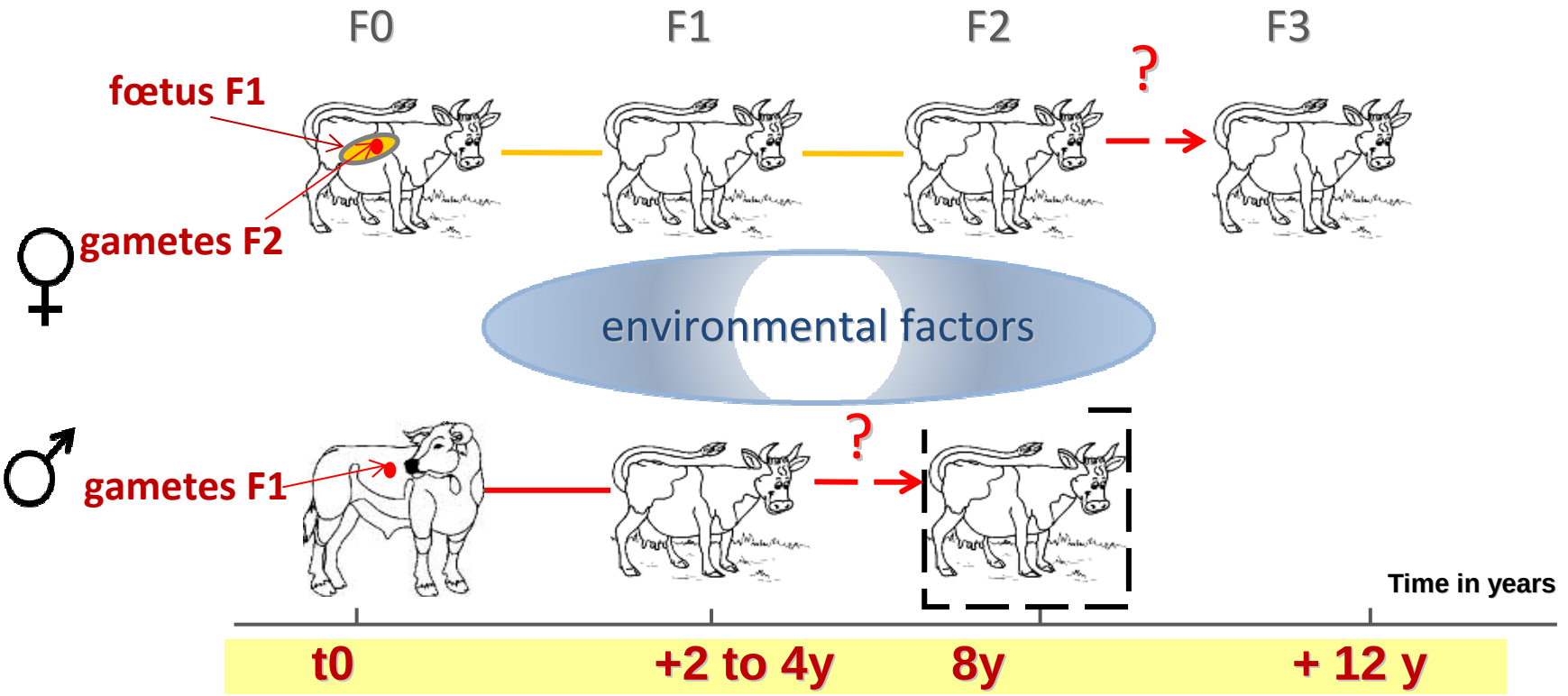
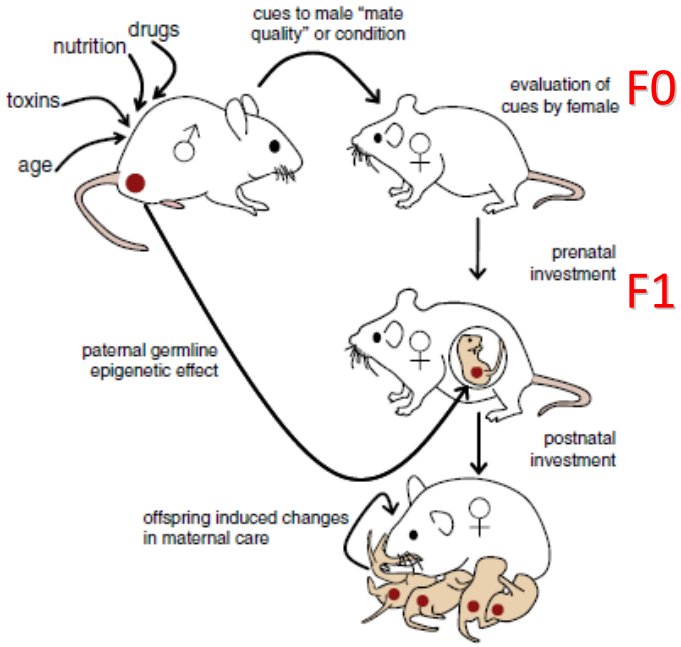
Intergenerational effects in domesticated mammals are favoured by long gestation and long generation interval periods :



Intergenerational effects: non-DNA sequence-based effects that are transmitted from one generation to the next.

transgenerational effects: non-DNA sequence-based effects that can be to transmittesd to generations that were not exposed to the initial signal or envi- ronment that triggered the change ; demonstrated in plants, nematodes… up to now not mammals



Heard and Martienssen

Cell *157*, March 27, 2014


Genomic selection: marked successes
but for a limited number of breeds
Resilience: essential for the adaptation of
individuals to their (changing) environment
and amenable to a variety of computing tools

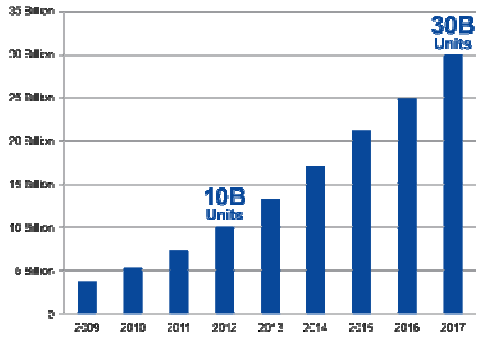
The Analog World is already getting digitized

Electronic Circuits are Cheaper and More Powerful

32x improvement in capability over the past 10 years

Source: CNET.com, processortimeline.info,thocp.net

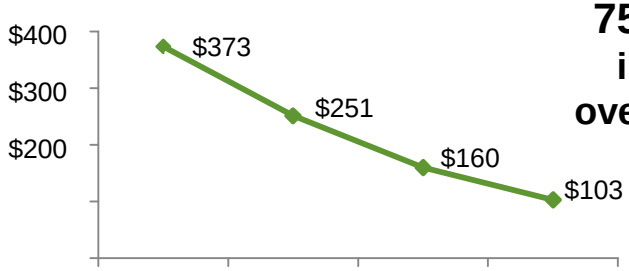
Increasing monitoring capabilities



100 x10^9 captors /sensors installed over the next 4 years

Source: Semico Research, 2013

Wireless Data Transfer is Getting Cheaper

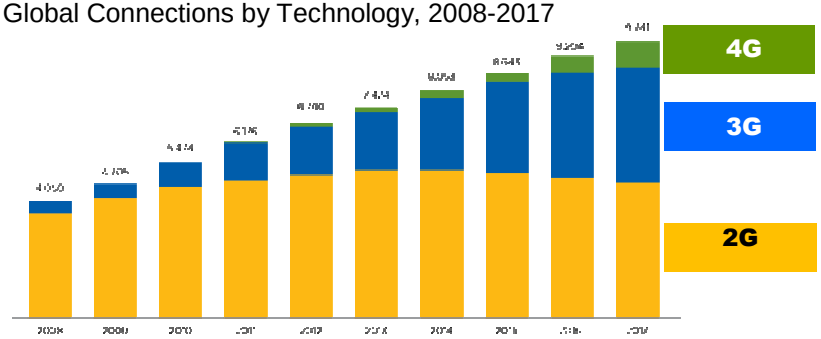


75% drop in price over 4 years

Source: Cisco (global wireless data use) ; Statista (global carrier data revenue estimate)

More Connected Mobile Devices Than People

Global Connections by Technology, 2008-2017



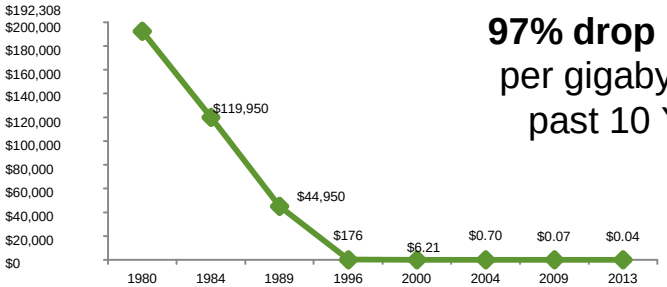
Source: GSMA Wireless Intelligence, Machina Research, A.T. Kearney Analysis

THE CLIMATE CORPORATION

Computing applications make data relevant to Agriculture

Storing Data is Getting Cheaper

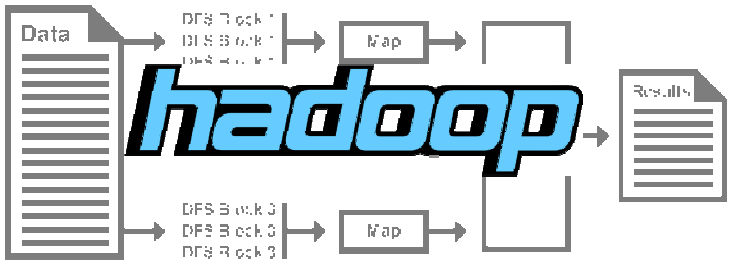
Average Price Per Gigabyte, 1980-2013



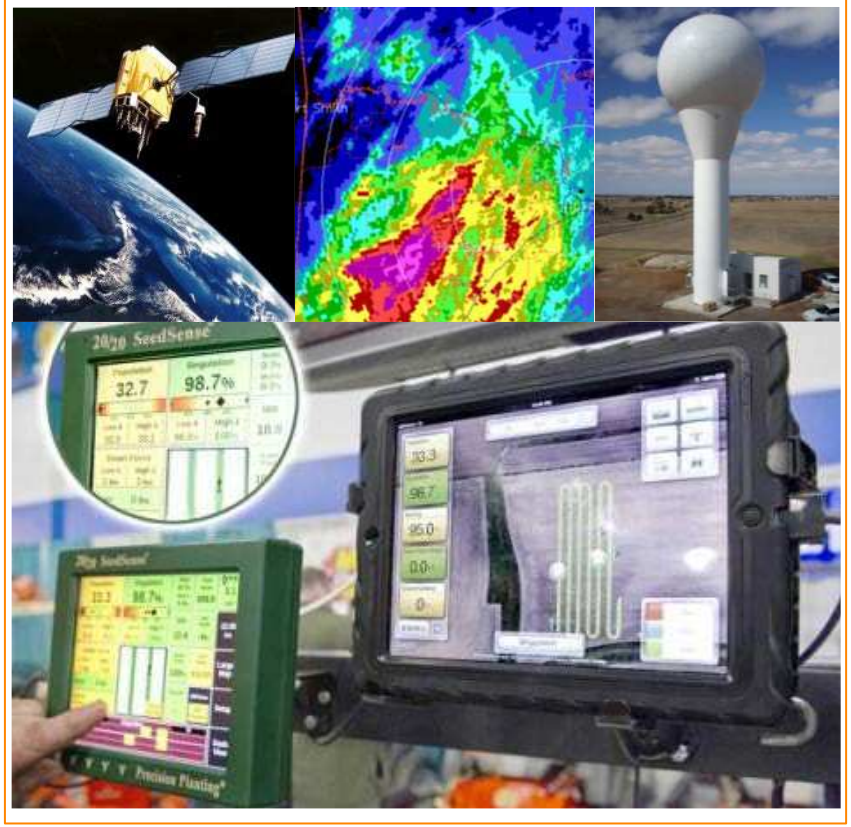
97% drop in price per gigabyte over past 10 Years

Source: Wayback Machine (Statistics Brain)

Low Cost Computing is Proliferating



In Agriculture, Environmental and Operating Data Are Taking Shape



Hadoop: a platform that provides an open-source implementation of frameworks for reliable, scalable, distributed computing and data storage

Computing Applications are amenable to animal breeding

Genomic data
phenotypical data
environmental data

on an individual basis

Genome and functions

- Genomics (QTL, SNPs…
- **Epigenomics**
- Metabolomics
- Ruminomics

Traits

size, growth,

Productive traits

Reproductive traits

puberty
ovulation rates
fertilisation
embryo death
fetal losses…..

Phenomes

- more data
- higher resolution

environment

Animal management

Animal health/treatment

What happened during the reproductive cycle?

- What was the outcome?

- more data
- higher resolution

The individual animal within its environment as the reference

Genomics and resilience:

In-house farming

- intensive production
- animals within a controlled environment
- more amenable to precision farming
- already bound to functional databases
- embedded in efficient genomic selection
- genetic first, resilience too

Out-door farming:

- extensive / less intensive production
- animals in an open environment
- more amenable to smart farming
- still a moderate access to databases
- embedded in friendly breeding
- resilience first , genetic too