Animal biotechnology applied in poultry
opportunities and impacts
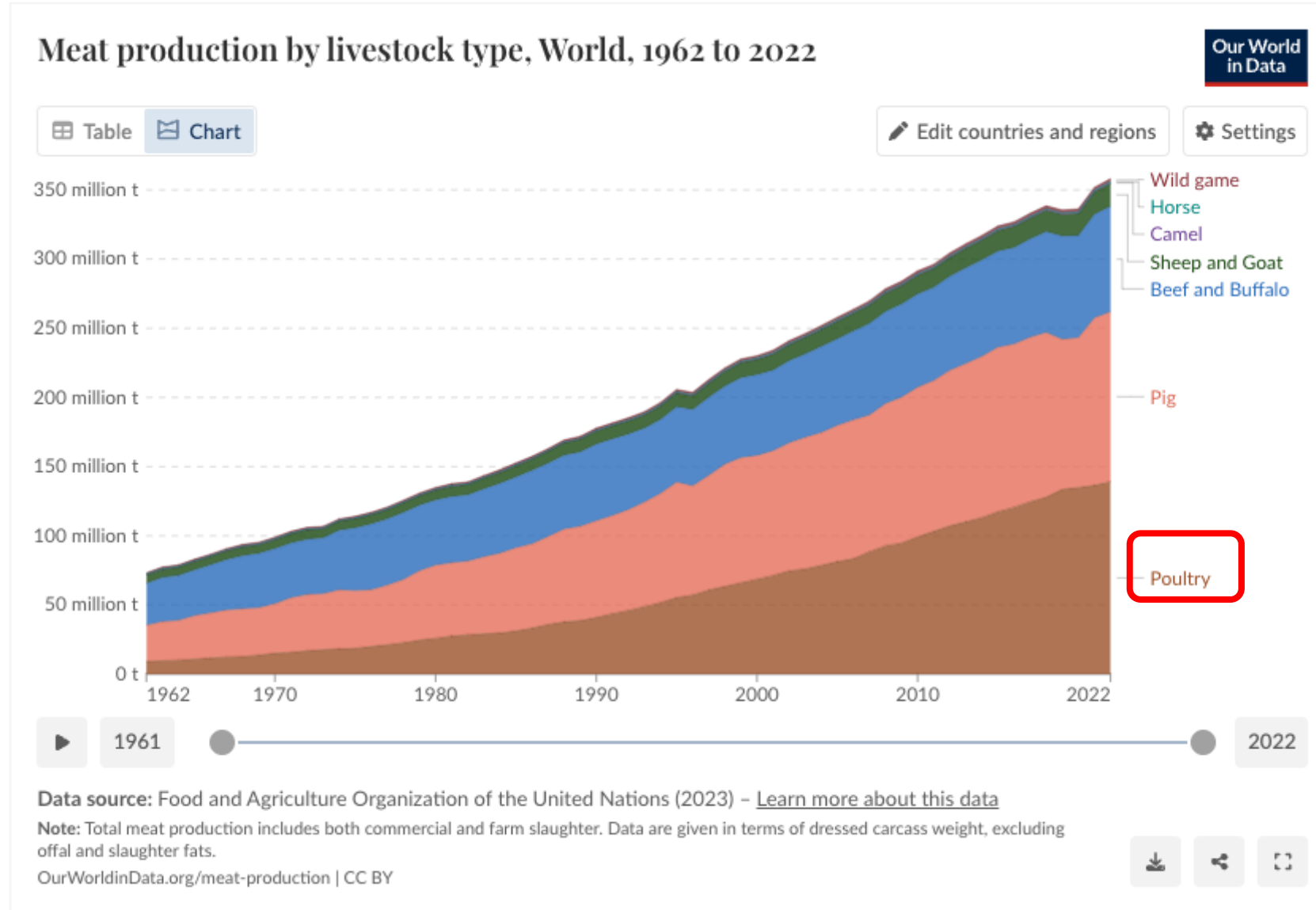
Dr Mark Tizard | Australian Animal Health Laboratory

CSIRO HEALTH & BIOSECURITY

www.csiro.au

What is so good about poultry?

Meat production by livestock type, World, 1962 to 2022

Wild game
Horse
Camel
Sheep and Goat
Beef and Buffalo
Pig
Poultry

Data source: Food and Agriculture Organization of the United Nations (2023) – Learn more about this data
Note: Total meat production includes both commercial and farm slaughter. Data are given in terms of dressed carcass weight, excluding offal and slaughter fats.
OurWorldinData.org/meat-production | CC BY

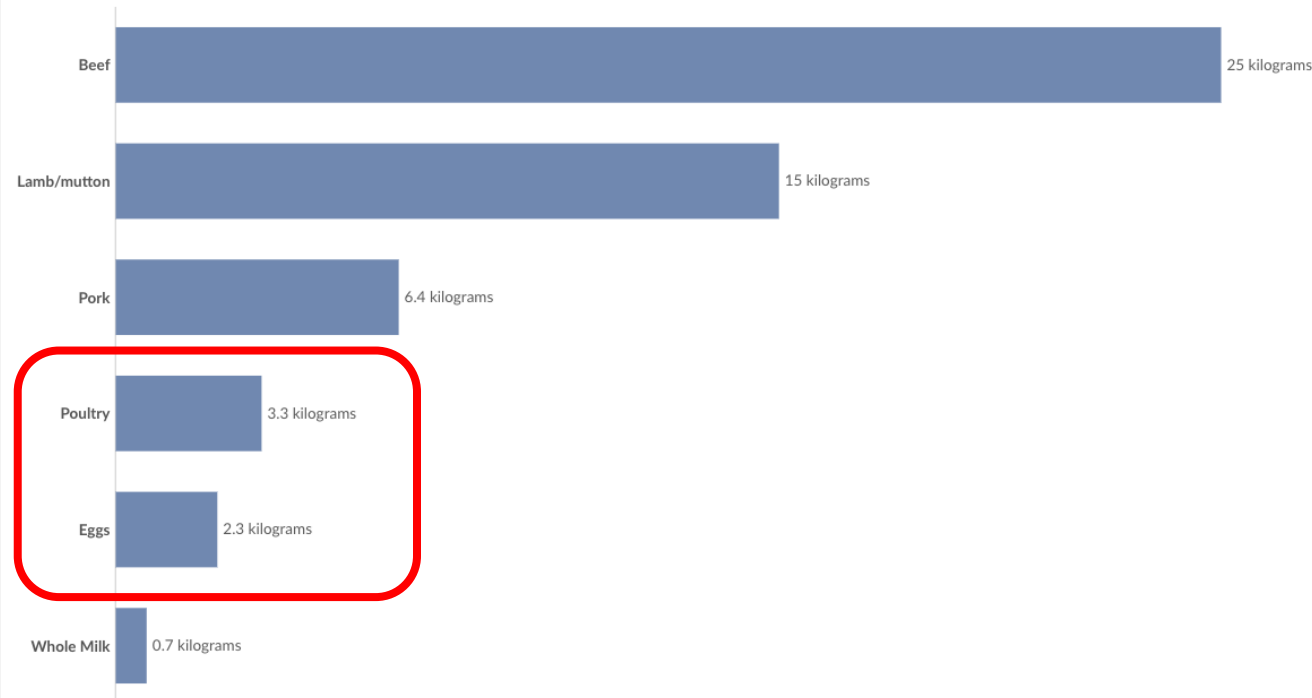SOURCE - https://ourworldindata.org/search?q=chickens

Efficient use of land and feed to generate versatile high-quality food

Feed required to produce one kilogram of meat or dairy product

Quantity of animal feed required to produce one kilogram of meat, egg or milk product. This is measured as dry matter feed in kilograms per kilogram of edible weight output.

Product	Feed
Beef	25 kilograms
Lamb/mutton	15 kilograms
Pork	6.4 kilograms
Poultry	3.3 kilograms
Eggs	2.3 kilograms
Whole Milk	0.7 kilograms

Data source: Alexander et al. (2016). Human appropriation of land for food: the role of diet. Global Environmental Change. – Learn more about this data
OurWorldInData.org/meat-production | CC BY

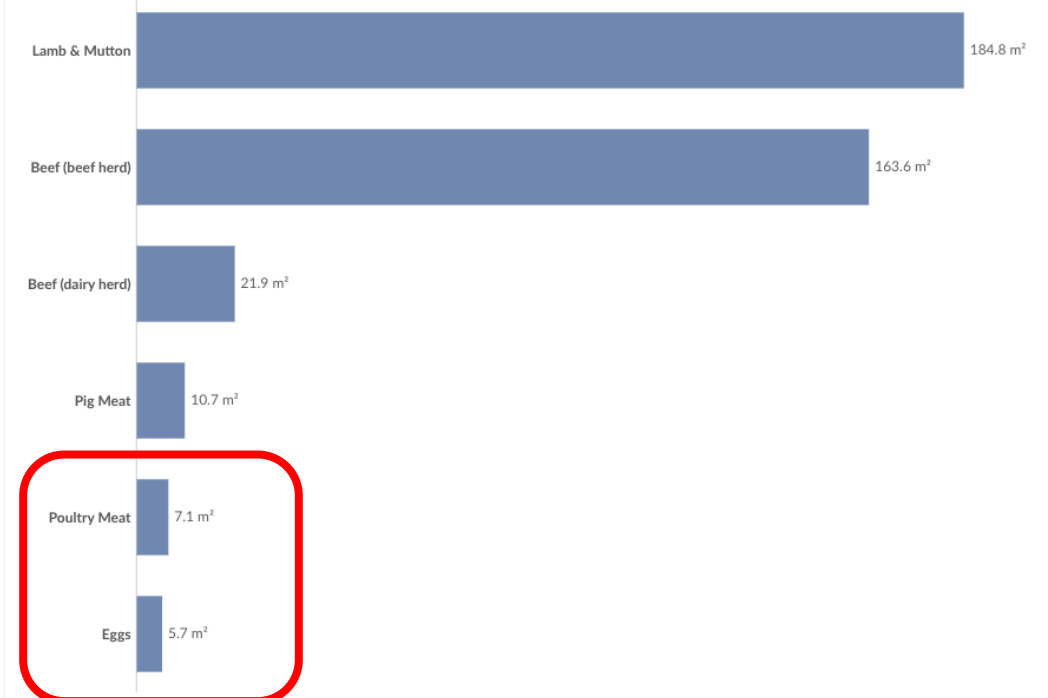## Land use per 100 grams of protein

Land use is measured in meters squared (m^2) per 100 grams of protein across various food products.

Product	Land use
Lamb & Mutton	184.8 m^2
Beef (beef herd)	163.6 m^2
Beef (dairy herd)	21.9 m^2
Pig Meat	10.7 m^2
Poultry Meat	7.1 m^2
Eggs	5.7 m^2

Data source: Joseph Poore and Thomas Nemecek (2018). Additional calculations by Our World in Data. – Learn more about this data
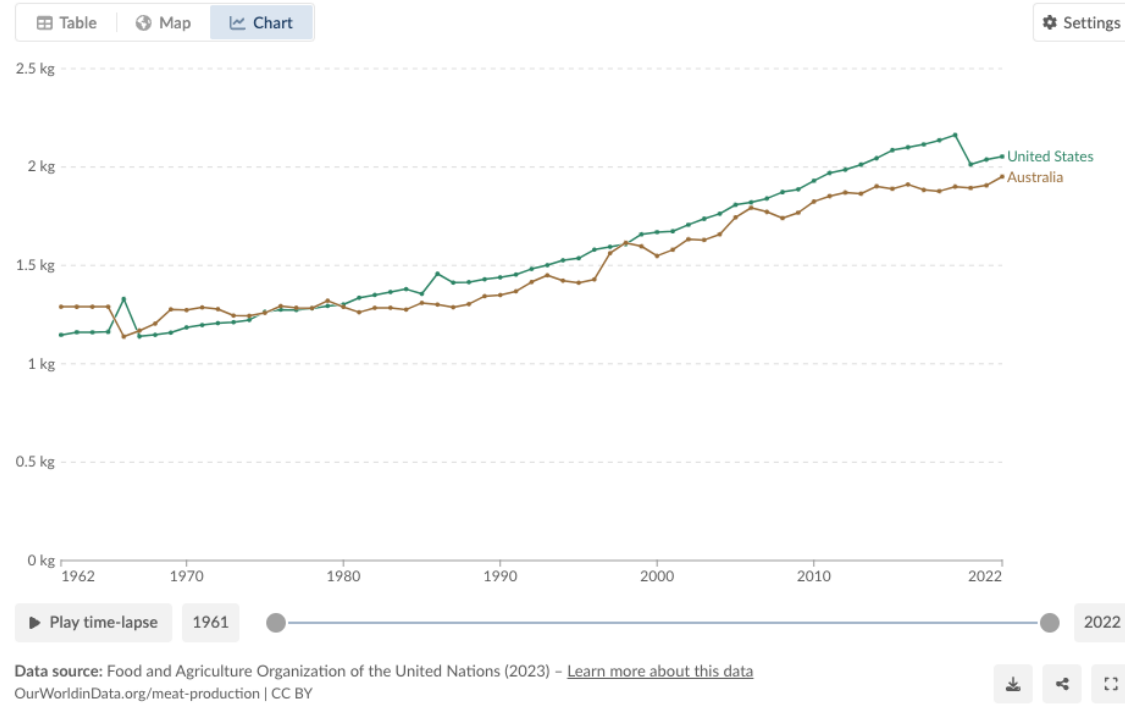OurWorldInData.org/environmental-impacts-of-food | CC BY

Related: FAQs: Data on the environmental impacts of food

SOURCE - https://ourworldindata.org/search?q=chickens

Short generation intervals empowers breeding for improvements

Chicken meat yield per animal, 1962 to 2022
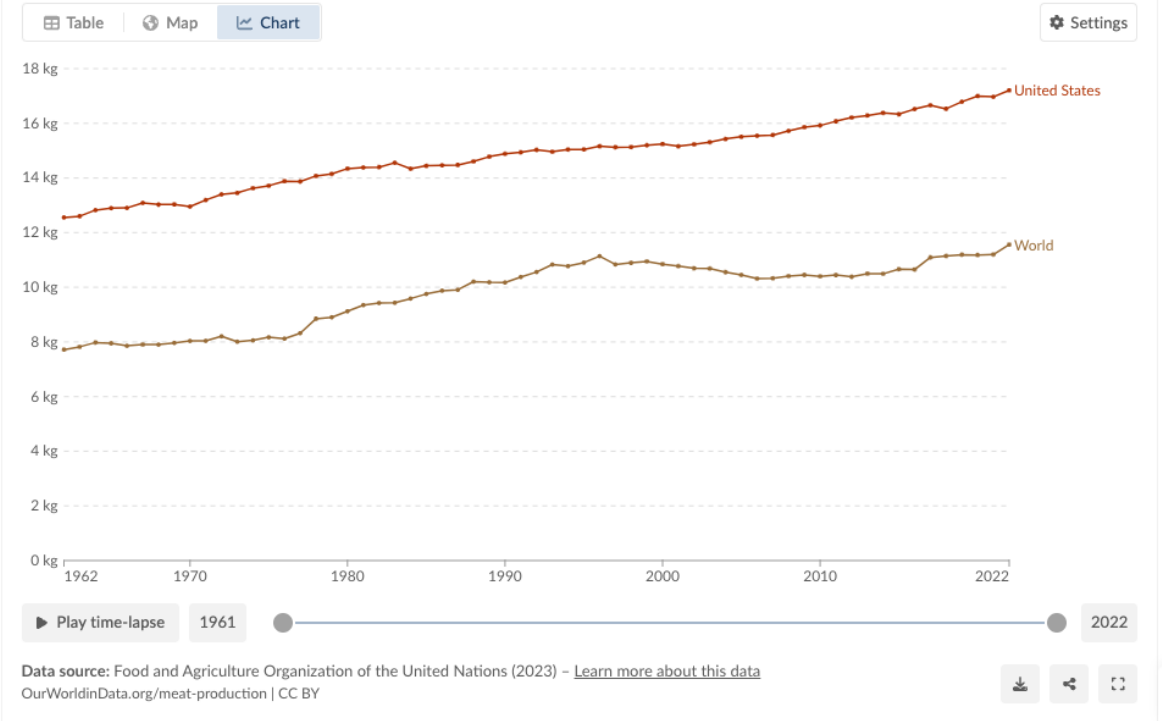Average meat yield per carcass, measured in kilograms per chicken.

United States
Australia

Eggs per bird, 1962 to 2022
Annual egg yield per bird, measured in kilograms per animal.

United States
World

Data source: Food and Agriculture Organization of the United Nations (2023) – Learn more about this data
OurWorldinData.org/meat-production | CC BY

Improvement: 1.1 kg –> 2.0 kg = **90%**   Improvement: 12.5 kg –> 17.2 kg = **40%**

SOURCE - https://ourworldindata.org/search?q=chickens

So why genetically engineer birds?

- Biology - chicken and quail as models for developmental biology

- Bio-pharma - generating valuable biologicals for medicine

- Conservation - genetic rescue of endangered bird species

- **Agriculture - improved poultry production (meat and eggs)**

- **For traits that are difficult to affect via selective breeding**

  - **Disease resilience (e.g. avian influenza, and others) ***
  - **Sex sorting for the layer industry (welfare, waste & sustainability) ***
  - **Safer food products (eggs and allergens) ***

- ~20 million male chicks culled in Australia every year

- ~300 million male chicks culled in the US every year

- **~7 billion male chicks culled globally every year**

- Industry wants and needs a solution
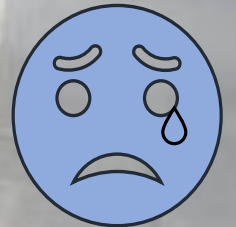
THE POTENTIAL TO IMPROVE THIS *WELFARE, ETHICS AND SUSTAINABILITY* ISSUE

CURRENT GLOBAL PRACTICE	NEW TECHNOLOGY IN EUROPE	MARKER SORTING – POINT OF LAY
DAY 21	DAY ~ 9	DAY 0
INCUBATION, HATCH, MANUAL SEXING, REMOVAL & CULL	INCUBATION, SAMPLING, ANALYSIS, REASSORTMENT, REMOVAL & CULL	DETECTION, REMOVAL (NO INCUBATION, NO GROWTH, NO CULL)
TACKLING THE ISSUE	BIG MPROVEMENTS ACHIEVED	POTENTIAL COMPLETE SOLUTION
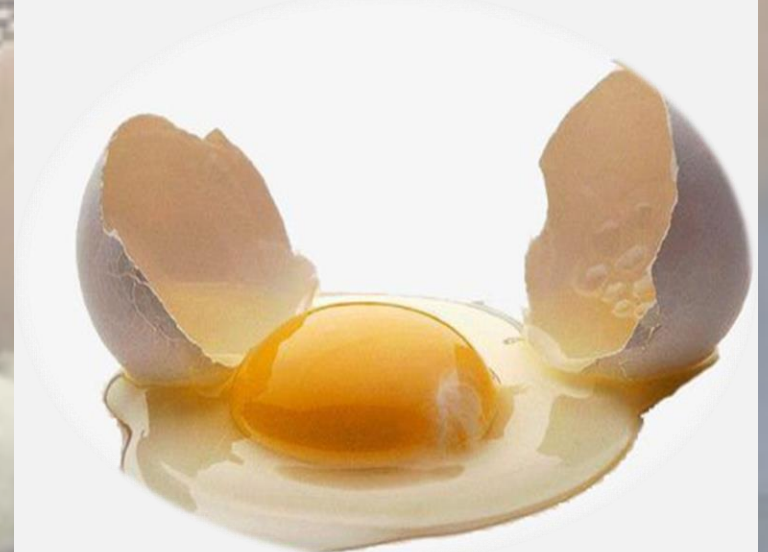
https://www.respeggt.com

https://inovo.nl

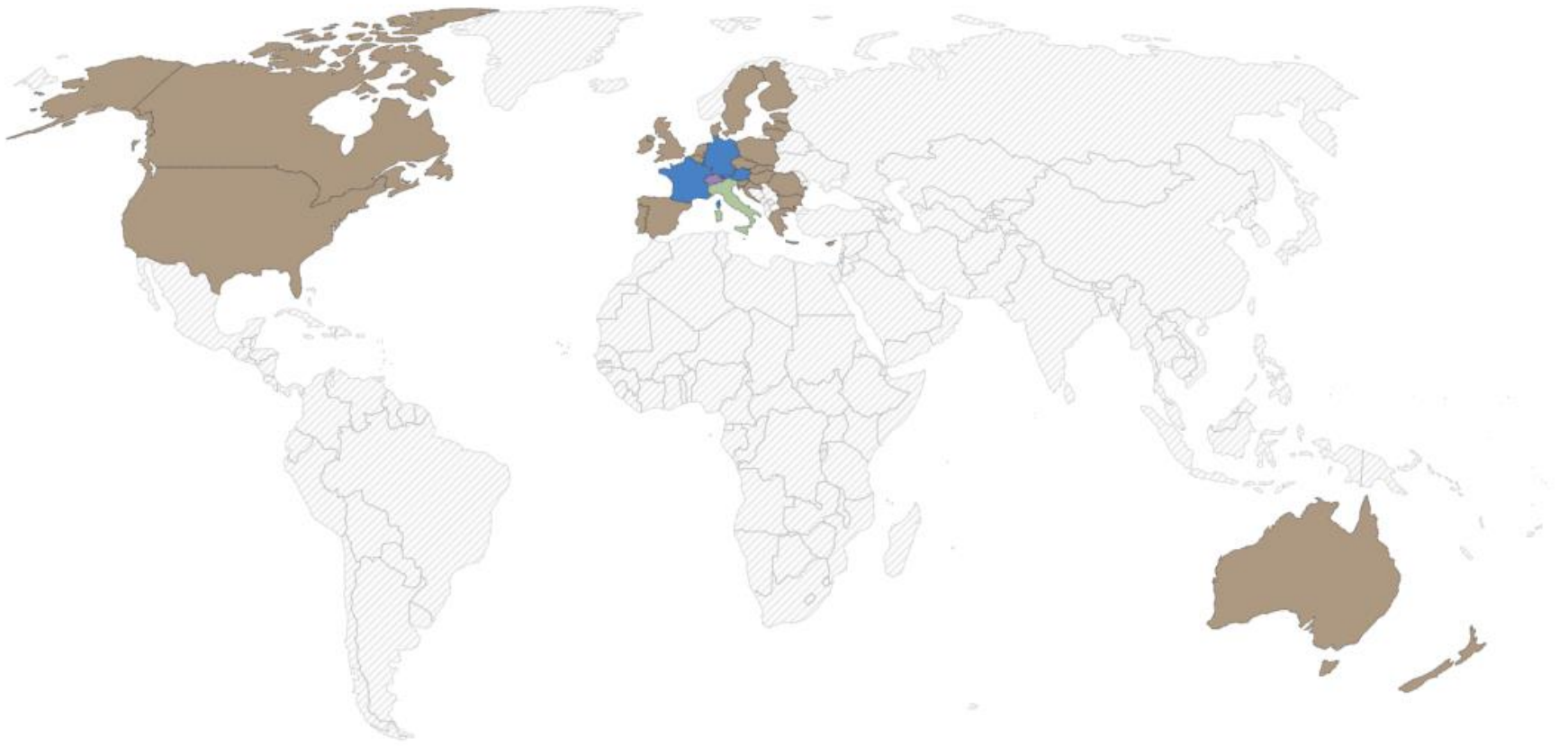IMAGES AND LOGOS FROM THESE PUBLICLY AVAILABLE WEBSITES

Which countries have banned chick culling? 2023

Chick culling is the process of separating and killing unwanted male and unhealthy female chicks that cannot produce eggs in industrialized egg facilities.

Table   Map

World ▾

■ Banned   ■ Banned but not yet in effect   ■ Not banned   ■ Partially banned   ▨ No data

Data source: Various sources (2023) – Learn more about this data

Note: Switzerland has only partially banned chick culling because grinding is banned but gassing is still allowed.
OurWorldinData.org/animal-welfare | CC BY

⬇ Download   ◄ Share   ⤢ Enter full-screen

New technology in sex selection for egg layers

Organisation	Detects at:	Invasive:	Biotechnology:	Economy of origin
CSIRO	Point-of-Lay	N	Y	Australia
eggXYt	Point-of-Lay	N	Y	Israel
Next Hen	Male linked terminator gene	N	Y	Israel
Cheggy	Day 9+	N	N	Leipzig, Germany
SELEGGT	Day 9+	Y	N	Leipzig, Germany
IN OVO	Day 9+	Y	N	Leiden, The Netherlands
Orbem	Day 8+	N	N	Munich, Germany

Why is biotechnology needed for sex sorting?

- **Legislation in Germany and France banning male chick culling**

- "Sampling and analysis systems" reduce hatchability, involve complex machinery, incur additional costs and increase carbon footprint

- **Sustainability benefits from stopping "male" eggs prior to incubation (potential for high protein value recovery)**

- **Reducing the carbon footprint of production by halving the number of eggs incubated (millions)**

- **Improving the ethics and welfare aspects of egg production (optics for consumers)**

SEGREGATION OF SEX CHROMOSOMES AS OVUM AND SPERM ARE FORMED

Marker on female Z inherited only by male embryos

Z Z ♂

	SPERM Z	SPERM Z
OVUM Z	Z Z	Z Z
OVUM W	Z W	Z W

♂ Eggs removed at point of lay
No more culling of day old male chicks

♀ Hatched female chicks are "null-segregants"
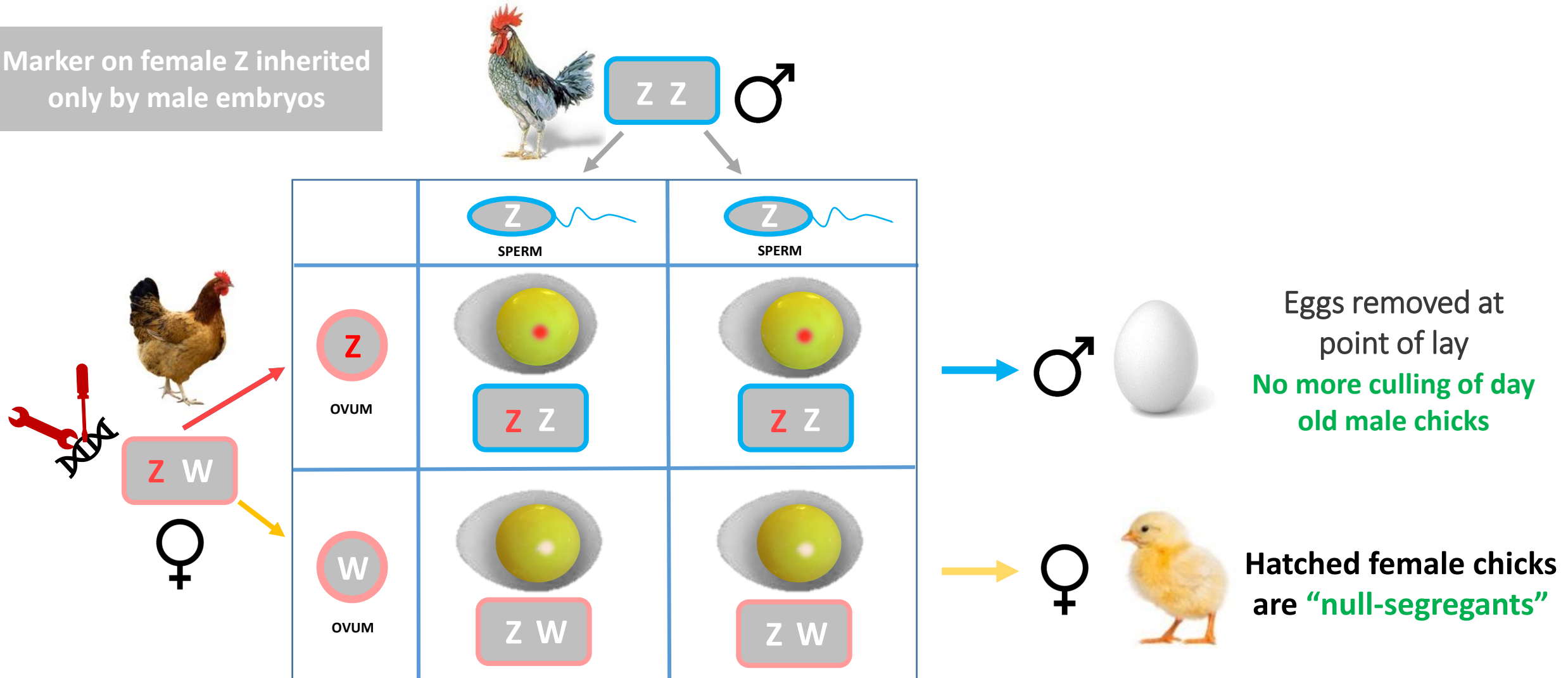
Natural lighting:
Gene Edited Blastoderm
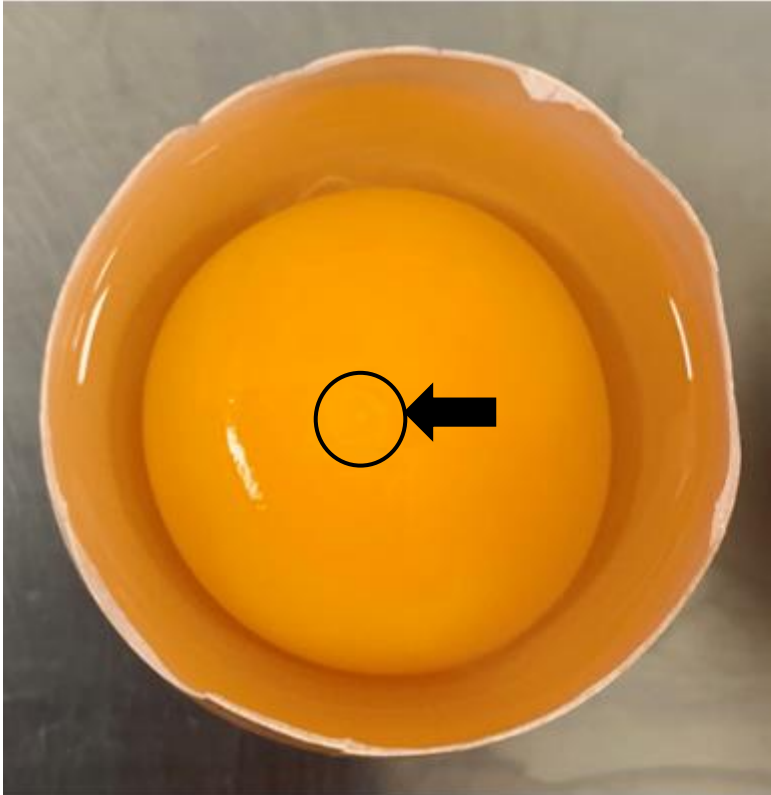
RFP filter:
Gene Edited Blastoderm
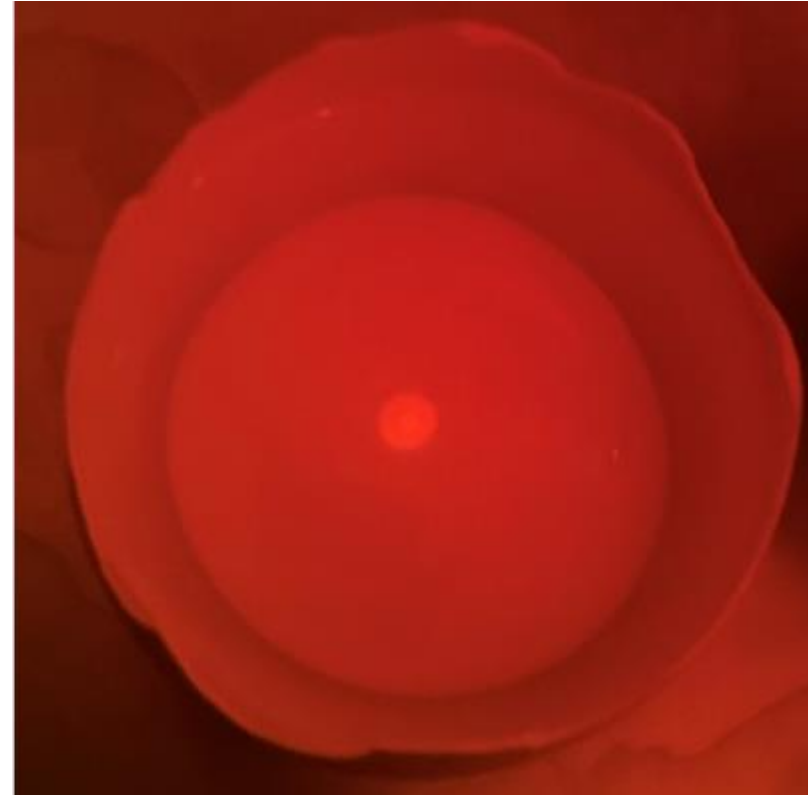
POINT OF LAY SORTING: MARKER DETECTION TO SEPARATE EGGS WITH MALE EMBRYOS

Male eggs removed

Detection system identifies point of lay embryo as male or female

Female eggs incubated to hatch layer hens
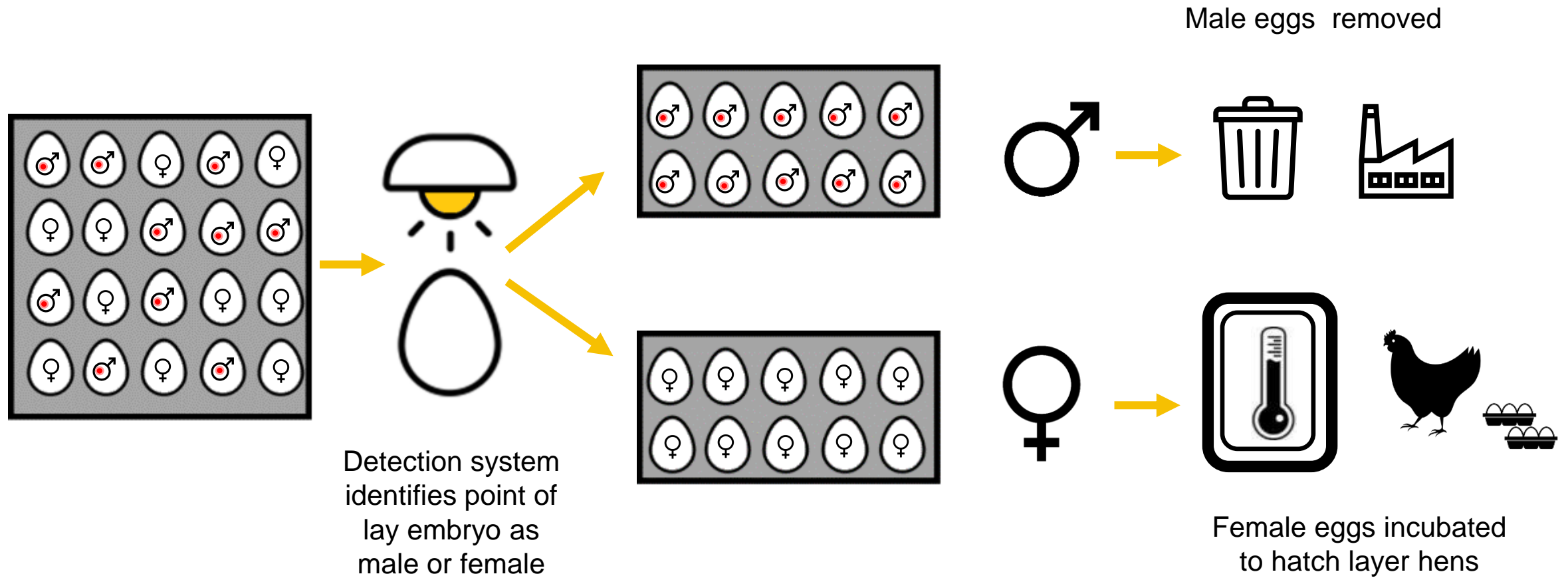
Integrating Marker Assisted Sex Sorting into the layer industry breeding structure

A line • **B line** • **C line** • **D line**

C line: $Z^{FP} Z^{FP}$ • $Z^{FP} W$

Pure Lines & GGP Lines
Genetic selection and improvement

$Z^{FP} Z^{FP}$ • $Z W$

Grand Parent Lines

$Z Z$ • $Z^{FP} W$

Parent Lines

$Z W$ • $Z^{FP} Z$

Detected and removed at **point of lay**

Commercial Layers
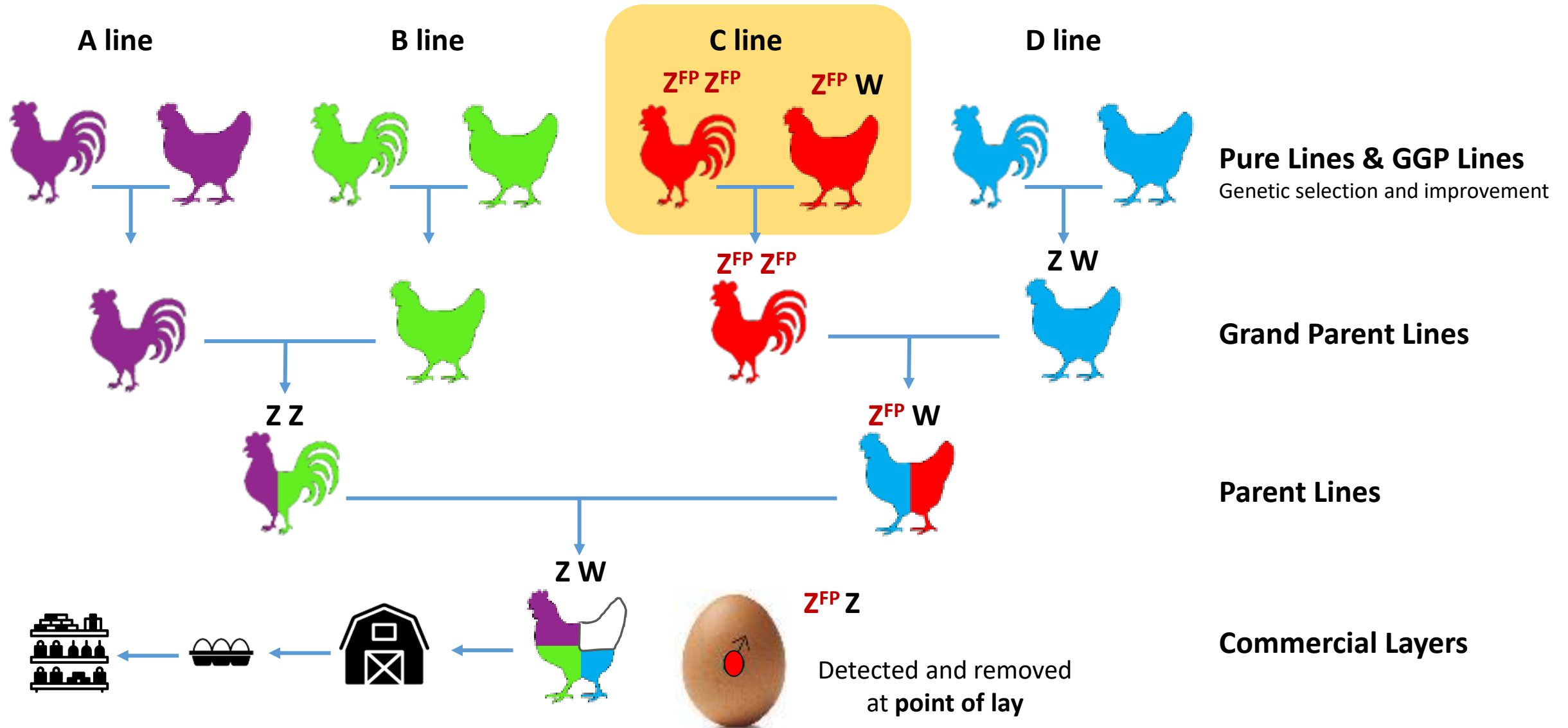
INTEGRATION INTO THE COMMERCIAL BREEDING PYRAMID

Marker integration

Genetic improvement | Pedigree selection

GGP

Grandparent Stock

Parent Stock

Marker Present

Null Segregation

No Marker

Commercial layers

Point of lay detection

Processing/Retailers

Consumers
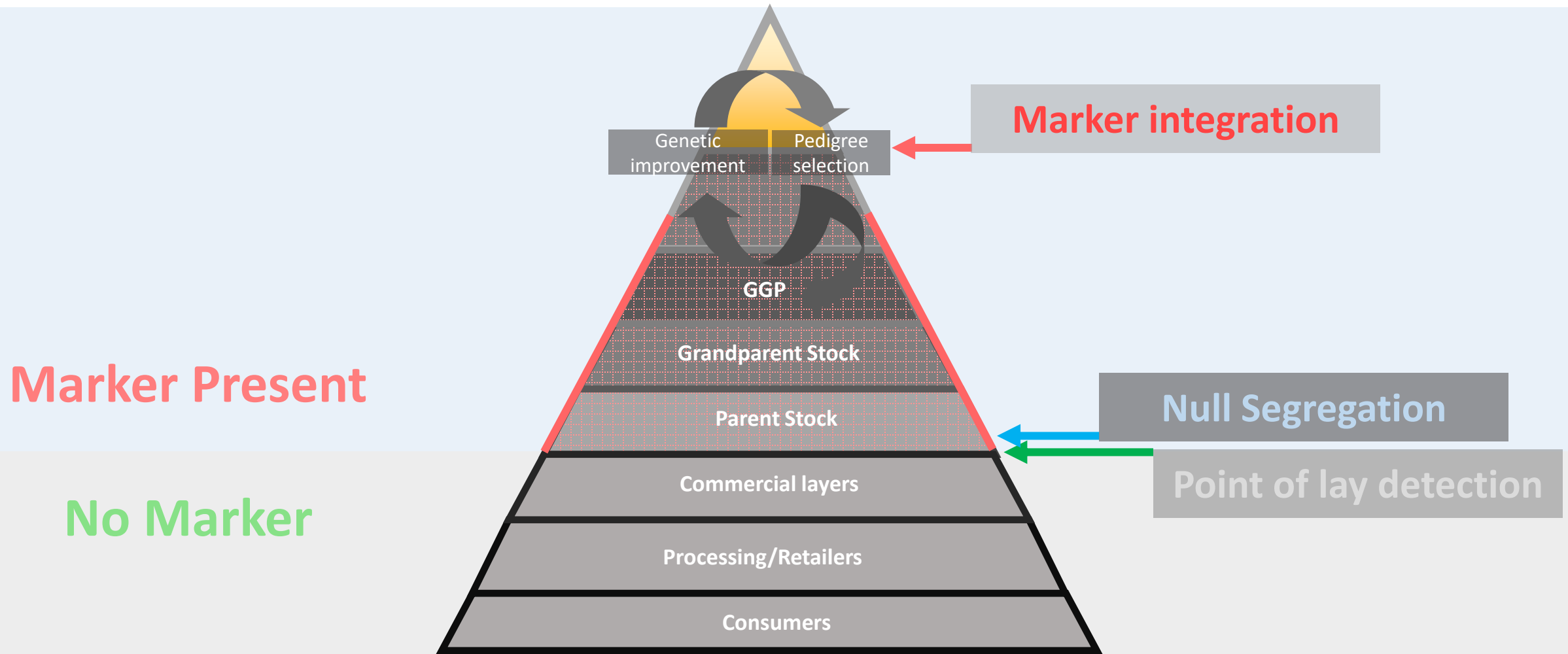
Through-chain map in Australia
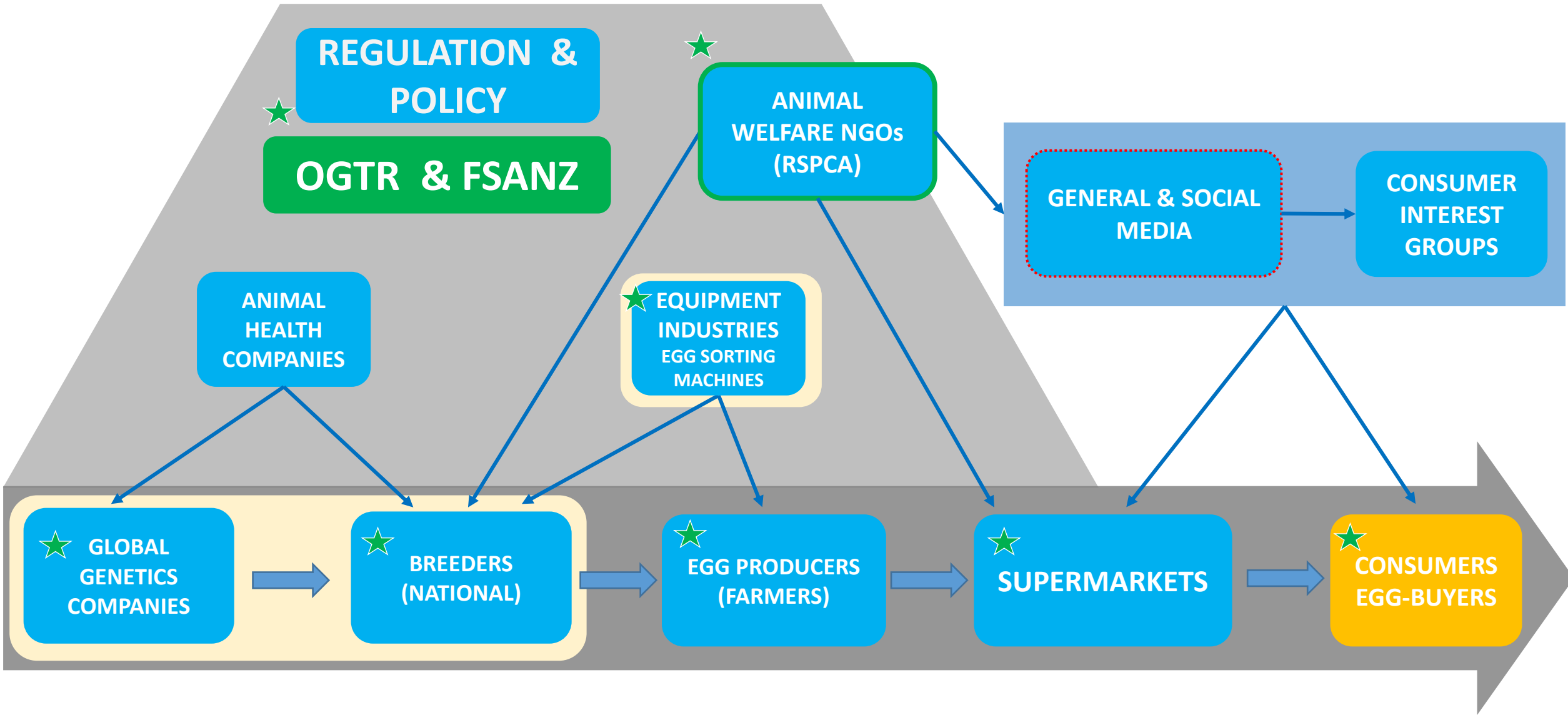
SEX SORTING – BENEFITS THE ENTIRE SUPPLY CHAIN

Global Genetics Companies

Nation-wide Breeders and hatcheries

Local Farmers

Supermarkets Local Retail

Local Consumers

Hens to the farm exactly the same as they are today

Eggs on the shelves exactly the same as they are today

Nothing changes for the consumer

Marker removed
No male chick culling

No Marker : Improved ethics/welfare, improved sustainability, reduced carbon footprint

Will this be regulated as a GM food?   - OGTR

Overview of the Gene Technology Amendment (2019 Measures No. 1) Regulations 2001   September 2019

Australian Government

Department of Health

Office of the Gene Technology Regulator

Organisms derived from GMOs but with no traits from gene technology

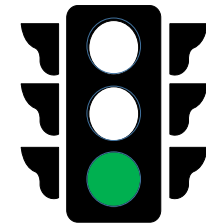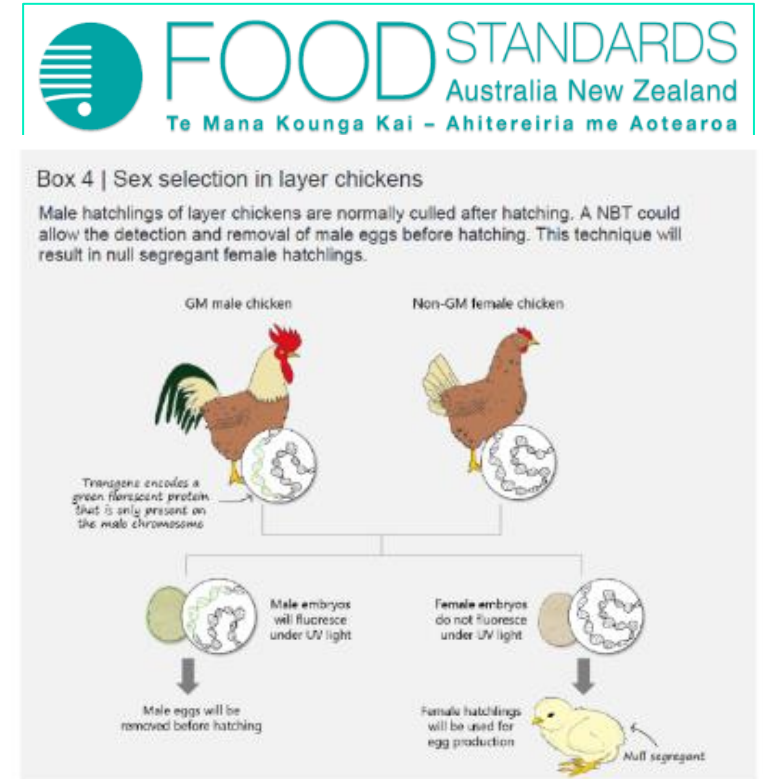This amendment will clarify the non-GMO status of organisms derived from GMOs but which do not possess traits as a result of gene technology. The purpose of this amendment is to provide clarity for the avoidance of doubt, and it does not change the status of any organisms. These organisms are:

- offspring of GMOs that have not inherited traits that occurred in a parent because of gene technology, commonly referred to as null segregants (**Schedule 1 item 8**)
- organisms temporarily modified using gene technology but which have lost all traits (e.g. transgenes, products expressed from transgenes) that occurred because of gene technology (**Schedule 1 item 10**).

Modifications produced using SDN techniques are traits that occurred because of gene technology, so item 8 does not exclude these organisms from being GMOs. However, other items described above do exclude SDN-1 organisms from regulation.

- **The technology is based on the "null segregant" process (widely used and accepted in plant breeding).**

- **They are happy with it, in principle.**

- **Food Standards Australia New Zealand (FSANZ)**
  - Food from **"null-segregant"** animals likely only to require an equivalence test (i.e. simple analysis to show an egg is an egg)

- **Of course, they will oversee this.**

- **A final decision will come when we show them data from the eggs.**

Box 4 | Sex selection in layer chickens

Male hatchlings of layer chickens are normally culled after hatching. A NBT could allow the detection and removal of male eggs before hatching. This technique will result in null segregant female hatchlings.

What do the regulator make of the food egg this would produce?

- **All consultations and discussions, globally - positive**

- **Argentina – CONABIA**

- **Brazil - CTNBio**

- **Canada – Health Canada**

- **Japan – National Agriculture and Food Research Organisation**

- **USA – FDA CVM**

* **Final decisions rest on presentation of appropriate data packages**

Partners in research

New partnership to study innovative sex sorting technology for the egg laying industry

Hendrix Genetics is partnering with Australia's national science agency, CSIRO, to test the viability of an innovative point of lay sex sorting technology for the egg laying industry.

https://www.hendrix-genetics.com/en/news/new-partnership-to-study-innovative-sex-sorting-technology-for-the-egg-laying-industry/

CSIRO – Genome Engineering Team

- **Mark Tizard**
- **Olivier Serralbo**
- **Kirsten Morris**
- **Shuning Shi**
- **Terri O'Neil**
- **Terry Wise**

- **Tim Doran**
- **Kristie Jenkins**
- **Kiran Krishnankutty Nair**
- **Arjun Challagulla**

Supporting Teams

- **Ali Cuneen (Vet)**
- **WAHF Team**
- **SAF Team**
- **AWO Team**

- **Caitlin Cooper**
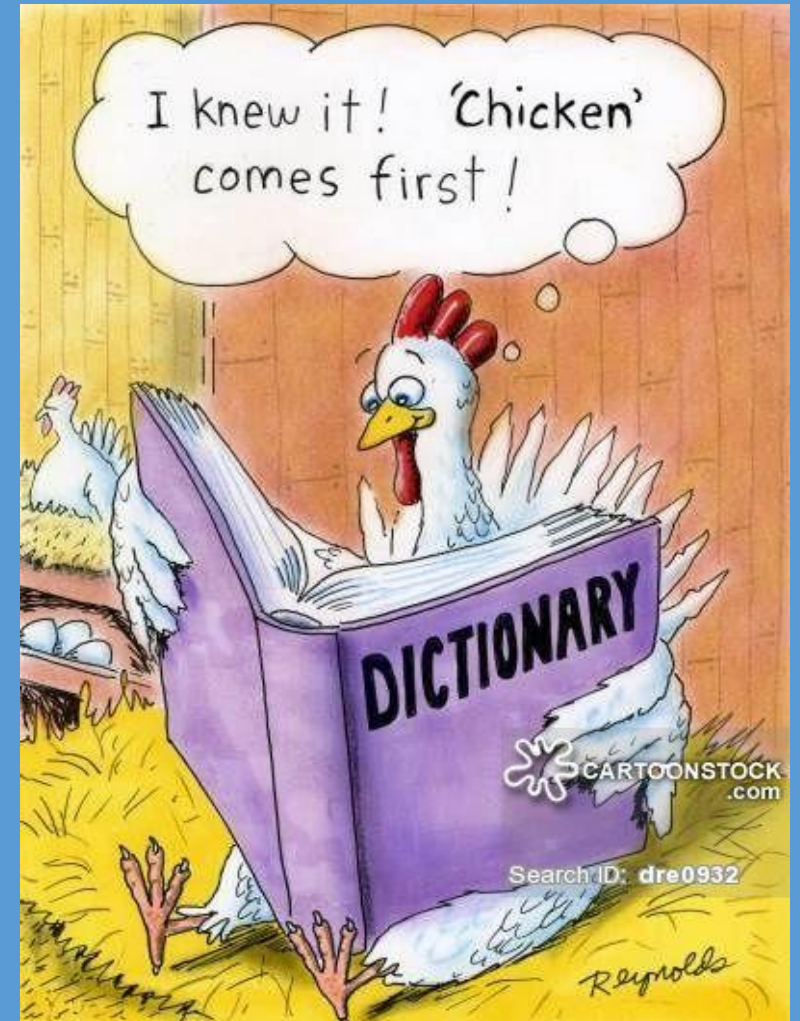
Thank you

Mark Tizard

Principle Research Scientist & Team Leader
Genome Engineering for Biosecurity

mark.tizard@csiro.au

*NB subject not accredited by evolutionary biologists

EGG   VS   MILK

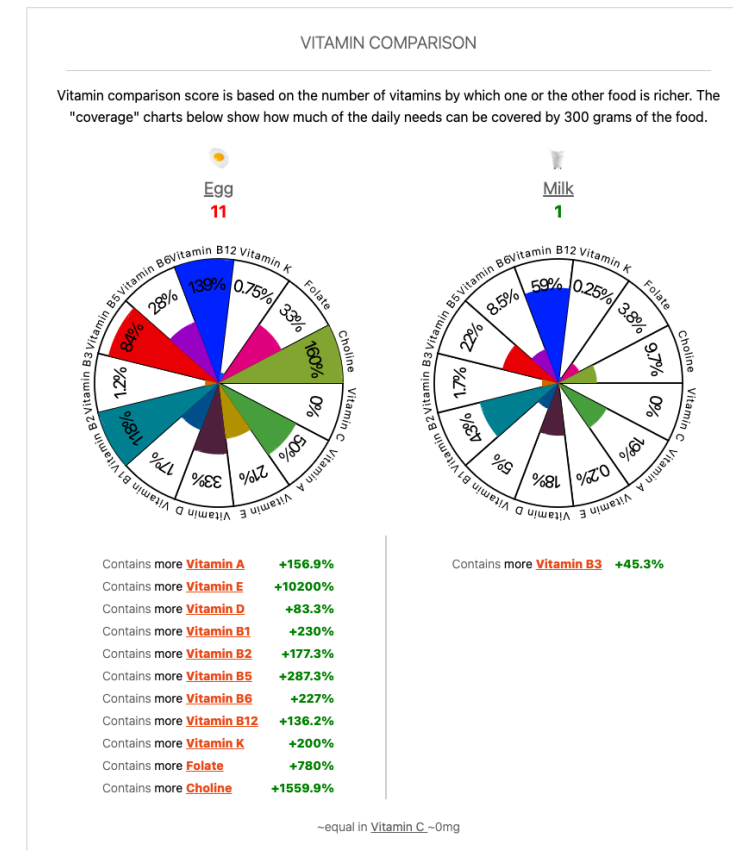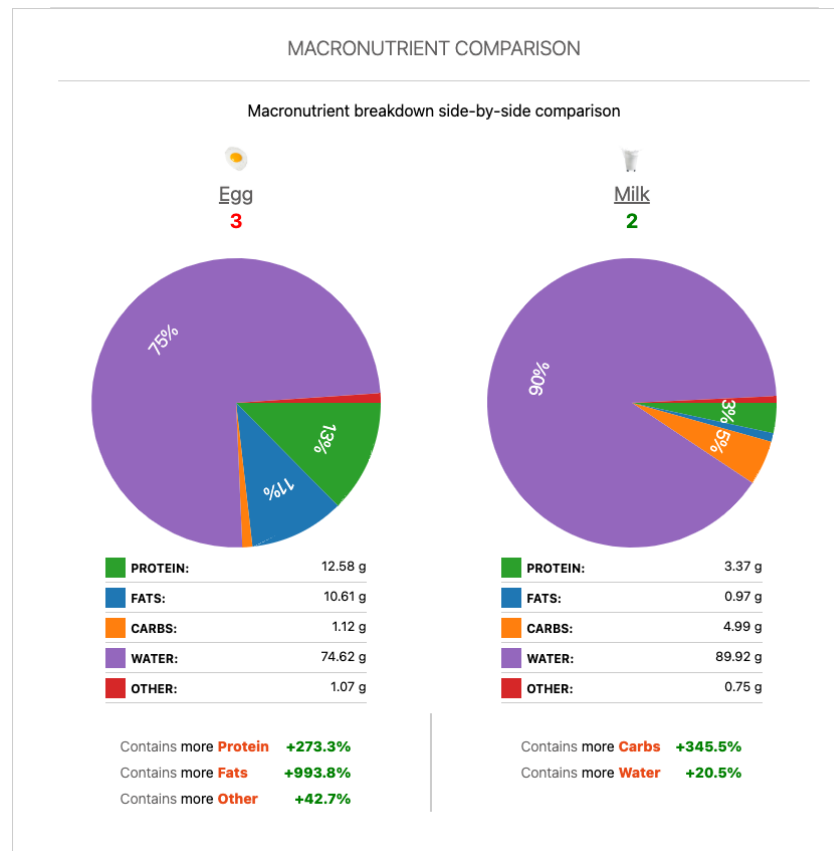| EGG		MILK
2 mg	Copper	0.01 mg
1.03 mg	Vitamin E	0.01 mg
373 mg	Cholesterol	5 mg
1.414 g	Polyunsaturated fat	0.035 g
1.19 mg	Iron	0.03 mg
293.8 mg	Choline	17.7 mg
4.077 g	Monounsaturated fat	0.277 g
30.8 µg	Selenium	3.3 µg
44 µg	Folate, total	5 µg
3.267 g	Saturated fat	0.633 g

The nutrient name is displayed in the color of the food we considered as 'winner'.
The amounts are specified per 100 gram of the product.
The infographic aims to display only the significant differences, ignoring minor ones.
The main source of information is USDA Food Composition Database.

MACRONUTRIENT COMPARISON

Macronutrient breakdown side-by-side comparison

Egg
3

75%   13%   11%

	PROTEIN:	12.58 g
	FATS:	10.61 g
	CARBS:	1.12 g
	WATER:	74.62 g
	OTHER:	1.07 g

Contains more **Protein**   **+273.3%**
Contains more **Fats**   **+993.8%**
Contains more **Other**   **+42.7%**

Milk
2

90%   5%   3%

	PROTEIN:	3.37 g
	FATS:	0.97 g
	CARBS:	4.99 g
	WATER:	89.92 g
	OTHER:	0.75 g

Contains more **Carbs**   **+345.5%**
Contains more **Water**   **+20.5%**

VITAMIN COMPARISON

Vitamin comparison score is based on the number of vitamins by which one or the other food is richer. The "coverage" charts below show how much of the daily needs can be covered by 300 grams of the food.

Egg
11

Milk
1

Contains more **Vitamin A**   **+156.9%**
Contains more **Vitamin E**   **+10200%**
Contains more **Vitamin D**   **+83.3%**
Contains more **Vitamin B1**   **+230%**
Contains more **Vitamin B2**   **+177.3%**
Contains more **Vitamin B5**   **+287.3%**
Contains more **Vitamin B6**   **+227%**
Contains more **Vitamin B12**   **+136.2%**
Contains more **Vitamin K**   **+200%**
Contains more **Folate**   **+780%**
Contains more **Choline**   **+1559.9%**

Contains more **Vitamin B3**   **+45.3%**

~equal in Vitamin C ~0mg

https://foodstruct.com/compareimages/egg-vs-milk.jpg