Harnessing genomic engineering and biotechnology for the future of aquaculture

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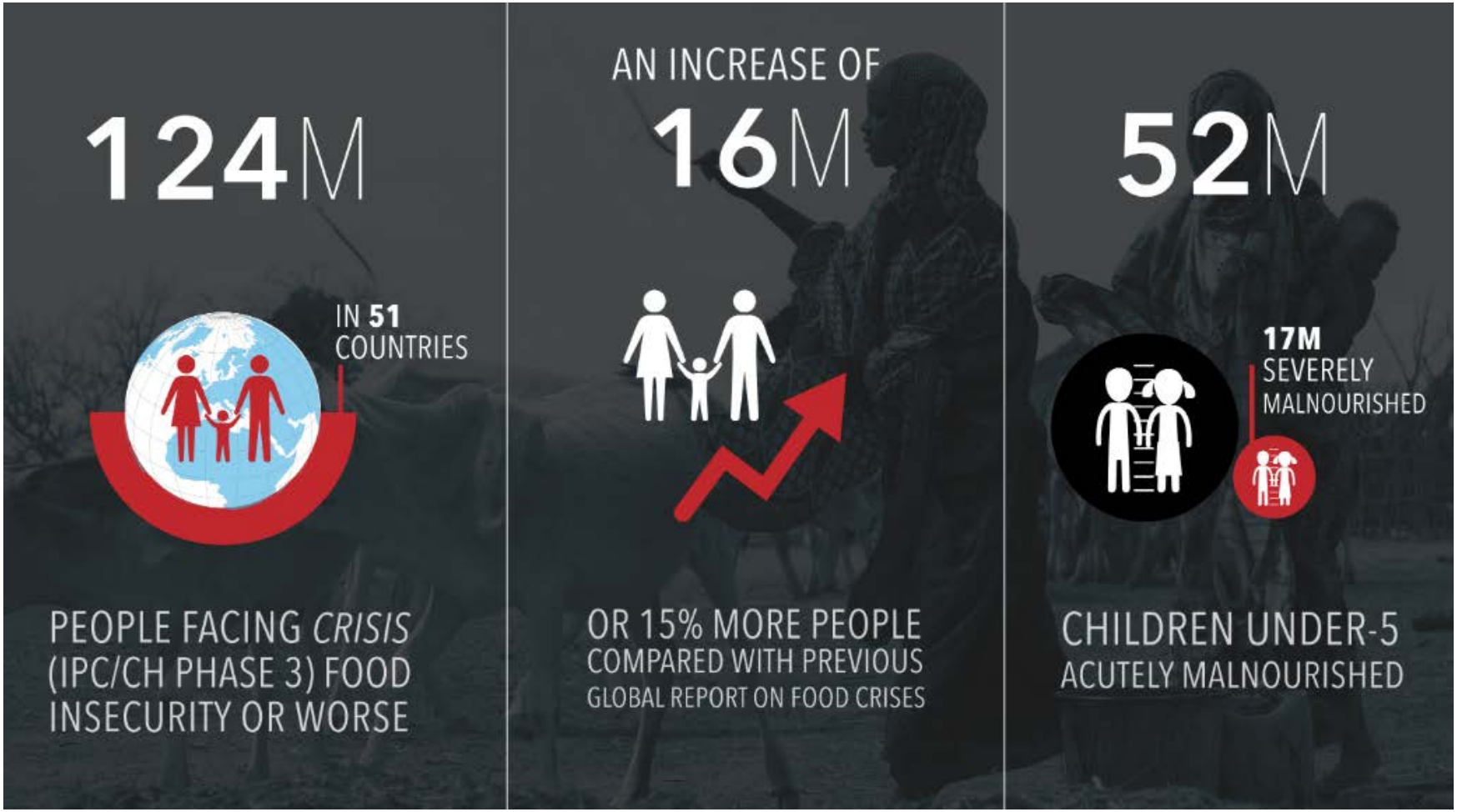
We Are Headed for a World Food Crisis

WFP
World Food Programme
wfp.org



SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY

2 ZERO HUNGER

3 GOOD HEALTH AND WELL-BEING

4 QUALITY EDUCATION

5 GENDER EQUALITY

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

10 REDUCED INEQUALITIES

11 SUSTAINABLE CITIES AND COMMUNITIES

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

14 LIFE BELOW WATER

15 LIFE ON LAND

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

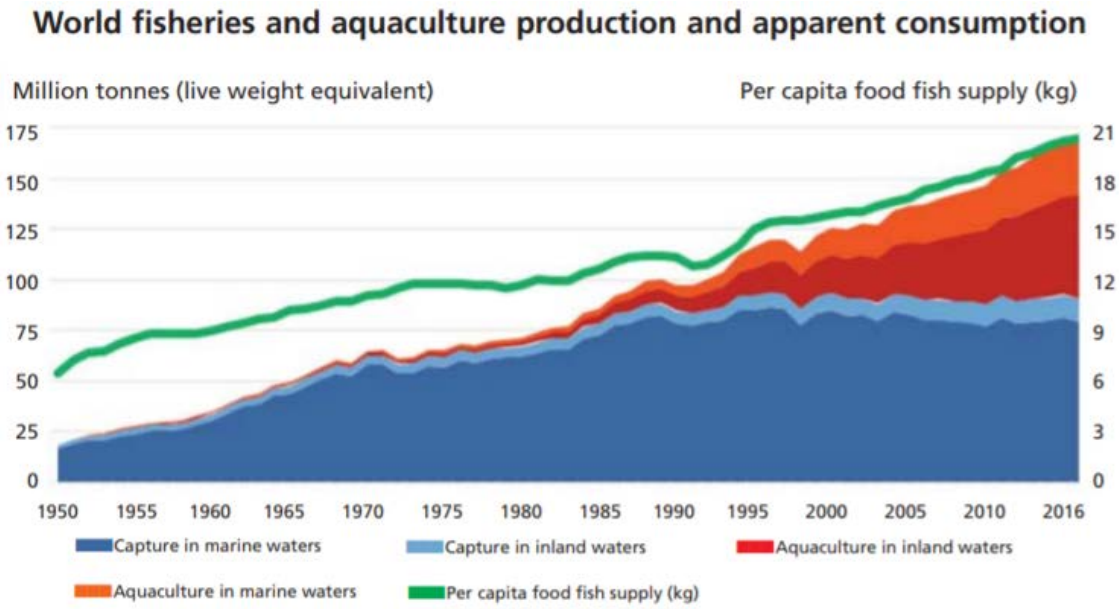
17 PARTNERSHIPS FOR THE GOALS

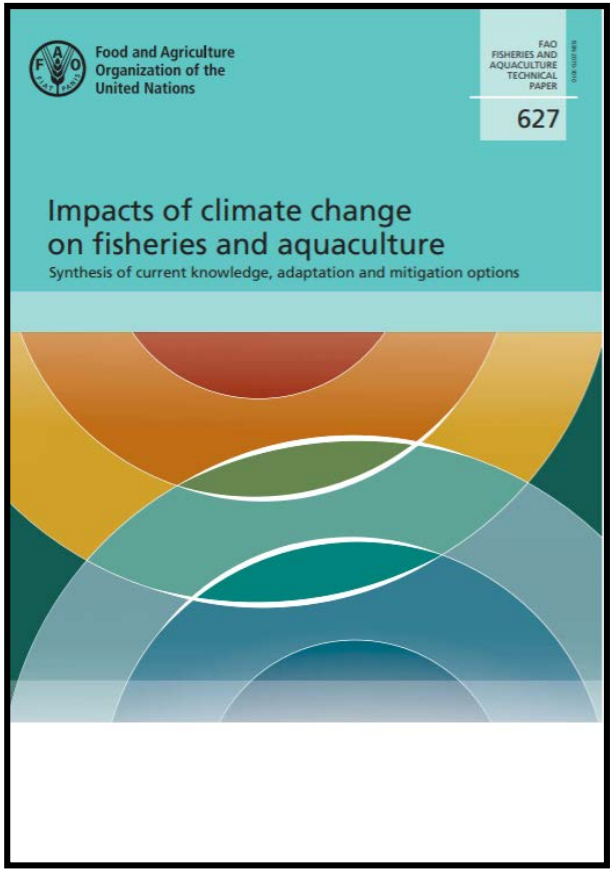
SUSTAINABLE DEVELOPMENT GOALS

14 LIFE BELOW WATER

Goal 14: Conserve and sustainably use the oceans, seas and marine resources

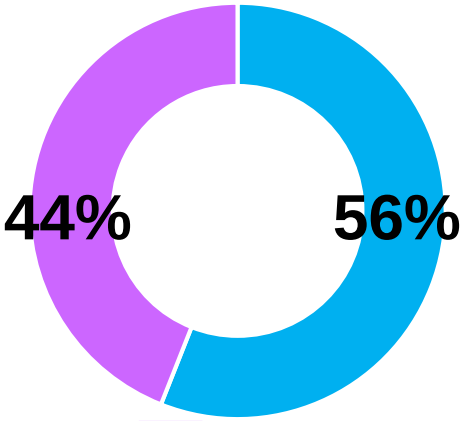
- Careful management of this essential global resource is a key feature of a sustainable future.





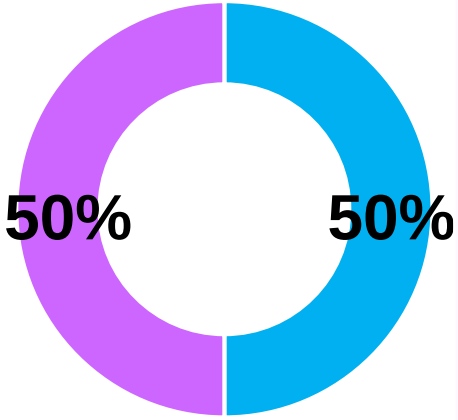
Global fisheries

2013~2015



Global fish consumption

2013~2015



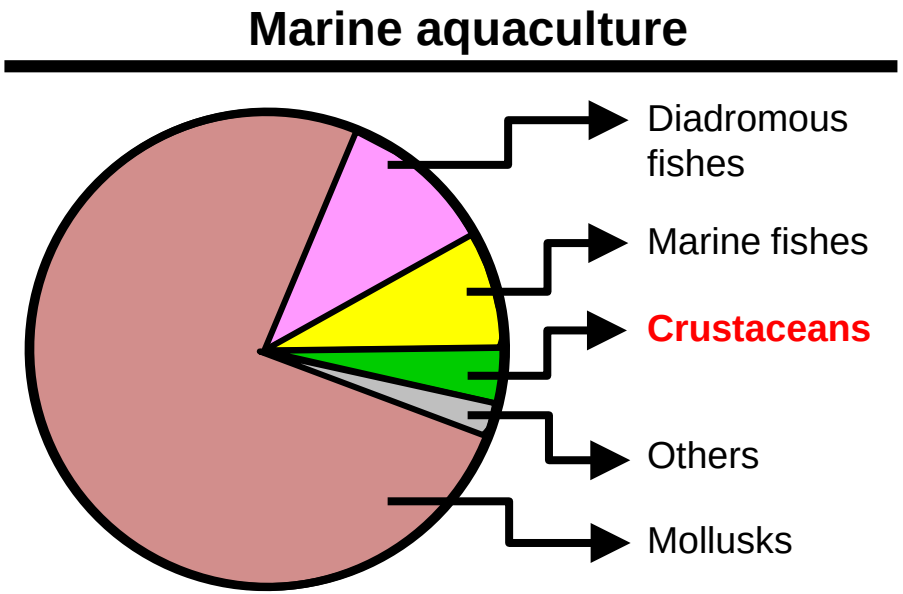
Aquaculture Capture

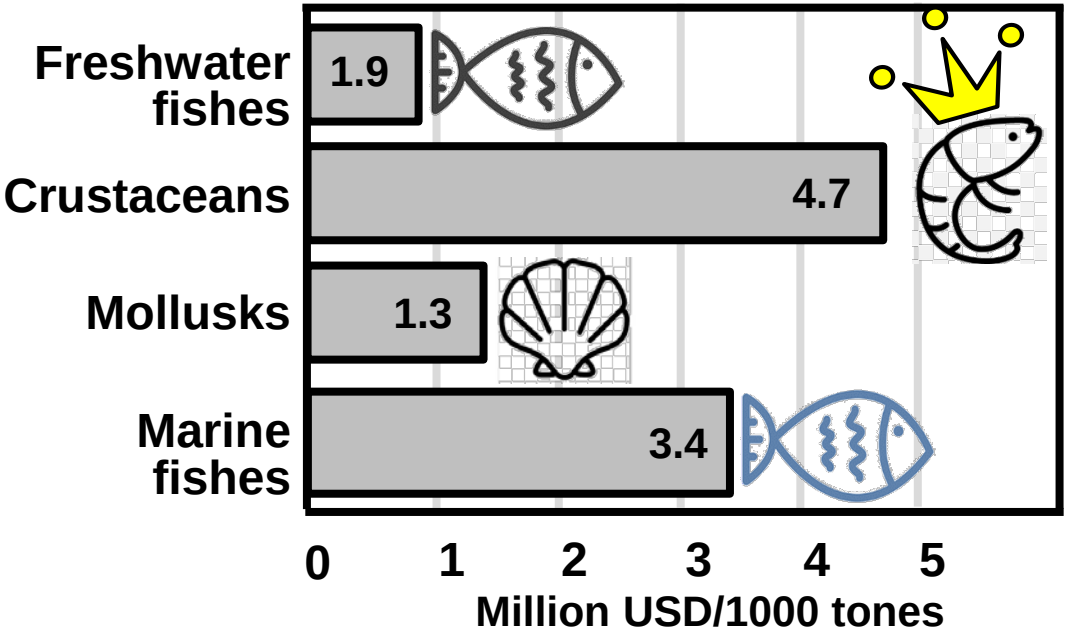
Resource: OECD and FAO

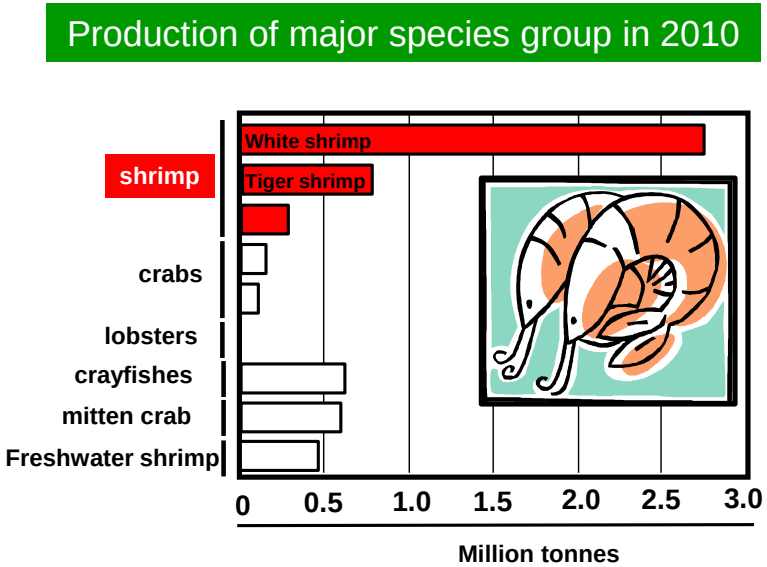
AQUACULTURE

The increasing role of aquaculture in global seafood production

Marine-water aquaculture production



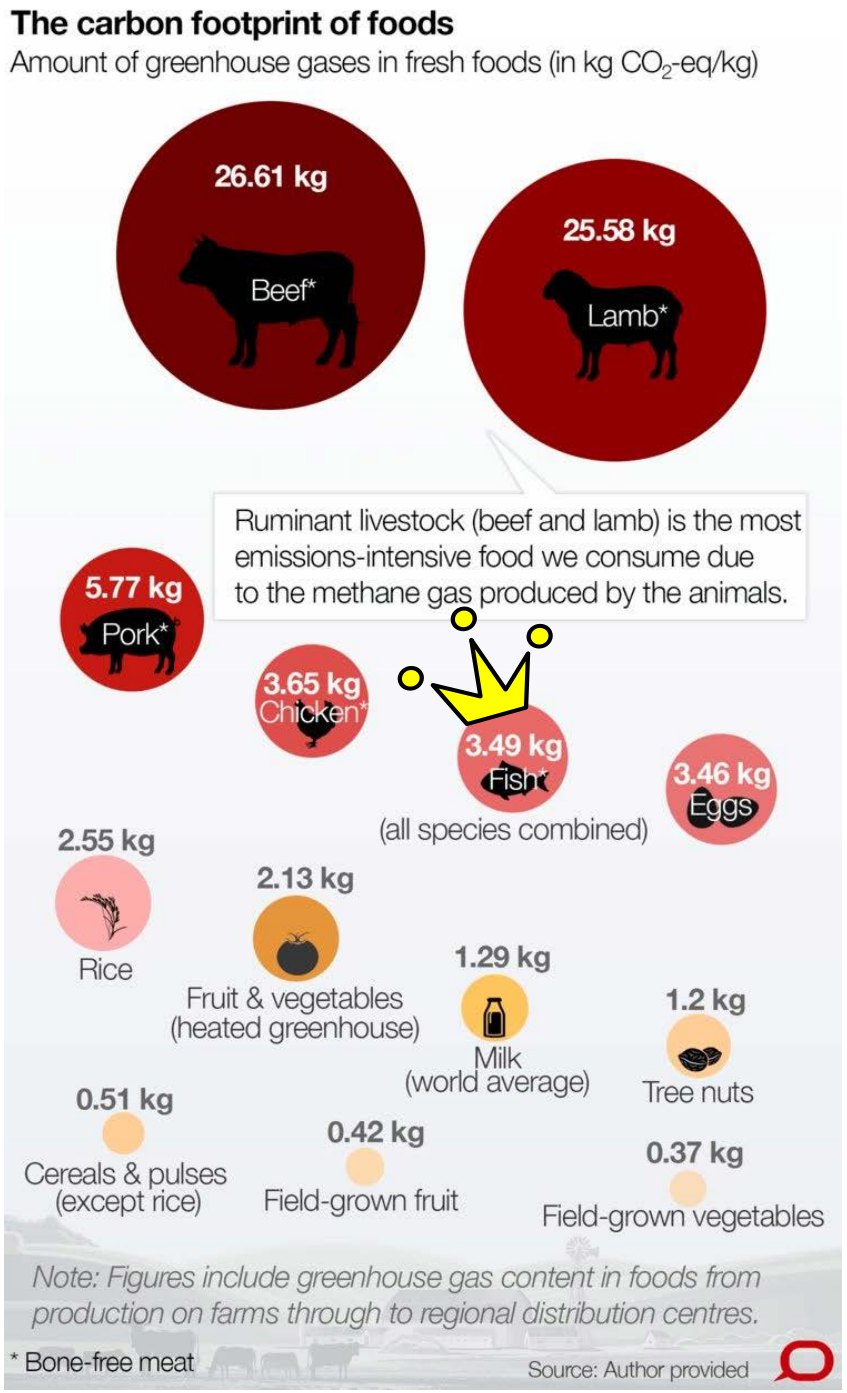




Resource: OECD and FAO

Carbon footprint

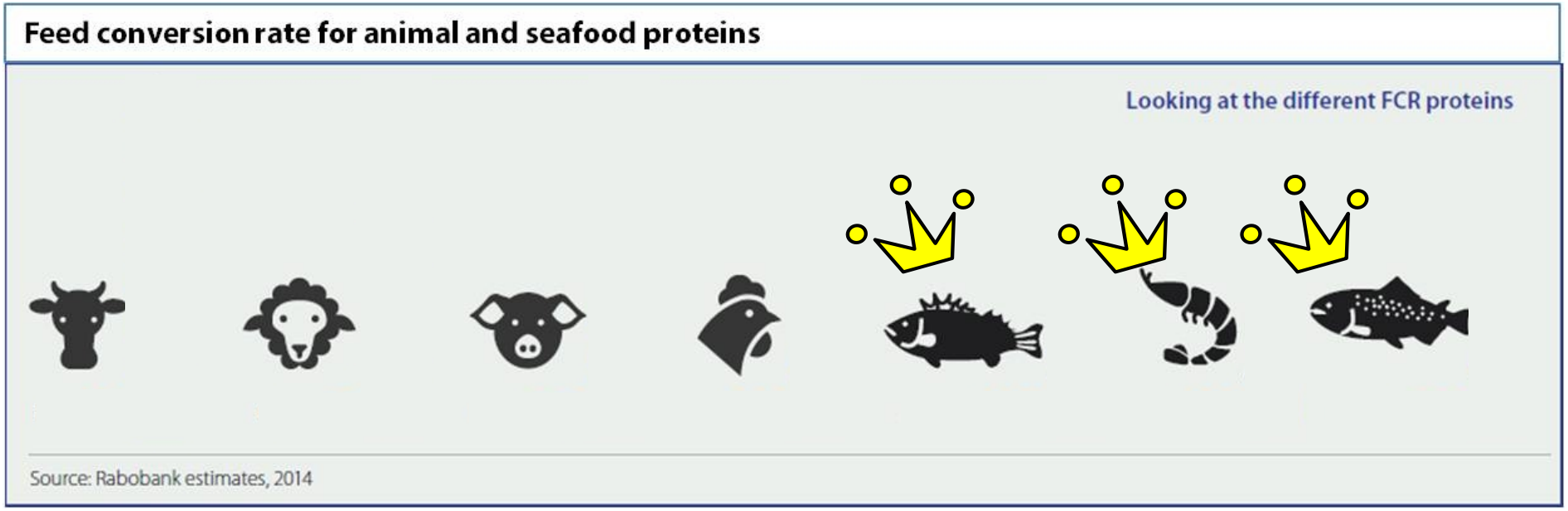
- **Amount of carbon dioxide (CO_2) emissions associated with all the activities of a product**
  - Reducing the carbon footprint of a product can help earth save energy



Resource: World Economic Forum

Feed conversion ratio

- Kgs of feed required to produce a kilogram of protein
  - A low FCR are considered efficient users of feed

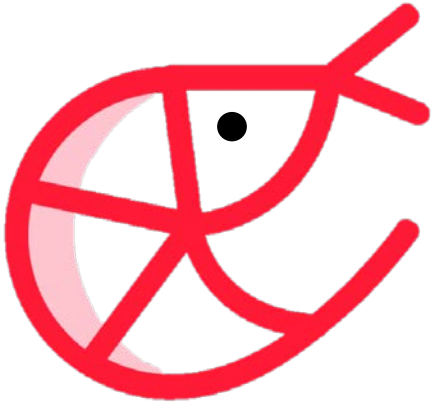


Resource: Rabobank estimates

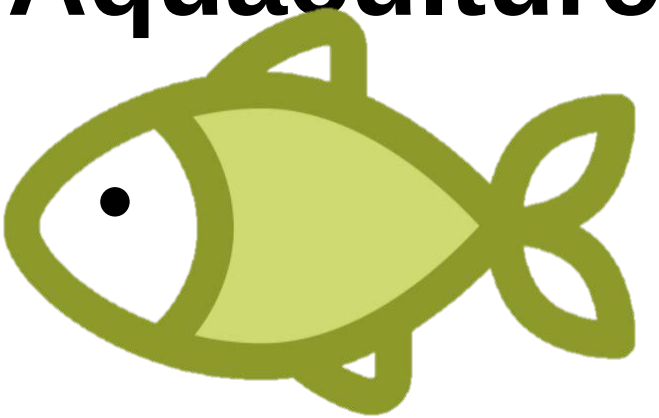
Managing in the next society: Beyond the information revolution

- **Author: Peter F. Drucker**

- Within the next fifty years fish farming may change us from hunters and gatherers on the seas into "**marine pastoralists**"-- just as a similar innovation some 10,000 years ago changed our ancestors from hunters and gatherers on the land into agriculturists and pastoralists



Problems Inherent to Aquaculture



https://pngtree.com/free-icon/

Climate change impact

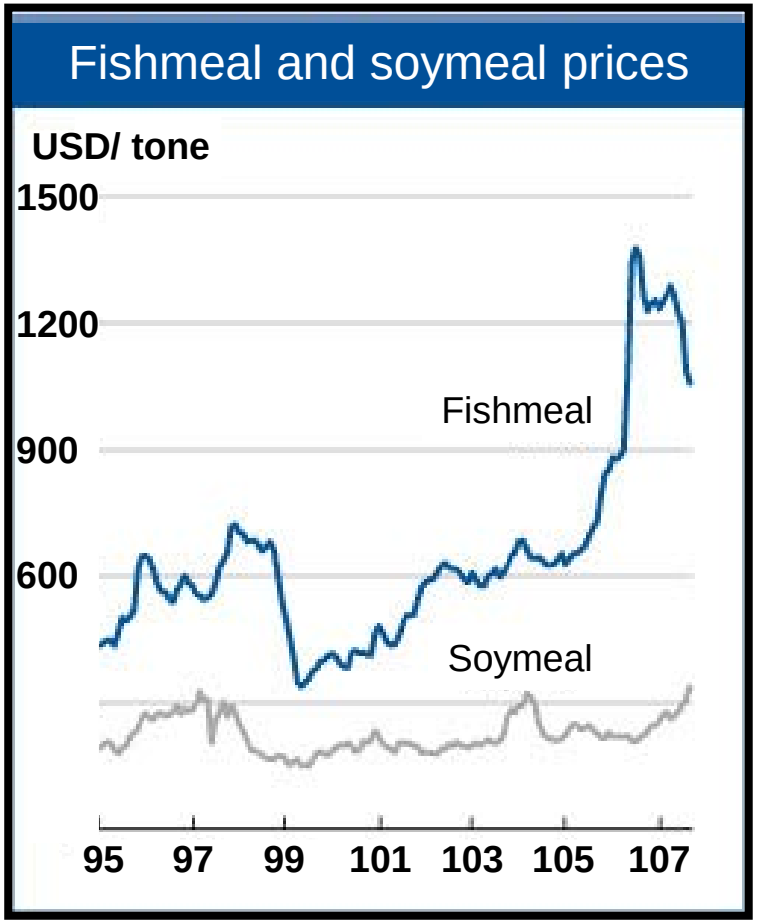
- **Biological and ecological responses to physical changes (e.g. productivity, species abundance, ecosystem stability, stock locations, pathogen levels and impacts)**

Extreme cold spell leaves ponds full of dead fish in Taiwan

Resource: FAO; TVBS; 聯合晚報

Resource use

- **Aquaculture**
  - **demand large volumes of fish meal**
  - **utilize large areas of land that might have vulnerable dependents**
- **A dilemma**
  - **Food comes from feed**
  - **The production of feed wastes more energy (or food)**



Resource: FAO

Genetics and biodiversity

- Aquaculture
  - Introduction of exotic species
  - Inter-breeding
  - Unintentional hybridization

Biosecurity

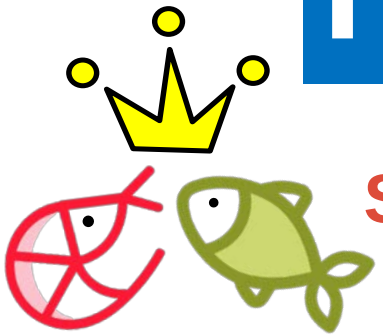
- Aquaculture
  - Introduction of pathogens
  - Increased resistance to antimicrobials

GOAL 2017 Survey
Issue & Challenges in Shrimp Aquaculture
All Countries

Environment

Feed

HQ animal



Sustainable Eco-Friendly Aquaculture

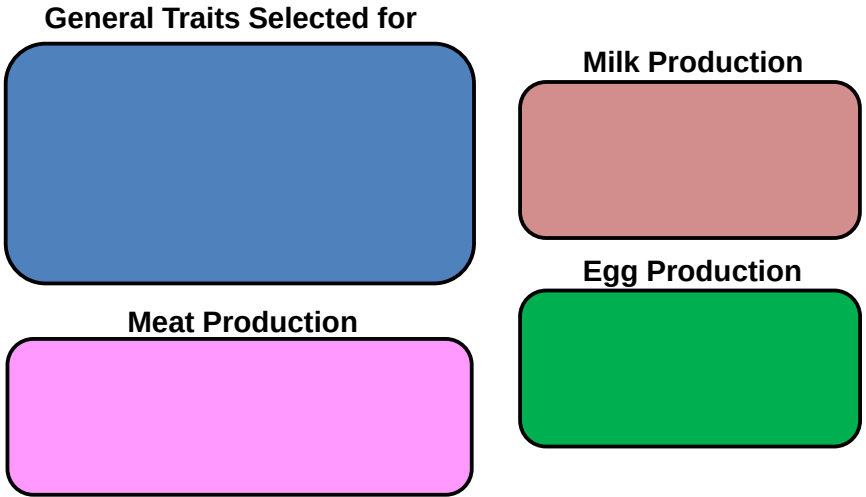
Disease

Production cost

Breeding program

- **Aim at**
  - generating genetic improvement in a population
  - defined breeding objectives for the production of a next generation of animals
- **Achievement**
  - has been successful across livestock sectors, increasing food production worldwide.

Traits for Livestock Improvement



Groen Kennisnet

Traditional breeding program

Time-consuming

- **Mankind started to create breeds accompanied with artificial selection 250 years ago**
- **The first family-based breeding program in aquaculture**
  - in 1975 for Atlantic salmon in Norway

Aquaculture

Groen Kennisnet

Managing in the next society: Beyond the information revolution

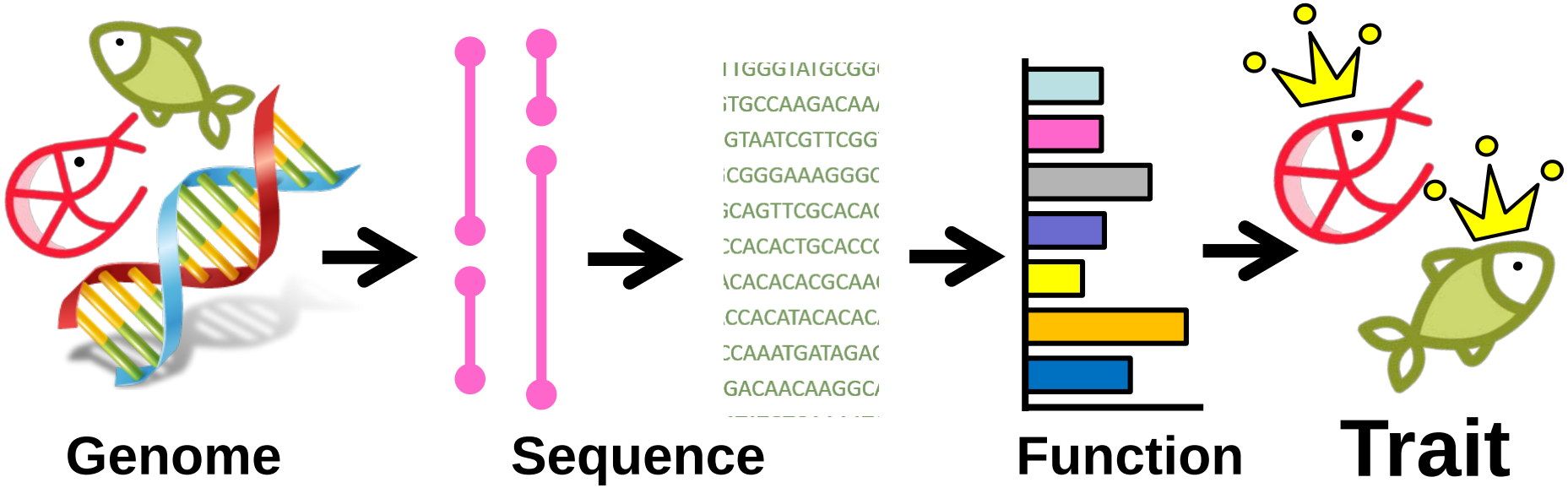
- Author: Peter F. Drucker

- At the same time, new and unexpected industries will no doubt emerge, and fast. One is already here: **biotechnology**. And another: **fish farming**.

Biotechnology
Fish farming

Genetic revolution

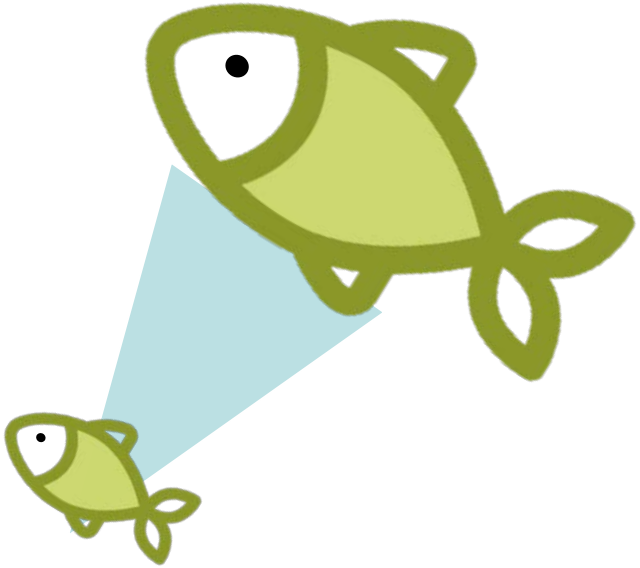
- **In today's new era of molecular biology**
  - the platforms such as next generation sequencing accelerate our progress in understanding the functions of genes
  - thereby allowing us to efficiently improve broodstock and to culture aquatic animals in shorter grow out cycles that save energy.



Genetically Modified Organisms and Aquaculture

- **Genetic modification**

Reverse genetics **Target**



- **Improve output/input ratios of aquatic animals (FAO)**
  - enhance growth and/or efficiency of food conversion
  - enhance commercially significant flesh characteristics
  - control reproductive activity and/or sexual phenotype
  - increase resistance of species to pathogens/parasites
  - increase tolerance to/of environmental variables such as temperature
  - modify behavior, e.g. aggression
  - control fertility and/or viability

Resource: FAO

Enhance growth and/or efficiency of food conversion

- **Normal Salmon**
- **AquAdvantage Salmon**

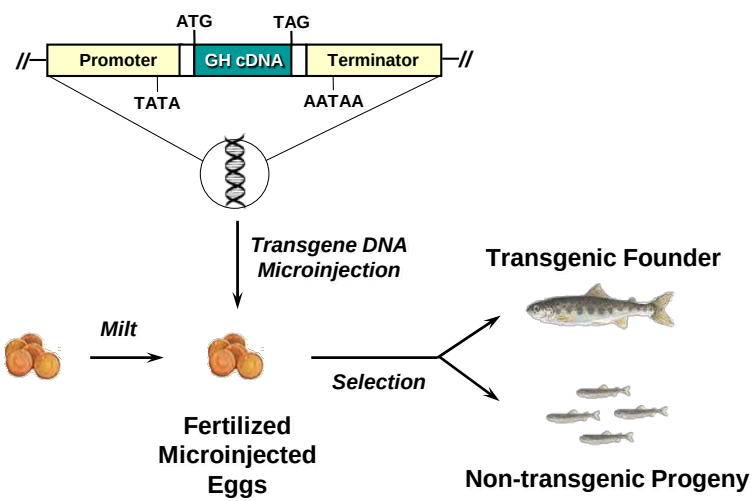
106年生物指考

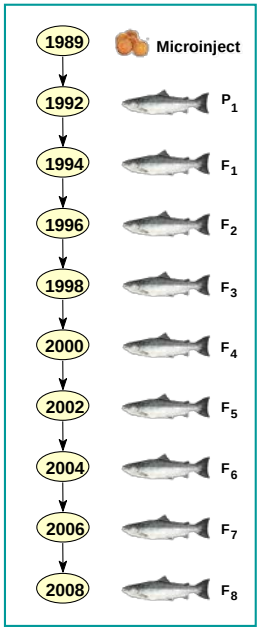
11-12為題組

美國聯邦食品藥物管理局於2015年核准通過一種經生物技術所產生的鮭魚上市，此類鮭魚產生的過程簡述如下：科學家在大西洋鮭中，加入了大洋鱈魚抗凍蛋白基因的啟動子及大鱗鮭魚的生長激素基因，利用大洋鱈魚的抗凍蛋白基因的啟動子來啟動大鱗鮭魚的生長激素基因。經過改良後的大西洋鮭，其生長速度加快。

11. 有關改良後所產生的大西洋鮭，下列敘述何者正確？
(A) 其體內來自於大洋鱈魚的抗凍蛋白會增加
(B) 此種基因編排的目的主要是增加鮭魚抗低溫能力
(C) 改良後的鮭魚會產生具有抗凍能力的生長激素
(D) 改良後的鮭魚長得快速是因為大鱗鮭魚生長激素所造成的結果

Regulatory sequences from ocean pout AFP gene & coding domain from chinook salmon GH-1 cDNA





AquaBounty TECHNOLOGIES

farmwars

Genetically modified salmon wins FDA approval

- From 1989
- In 2010
  - FDA announced that the salmon is safe to eat
- In 2012
  - A draft assessment released and found that it is unlikely to have any harmful impact on the environment.
- In 2015
  - A fast-growing salmon developed by AquaBounty Technologies today became the first genetically modified (GM) animal to win the blessing of the U.S. Food and Drug Administration (FDA)

ucn HOME PRICES SPECIES COMPANIES DOWNSTREAM UPSTRE

AquaBounty wins FDA approval to produce GM salmon in US facility

By Undercurrent News April 27, 2018 17:12 BST

FDA approves first genetically engineered salmon farm in US

Seth Slabaugh | Star Press | April 30, 2018

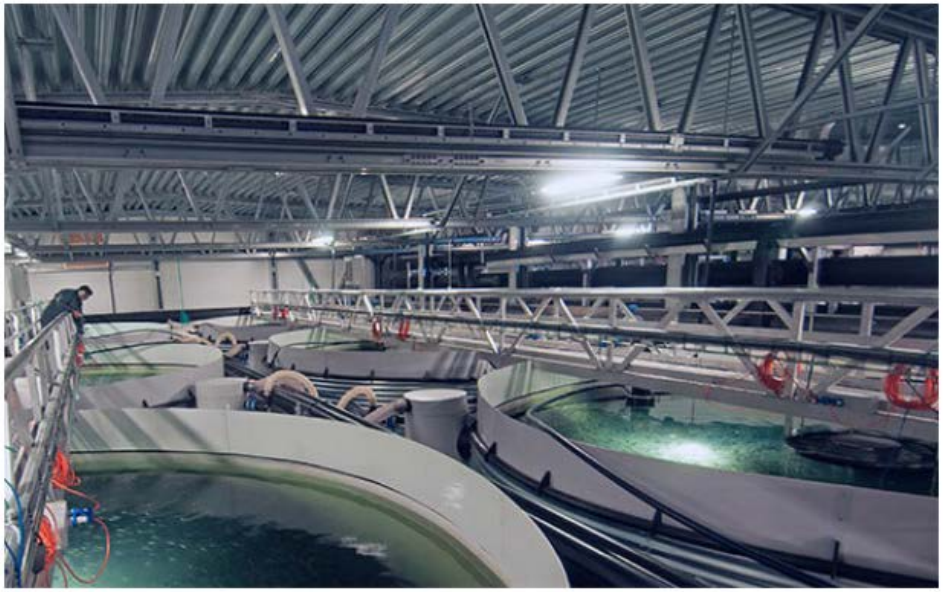
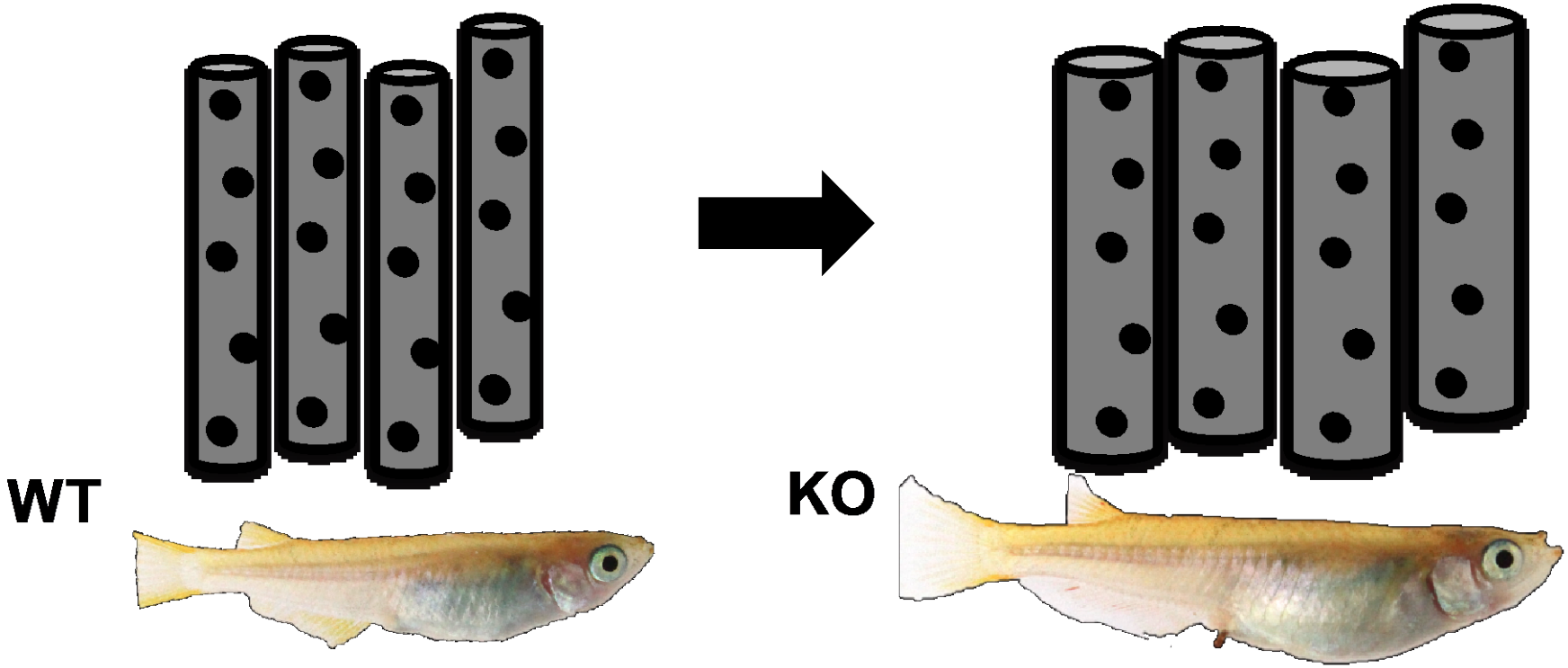


Image credit: AquaBounty Technologies

- AquaBounty, which received FDA approval to sell its salmon in the US in 2015, produces eggs in Canada and has a production facility in Canada.
- Controversial genetically engineered (GE) salmon pioneer AquaBounty Technologies has won Food and Drug Administration (FDA) approval to produce its fish in an Indiana facility

https://www.undercurrentnews.com/2018/04/27/aquabounty-wins-fda-approval-to-produce-gm-salmon-in-us-facility/

Except Genetic modification….



Myostatin in higher vertebrate

- **Name:**

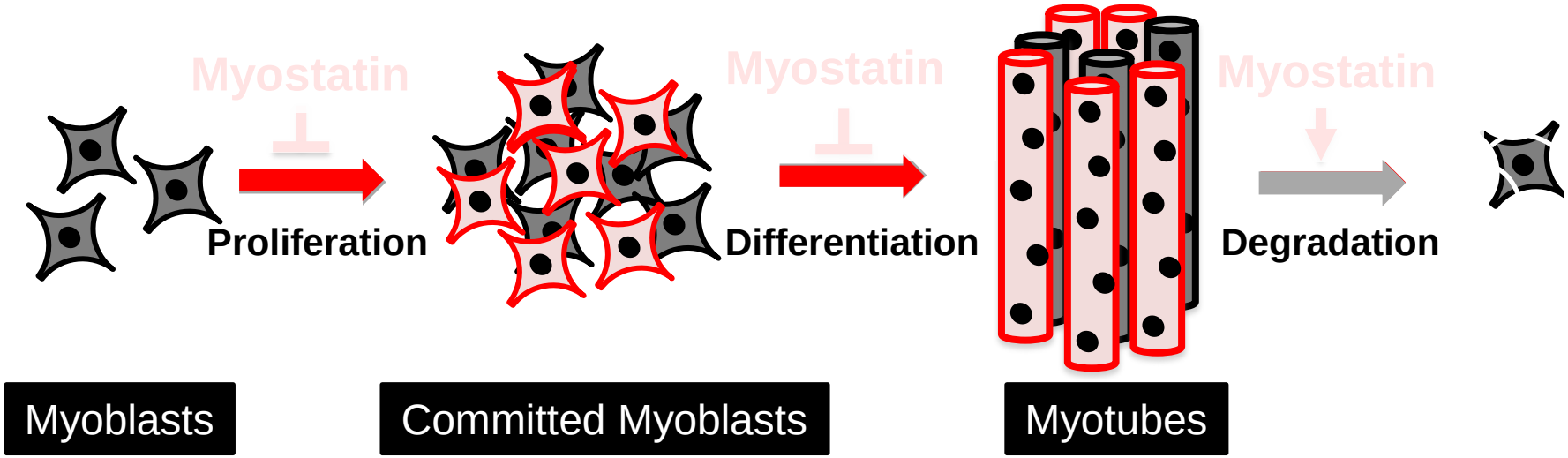
  myostatin, The Growth Differentiation Factor-8

- **Protein type:**

  Transforming Growth Factor beta superfamily

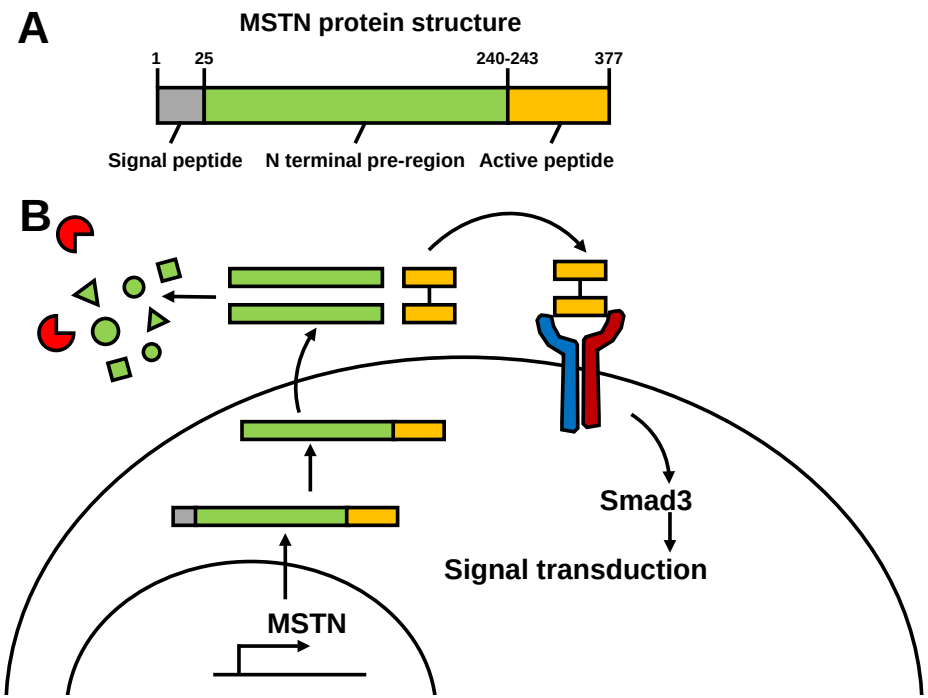
- **Function:**

  A negative regulator of skeletal muscle mass



Double-muscled cattle, Belgian Blue

- **The Belgian Blue myostatin sequence**
  - **contains an 11-nucleotide deletion in the third exon**
  - **causes a frameshift**
  - **eliminates virtually all of the mature, active region of the molecule.**



Resource: McPherron *et al*., 1997;農業生技產業季刊 新興生技 2016 NO.45 5

Myostatin in higher vertebrate

Myostatin

Teleost fish mstn gene **2001**

1807 “Doubled-muscled” phenotype

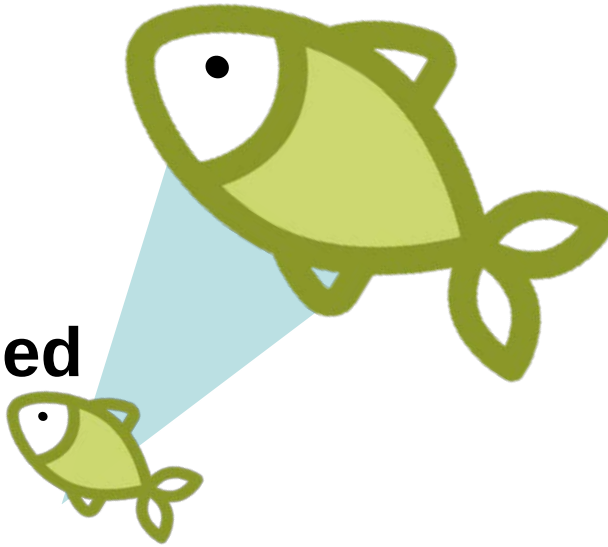
Belgian blue and Piedmontaise cattle

1997 mstn knock-out mice

2004 muscle hypertrophy child

2007 mstn mutant dog

Enhance growth and/or efficiency of food conversion

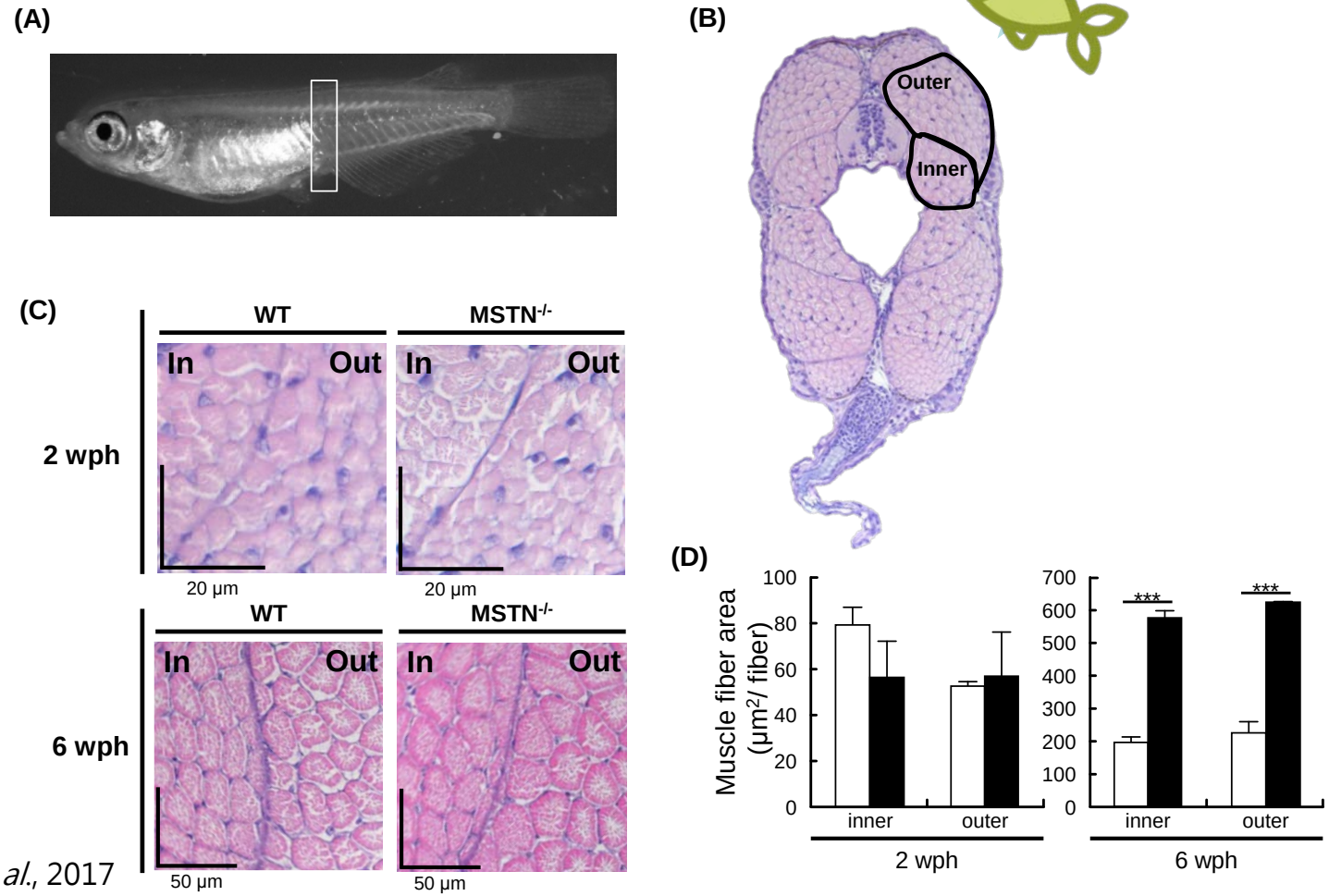


- Immuno-depletion and functional feed
- Gene editing

Resource: 農業生技產業季刊 新興生技 2016 NO.45 5

Enhance growth and/or efficiency of food conversion –Genome editing

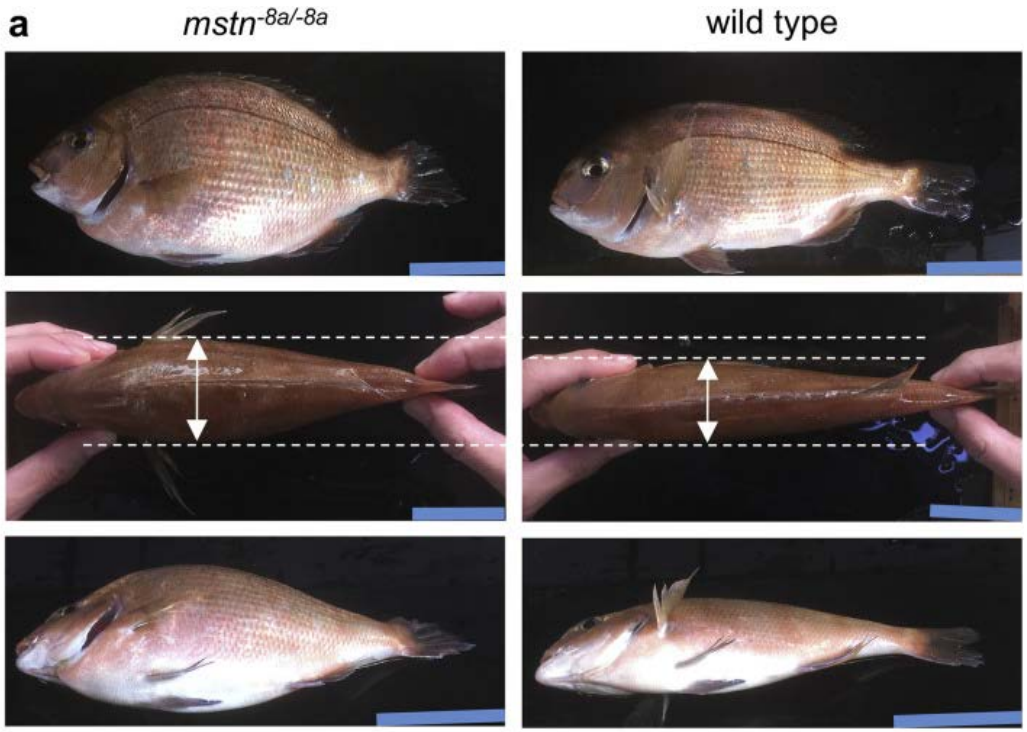
- CRISPR/Cas9-mediated MSTN mutation in MSTN-/- F4 fish caused muscle hypertrophy, not hyperplasia

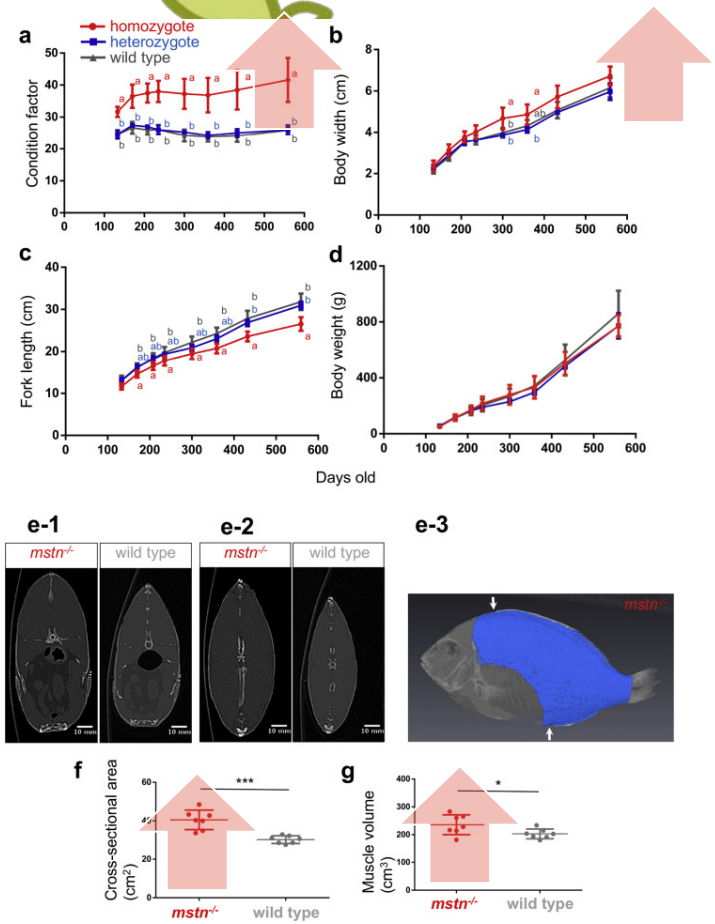


Resource: Yeh *et al.*, 2017

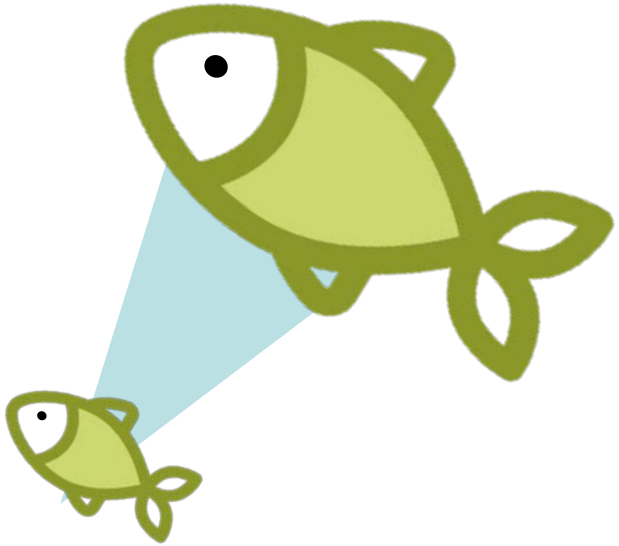
Enhance growth and/or efficiency of food conversion –Genome editing

- Production of a breed of red sea bream *Pagrus major* with an increase of skeletal muscle mass and reduced body length by genome editing with CRISPR/Cas9





Resource: Kishimoto *et al*., 2018.

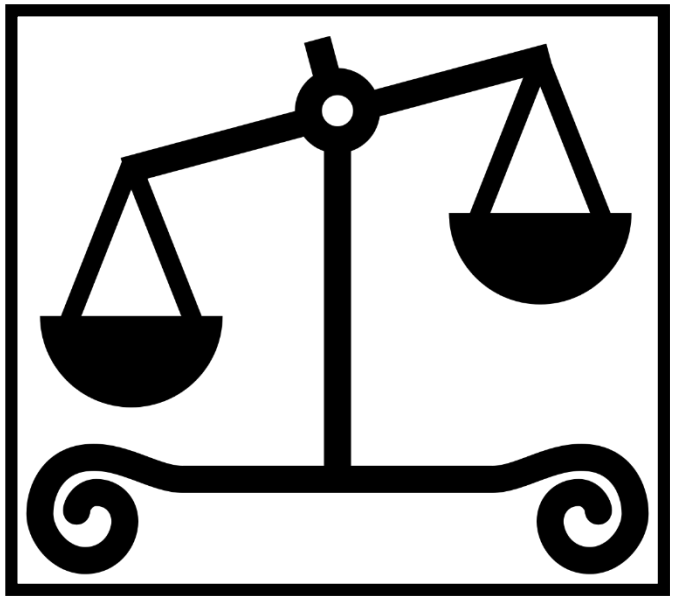


Genome editing technology

- The shortened period to generate beneficial aquatic breeds will contribute to
  - the development of aquaculture,
    - cost-saving
    - improvement in productivity
    - ultimately resolution of the global food sustainability.

Resource: Kishimoto *et al*., 2018.

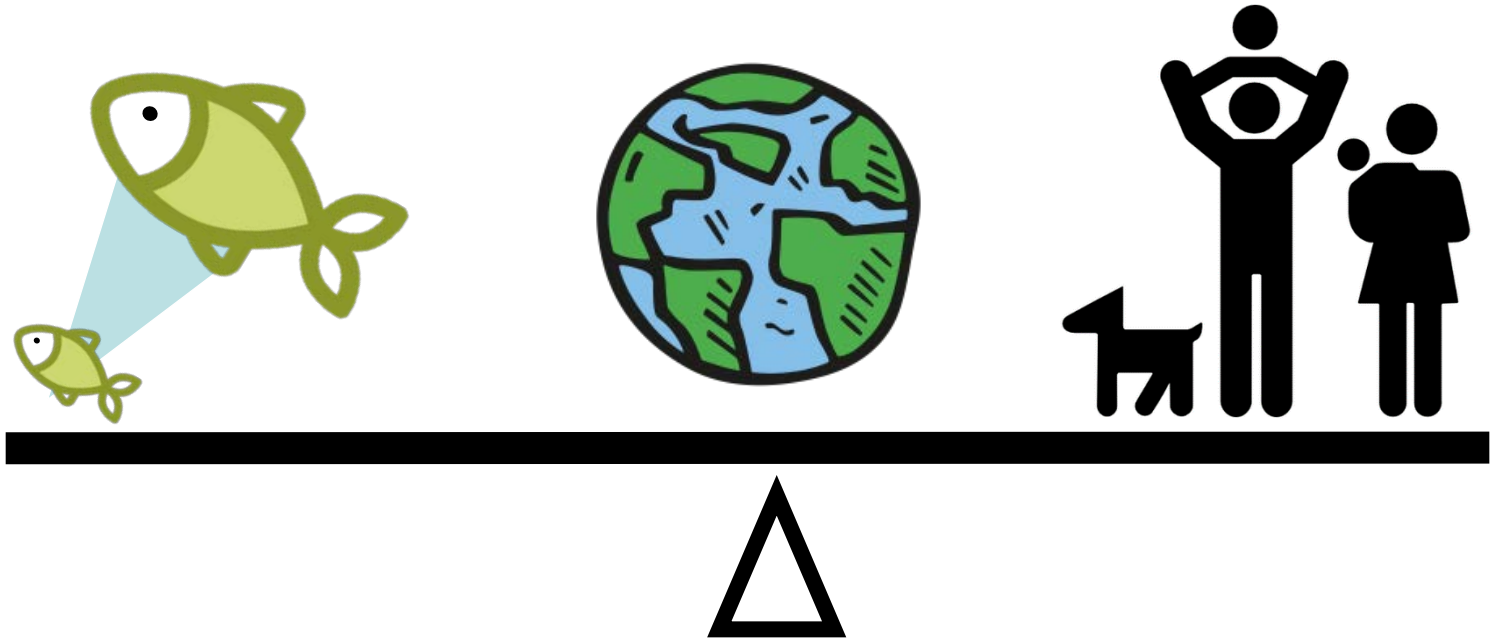
Trade-off



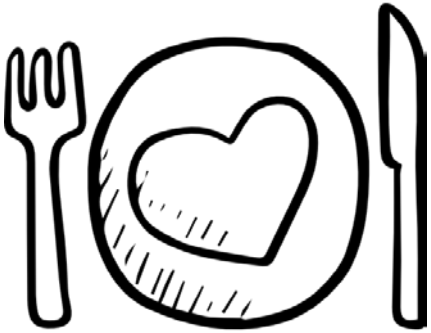
- **a fundamental concept**
  - in the course of an organism's life history
    - it needs to allocate resources between competing physiological processes
    - attempt to optimize the trade-off between various fitness-enhancing traits.
- **a trade-off exists**
  - when one trait cannot increase without a decrease in another (or vice versa)

Food we need and Food we want

A long-term evaluation of the interactions between animal traits and the environment is still important and necessary



What will be served in 20 years' time?



Thank you for your attention