



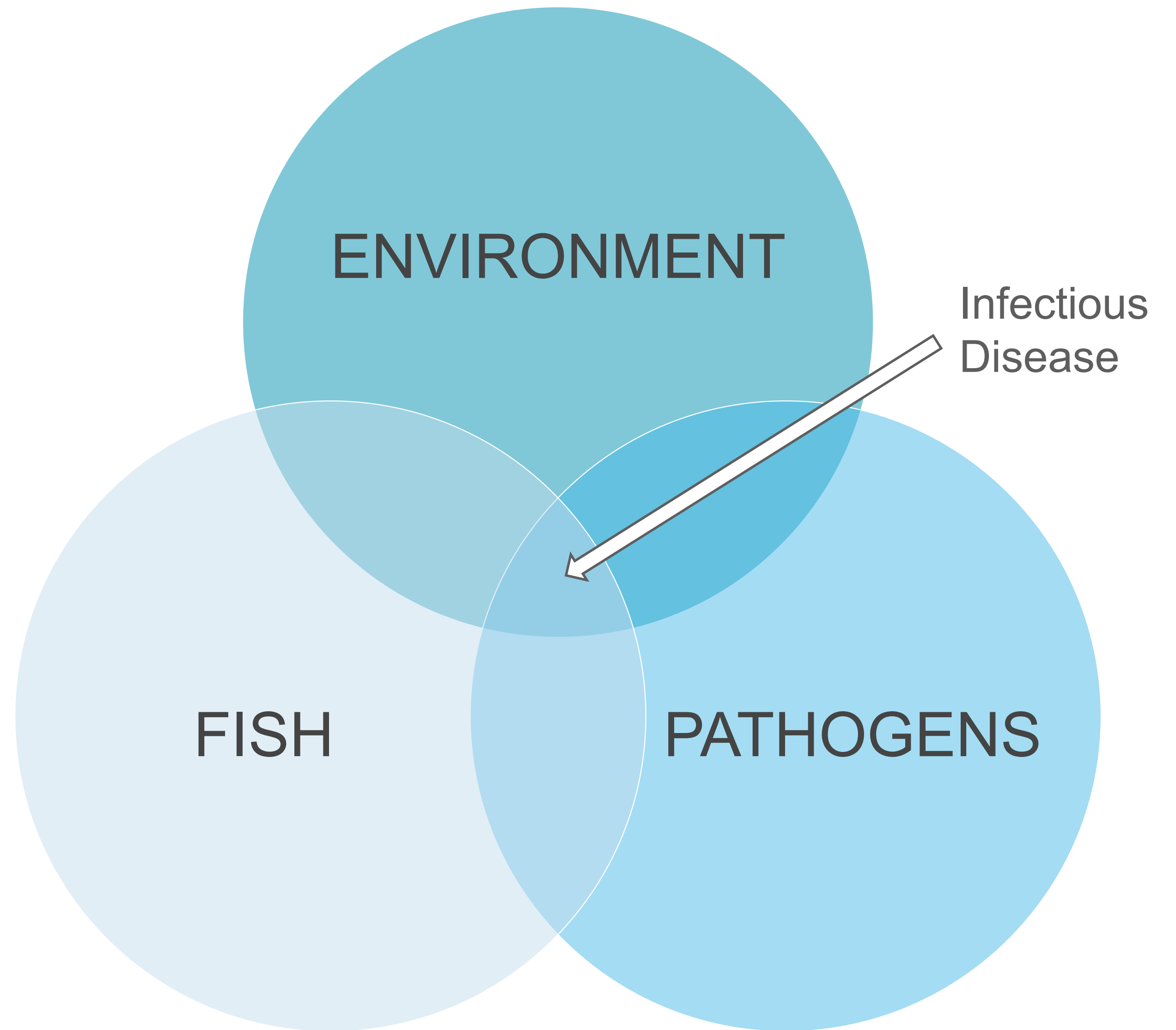
Stop blaming bugs

The broken biology of salmon and root causes of poor performance

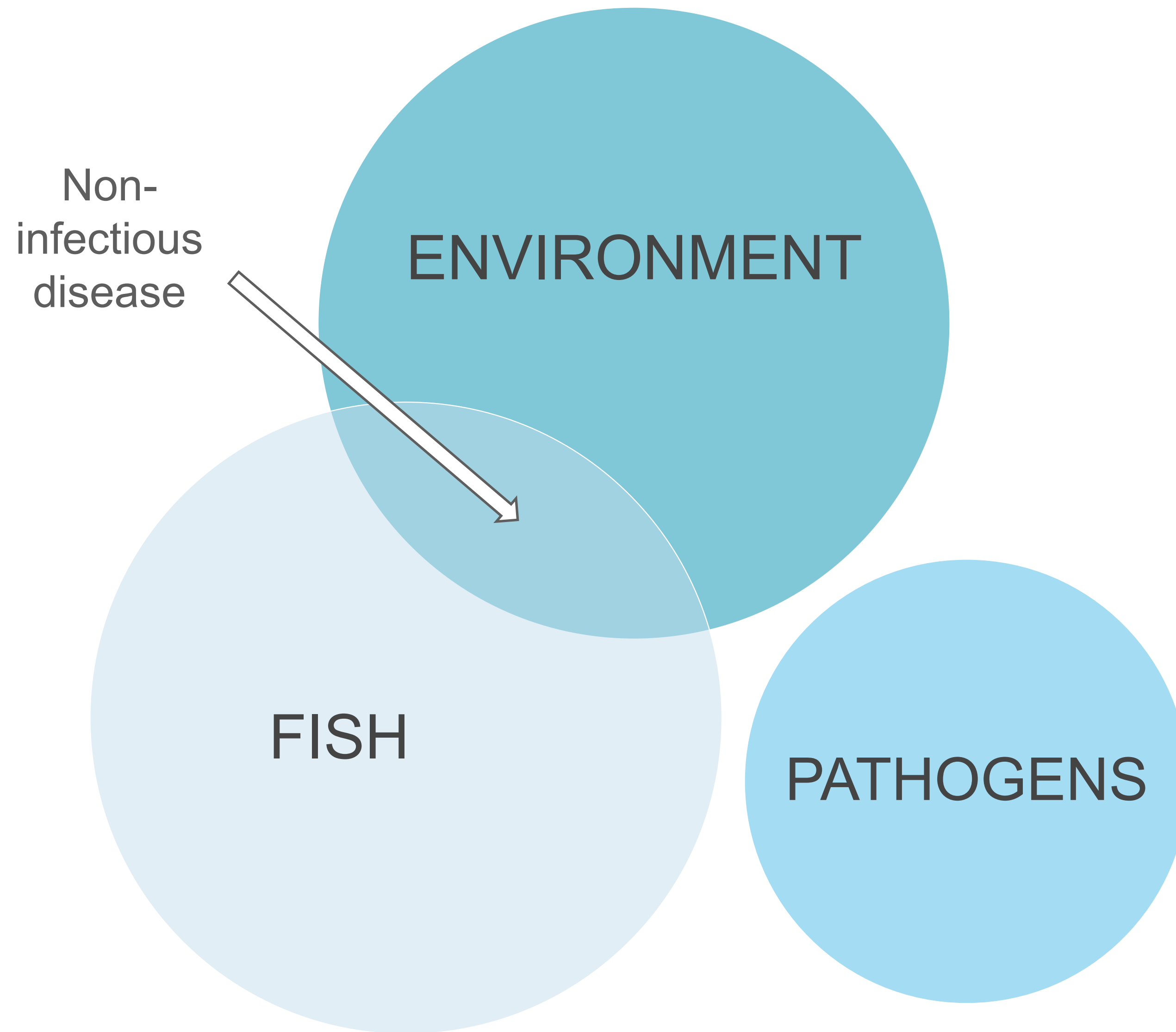
Jesse Trushenski / Lofotseminaret / 10-12 June 2026 / Henningsvær



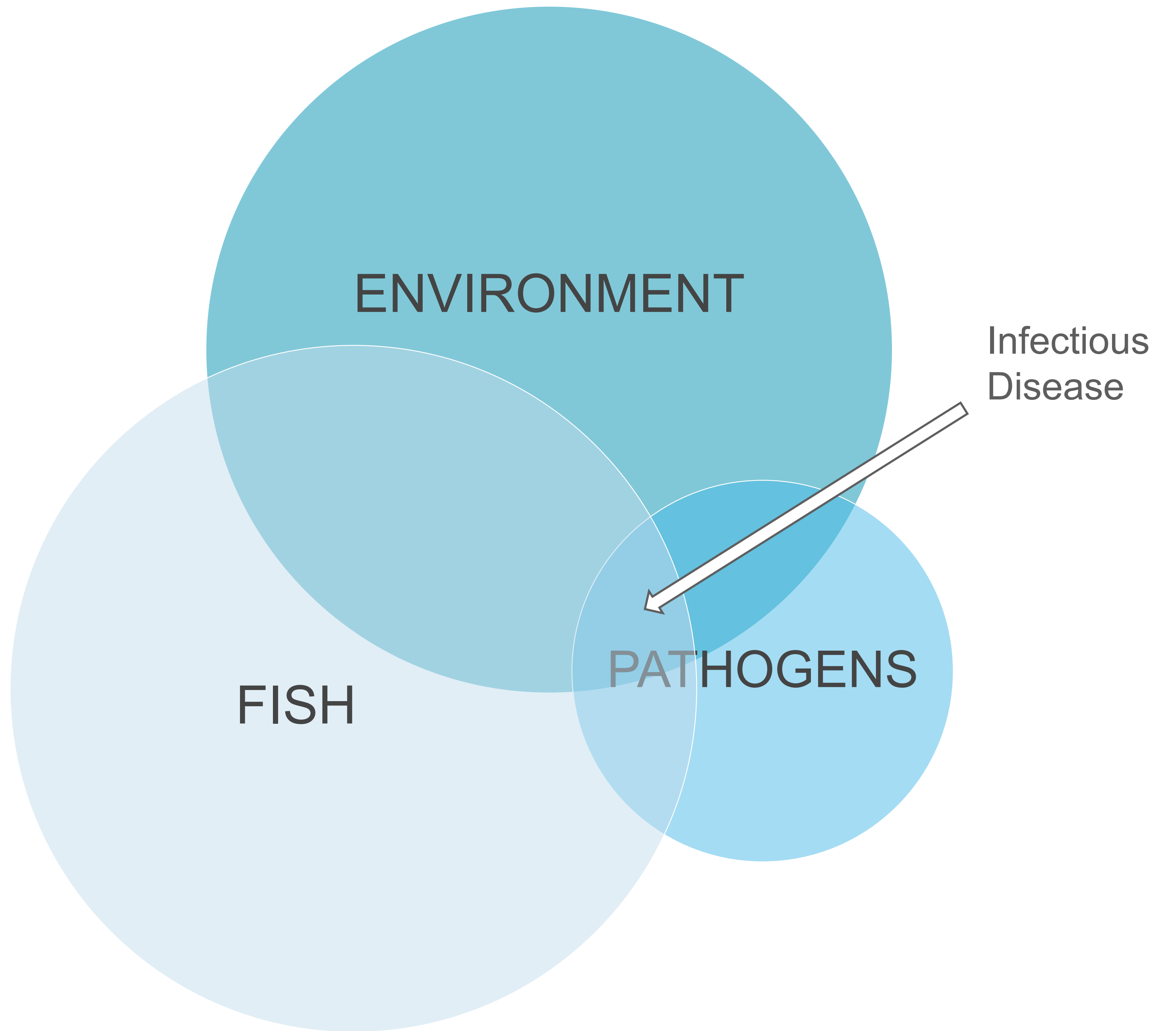
Presence of a pathogen does not necessarily mean a fish is diseased



Absence of pathogens does not necessarily mean a fish is healthy

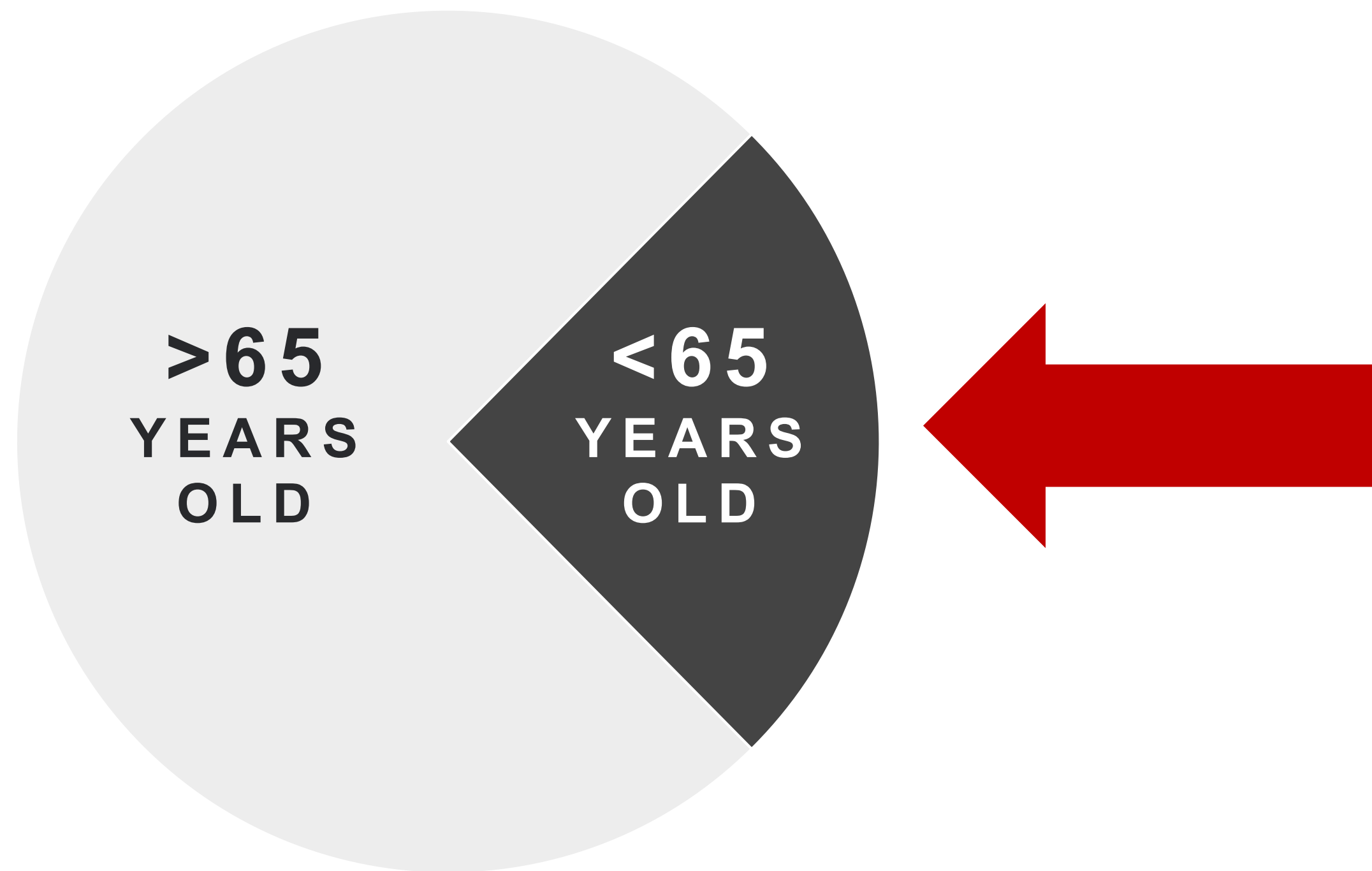


Infectious disease is more likely in compromised fish and environments



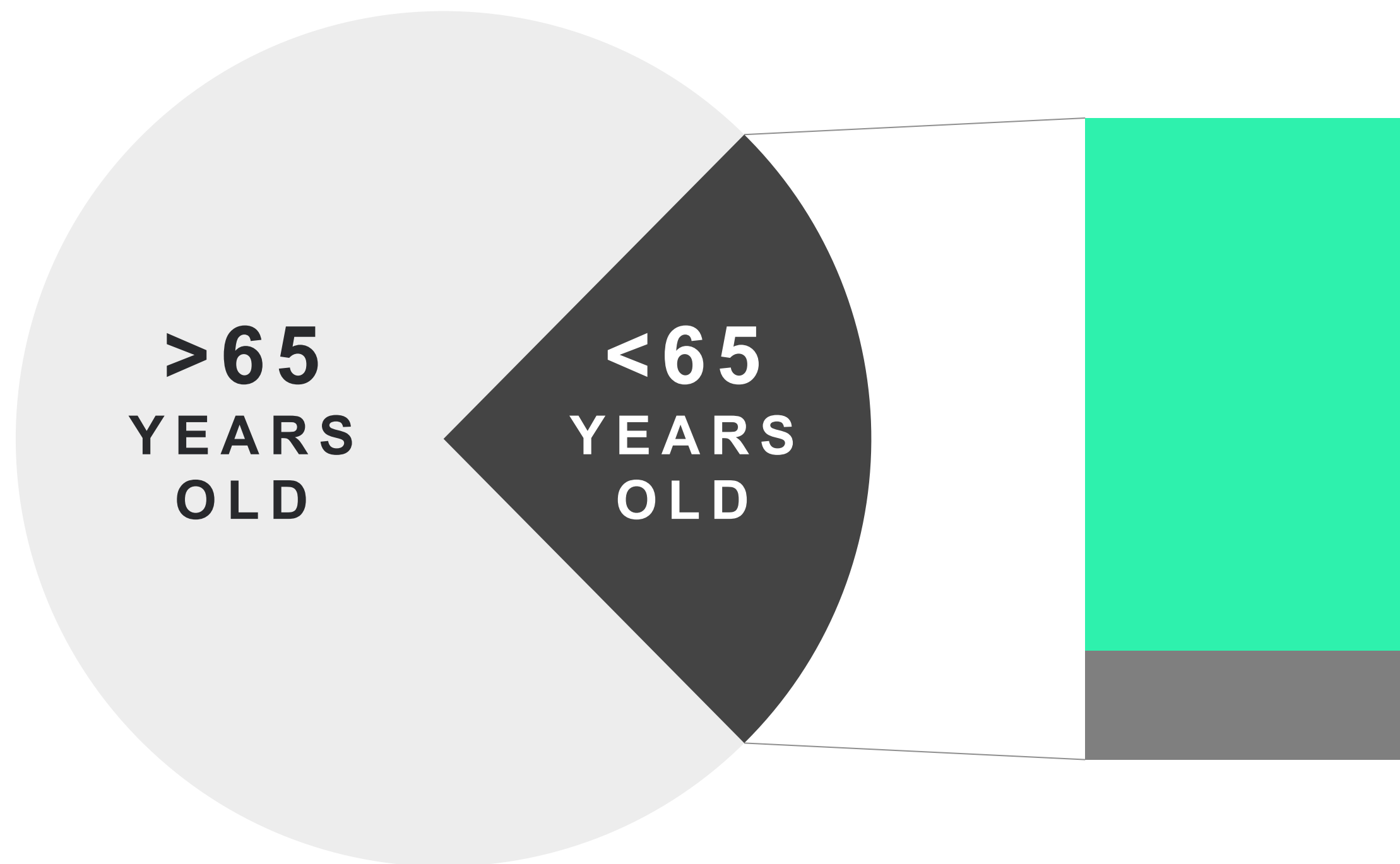
Overall health determines infectious disease outcomes

2020 COVID DEATHS



Overall health determines infectious disease outcomes

2020 COVID DEATHS



Cardiovascular disease	60%
Diabetes	50%
Kidney disease or failure	30%
Obesity	20%
Lung disease	20%
No underlying health conditions	



Fiskehelse rapporten

2025



Ichthyobodo-parasitter (Coxia) og blodceller på en laksegjelle (forstørret 12 000 ganger). Bildet er tatt med elektronmikroskop og fargelagt. Foto: Jannicke Wilk-Nielsen, Veterinærinstituttet

Level 1	2024*
Infectious diseases (A)	28.1%
Environmental impacts (B)	4.3%
Injuries (trauma) (C)	33.5%
Physiological causes (D)	4.7%
Other causes (E)	2.0%
Unknown cause (F)	27.4%
Total	100 %

ULCERS/WOUNDS

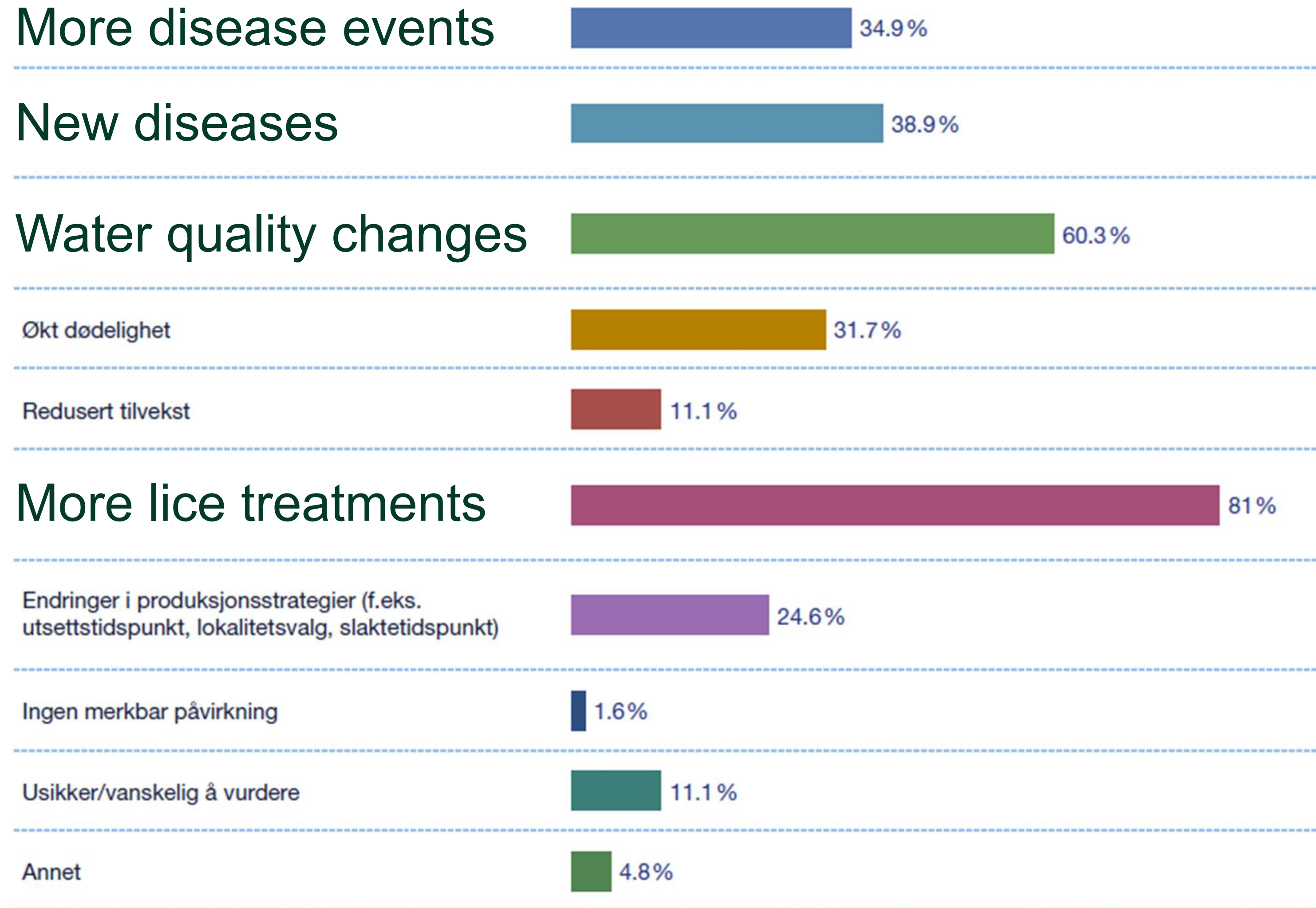
HANDLING

LOSER SYNDROME



Climate change
is affecting fish
health and
welfare...

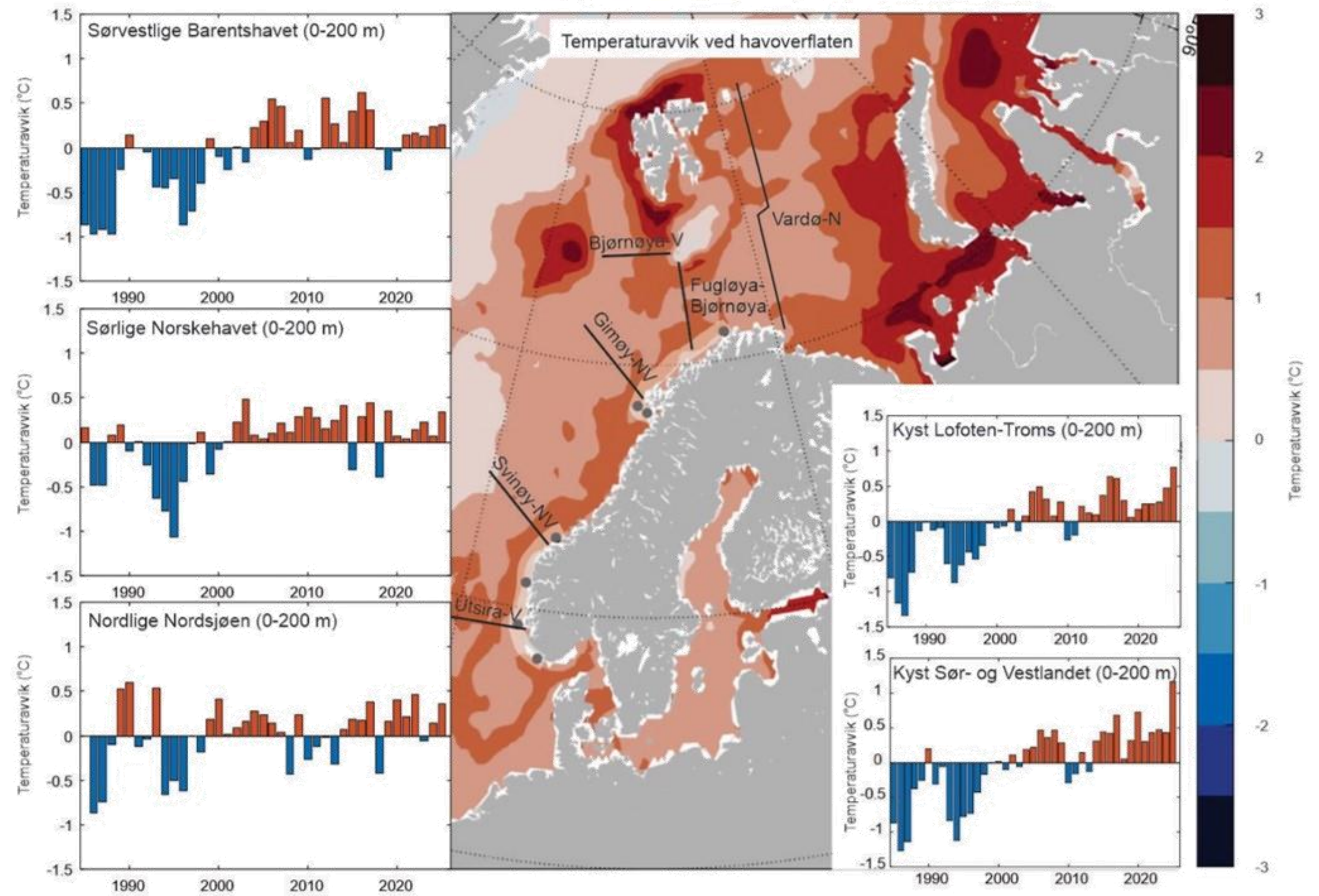
But how much?



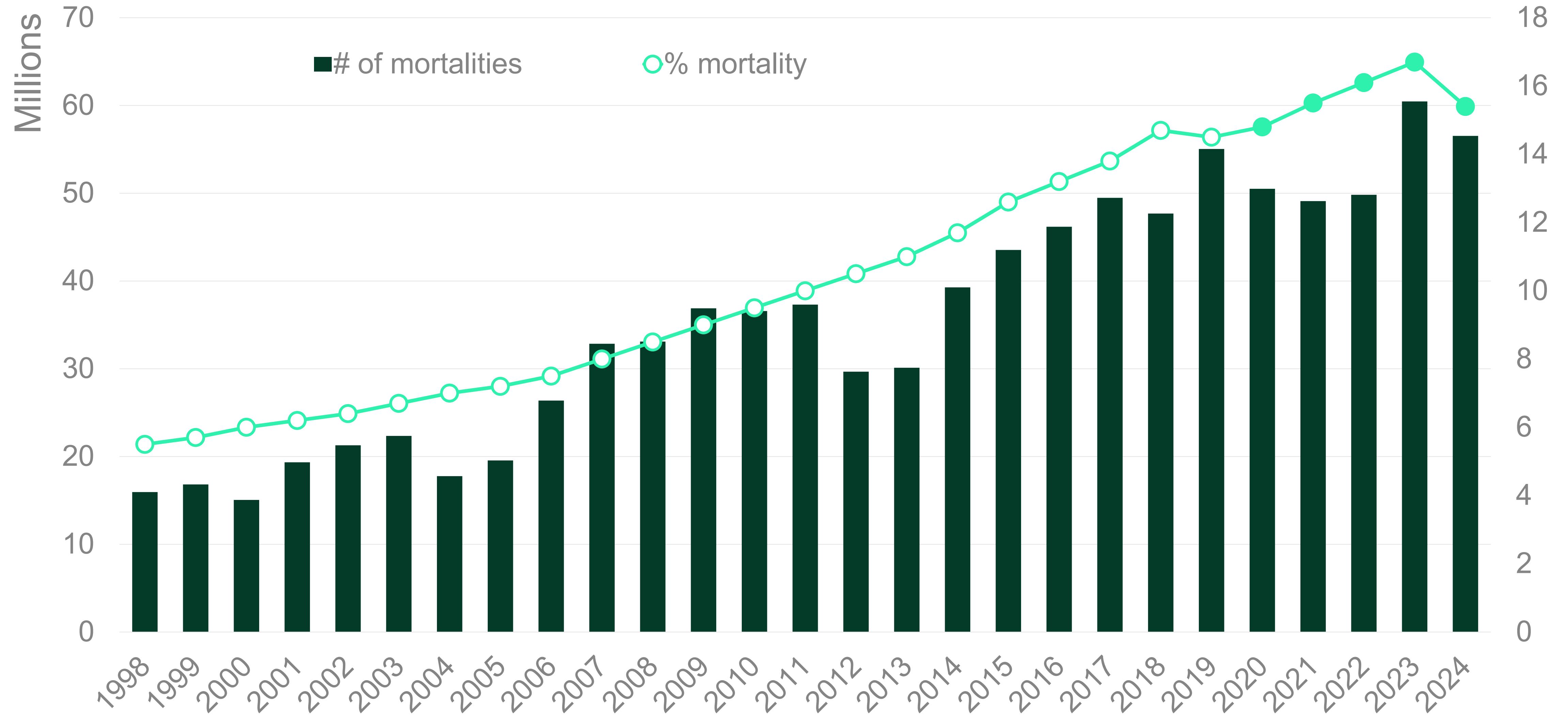
Fiskehelse rapporten 2025, Veterinærinstituttet



Seawater temperature has increased by less than 0.5°C in most regions



Salmon Mortality at Sea

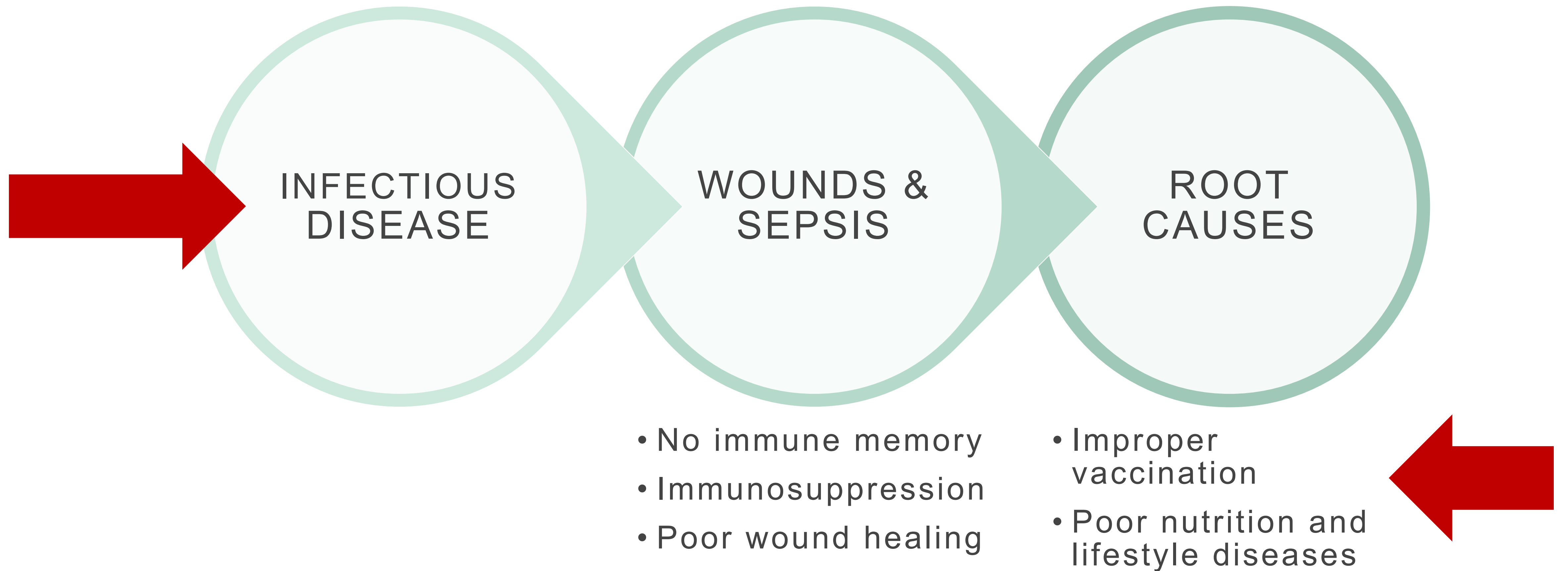


When
you hear
hoofbeats...

Think horses,
not zebras



Root causes of mortality



What is the proper timing for vaccination?



**PATHOGENS
IN RIVERS**

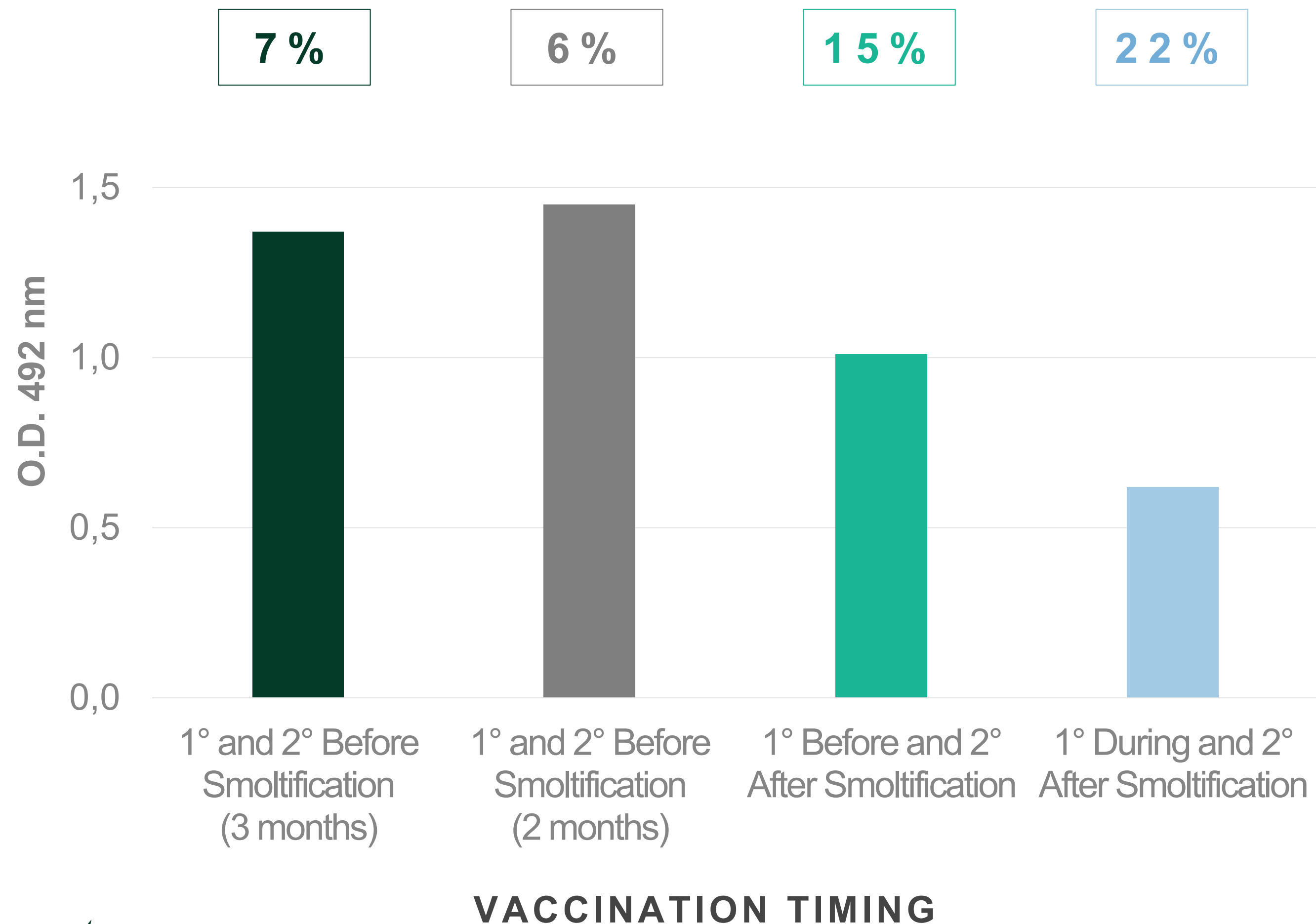


**PATHOGENS
IN THE SEA**



Vaccination during smoltification is less protective

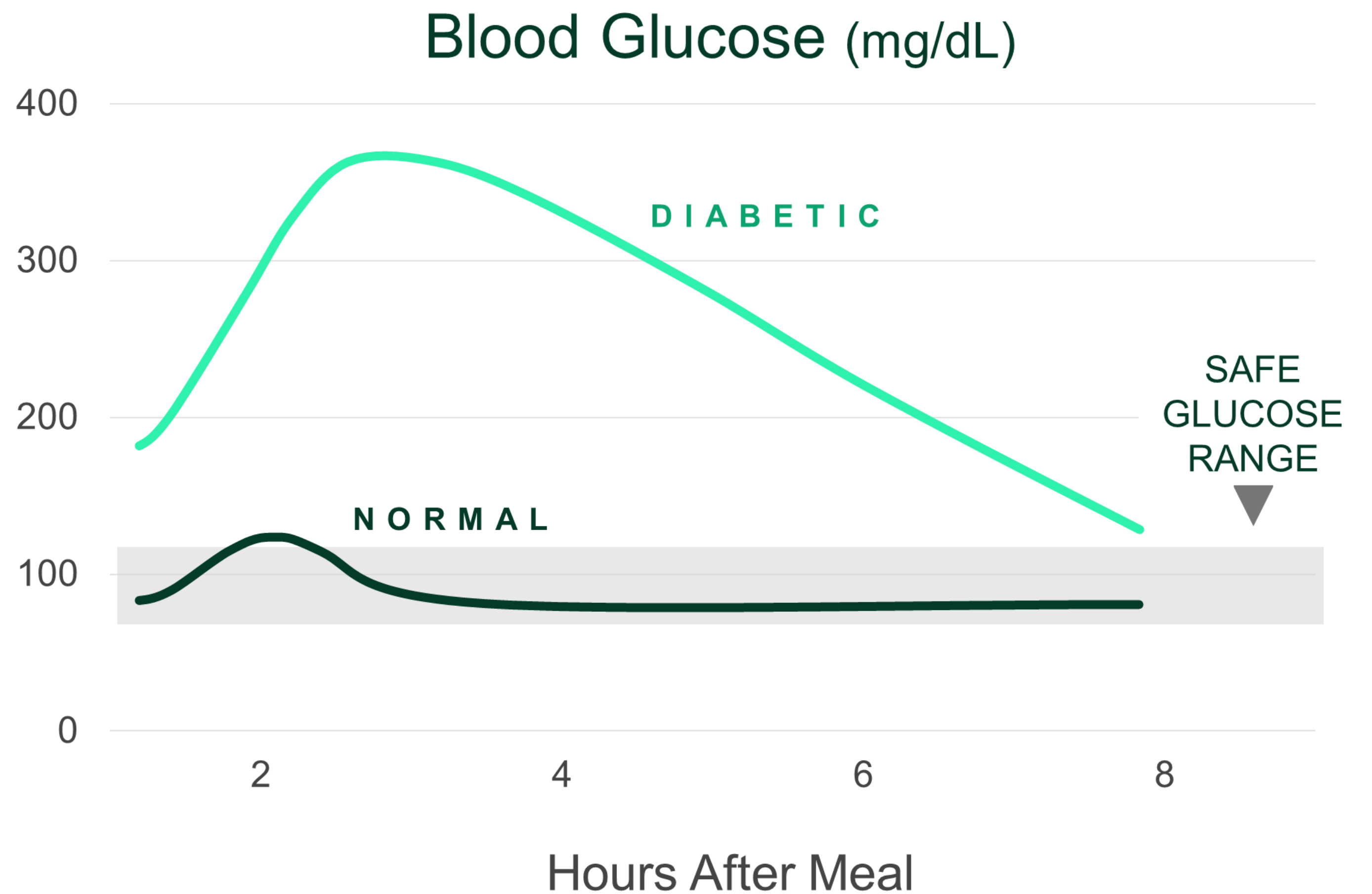
Vibrio salmonicida CHALLENGE MORTALITY



“...the smolting and seawater transfer period were an **unfavorable time** for vaccination of salmon...”

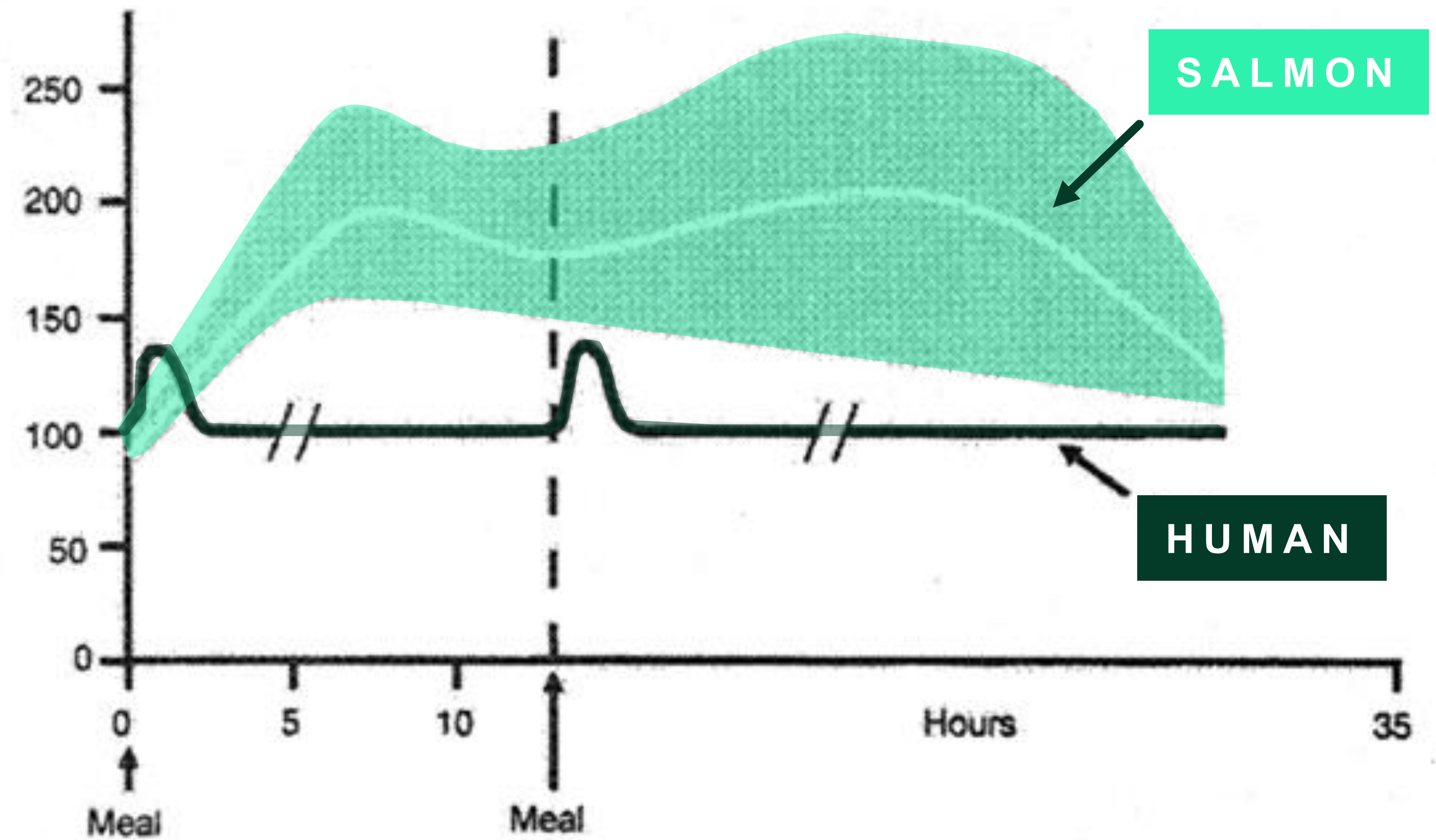


What about poor nutrition and lifestyle disease?



What about poor nutrition and lifestyle disease?

Blood Glucose (mg/dL)

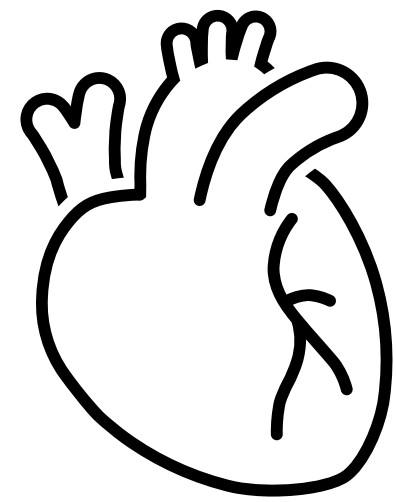


SALMON

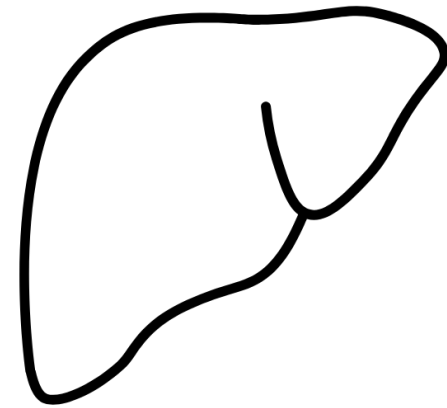
HUMAN



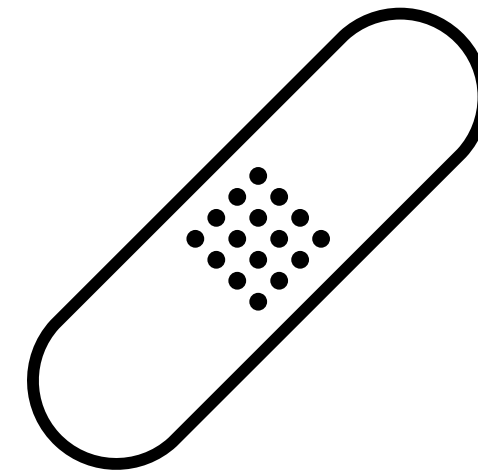
Complications of unmanaged diabetes



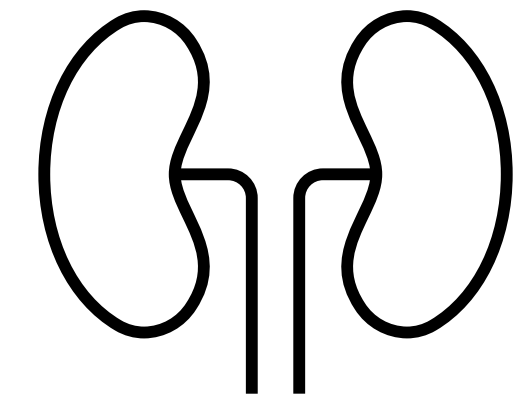
**HEART &
CIRCULATORY
PROBLEMS**



**LIVER
DISEASE**



**INJURIES &
SLOW WOUND
HEALING**



**KIDNEY
DISEASE**



RISK OF INFECTIOUS DISEASE IS MUCH GREATER FOR DIABETICS



Diabetics are...

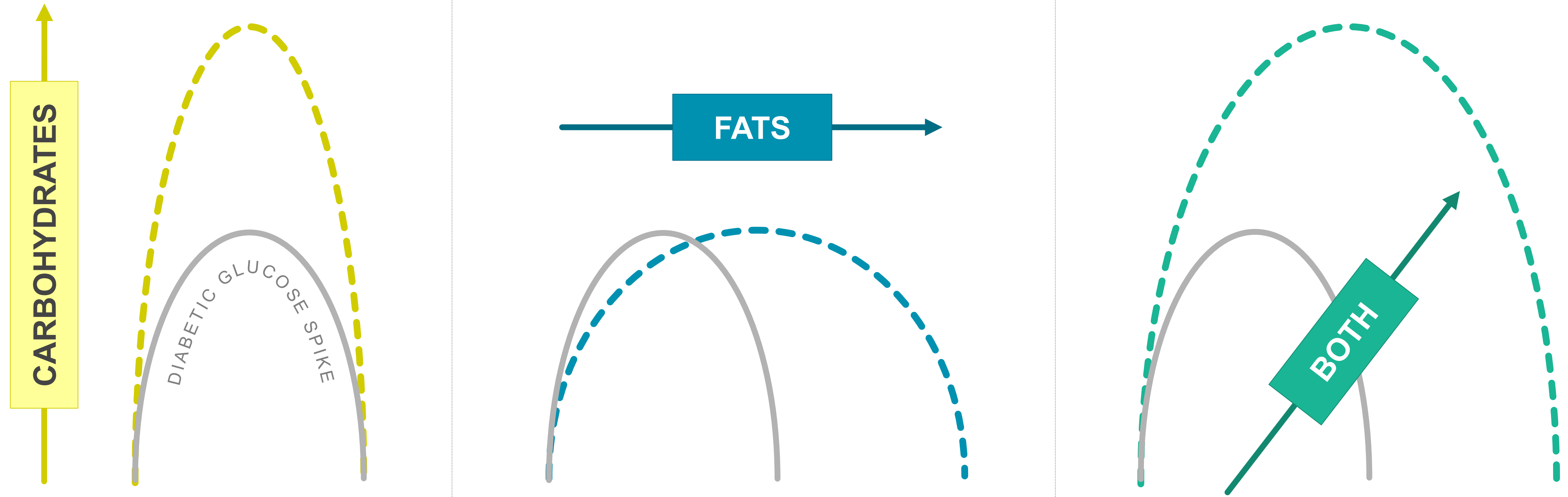
4× more likely to be **hospitalized**

8× more likely to **die**

...because of infections



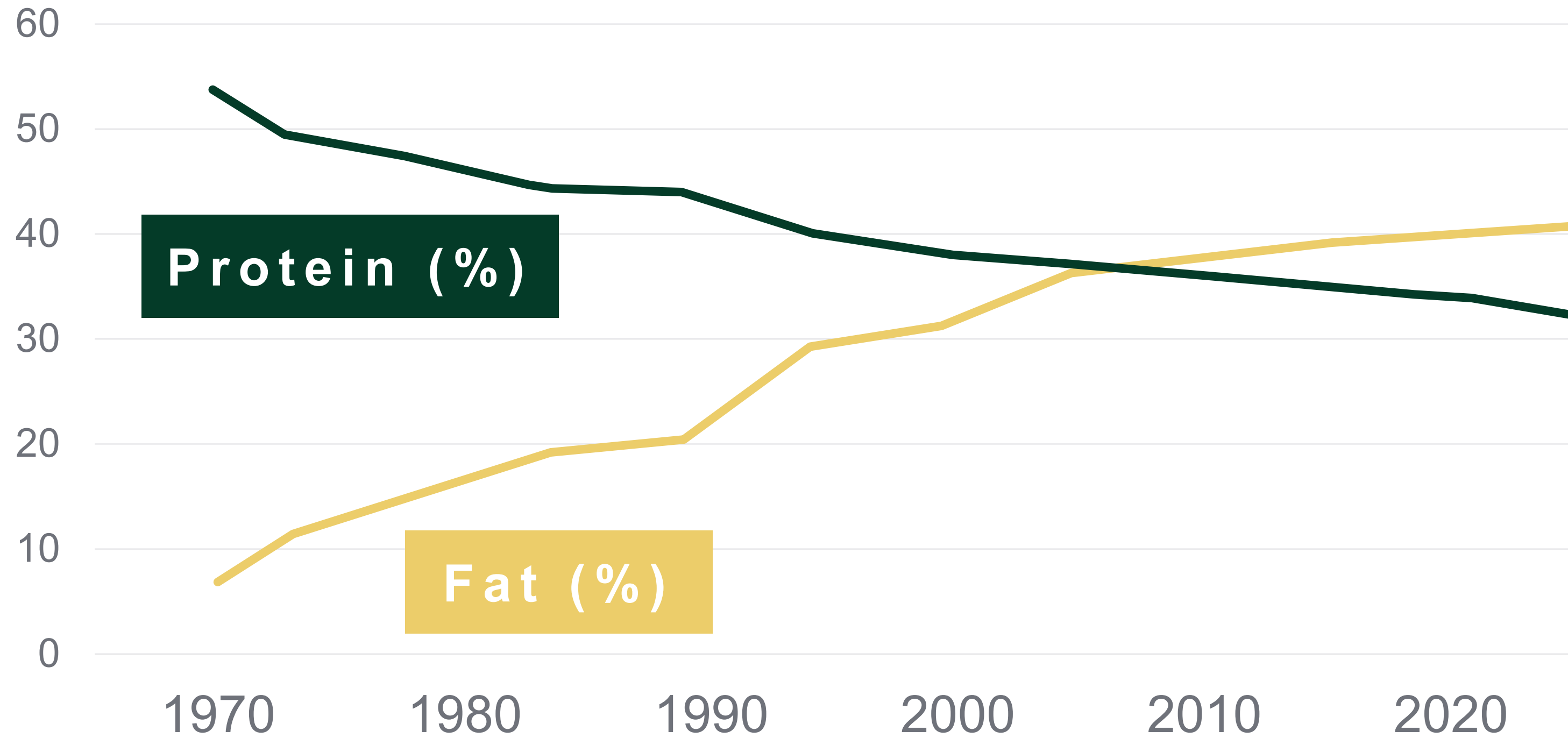
Poor nutrition makes diabetes worse



DIETS LOW IN PROTEIN, HIGH IN FAT AND CARBOHYDRATES MAKE DIABETES WORSE



The wrong feed can create 'lifestyle disease'



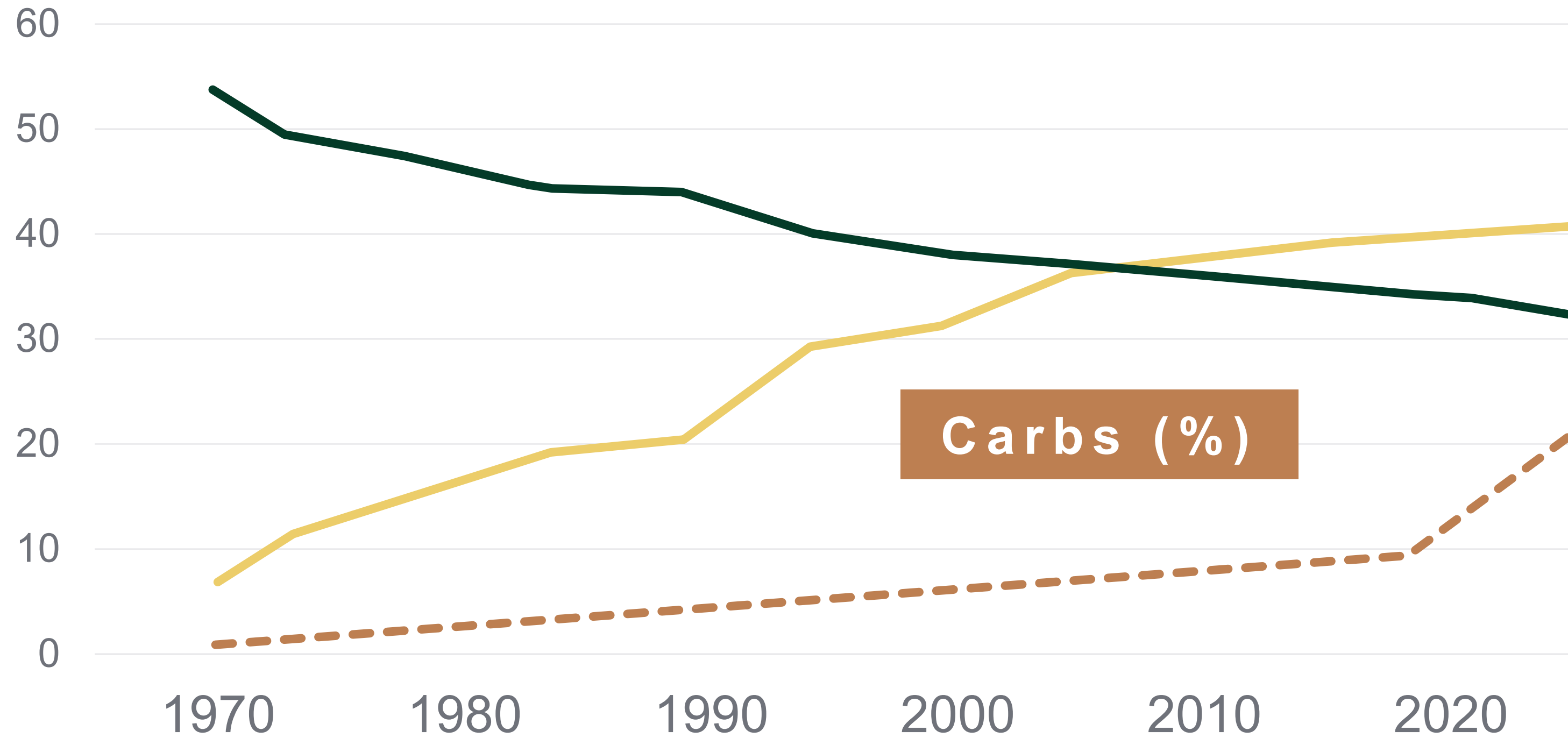
FAT HAS INCREASED AND PROTEIN HAS DECREASED DRAMATICALLY OVER THE LAST 30 YEARS



TYPICAL SALMON FEEDS ARE THE OPPOSITE OF WHAT THEY SHOULD BE TO MANAGE DIABETES



The wrong feed can create 'lifestyle disease'



Carbs (%)

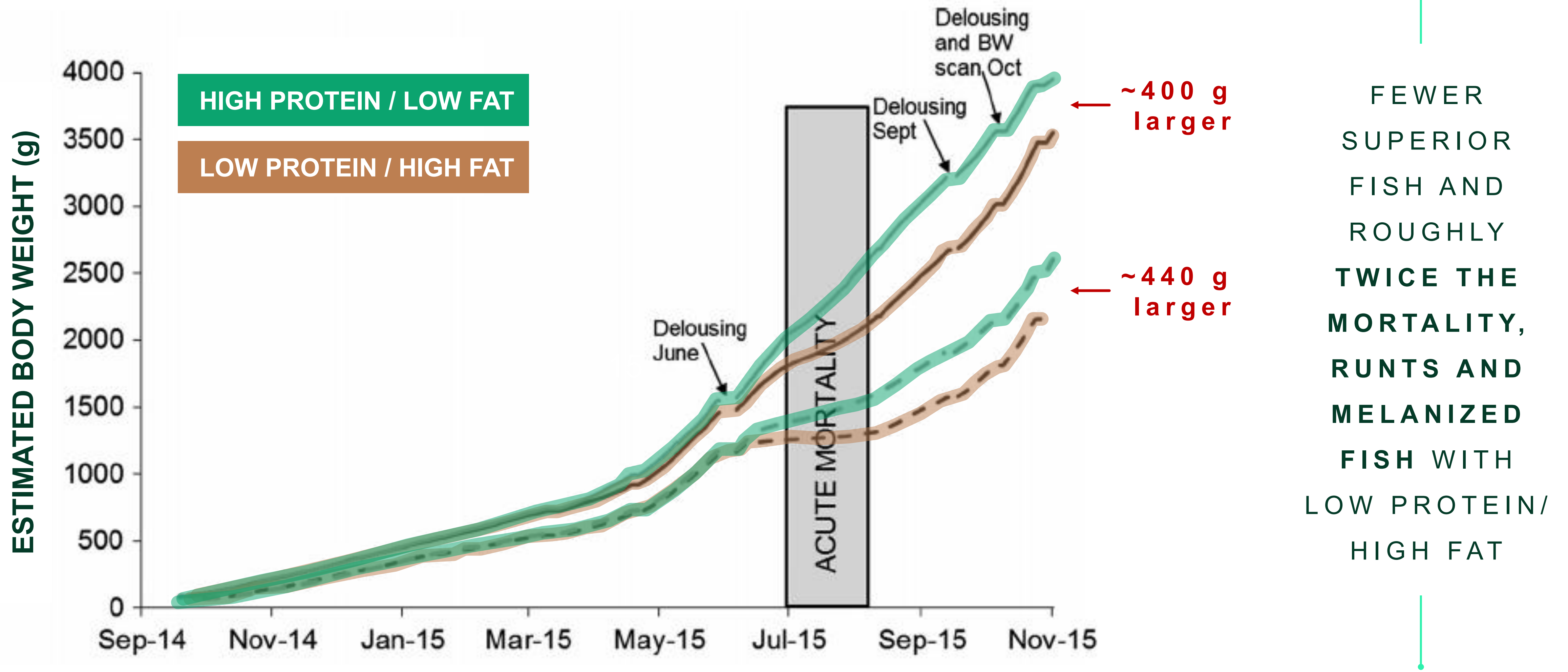
MORE VEGETABLE
PROTEINS MEANS
CARBOHYDRATES
HAVE BEEN
INCREASING, TOO



TYPICAL SALMON FEEDS ARE THE OPPOSITE OF
WHAT THEY SHOULD BE TO MANAGE DIABETES



Low protein / high fat reduces growth and quality












ROOT CAUSES
Lifestyle disease
associated with poor
diet and inadequate
vaccination are main
risk factors for mass
mortality events

REVIEW

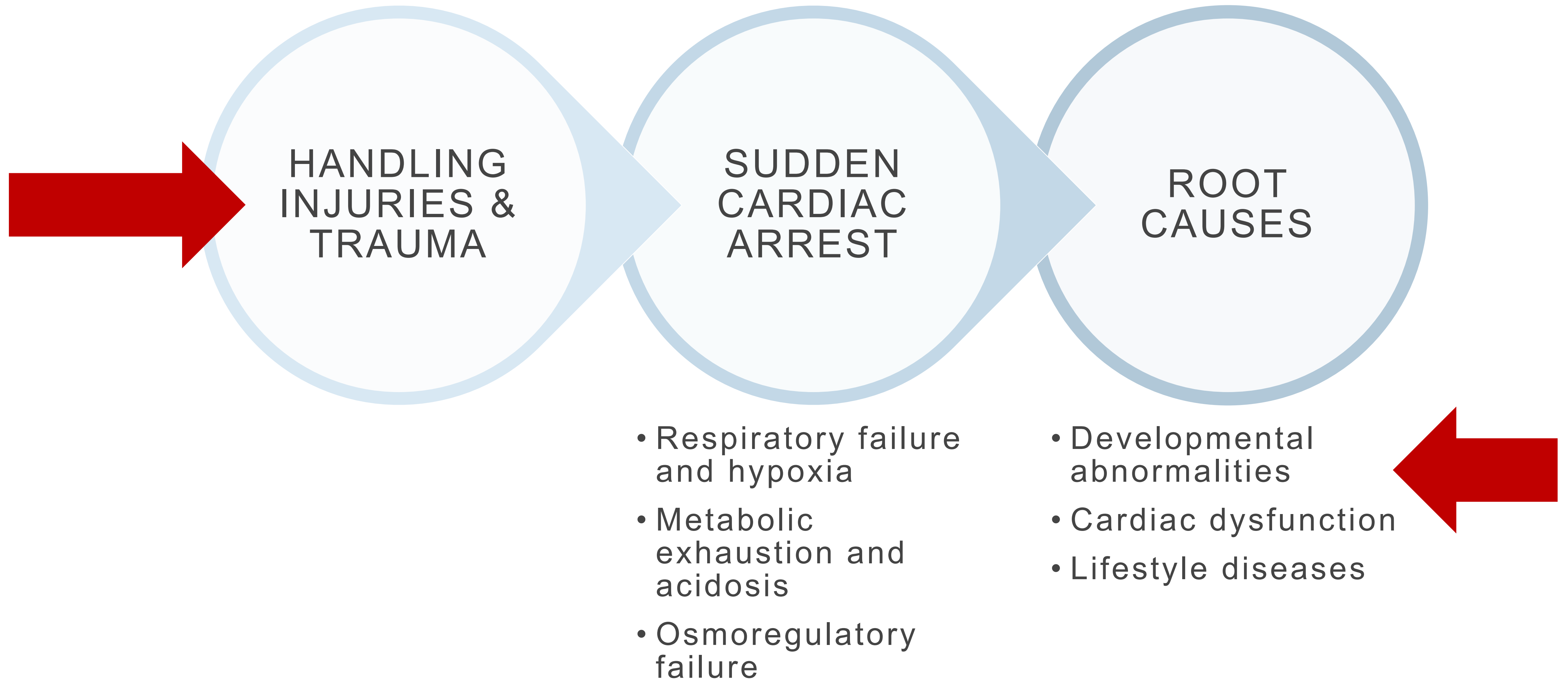
REVIEWS IN Aquaculture 

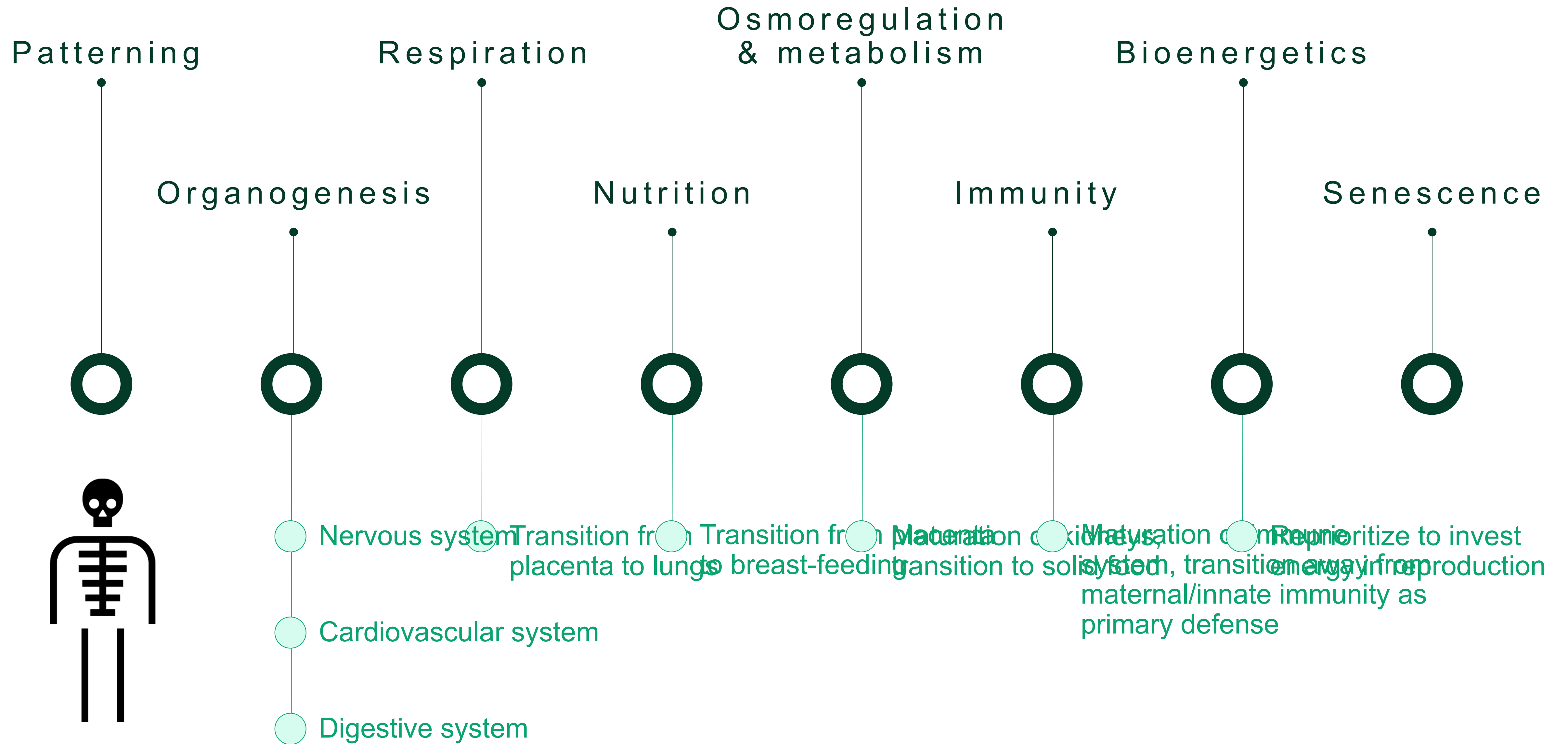
An aquaculture risk model to understand the causes and consequences of Atlantic Salmon mass mortality events: A review

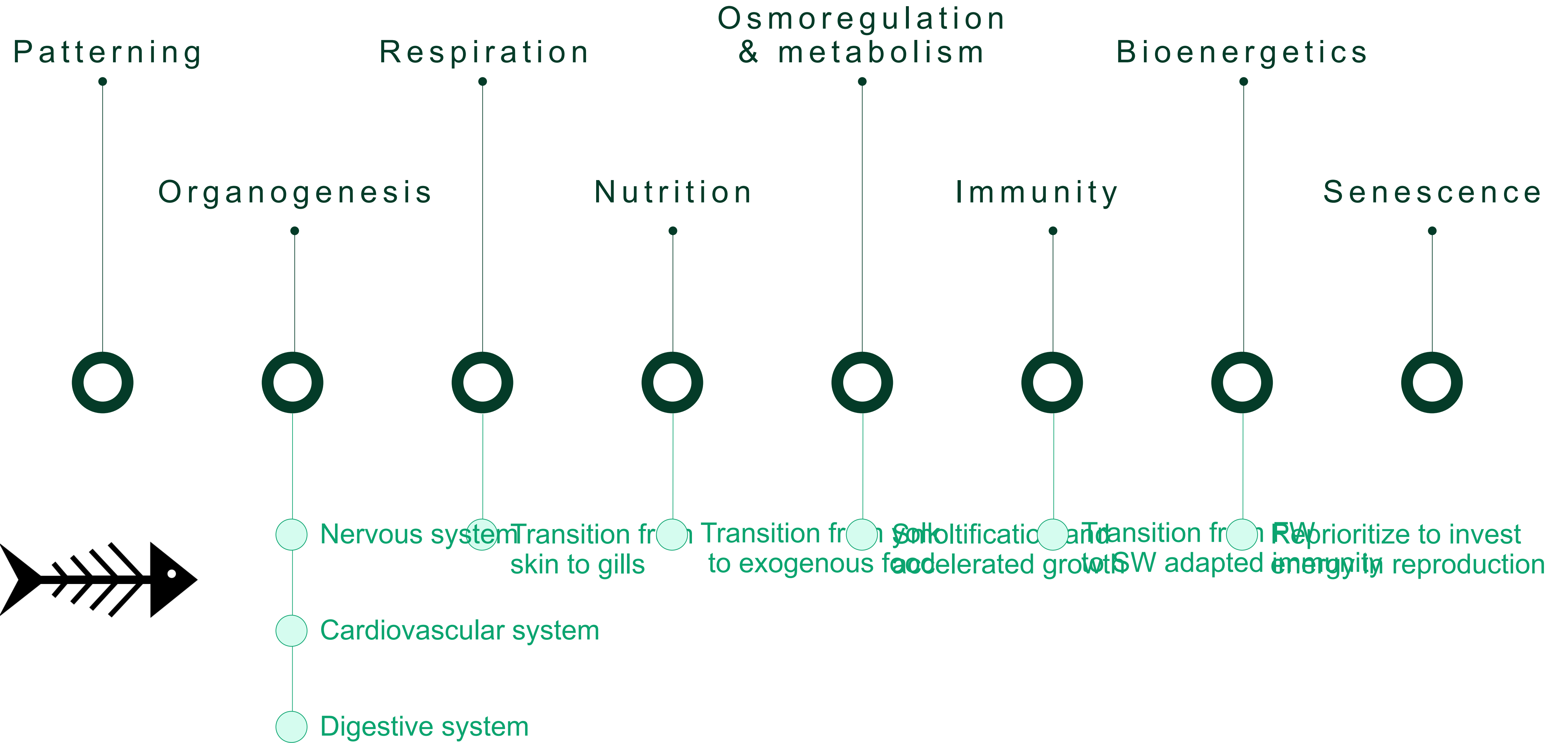
Zaman Sajid^{1,2}  | A. Kurt Gamperl³ | Christopher C. Parrish³ |
Stefanie M. Colombo⁴  | Javier Santander³ | Charles Mather⁵ | Barbara Neis⁶ |
Ingunn Marie Holmen⁷ | Ramón Filgueira⁸  | Cynthia H. McKenzie⁹ |
Lissandra Souto Cavalli¹⁰  | Mohamed Jeebhay¹¹ | Wenzhao Gao⁶ |
María Andrée López Gómez⁶  | Cory Ochs¹² | Sarah Lehnert¹³ |
Cyr Couturier¹⁴ | Christine Knott¹⁵ | João F. Romero¹⁶  |
Albert Caballero-Solares³  | Allan Cembella¹⁷ | Harry M. Murray¹³ |
Ian A. Fleming³  | Joel Finnis⁵ | Mark D. Fast¹⁸ | Mark Wells¹⁹ |
Gerald G. Singh²⁰ 

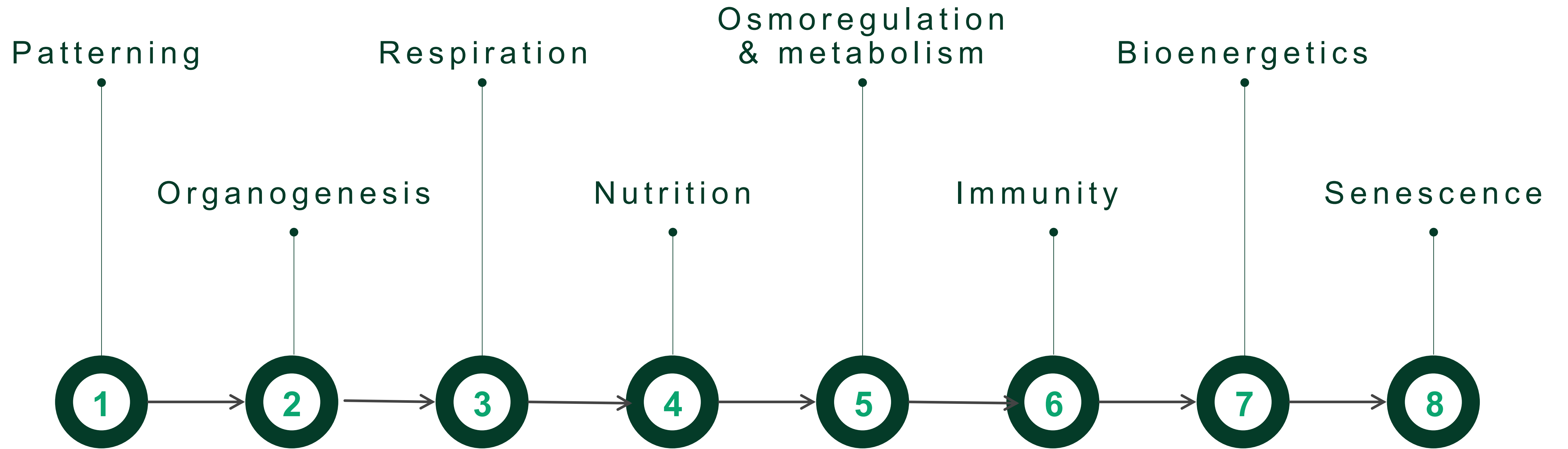


Root causes of mortality





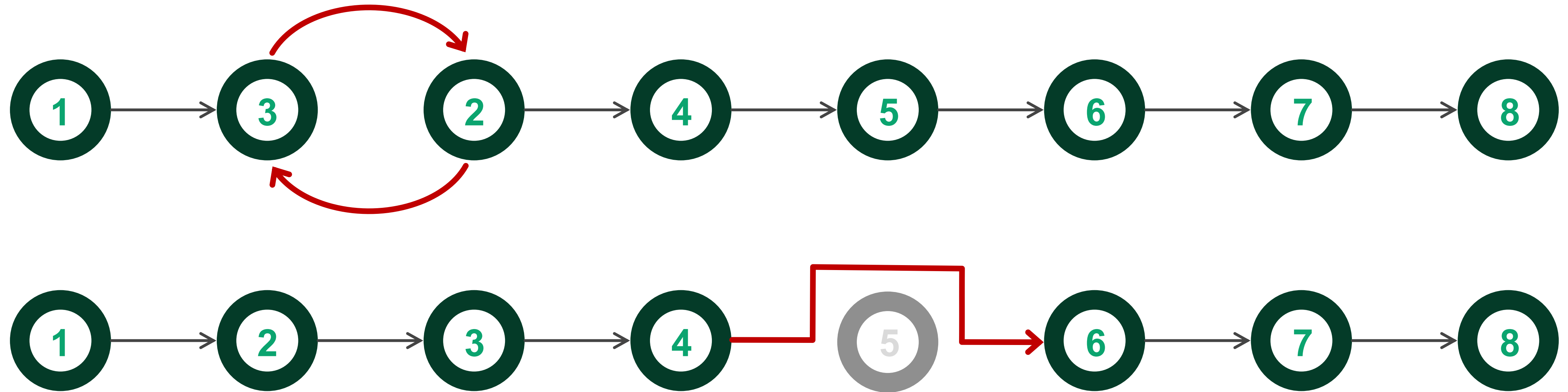




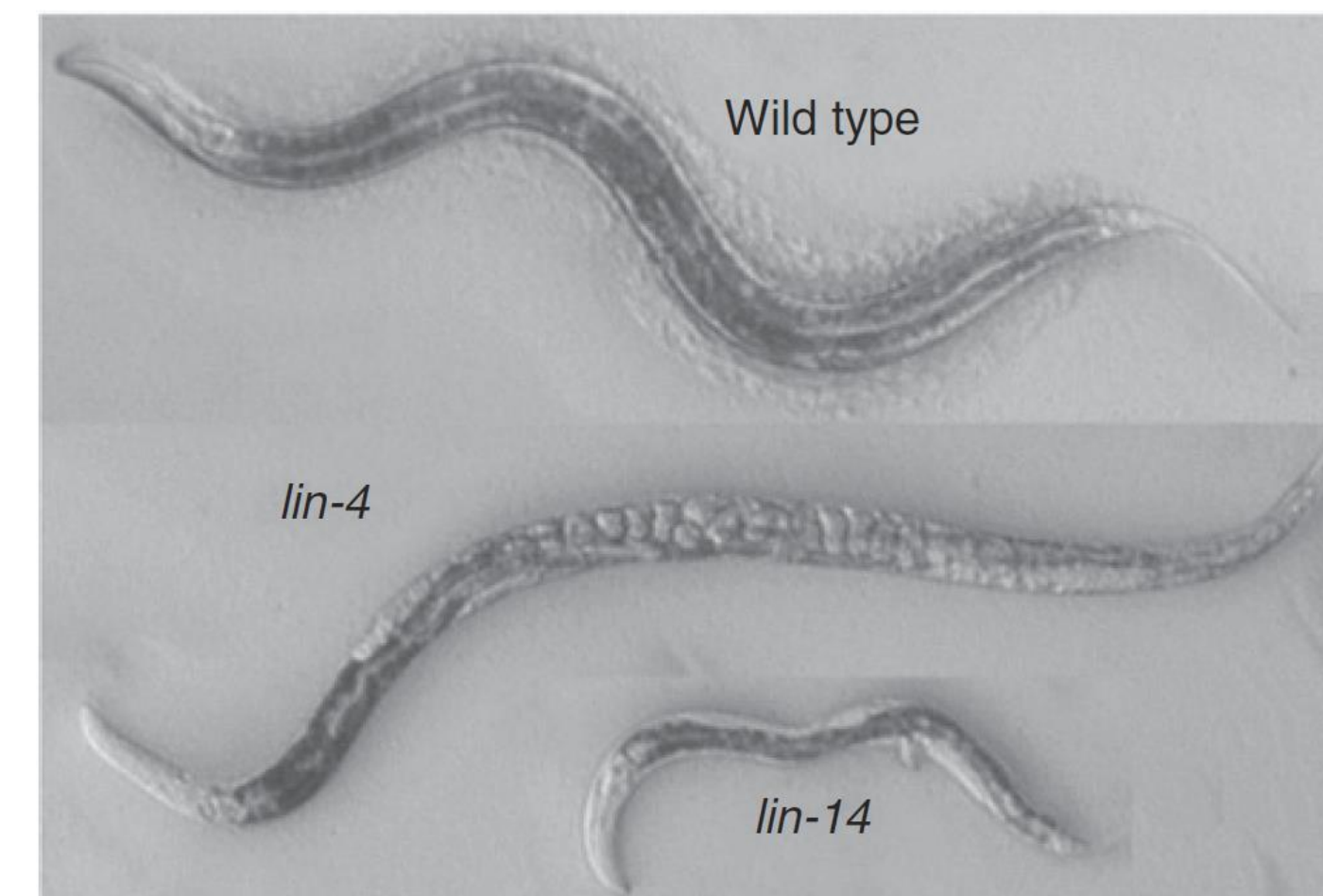
Normal ontogeny has a specific order and cadence



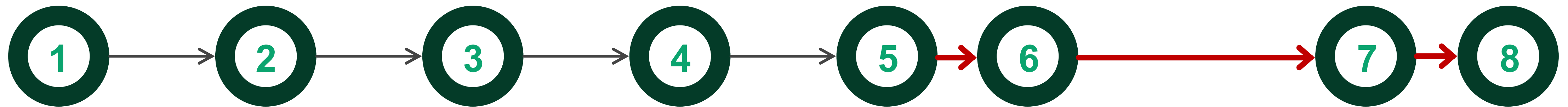
Heterochrony—a change in the order or timing of development



Skipping or repeating steps or completing them out of order can be adaptive in some cases, but is usually bad news

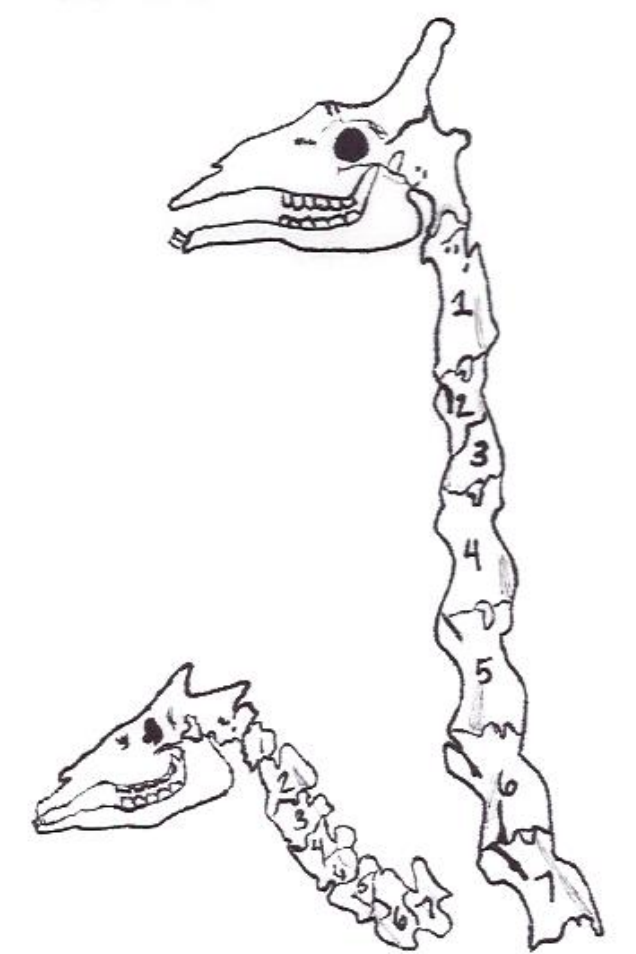
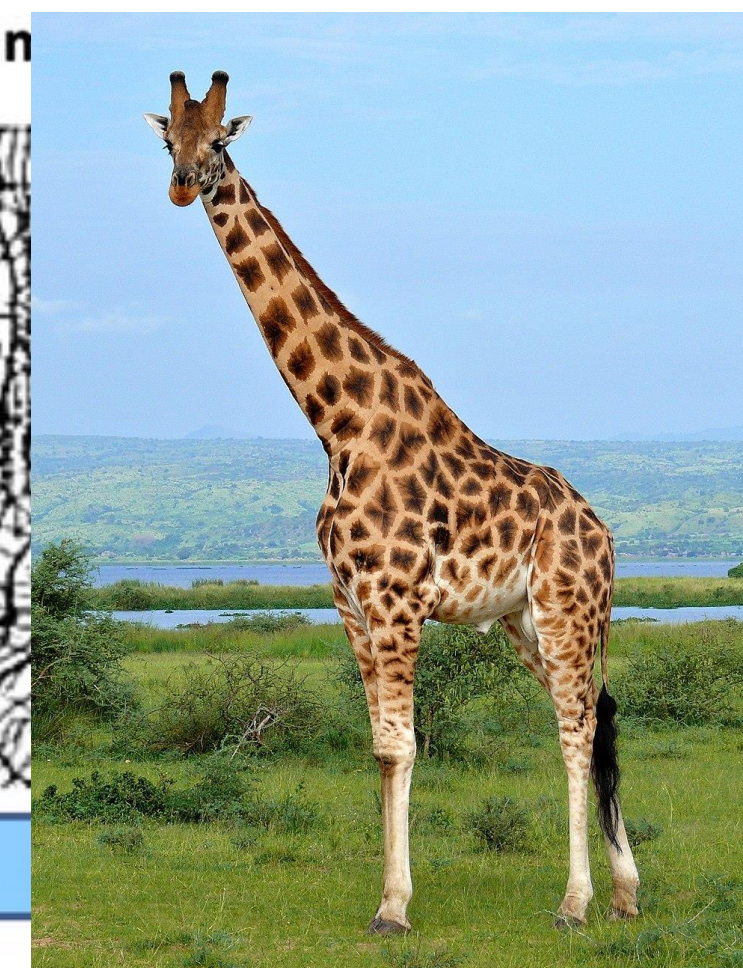


Heterochrony—a change in the order or timing of development

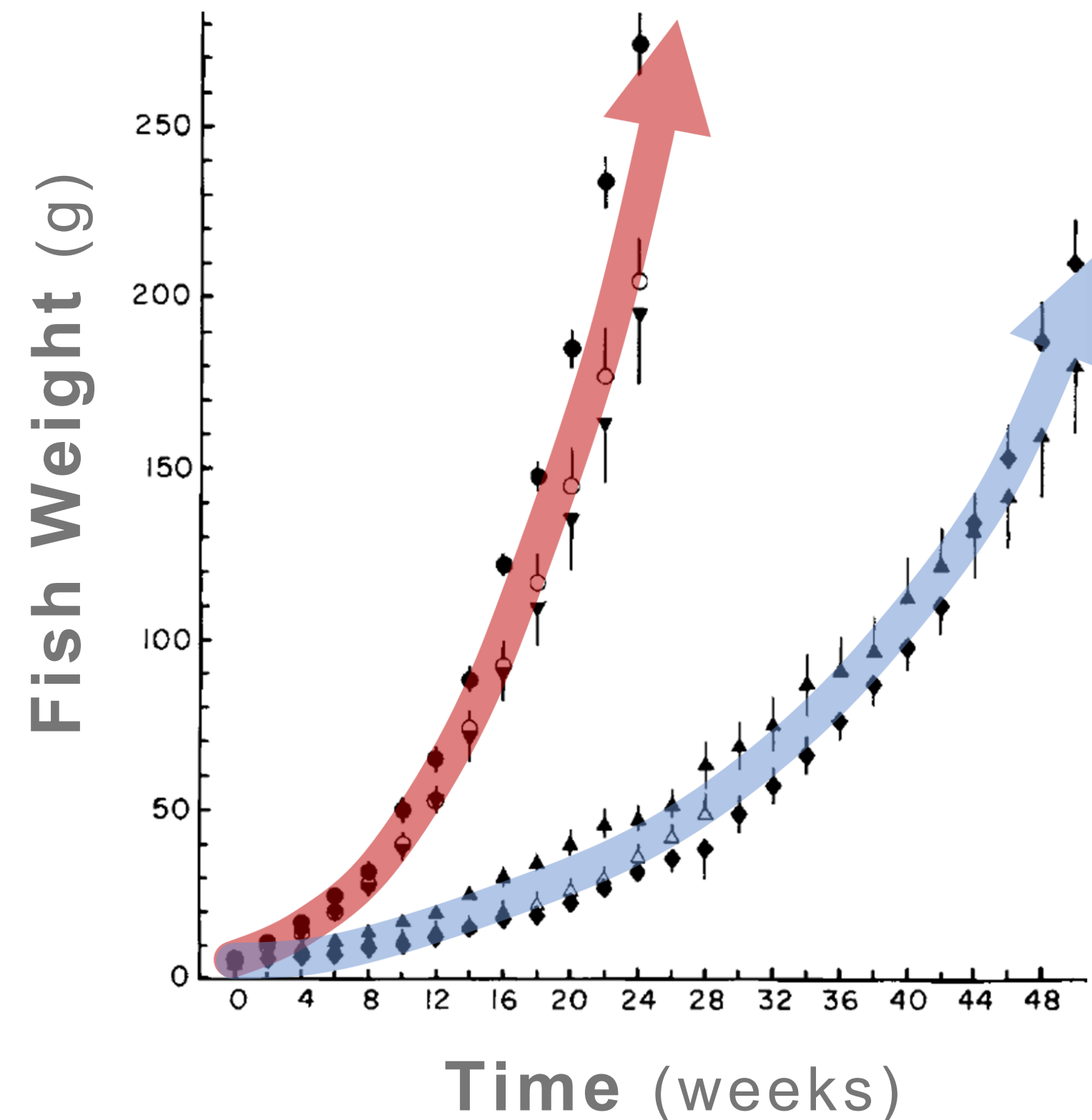


Starting earlier or later, speeding up or slowing down can be beneficial but usually leads to disease and other complications

36 weeks



Temperature is the master controller of growth



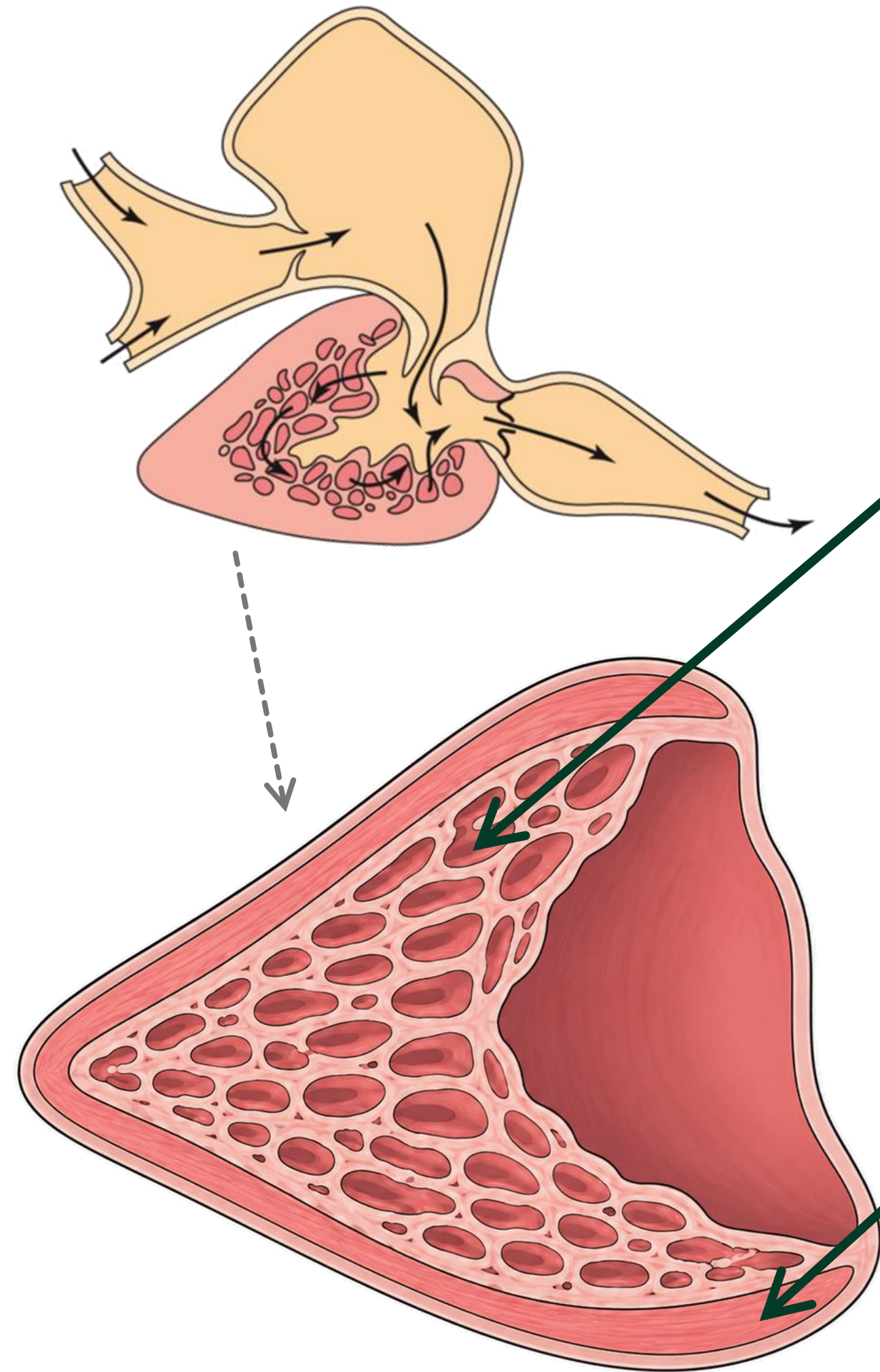
7°C → 12°C = faster growth, but...

...the body grows 30% faster than the heart at warmer temperature

THE SALMONID HEART DOES NOT RESPOND TO TEMPERATURE LIKE THE REST OF THE BODY



The salmonid heart



SPONGY MYOCARDIUM

Loosely arranged layers of heart muscle with spaces for blood flow

Provides structure and is more efficient at lower activity levels

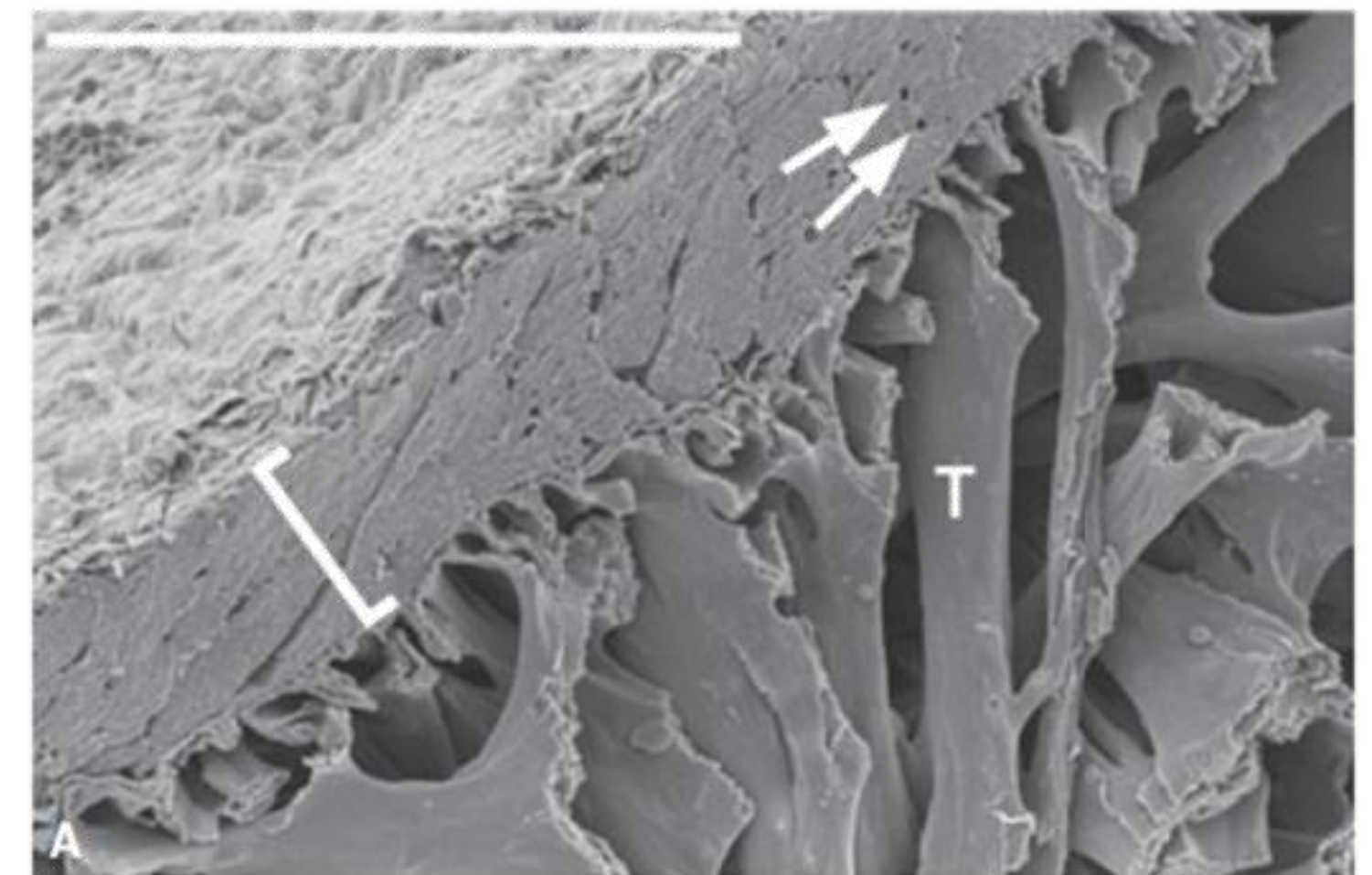
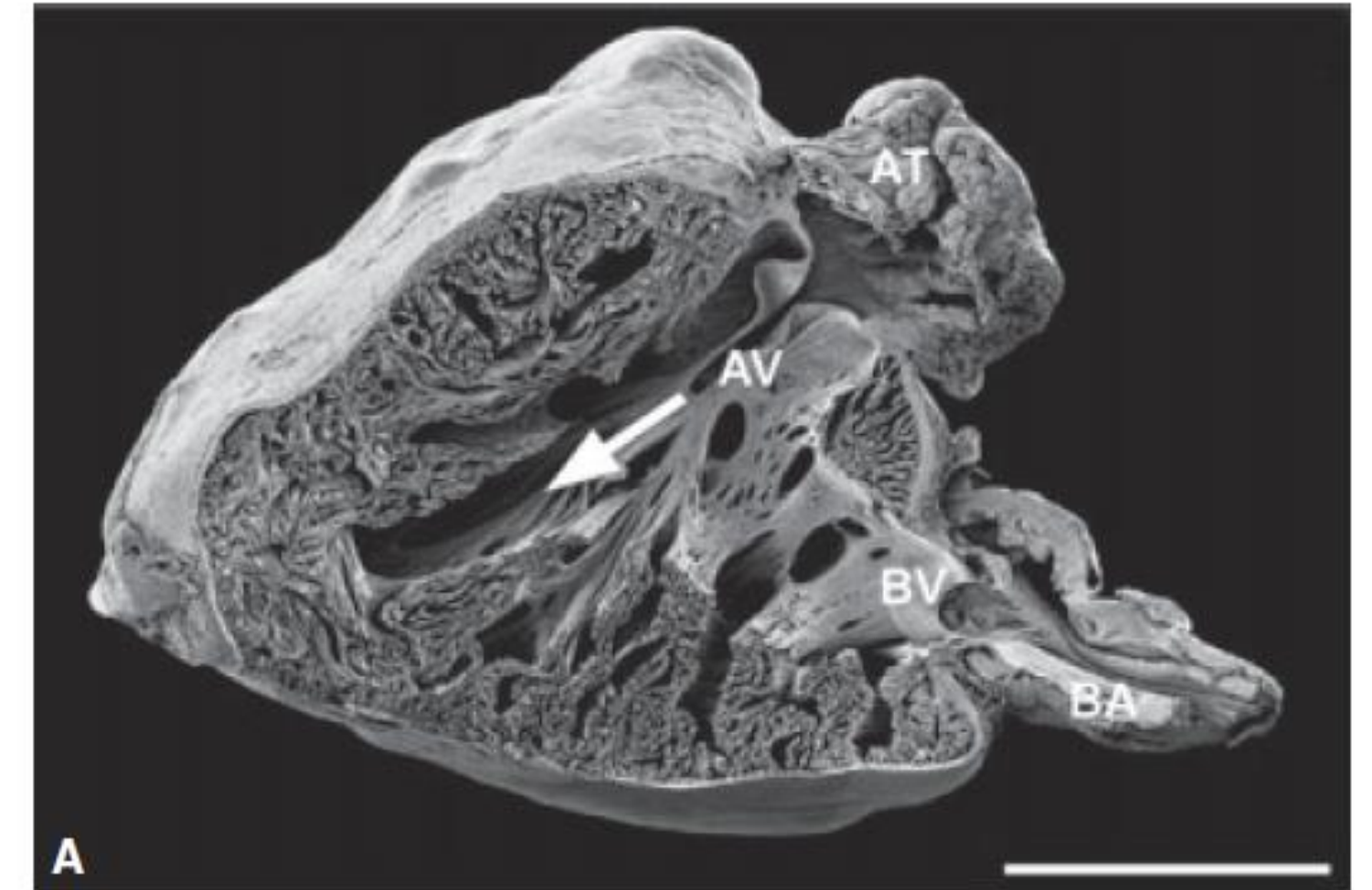
Receives 'used' blood returning from the rest of the body

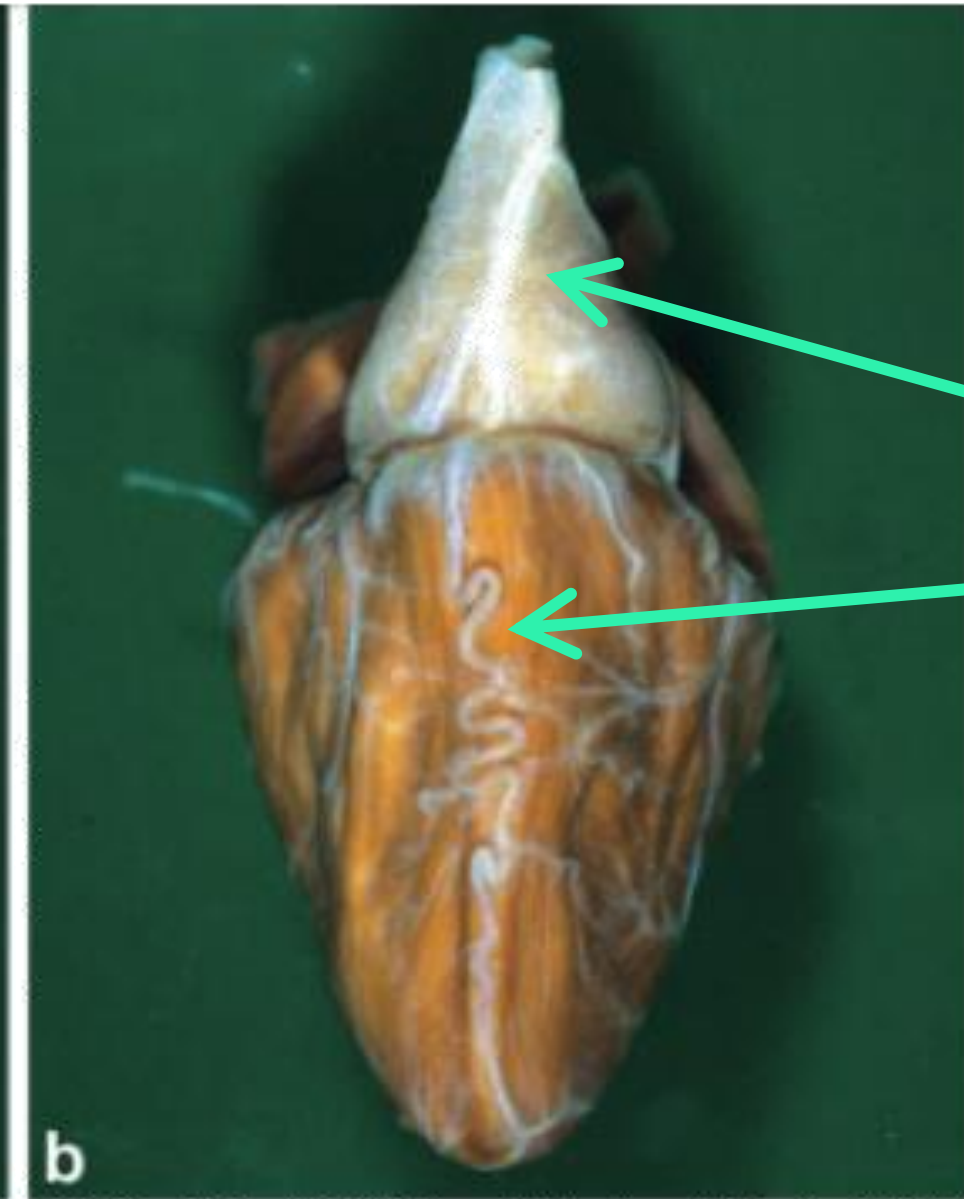
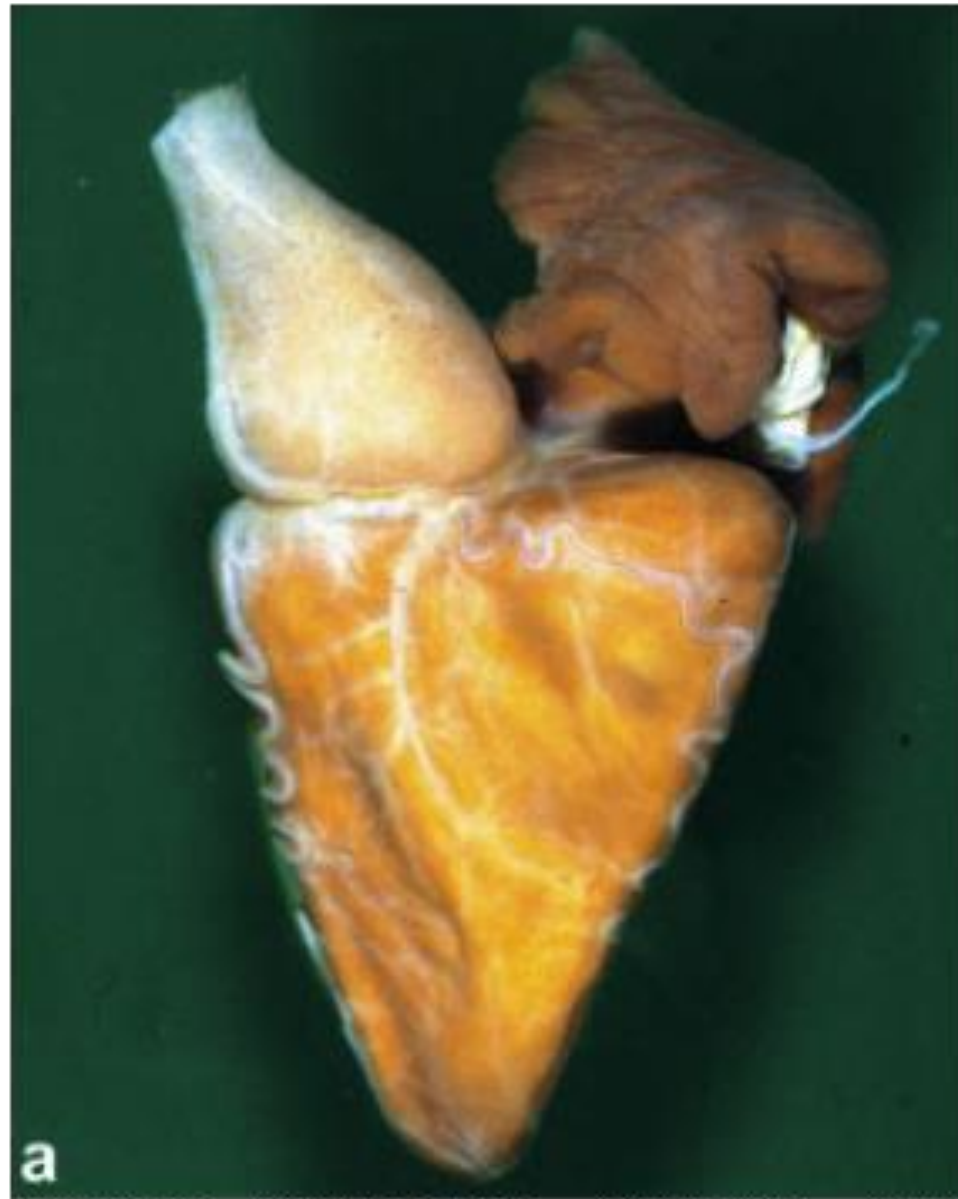
COMPACT MYOCARDIUM

Outer layer of tightly packed heart muscle that generates strong contractions

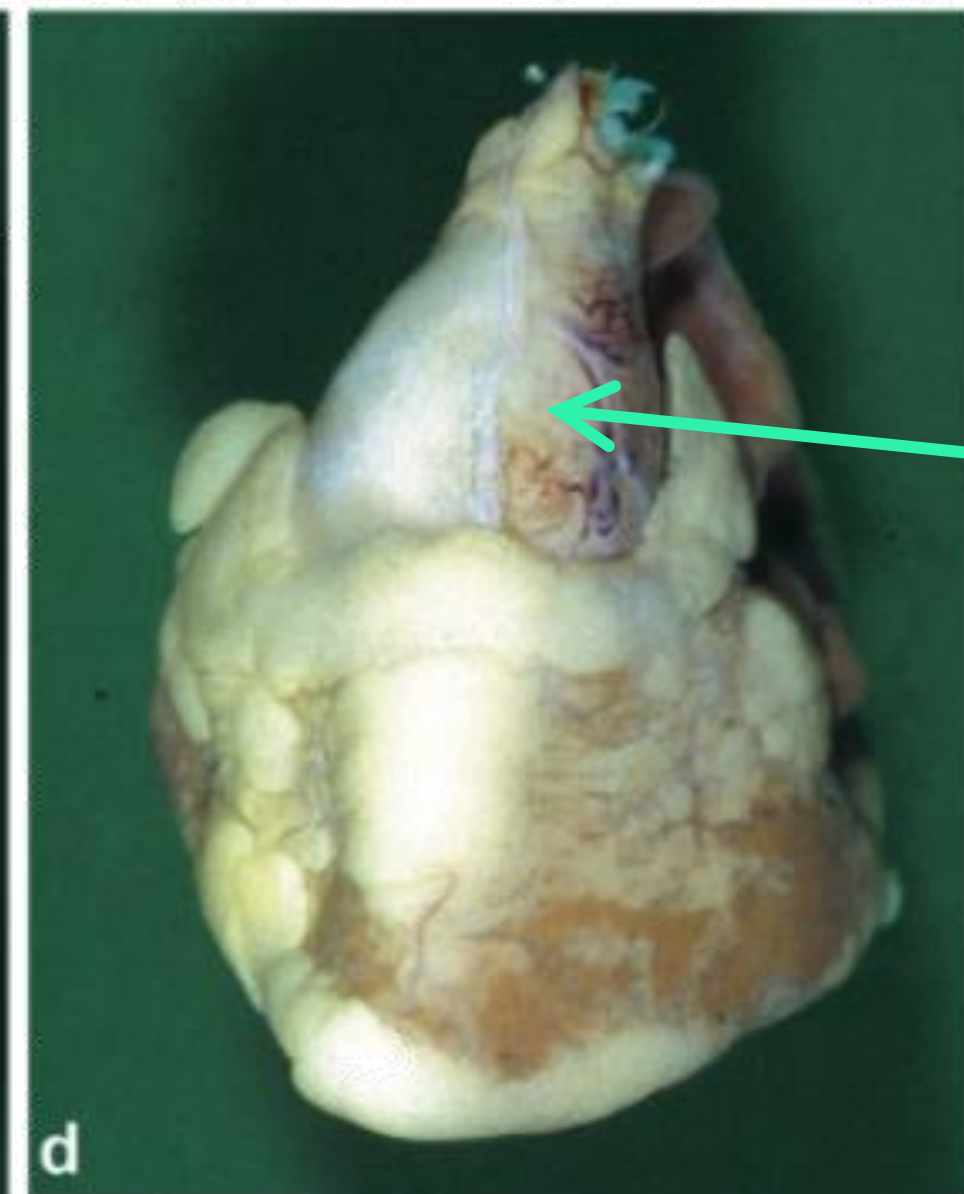
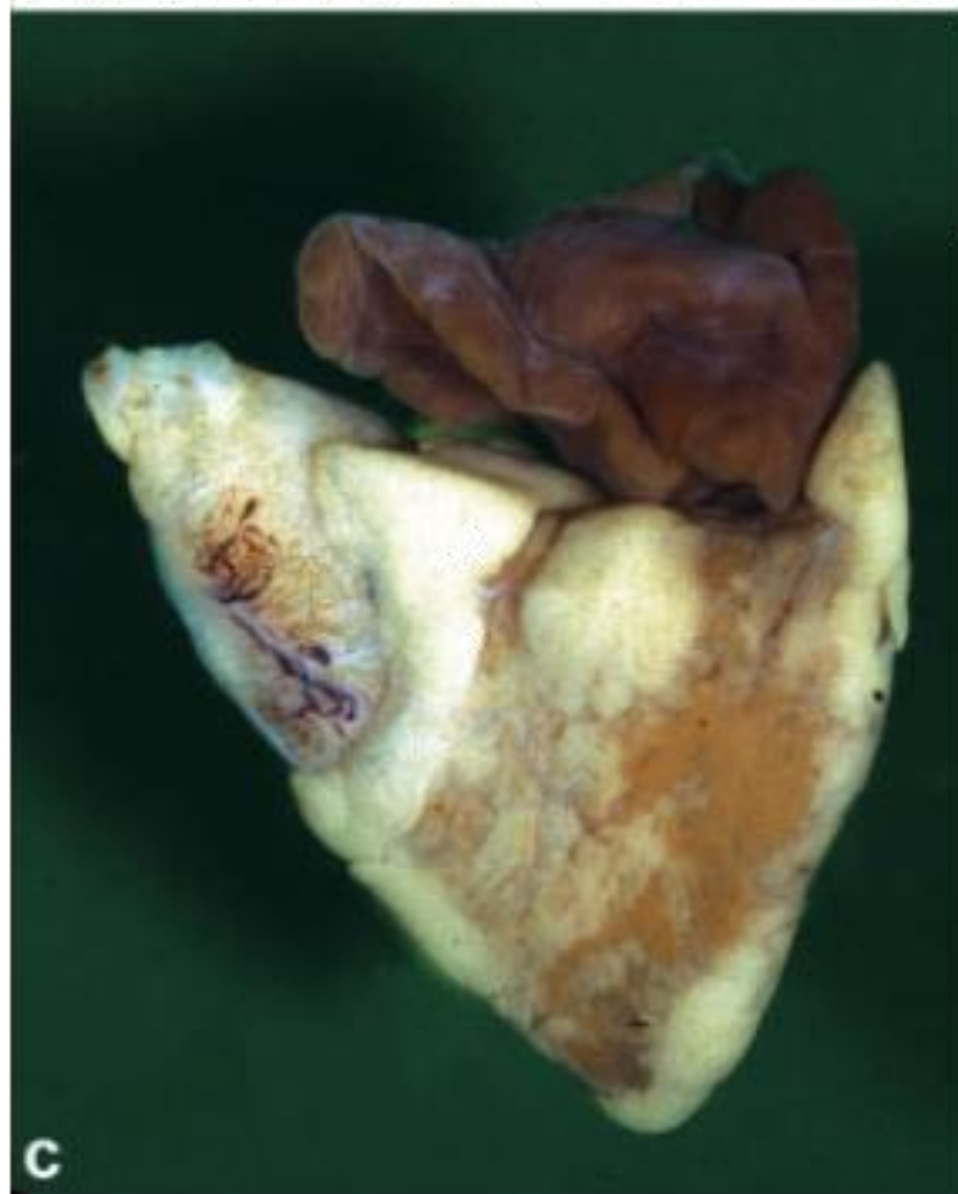
Present only in highly active species

Receives 'fresh' blood from gills



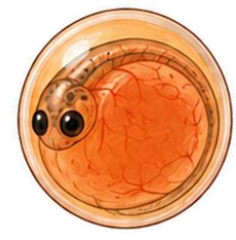


**Coronary arteries
in wild salmon**



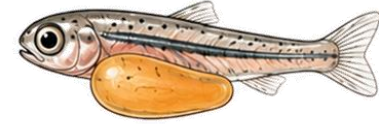
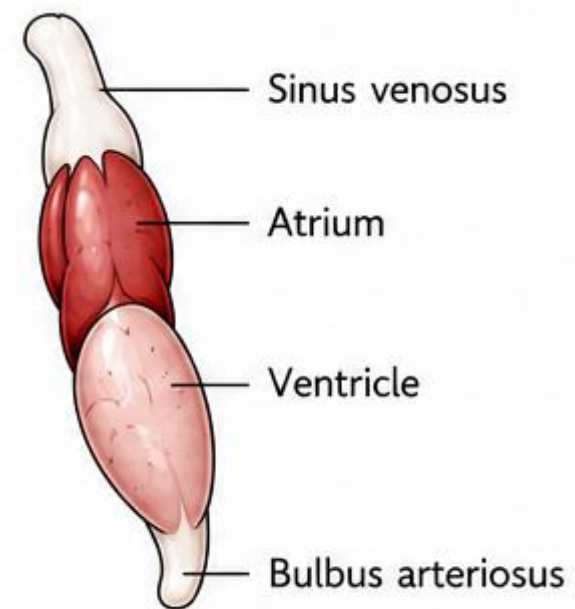
**Coronary arteries
in farmed salmon...?**





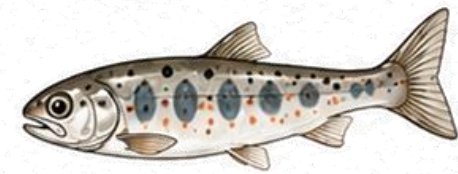
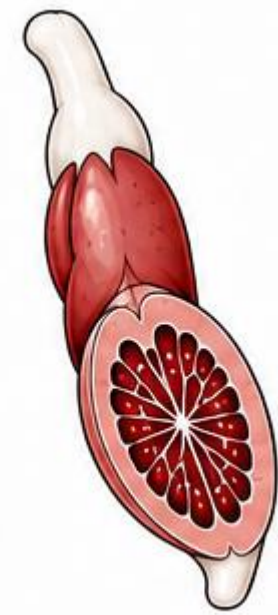
EMBRYO

- Basic structure of heart forms
- Onset of circulation



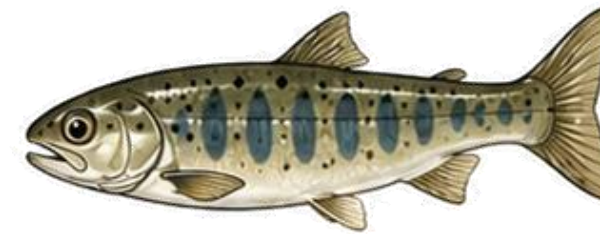
ALEVIN

- Cardiac chambers begin to take shape
- Development of spongy layer



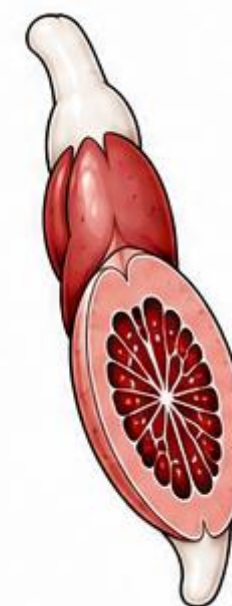
FRY

- Thin compact layer initially appears



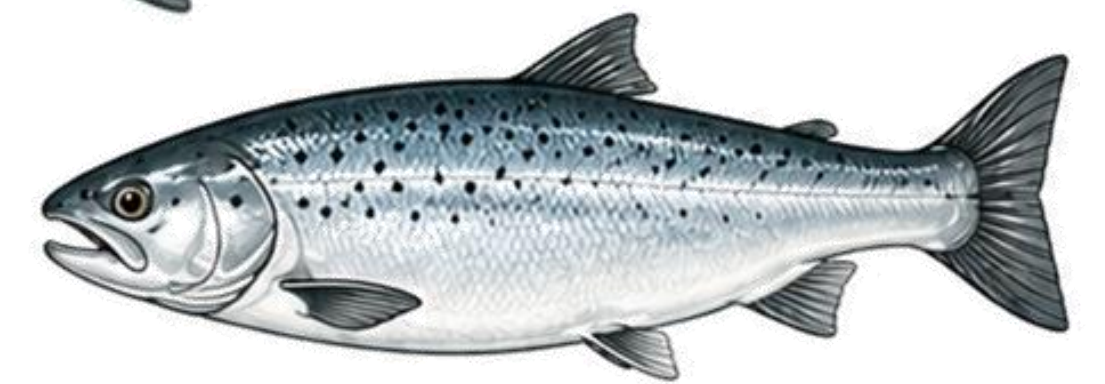
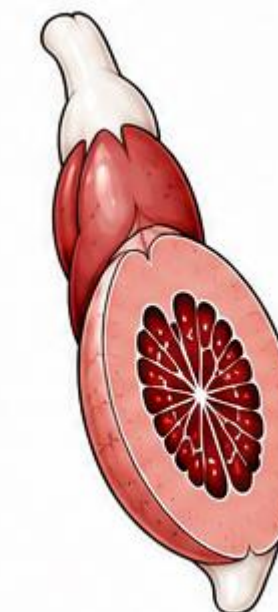
PARR

- Early development of compact layer and coronary circulation



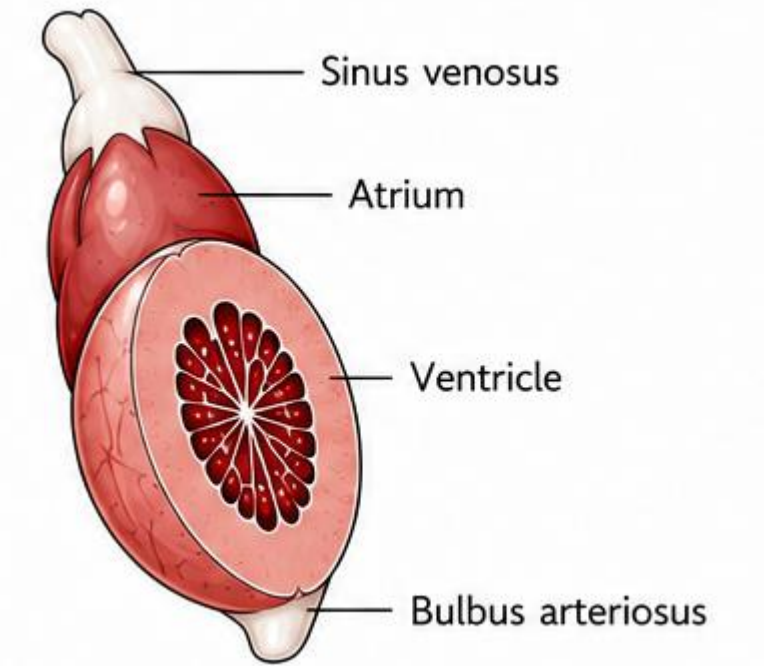
SMOLT

- Increase in heart size
- Major development of compact layer and coronary circulation



POST-SMOLT TO ADULT

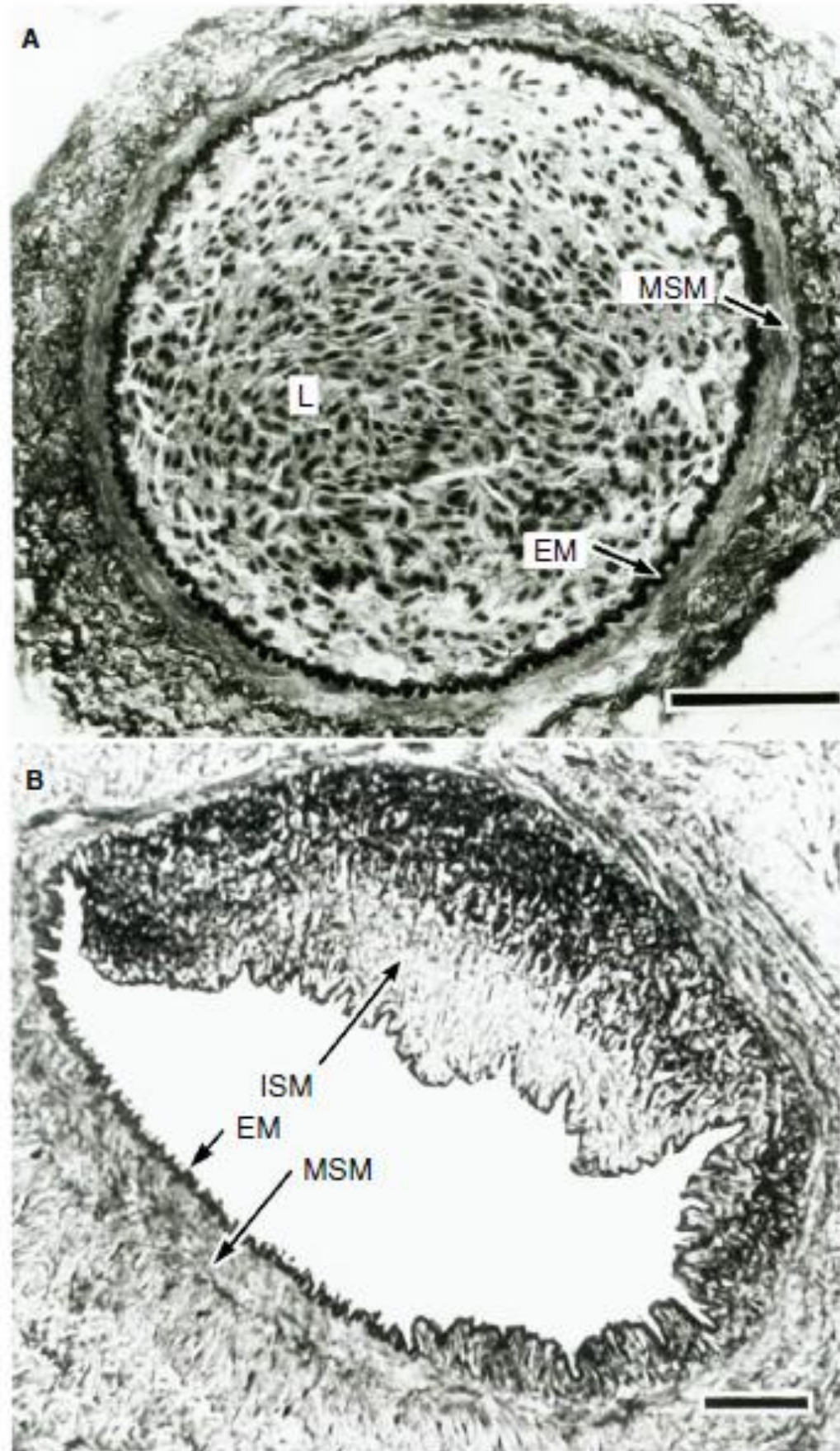
- Continued growth of compact layer
- Ongoing change in response to environment



Heart development occurs in stages

- Spongy layer is enough during early life stages
- Compact layer is necessary for greater activity
- Development is oxygen-dependent
 - Coronary circulation is necessary for growth of the compact layer
- Heart increases in size during smoltification
 - To prepare for increased aerobic activity
 - Coronary circulation is increased during smoltification
 - Compact layer increased 2× during this time





Normal coronary artery

Artery blocked by massive lesion

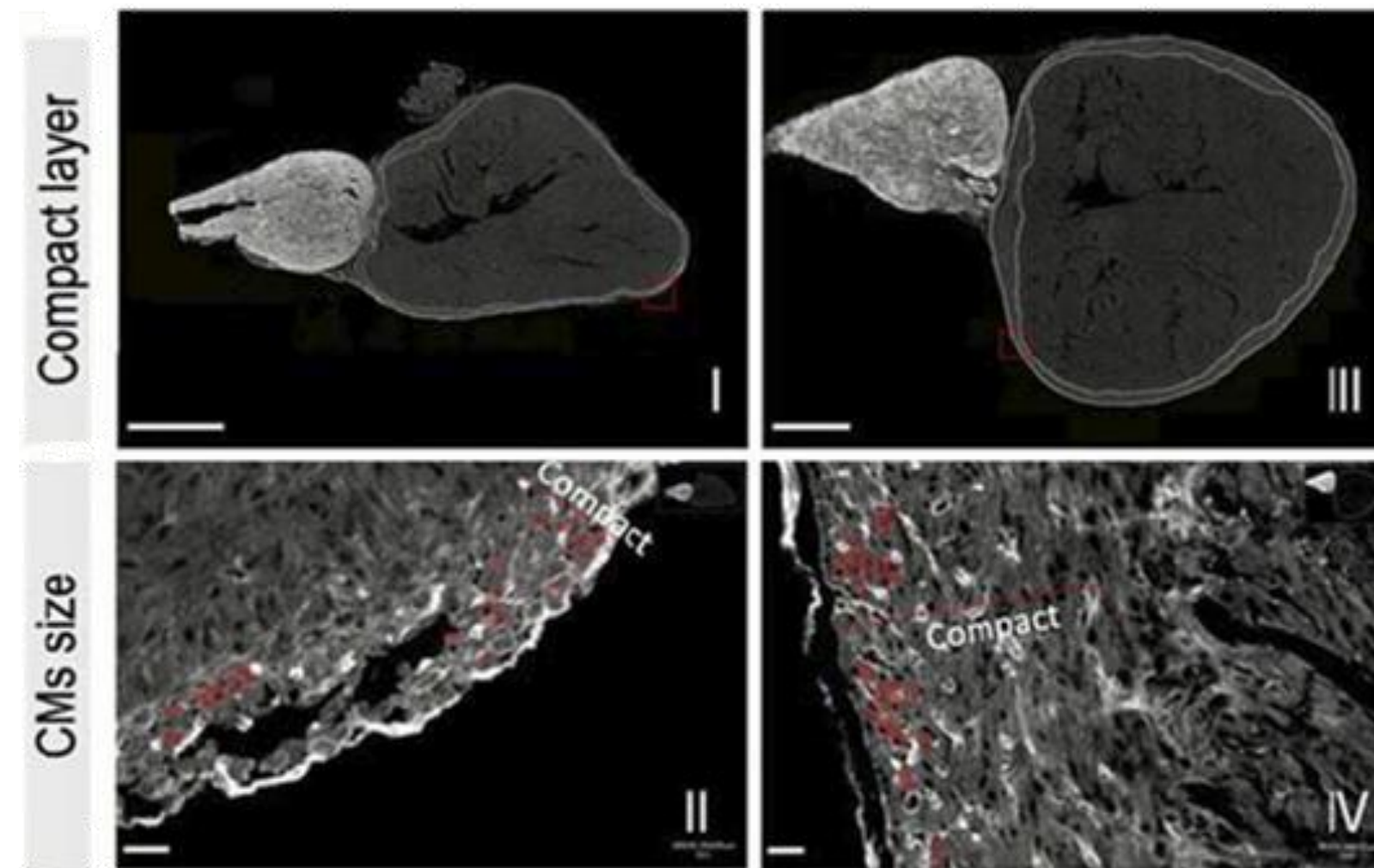
- If oxygen is limiting, heart development will be abnormal
- Increased temperature can cause developmental mismatch between stages of heart development
- Coronary artery lesions are common in farmed salmon, especially those growing fast at high temperature



Intensive smolt production causes heart pathology

WILD

FARMED



Loss of symmetry

Misalignment of structures

Round shape

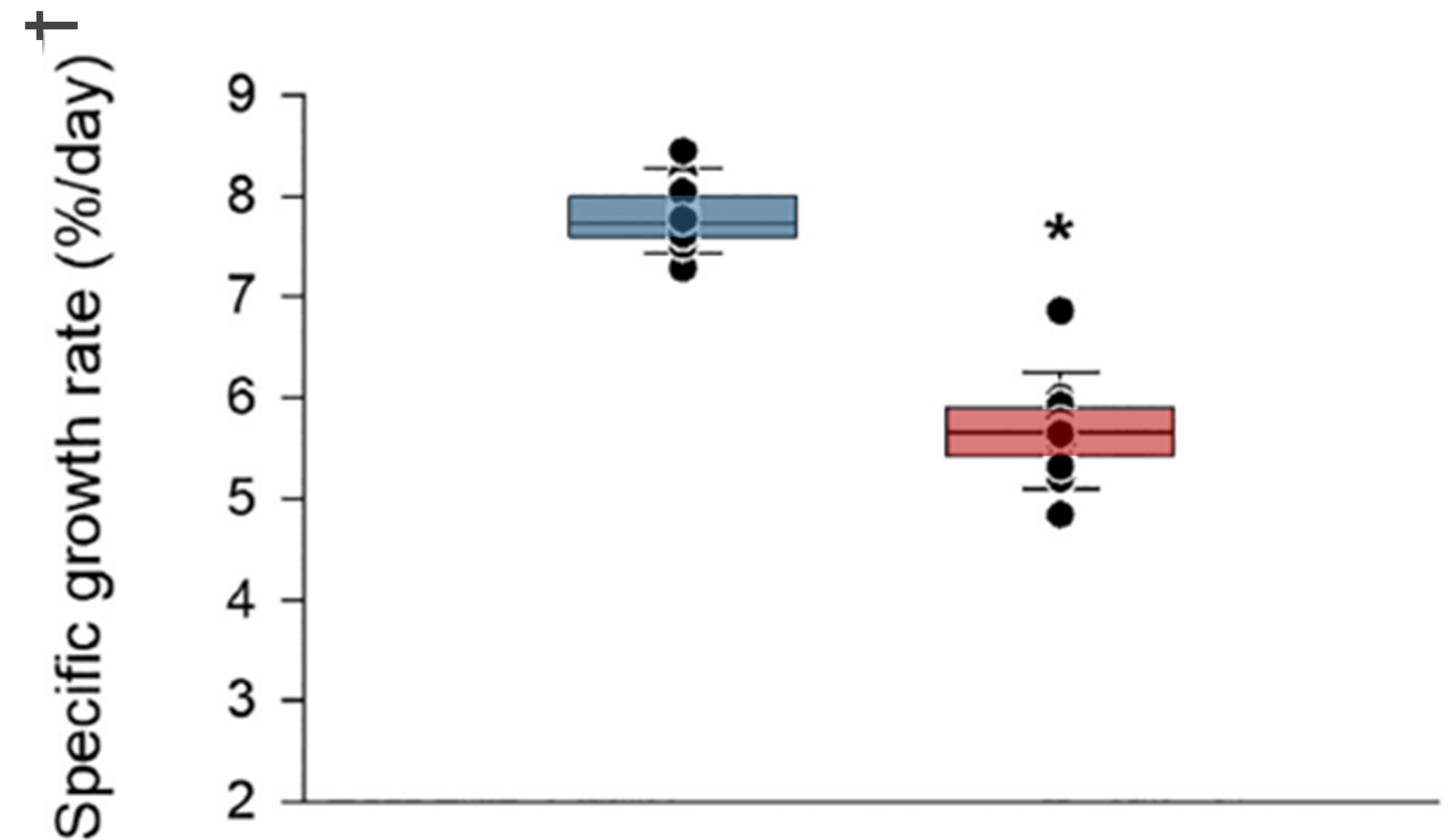
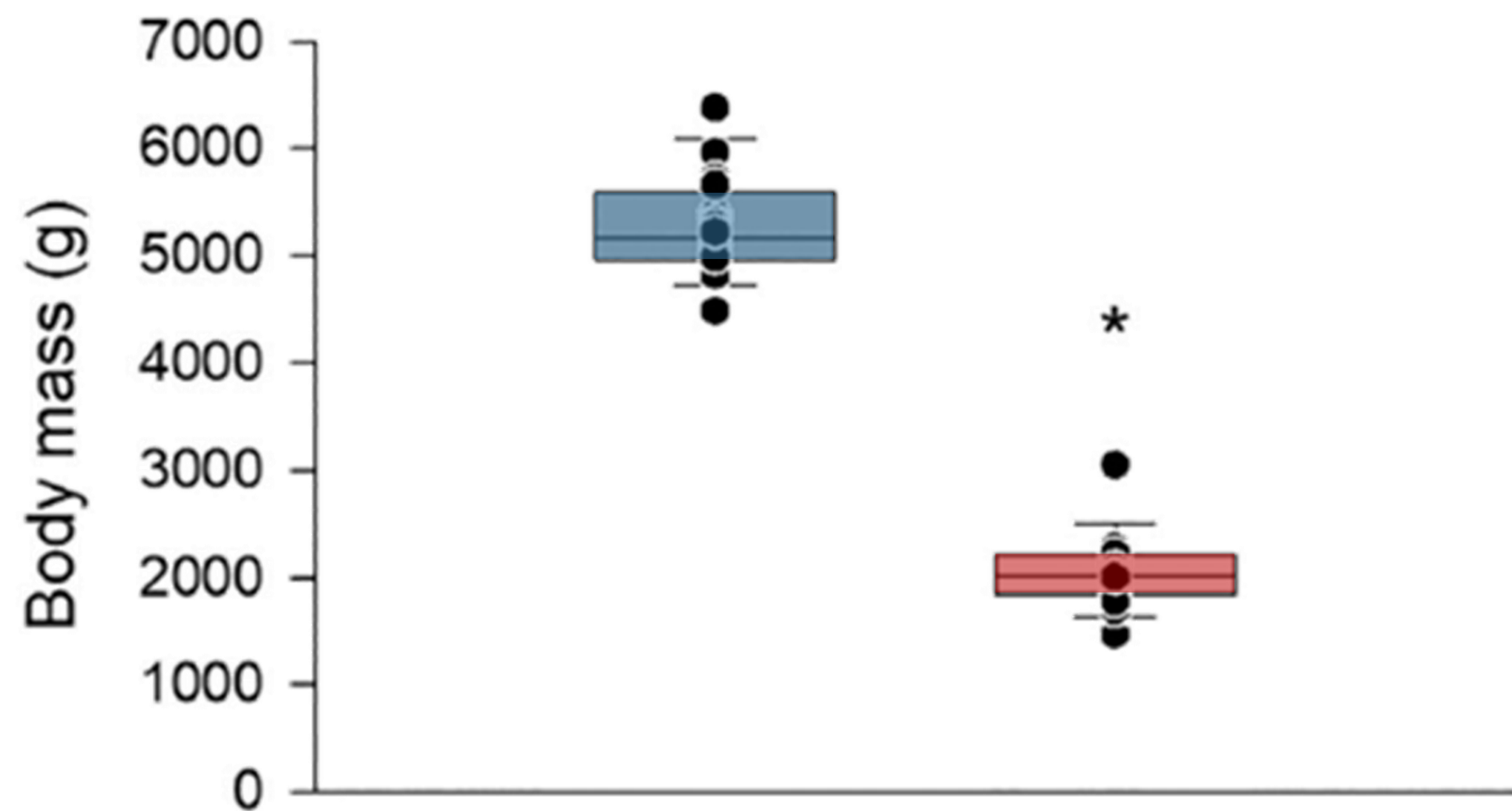
Thicker, but irregular compact layer

Compact layer cells increase in size, not number



**COLD = 8°C
18 MONTHS**

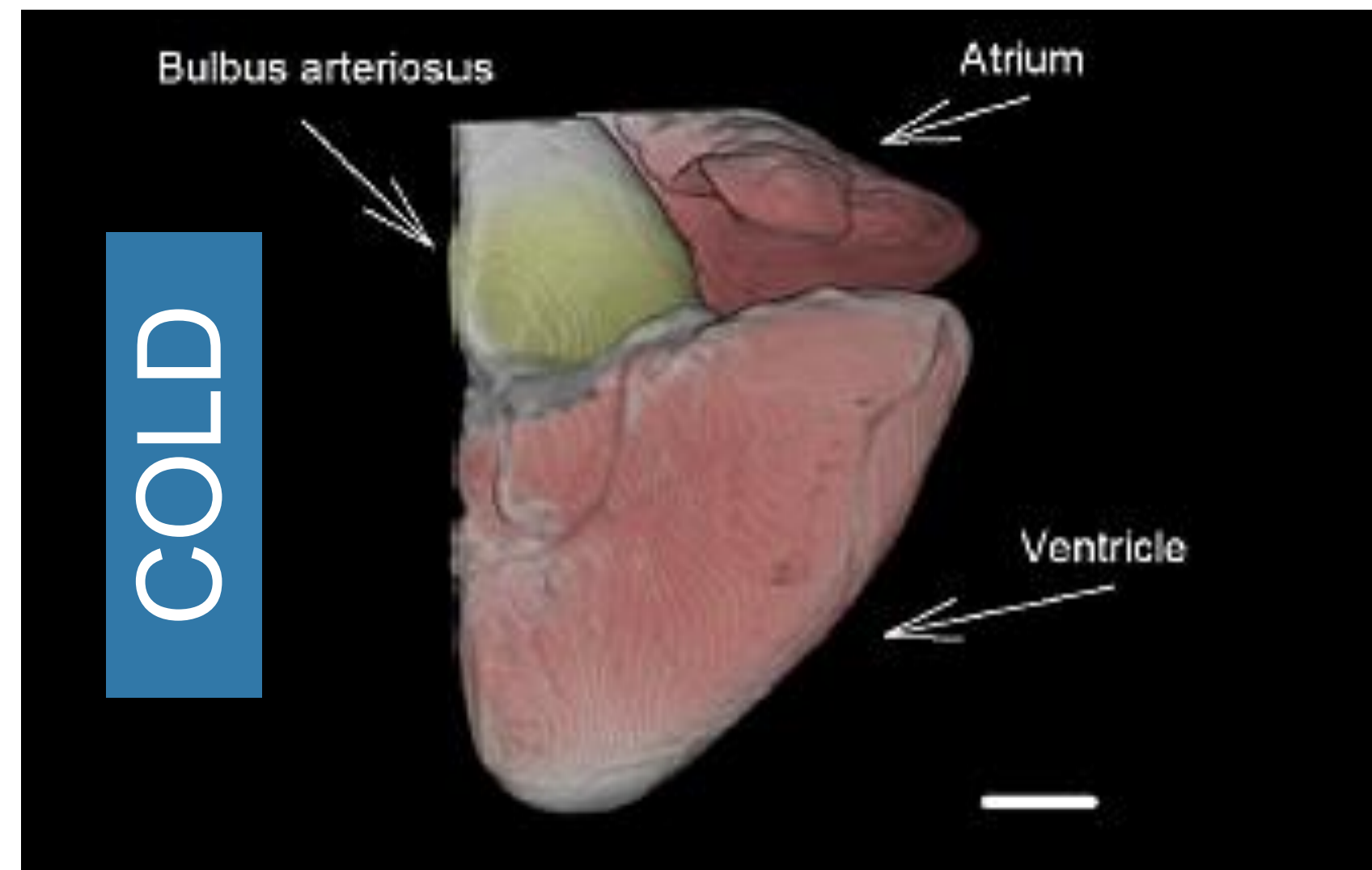
**WARM = 12.5°C
11 MONTHS**



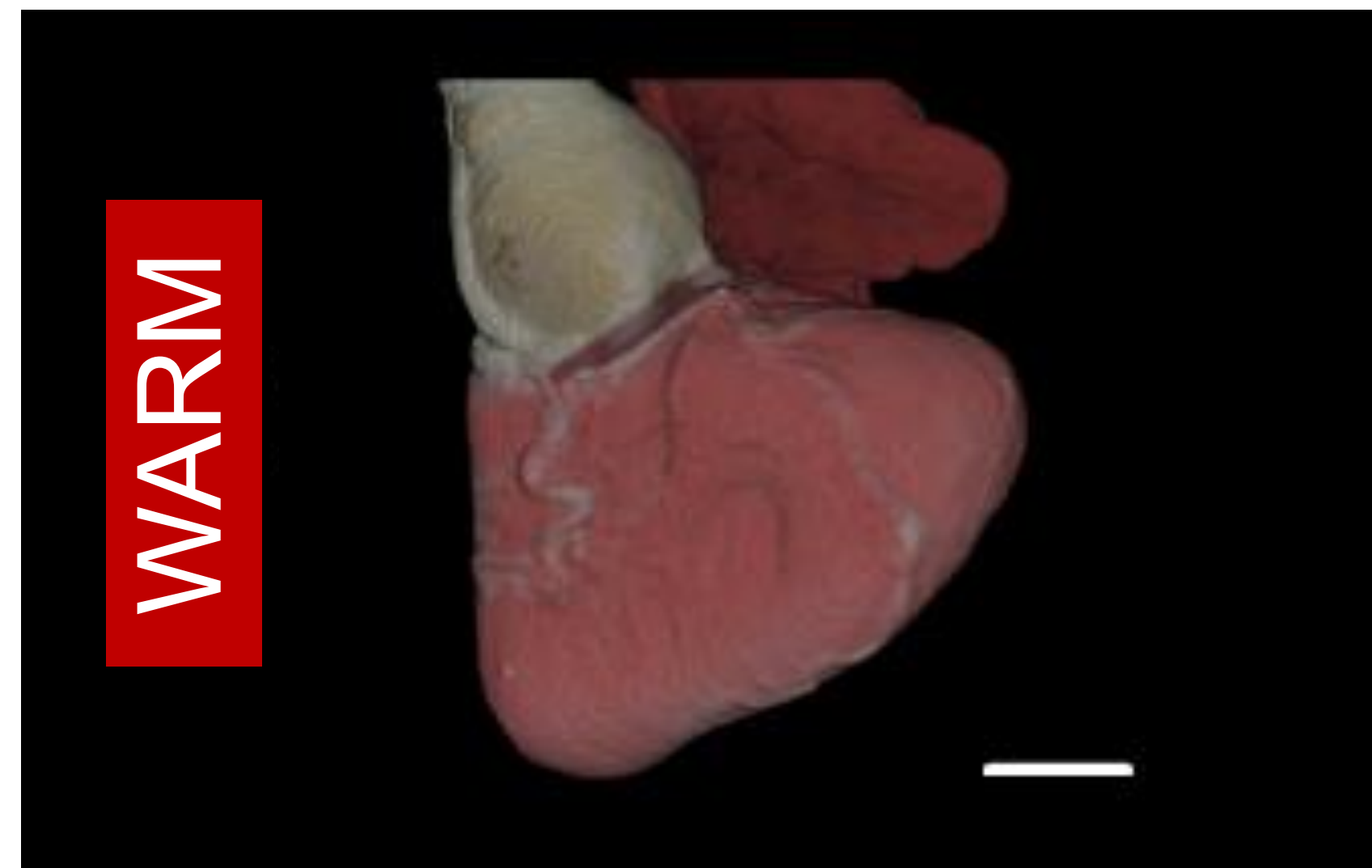
Slower growing 'cold smolts' outperformed intensively produced smolts after 1 year at sea



‘Cold smolt’
hearts
associated
with reduced
CMS and
delousing
mortality



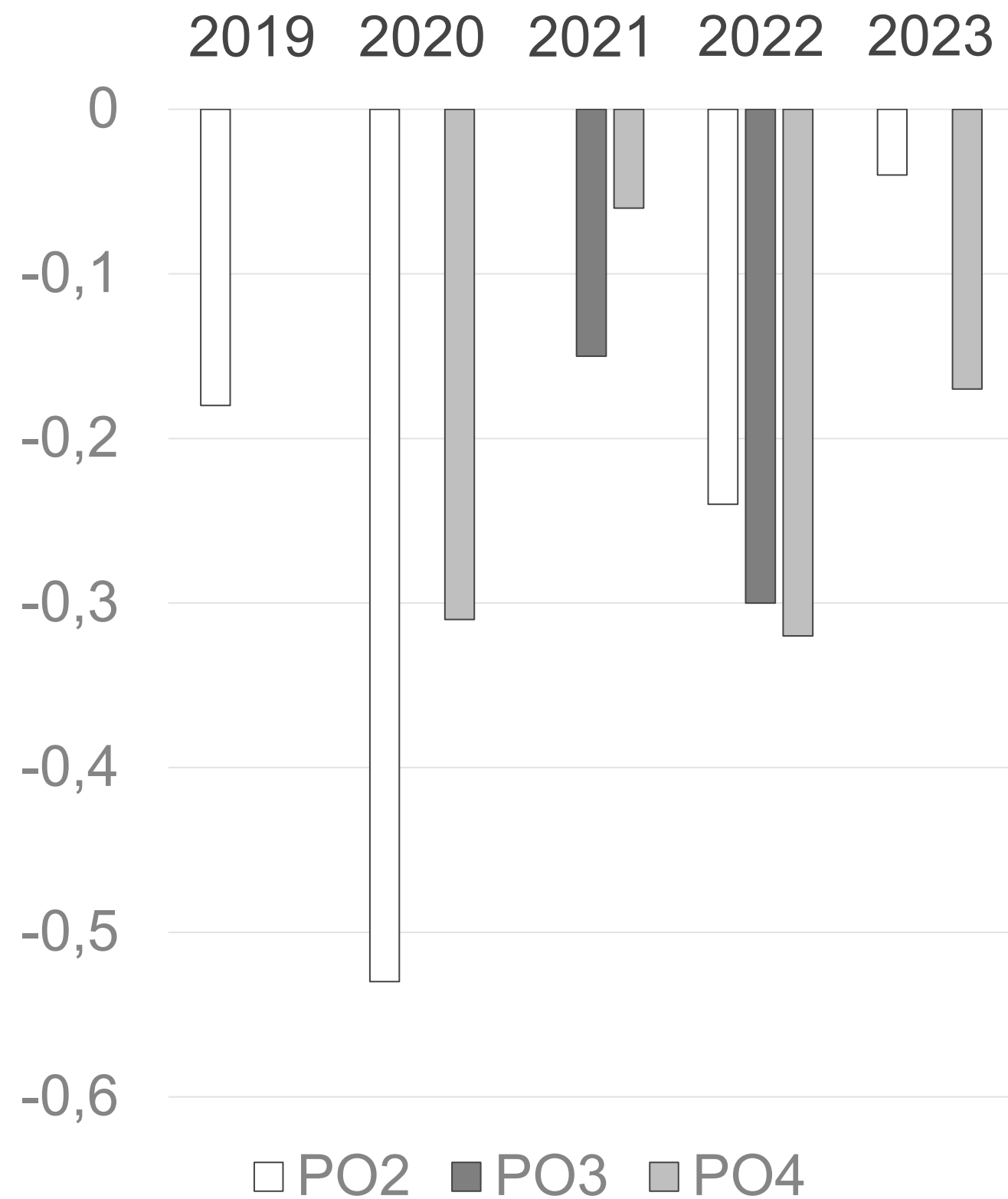
Smaller, stronger hearts
Normal pyramidal shape
Thinner, but well-structured compact layer
Normal growth pattern



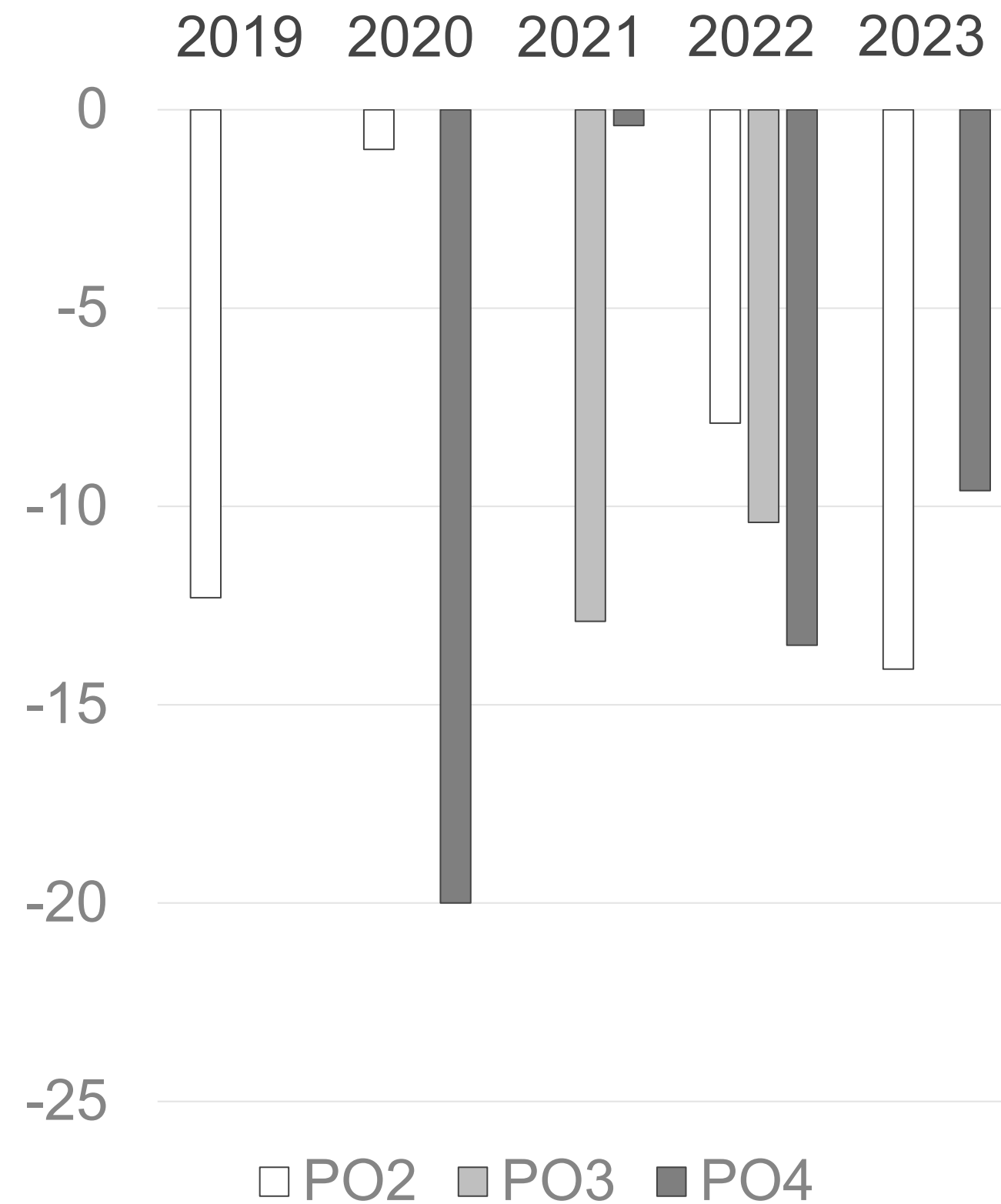
Larger, weaker hearts
Rounder shape, misaligned structures
Thicker, but irregular compact layer
Evidence of ‘overgrowth’



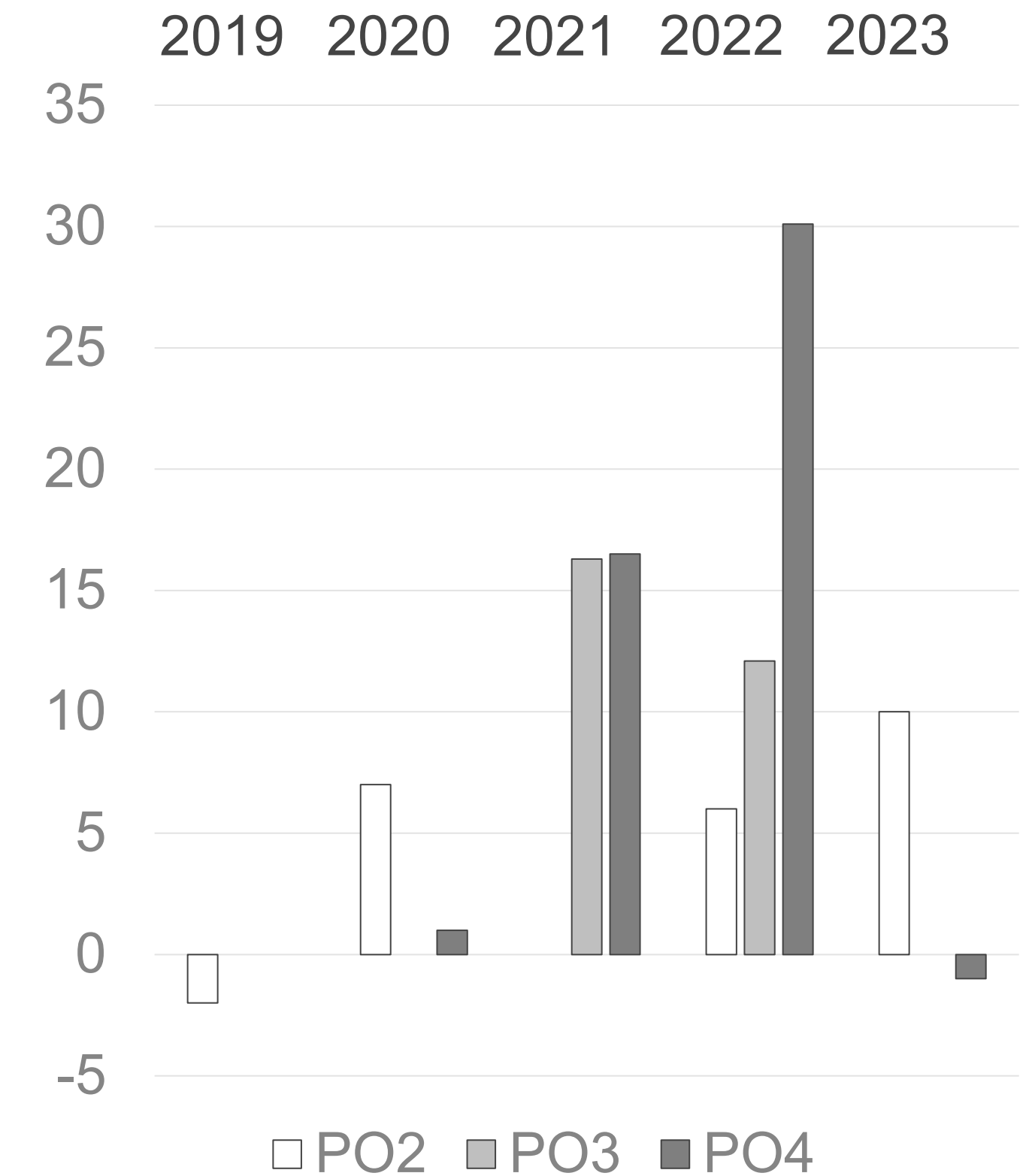
FCR = 1.17 vs. 1.27



Mortality = 10 vs. 20%



Superior = 89 vs. 79%



S1/S2 'cold smolts' consistently outperform intensively reared S0+/S1 smolts



ROOT CAUSES






Poor smoltification, intensification of smolt production, and transition to large smolts are risk factors for mortality

Aquaculture Research

WILEY

RESEARCH ARTICLE **OPEN ACCESS**

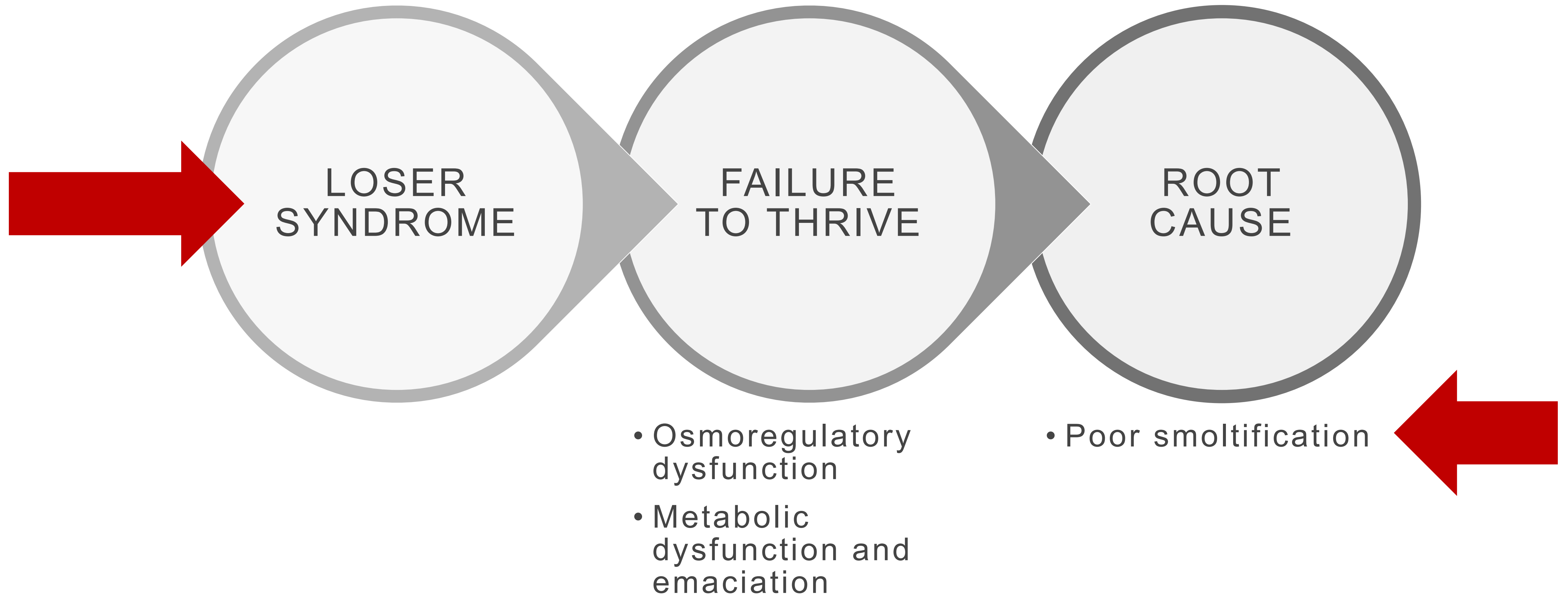
Mapping Hatchery Risk Factors for Mortality in Post-Smolts: A Qualitative Study

Siri Kristine Sollien Gåsnes¹  | Britt Bang Jensen²  | Kristine Størkersen³  | Marit Stormoen⁴  | Kristine Gismervik¹ 

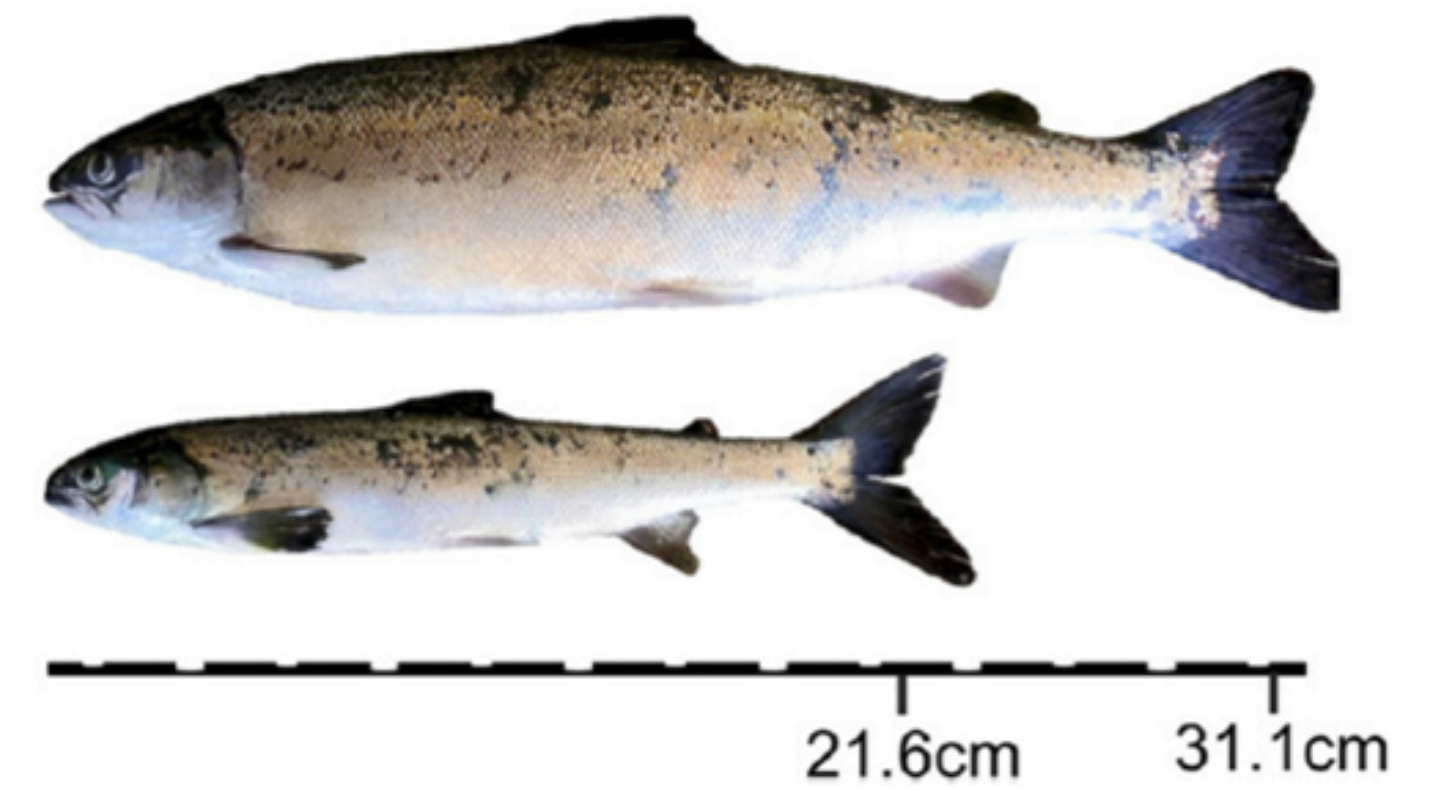
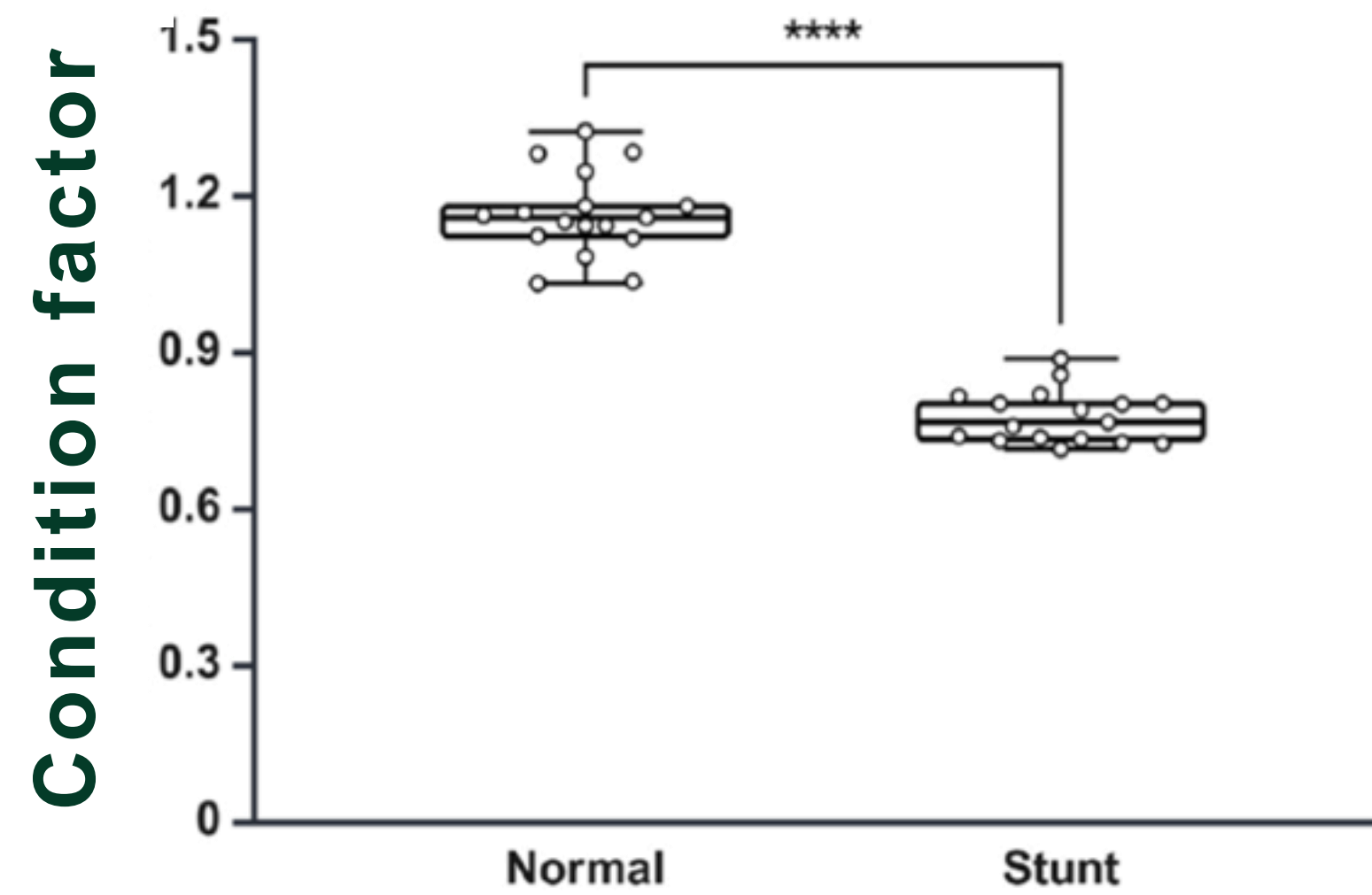
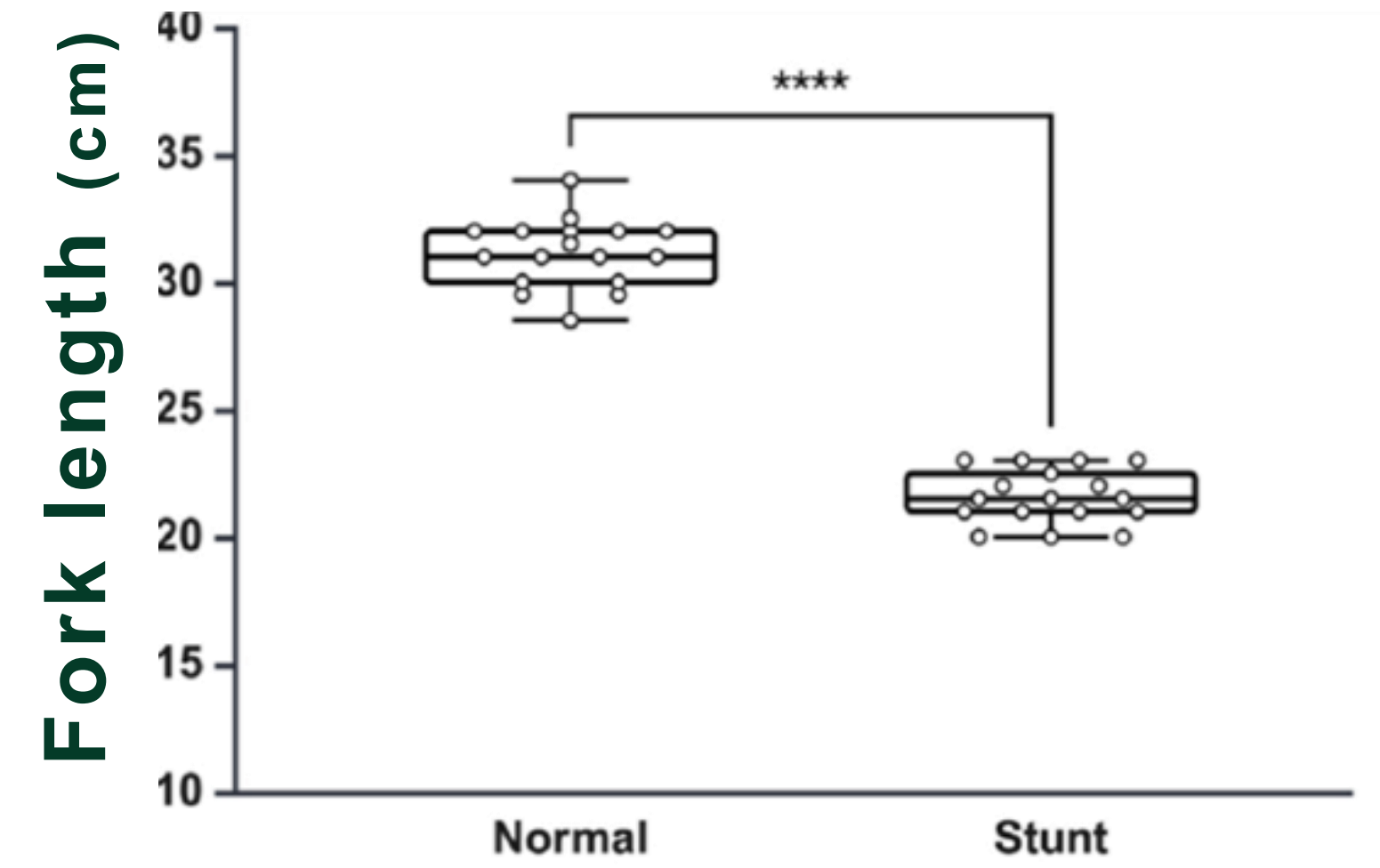
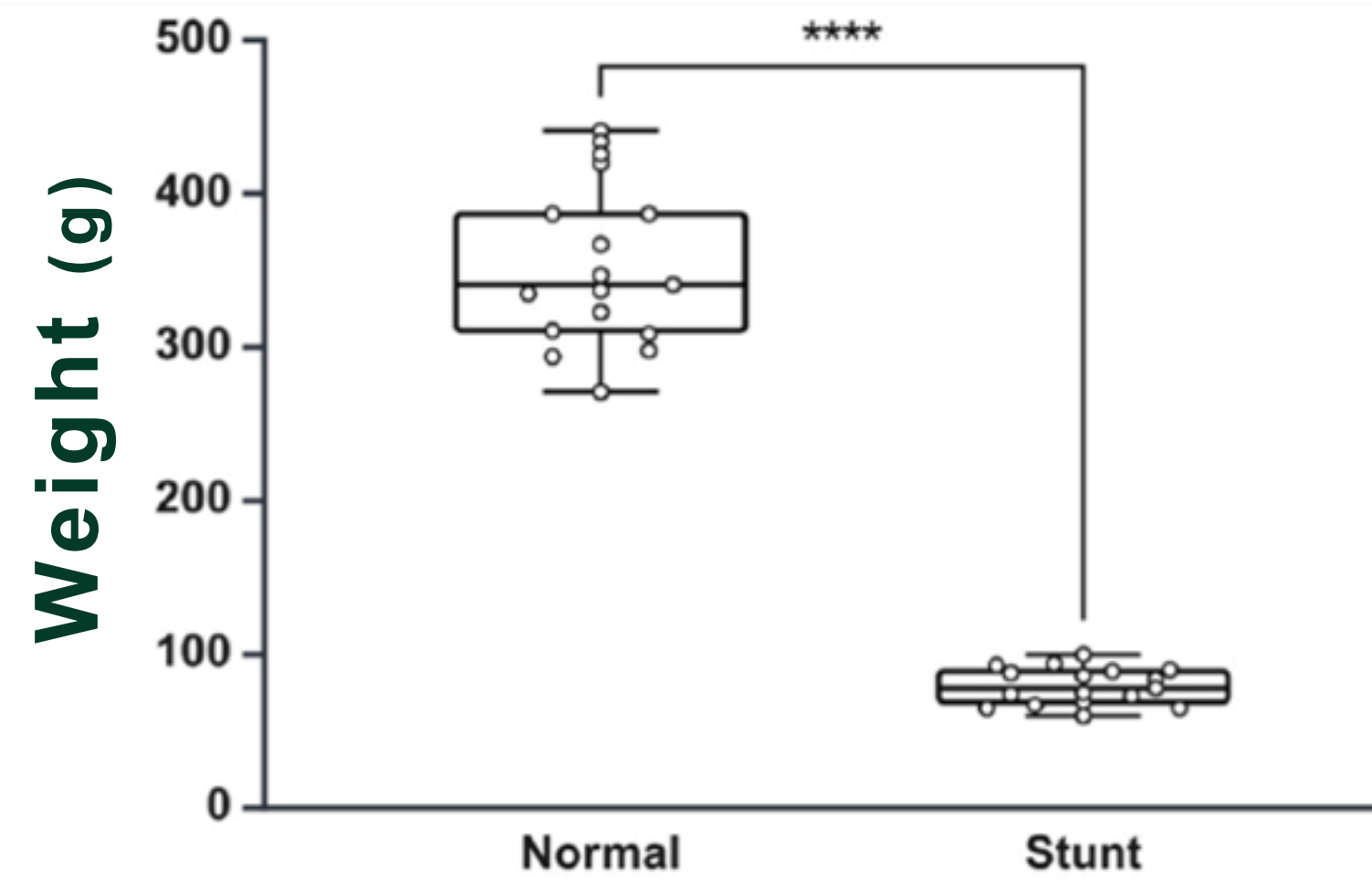
¹Norwegian Veterinary Institute, Arboretveien 57, Ås 1433, Norway | ²Technical University of Denmark, National Institute of Aquatic Resources, Henrik Dams Allé, Bygning 202, Lyngby 2800, Denmark | ³SINTEF Ocean, Pb 4760, Torgarden, Trondheim 7465, Norway | ⁴Faculty of Veterinary Medicine, Norwegian University of Life Sciences, Elizabeth Stephansens vei 15, Ås 1433, Norway



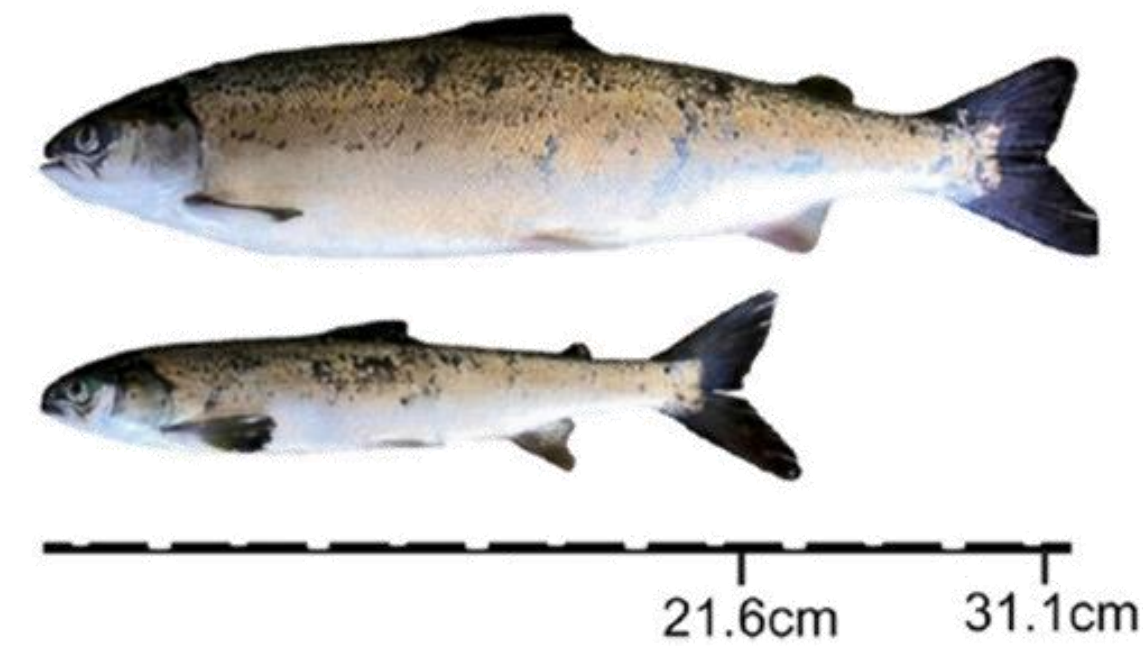
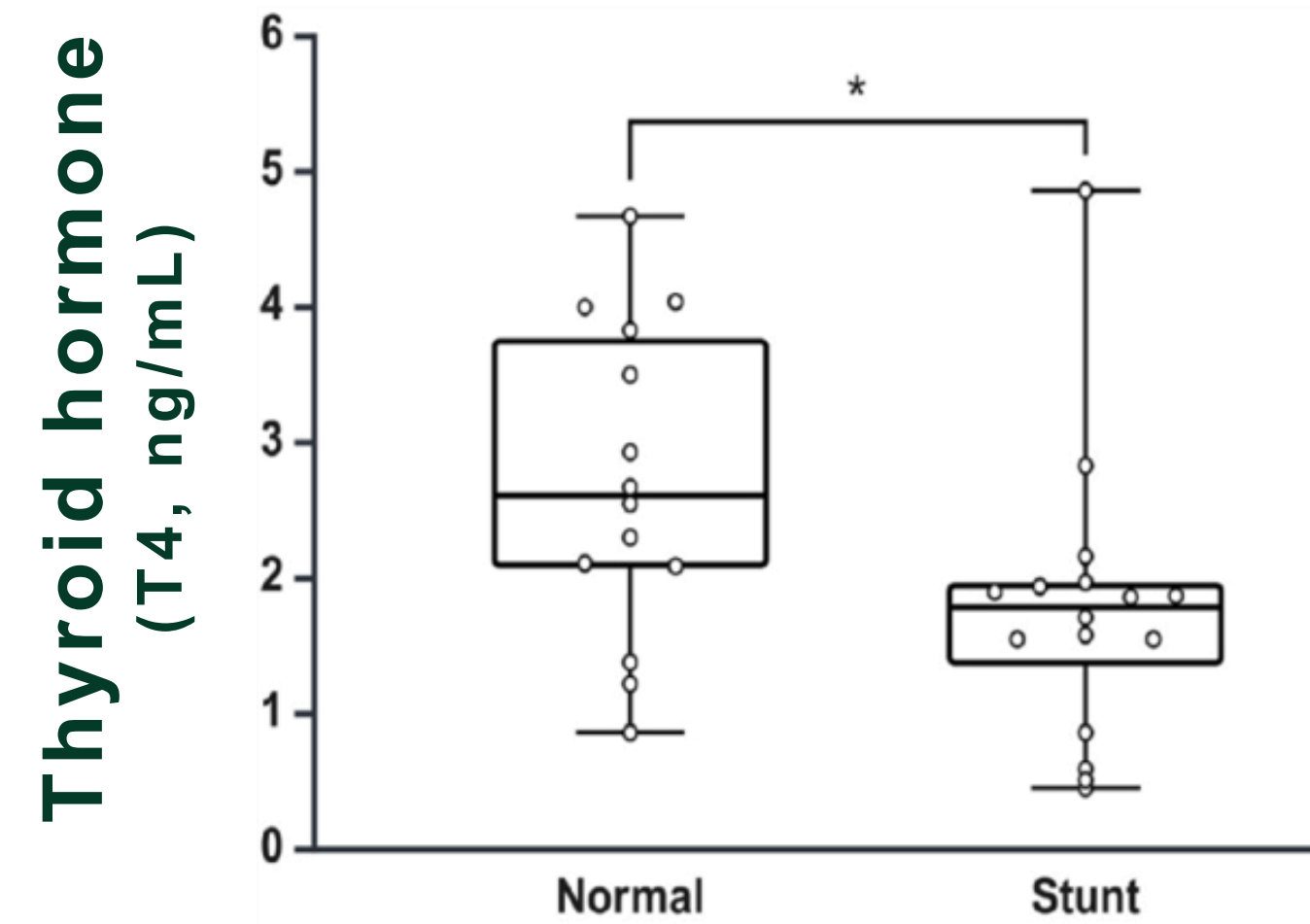
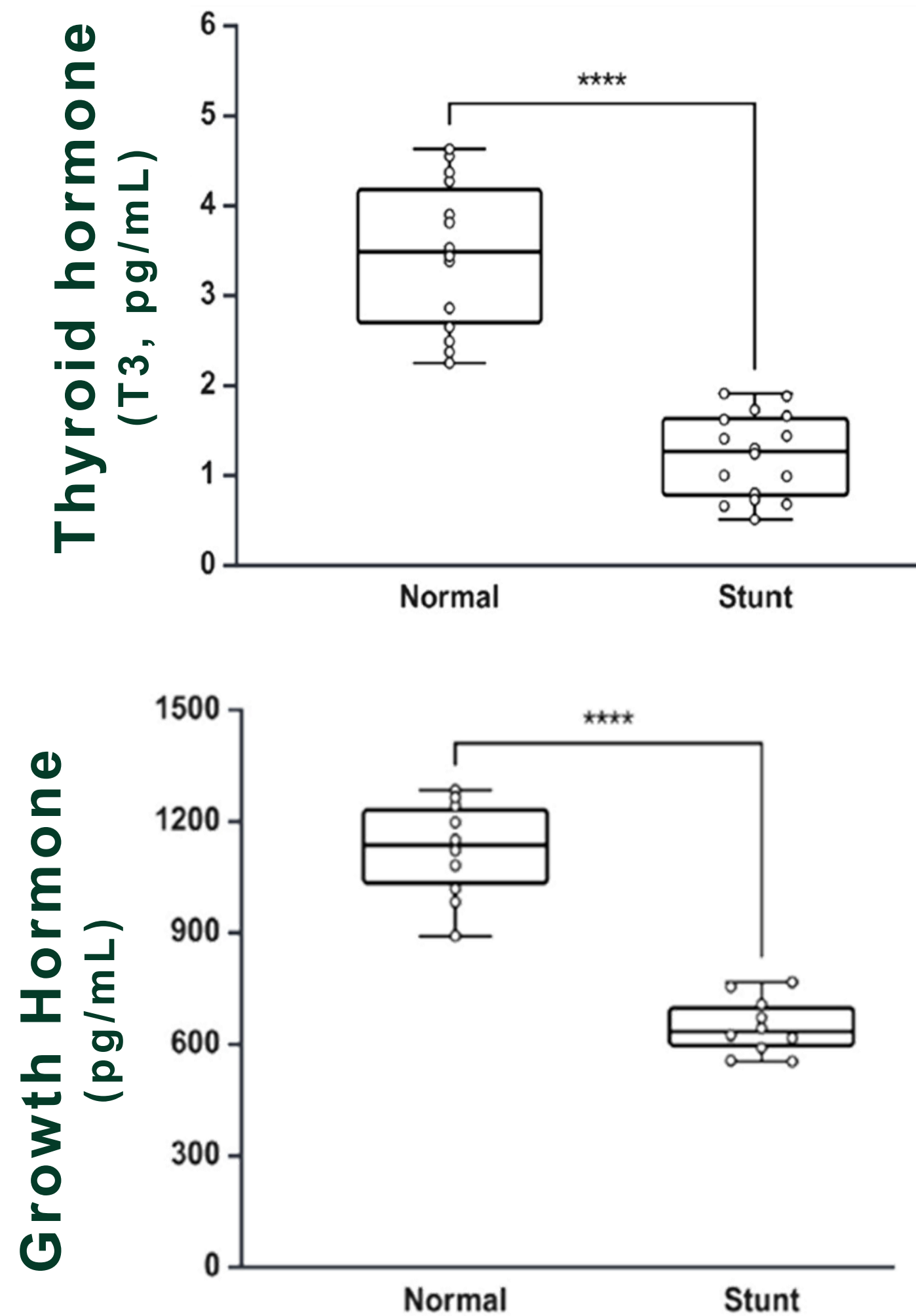
Root causes of mortality



Stunting occurs after seawater transfer

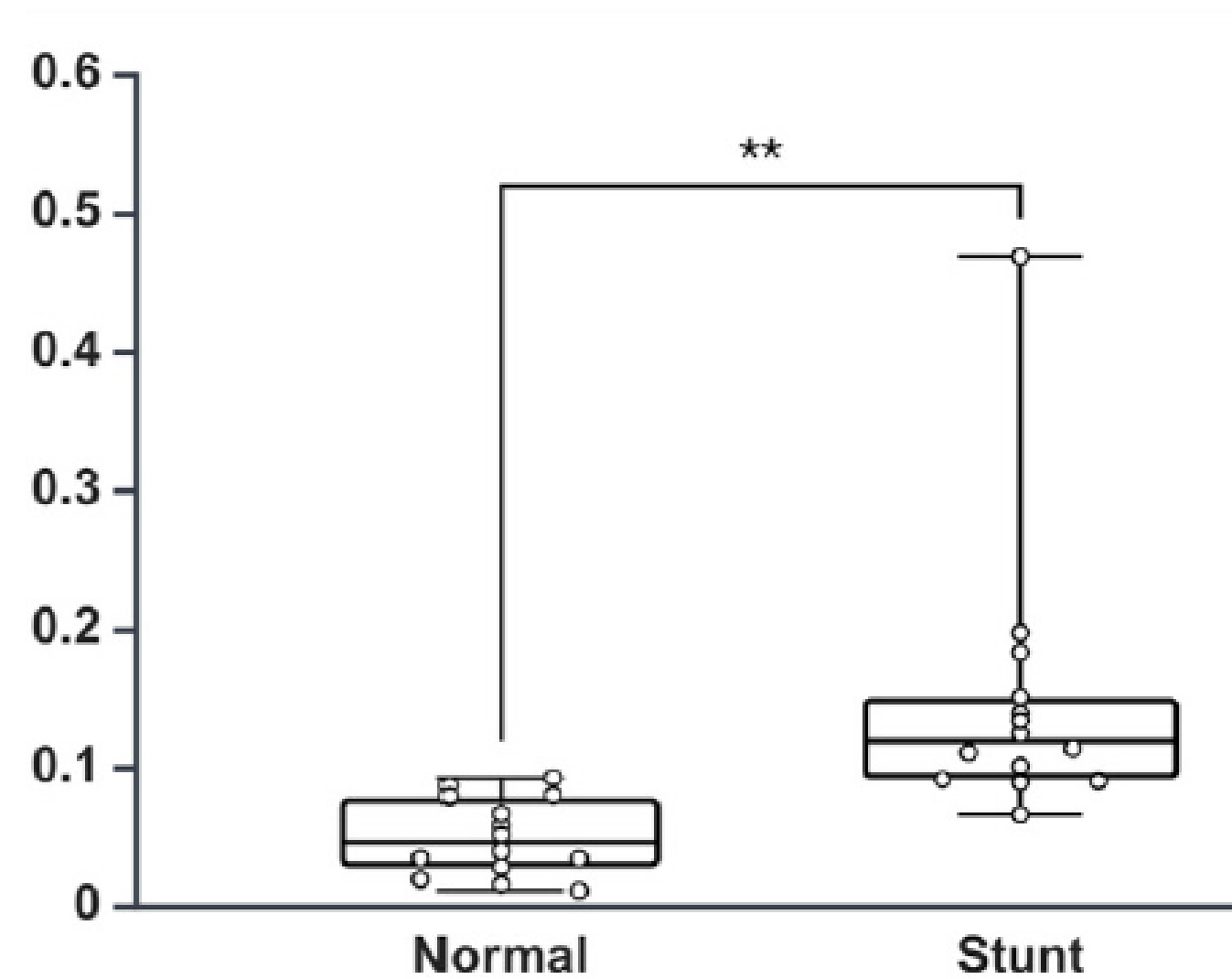


Stunting is synonymous with poor growth

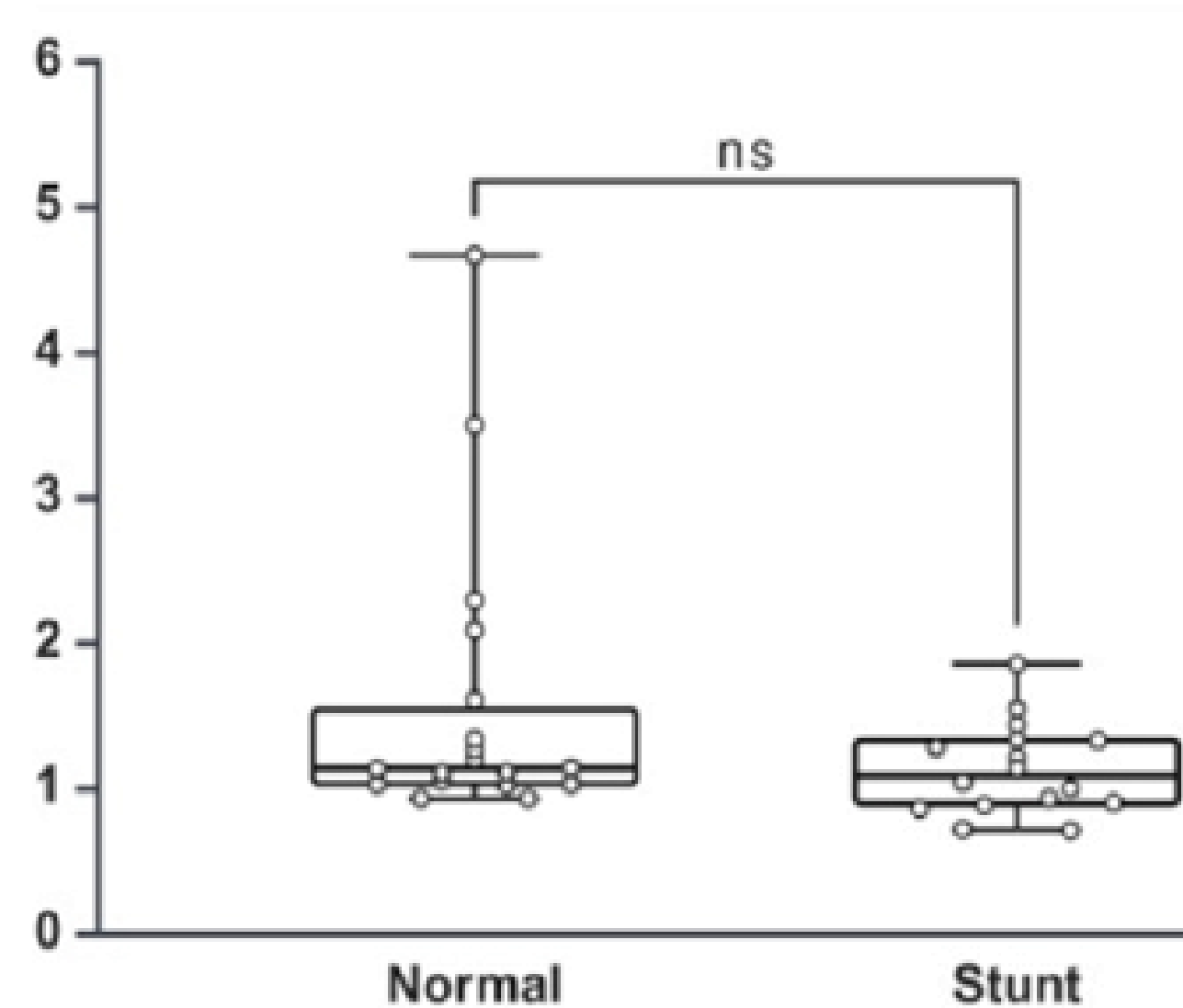


Stunting is also synonymous with poor smoltification

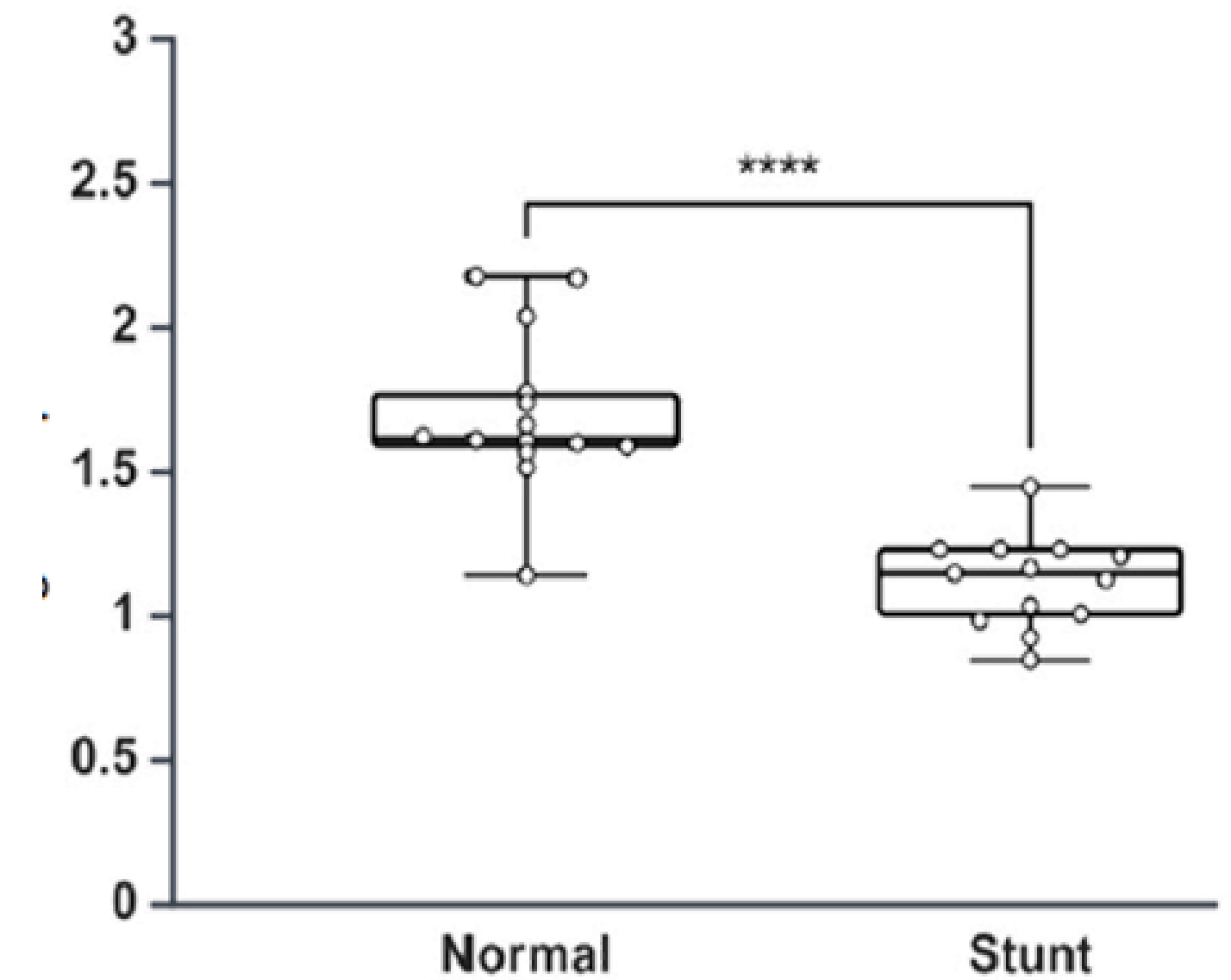
nka α 1a expression



nka α 1b expression



nka α 3 expression

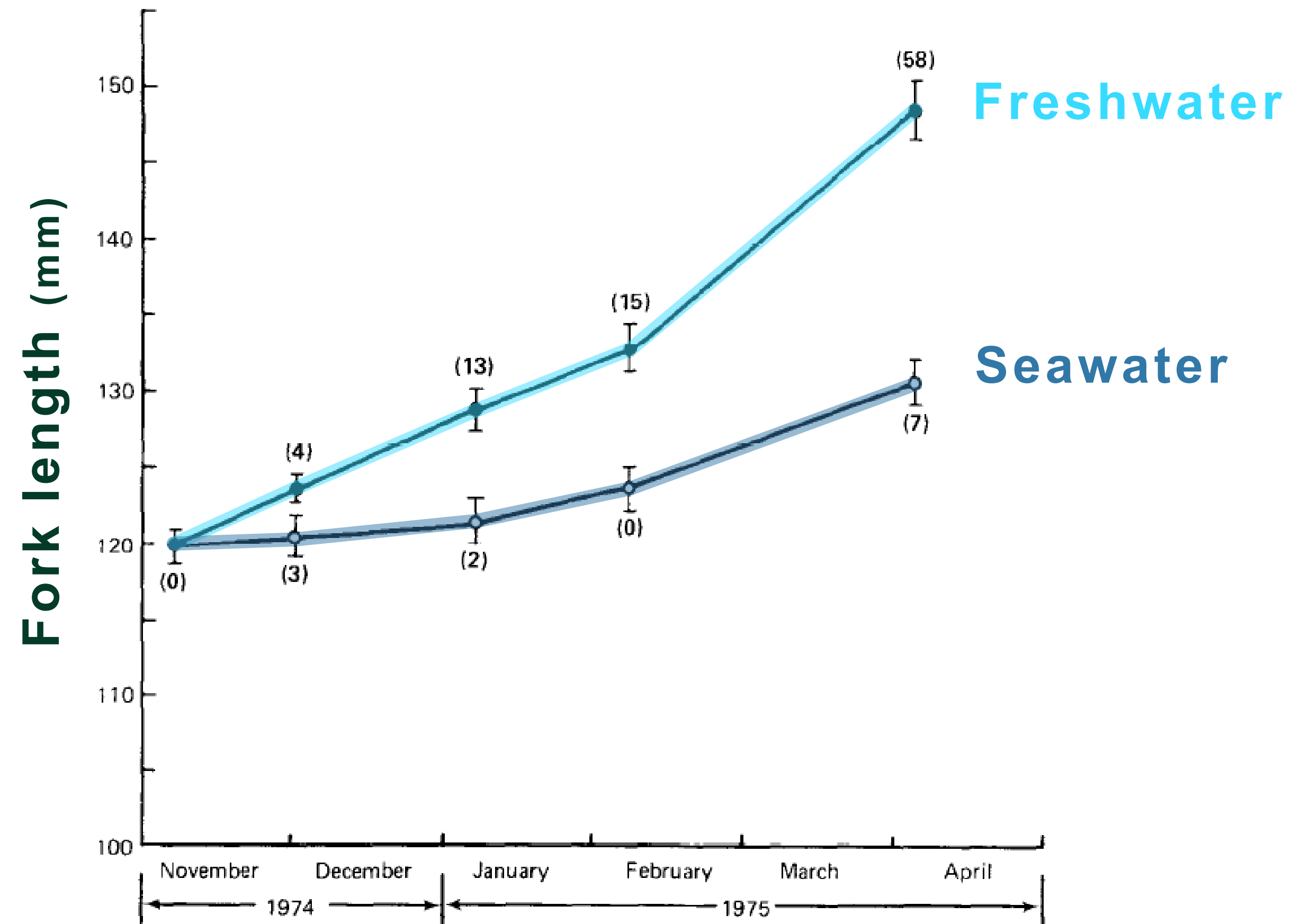


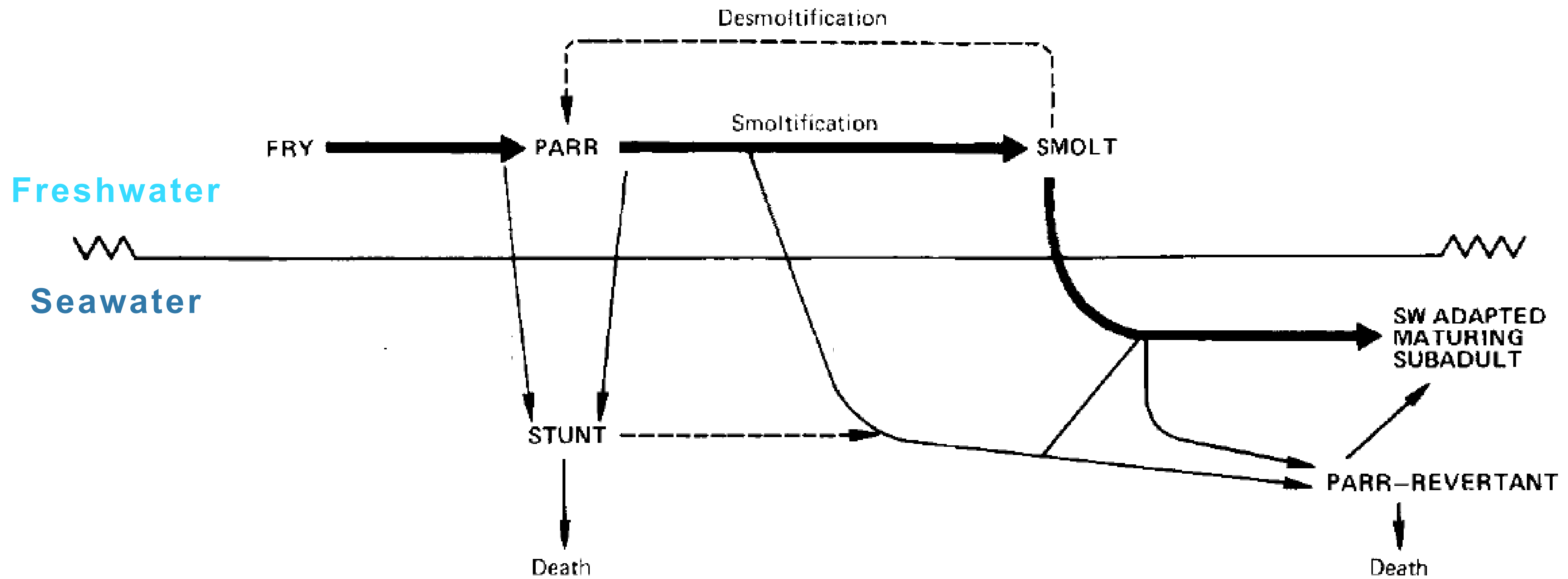
Stunted fish show signs of desmoltification and reverting to freshwater osmoregulation



Stunted or parr-revertant?

	Thyroxine	Triiodothyronine	Gill Na ⁺ -K ⁺ -ATPase
Smolt	11.4 ± 1.1	8.1 ± 0.7	18.6 ± 0.9
Parr-revertant	6.5 ± 0.3	7.1 ± 0.7	23.7 ± 0.9





STUNT = Transferred as parr before smoltification

PARR-REVERTANT = Transferred as pseudo-smolts or after desmoltification



ROOT CAUSES

Poor smolt quality is related to intensification, differences between species, misuse of salt feeds and brackish water, and the lack of appropriate assays

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Review



Smoltification strategies in intensively cultured salmonids

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Stop blaming bugs

- Pathogens are only part of the problem
- Rearing practices impact fish health and welfare, directly and indirectly
 - Poor nutrition
 - Intensive smolt production
 - Improper vaccination and smoltification strategies
- Addressing root causes will improve outcomes

