Metamorphosis or the larval-juvenile transition: Steering the future of the foodfish industry

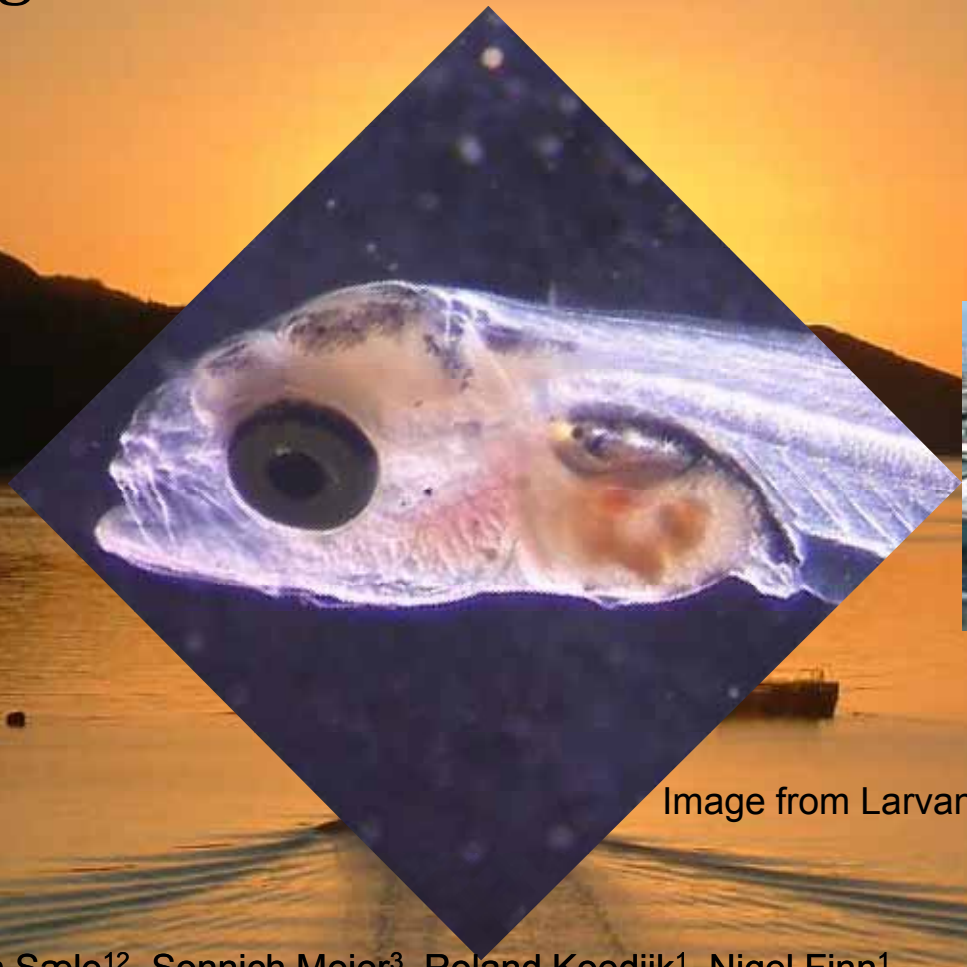

Image from Larvanet

Karin Pittman[1], Oystein Sæle[12], Sonnich Meier[3], Roland Koedijk[1], Nigel Finn[1]

1) Univ of Bergen

2) NIFES
Bergen
Norway

3) Inst of Marine Reseach

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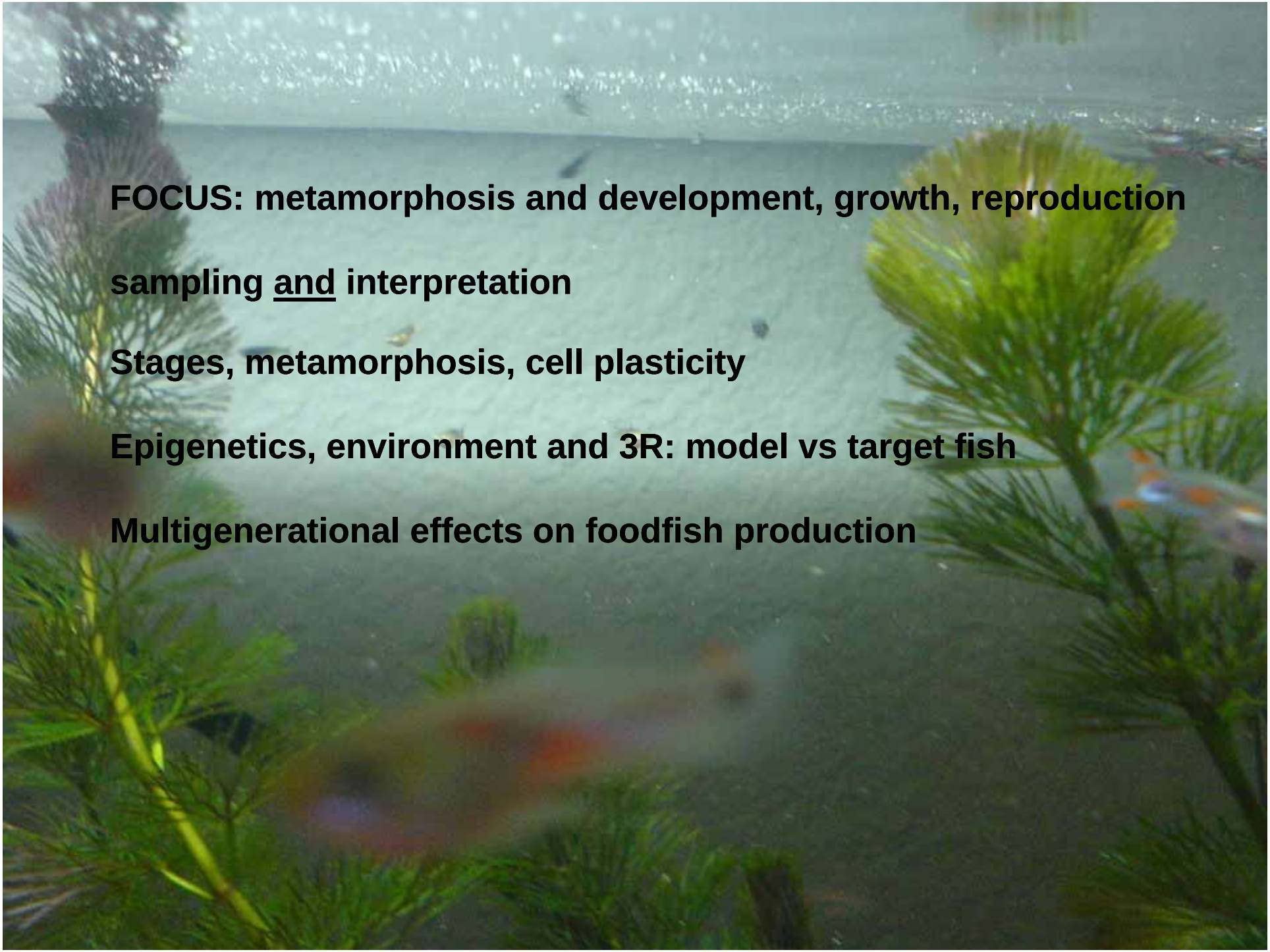
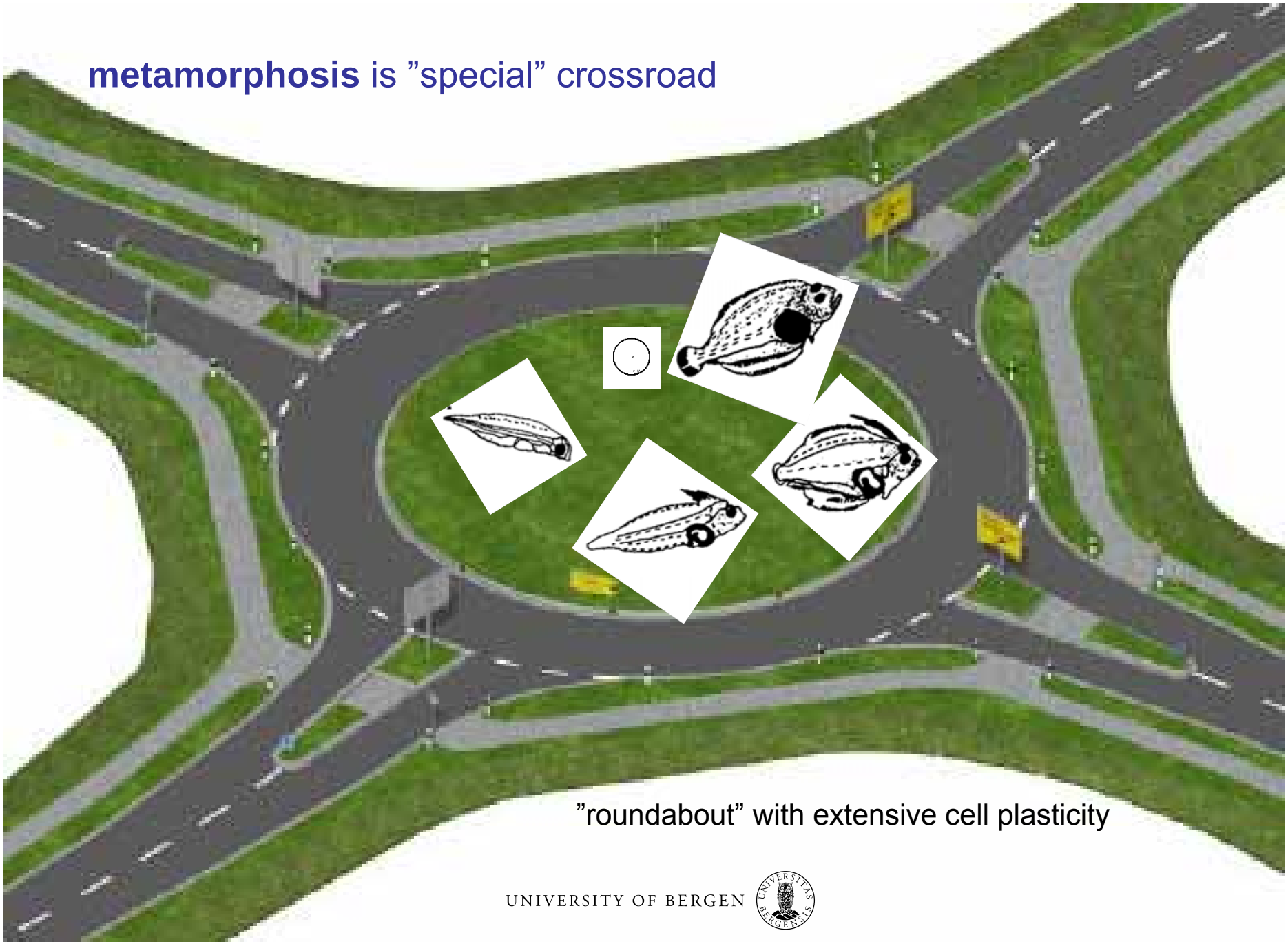

FOCUS: metamorphosis and development, growth, reproduction
sampling and interpretation
Stages, metamorphosis, cell plasticity
Epigenetics, environment and 3R: model vs target fish
Multigenerational effects on foodfish production

metamorphosis is ”special” crossroad



”roundabout” with extensive cell plasticity

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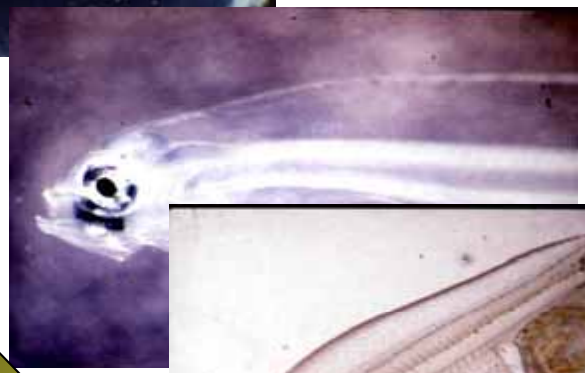
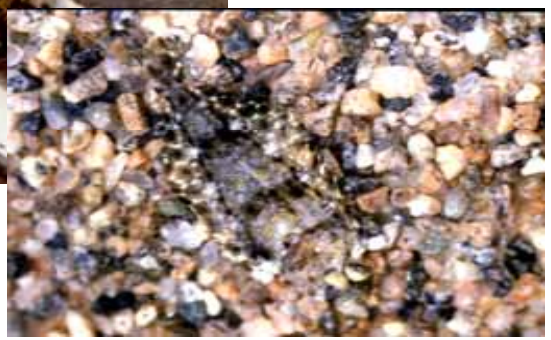
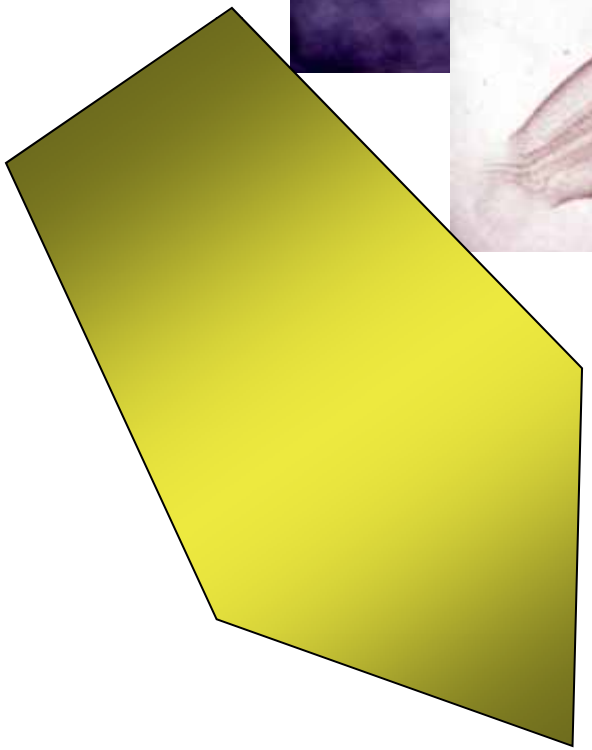
Metamorphosis or the larval-juvenile transition





Cell plasticity



Cell determination

Organogenesis:

brain, eyes, notochord,

gut, endocrine systems,

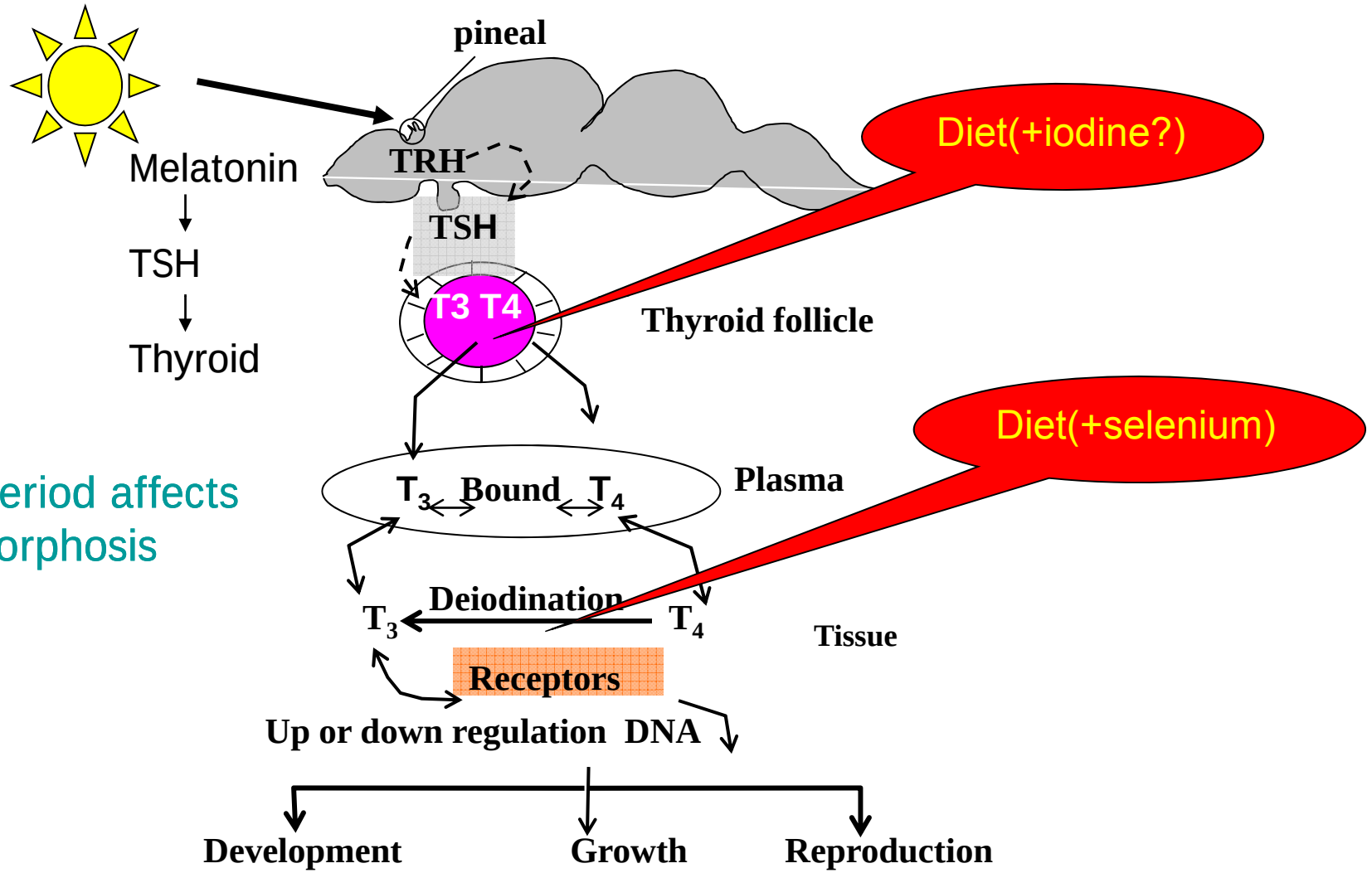
cranial skeleton,

gills, blood cells, skin,

gonads, axial skeleton

(endocrine controlled)

MODEL Hypothalamus-pituitary-thyroid axis directs transformation from larva to juvenile

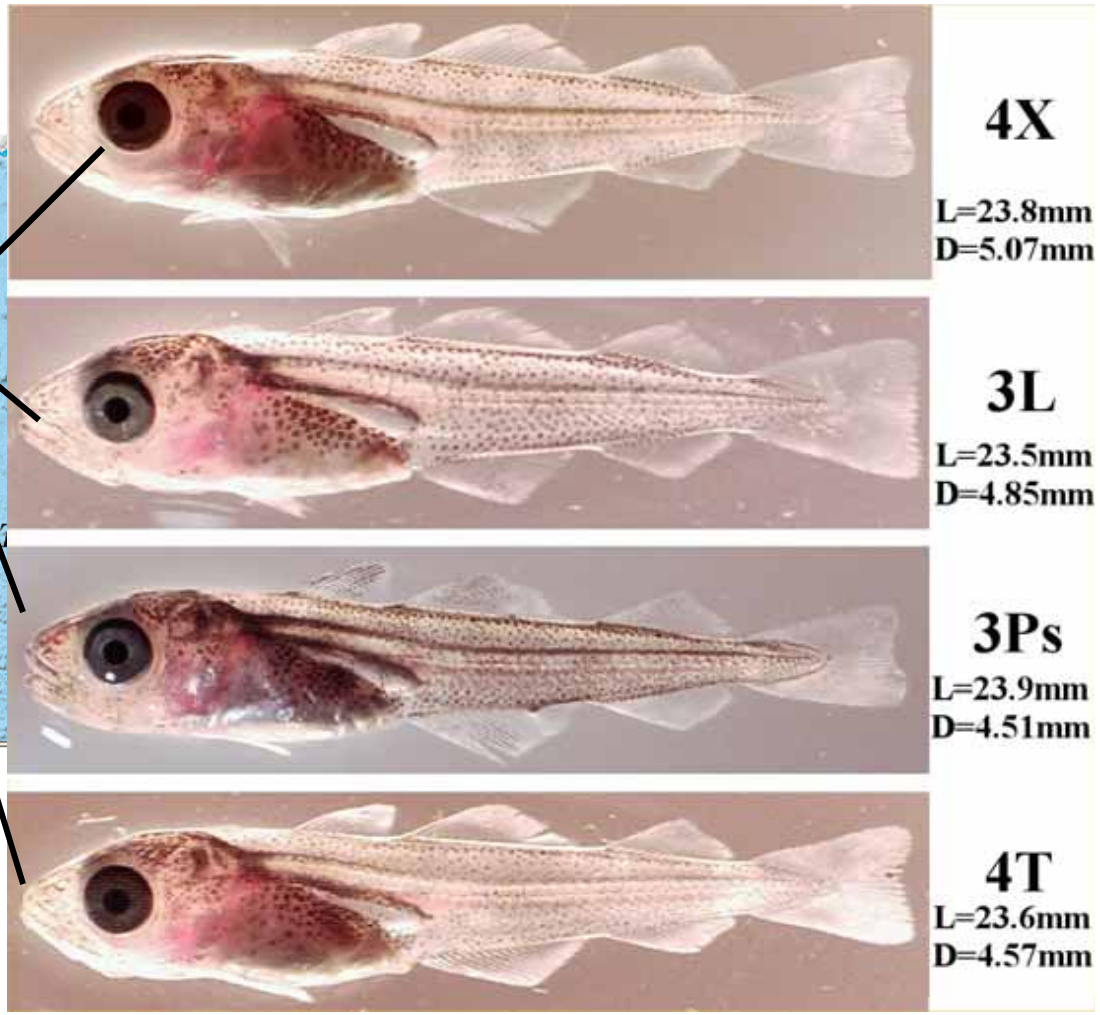


Photoperiod affects Metamorphosis

Model addresses several levels of organization

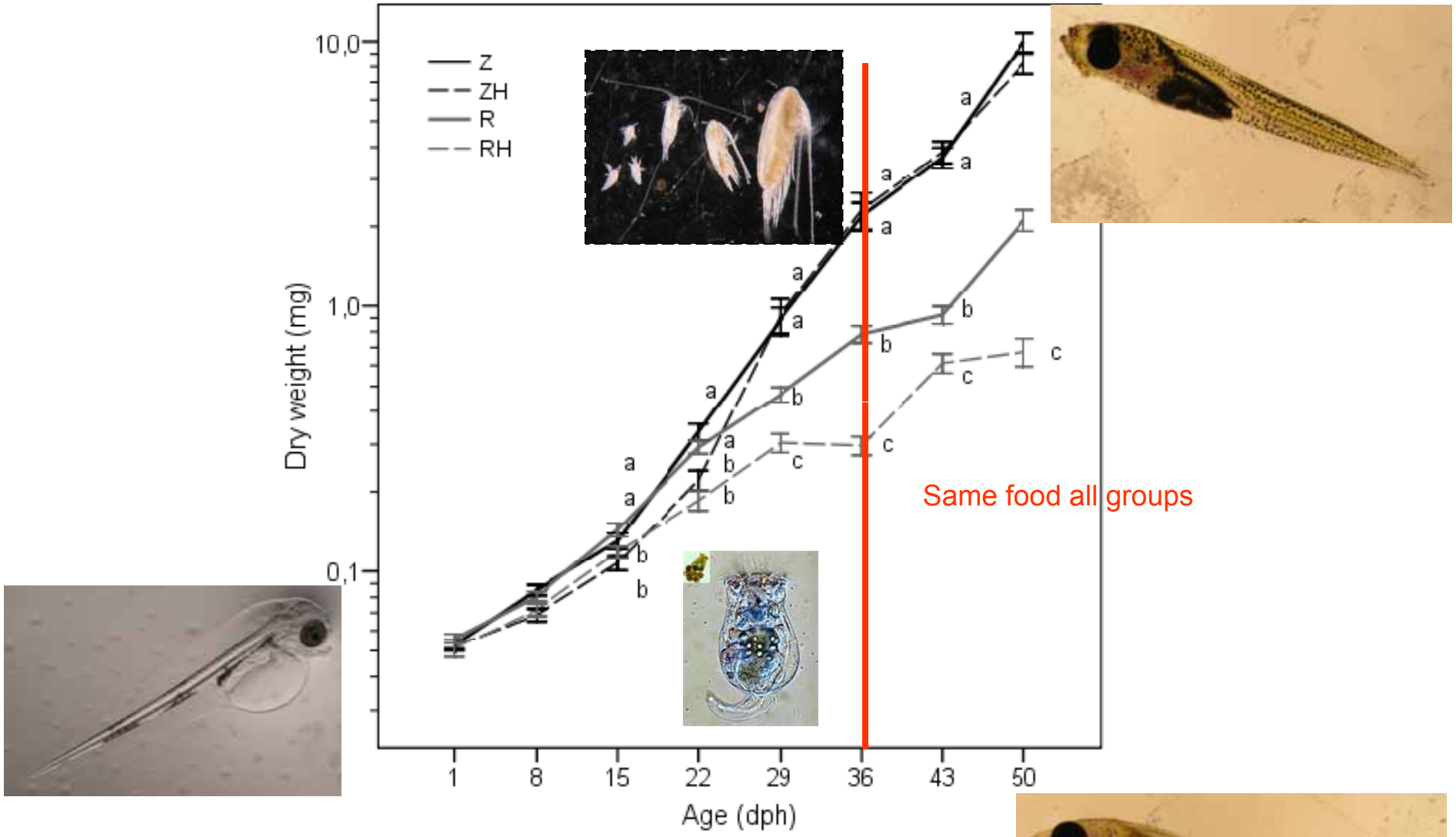
POPULATION: developmental differences begin before juvenile is established

(c) 1995 Dorling Kindersley Multimedia



Slide courtesy Dr. Joe Brown, Memorial Univ of Newfoundland

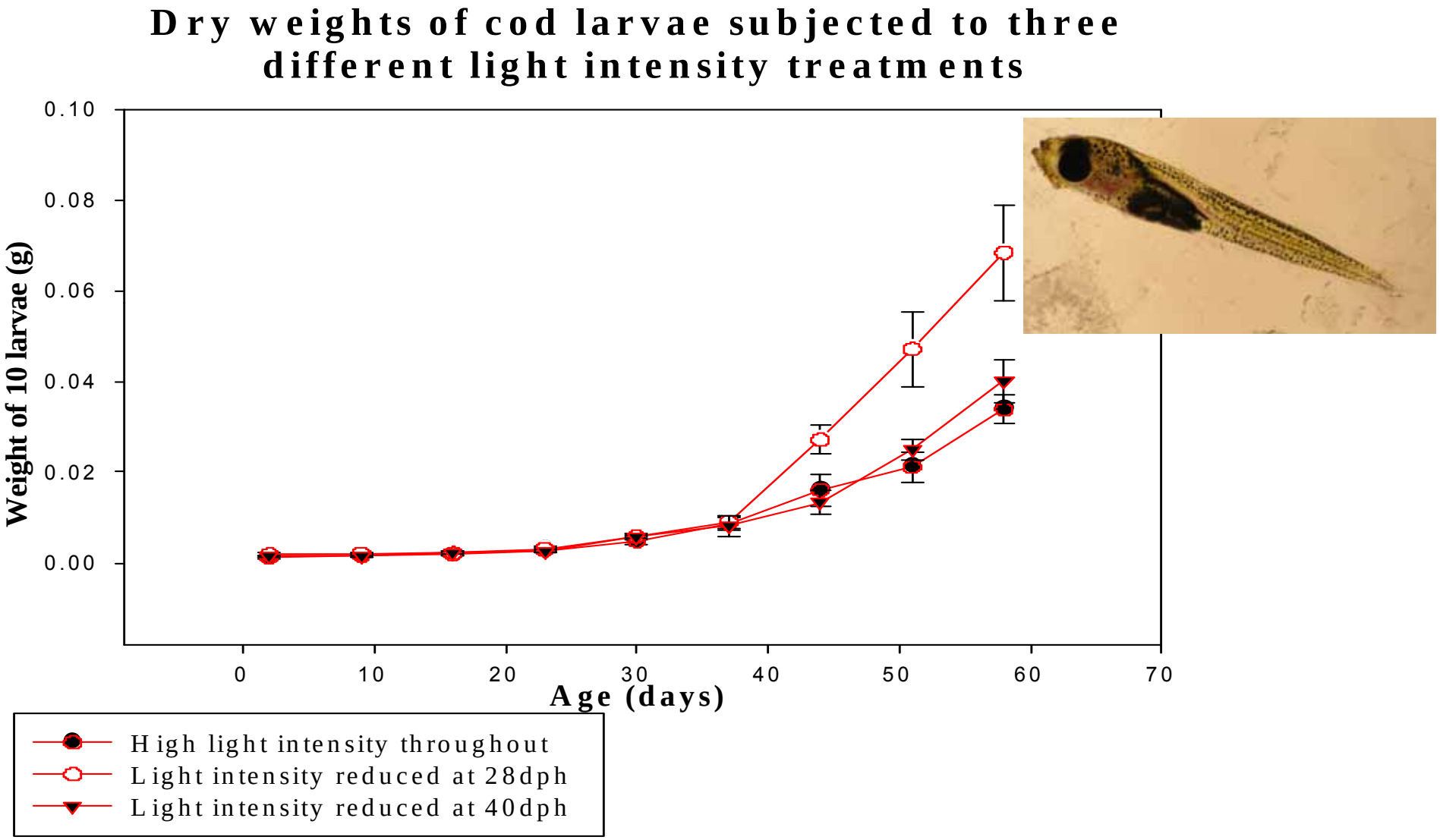
GROUP – development and further growth directed by first feed



Longterm growth benefit of first feeding on zooplankton (cod, *Gadus morhua*)

Koedijk et al., 2009 submitted

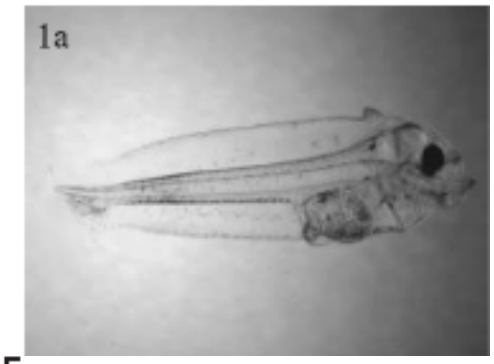
GROUP – growth (and development) directed by early photoperiod

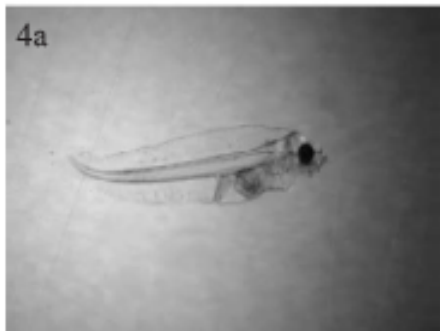


Slide courtesy Dr. Joe Brown, MUN, data Monk et al.

GROUP – development and growth directed by photoperiod

Southern flounder larvae, *Paralichthys lethostigma*



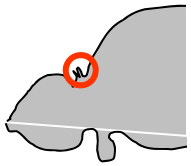


Moustakas et al., 2004

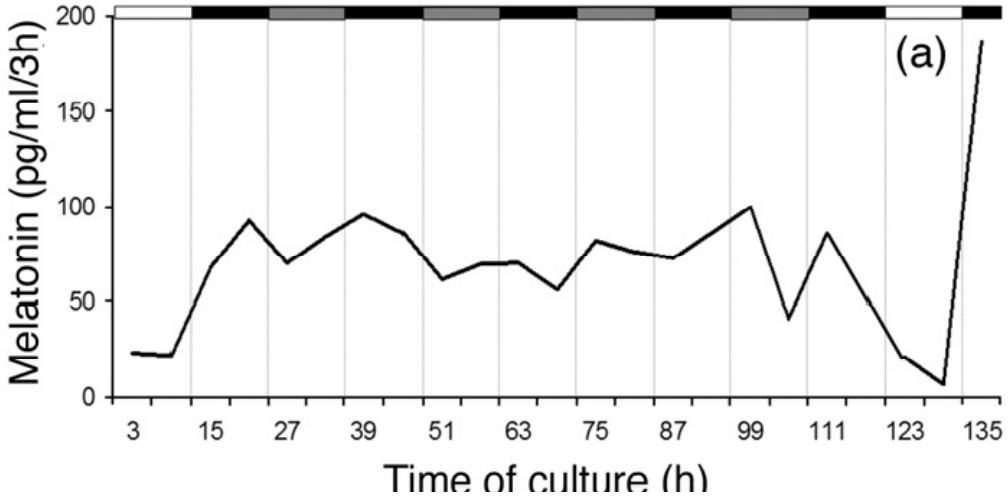
SPECIES + TISSUE – developmental control differentiates (pineal culture)

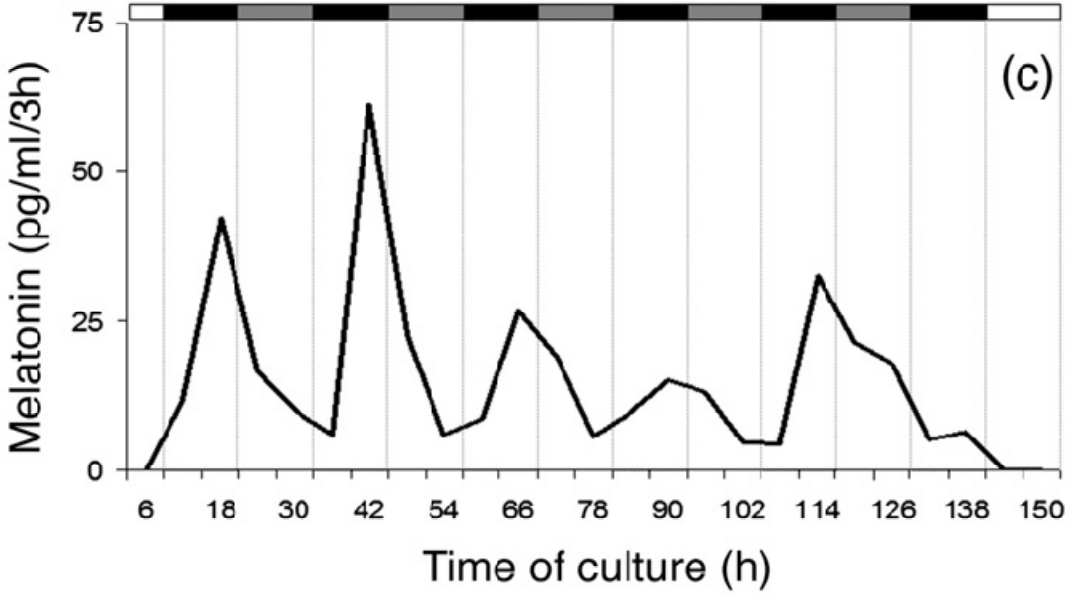
Solea senegalensis
Marine, flat
Photoperiod important
Exogenous rhythm

Tench (Tinca tinca)
FW, round
Photoperiod not so impt
Endogenous rhythm



Continuous dark

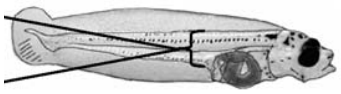




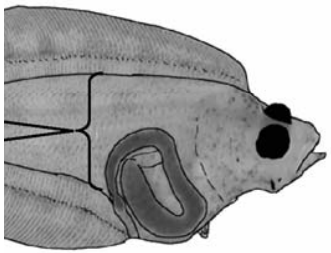
Oliveira et al 2009

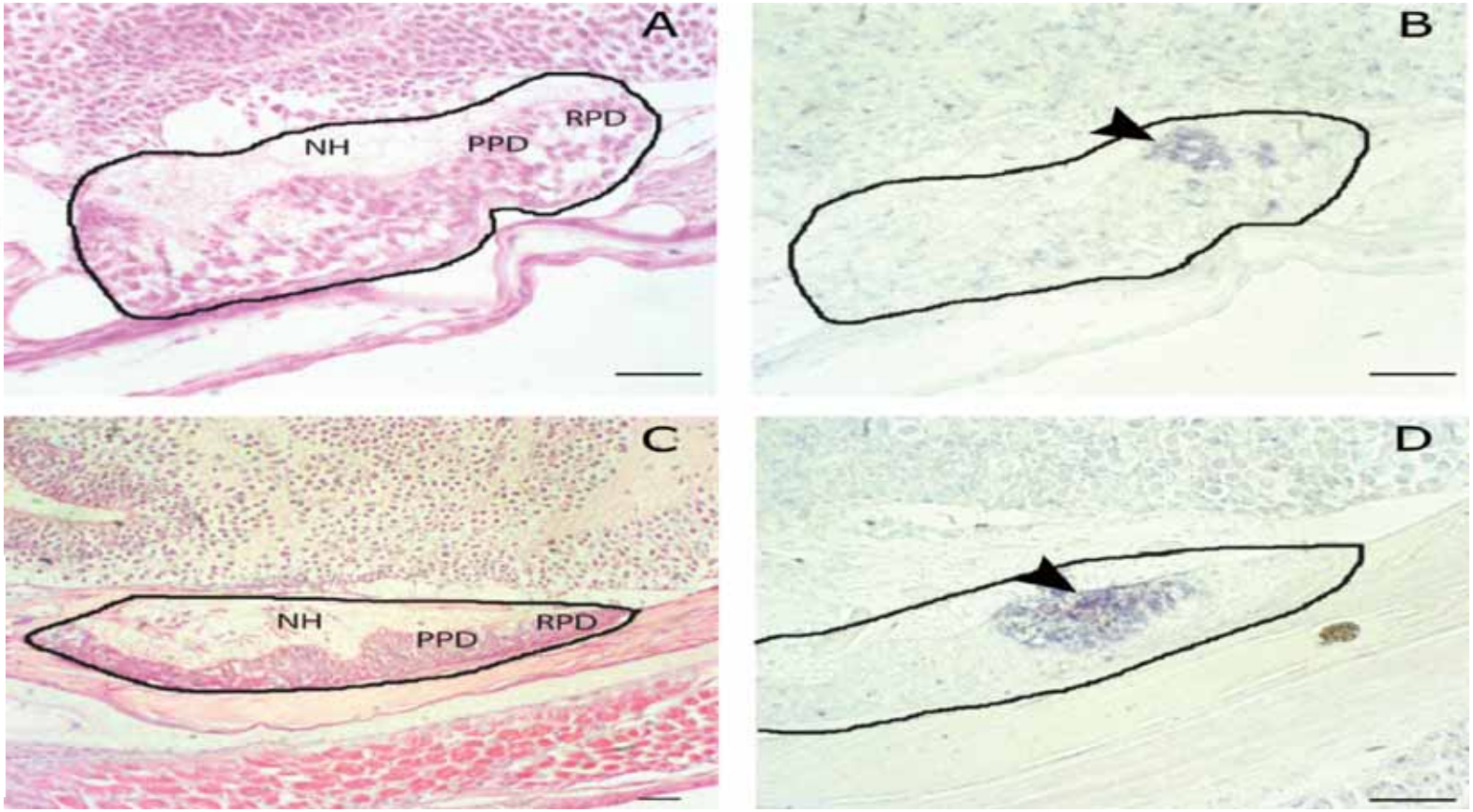
METAMORPHOSIS - Sampling by stage gives fundamental steering processes (species, groups, individuals, tissues)

Stage 5



Stage 8



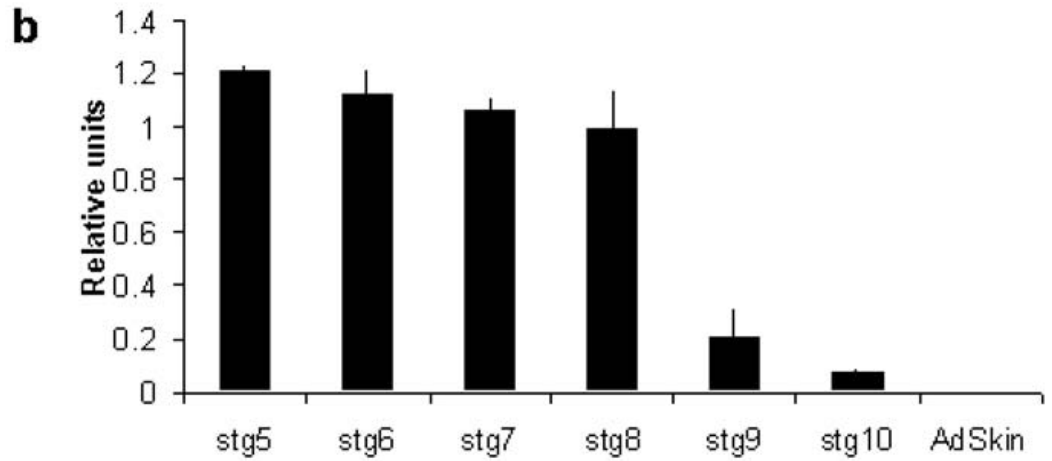


TSH β

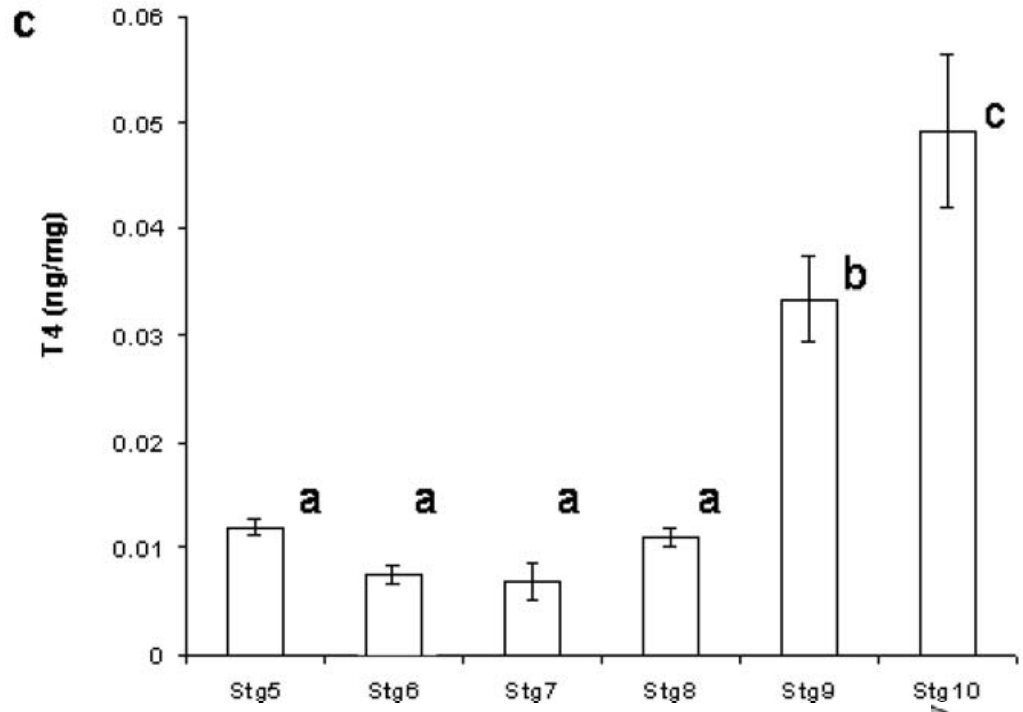
Power, Einarsdottir, Pittman, Sweeney, Hildahl, Campinho, Silva, Sæle, Galay-Burgos, Smaradottir & Bjørnsson 2008
The molecular and endocrine basis of flatfish metamorphosis. Reviews in Fisheries Science 16:95-111

INDIVIDUAL
development

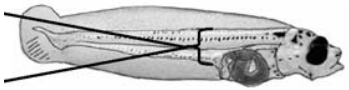
hhKer1:18S rRNA

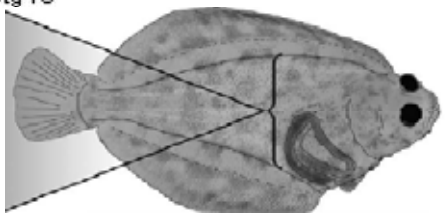


A keratin gene expression pattern in halibut



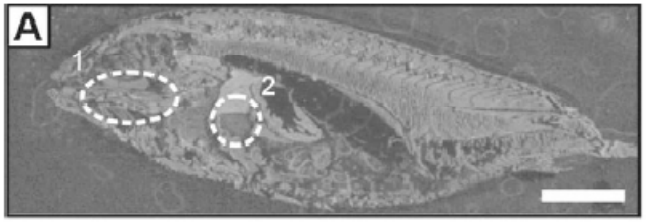
Thyroid hormone levels in halibut stages





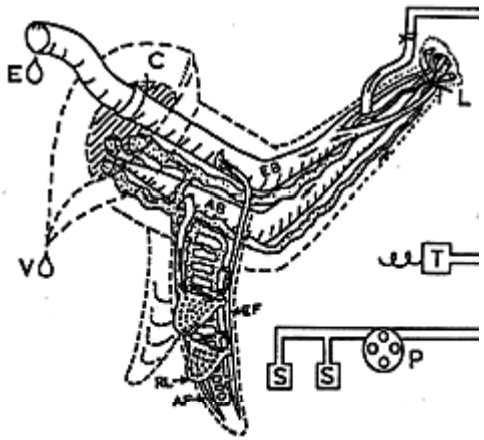
Campinho et al., 2007

SPECIES AND TISSUE- different tissues produce thyroid, steer development



Mozambique Tilapia – thyroid follicles in subpharyngeal

Common carp – thyroid follicles in kidney (87%), head kidney (3%) subpharyngeal,

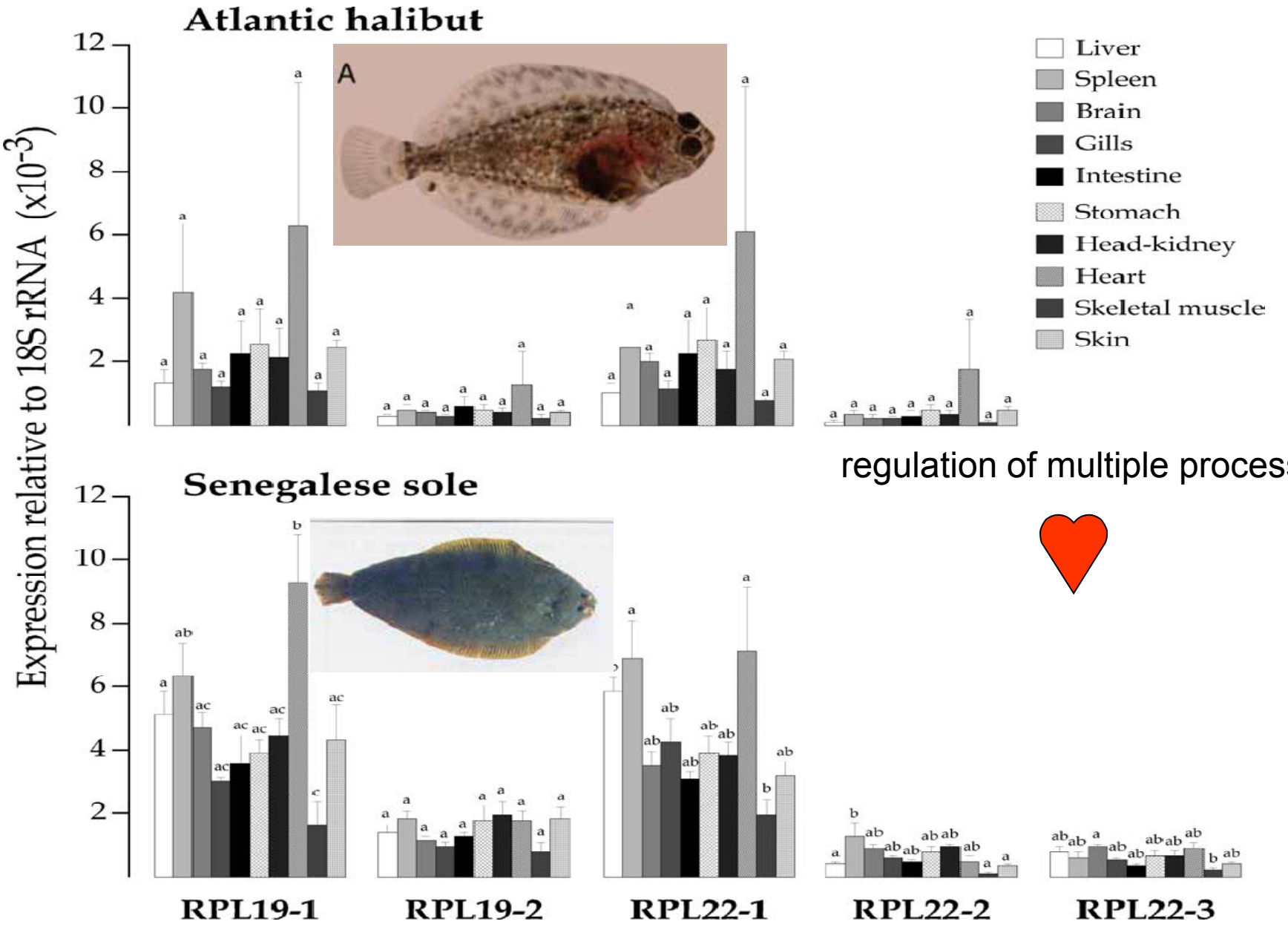


Platyfish *Xiphophorus maculatus*
Heterotopic in cardiovascular system

- Thyroid follicle cell populations are not physiologically equal in iodide uptake or hormone synthesis
- Multiple isoforms of thyroid hormone receptors exist

Adapted from Geven et al 2007, 2009; Finn unpub data

SPECIES, TISSUE, PROTEIN – different organs express ribosomal proteins

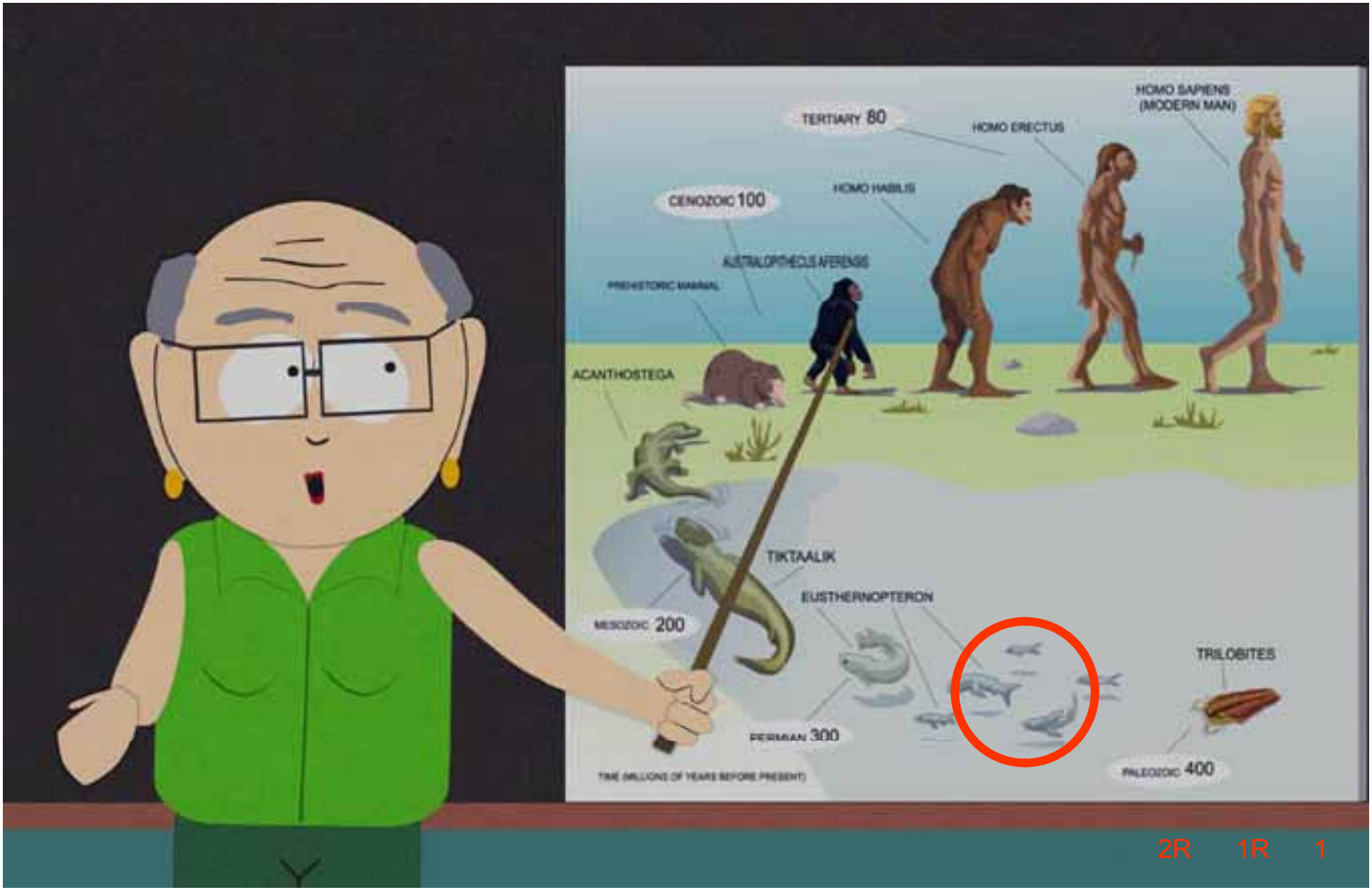


regulation of multiple processes

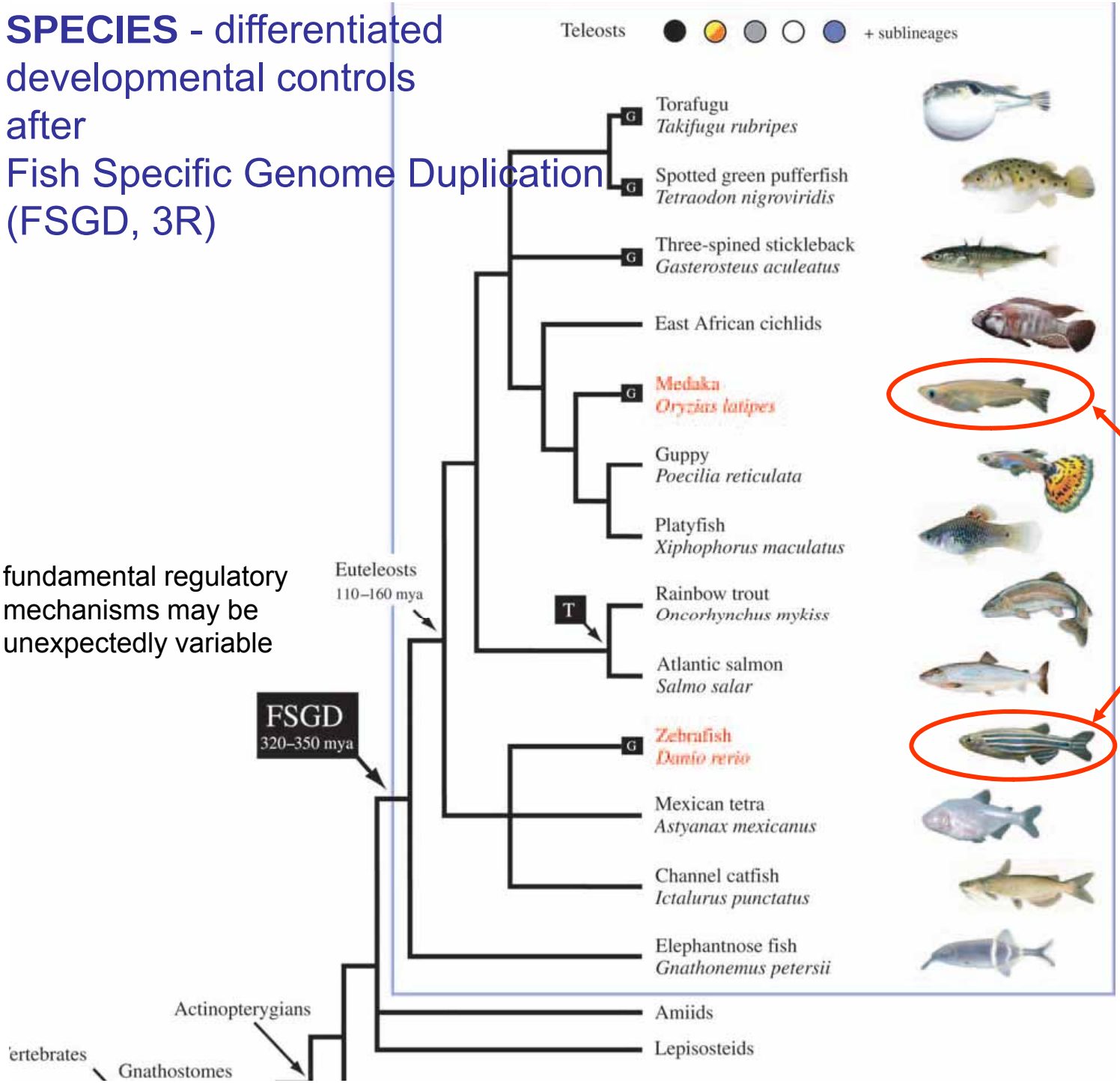
Fr Matsuoka et al 2008

CLASS ACT - Fish Specific Genome Duplication 350 mya (3R)

up to eight copies of the ancestral deuterostome genome
Osteichthyes (ray finned bony fishes)



SPECIES - differentiated developmental controls after Fish Specific Genome Duplication (FSGD, 3R)

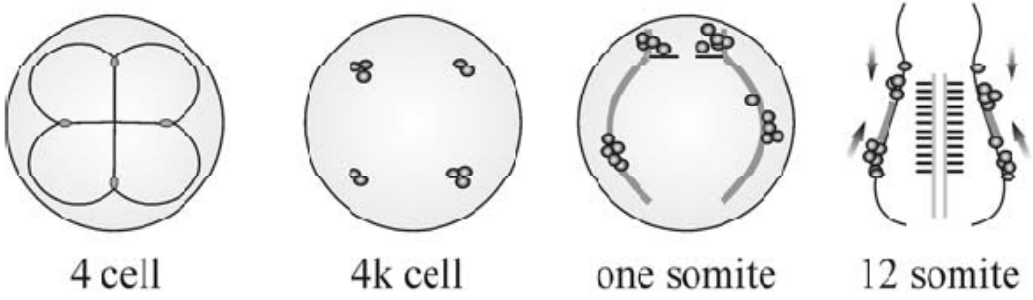


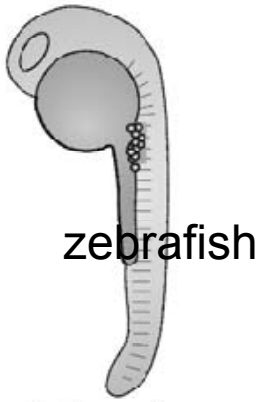
fundamental regulatory mechanisms may be unexpectedly variable

Common models diverge

Pigmentation genes (Braasch et al 2008)

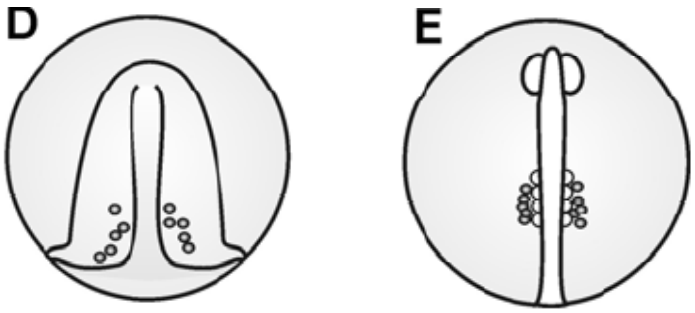
SPECIES, GROUPS – different pathways to reproduction, starting VERY early





zebrafish

Sex differentiation
Females and Males
21-42 dpf



Late gastrulation

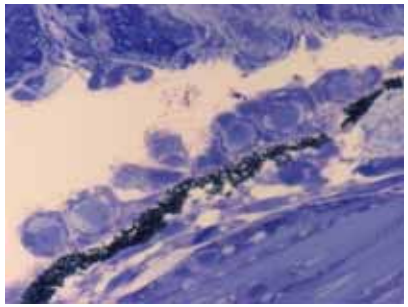
4 somites

medaka

Sex differentiation
Female < hatching
Male > 13 dph

cod

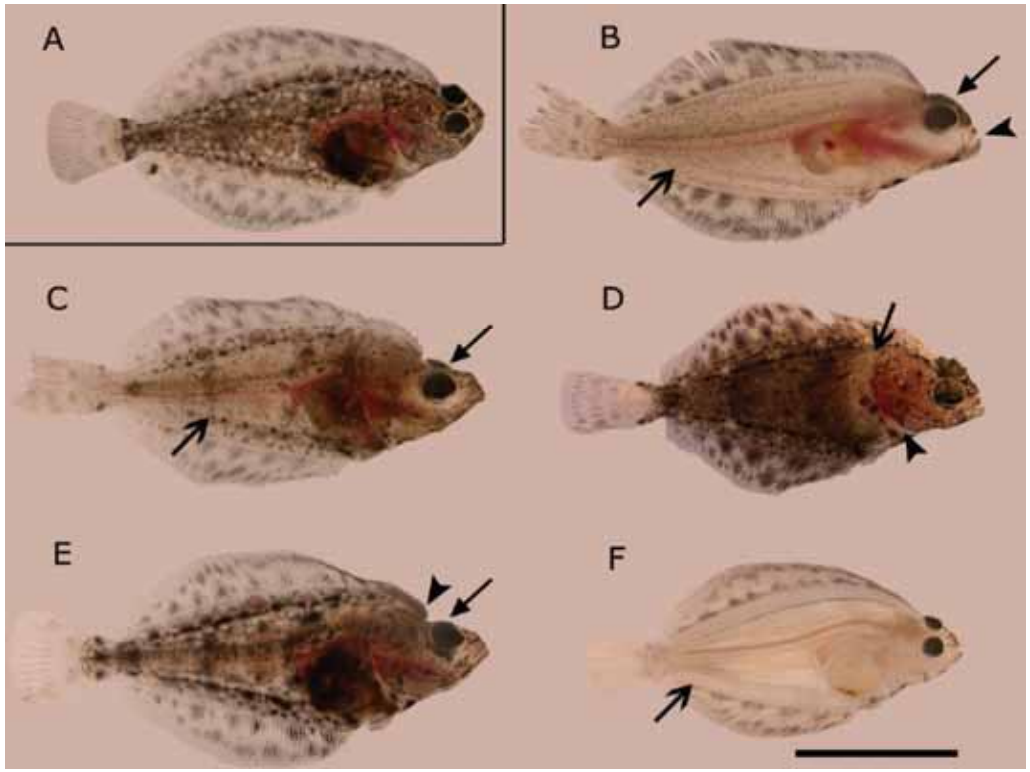
5mm cod larva – gonads developing,
Primordial Germ Cell migration
-Meier (unpub data)



(Kluver 2007; Brion et al., 2004)

EPIGENETICS

- changes in phenotype or gene expression
  NOT changes in DNA sequence (genome)
  much more than just deformities

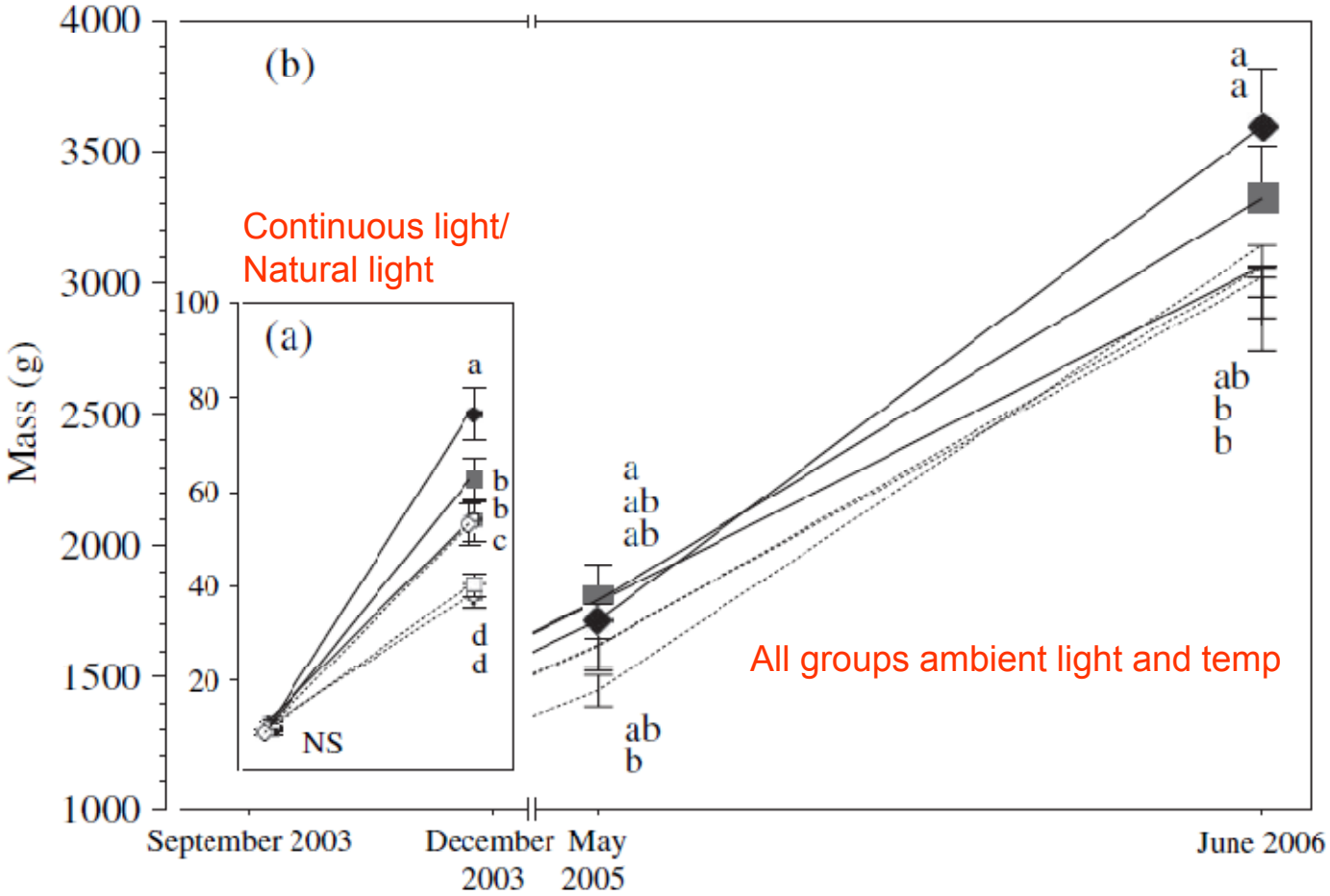


-especially obvious during cell differentiation,
pluripotent cells become a single cell type
Metamorphosis a series of critical periods?

mechanism: histone modifications and DNA methylation (chemical modification of DNA that can be inherited and subsequently removed without changing the original DNA sequence)
eg. nutrition, temperature, photoperiod

Power, Einarsdottir, Pittman, Sweeney, Hildahl, Campinho, Silva, Sæle, Galay-Burgos, Smaradottir & Bjørnsson 2008
The molecular and endocrine basis of flatfish metamorphosis. Reviews in Fisheries Science 16:95-111

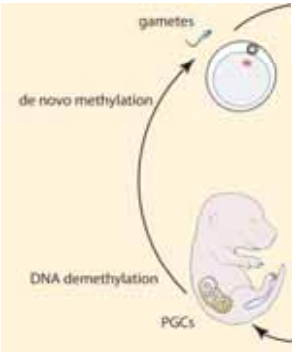
EPIGENETICS + GROUP - growth set by photoperiod in early life critical period



Imsland et al., 2007

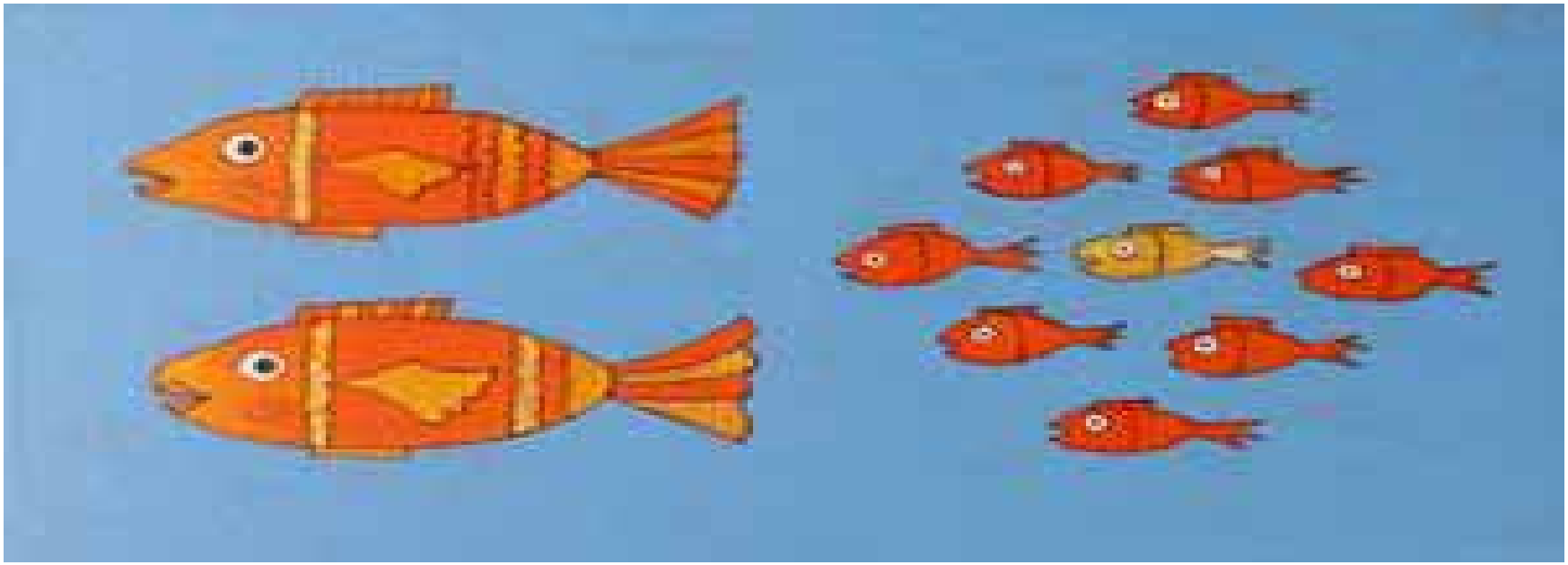
TRANSGENERATION – epigenetic inheritance and reprogramming

- diet induced metabolic programming can affect next generation
  (Patel & Srinivasan 2002)

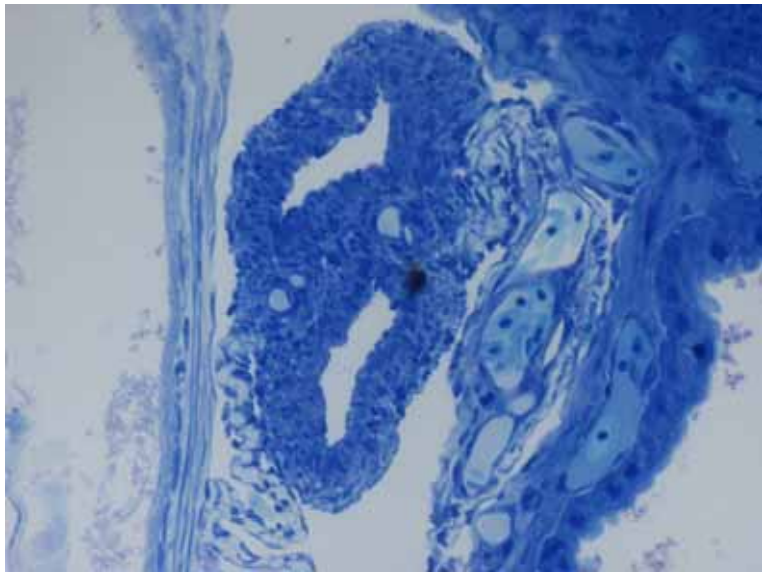


- epigenetic inheritance found in all taxa examined (Jablonka & Raz 2009)
  -model organisms report most cases of Epigenetic Inheritance

  -includes chromatin marks, RNA, self-reconstructing structures (eg. protein folding), and self-sustaining metabolic loops



SPECIES + GROUP – epigenetics and transgenerational effects



Early female 39 mm (44 days)

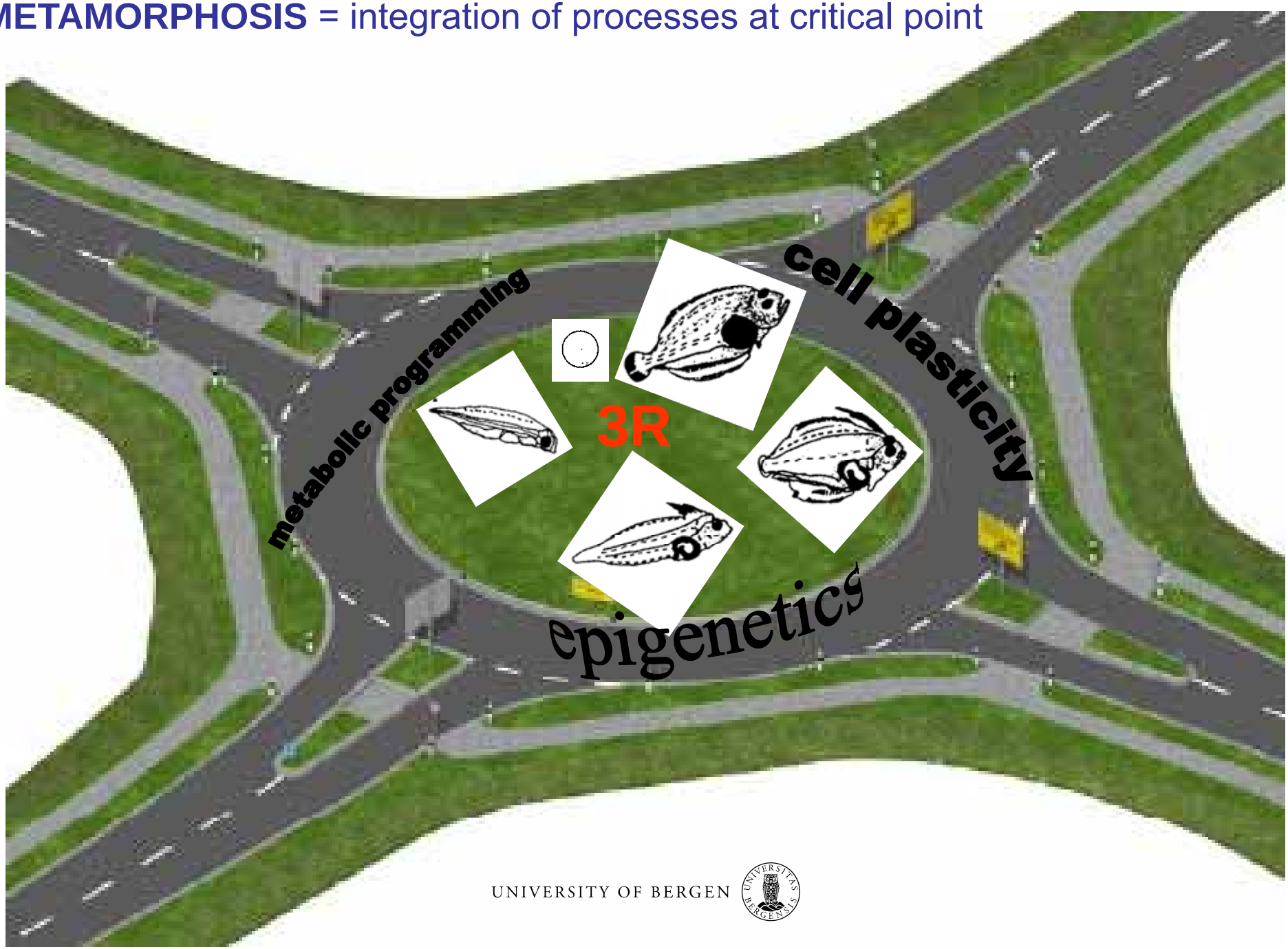
Estrogen exposure upto day 50 (larvae)

Adult w sperm and egg in one gonad

Level of Biological Organization

Individual	Organ	Cell
√	≠	√

METAMORPHOSIS = integration of processes at critical point



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Conclusions

Fish have most plastic and diverse biology of vertebrate groups (3R)
-transitioning fish more plastic (thyroid induced plasticity?)

-long duration of pluripotency in cell groups

-sampling by stage is necessary during larval-juvenile transition
large repertoire of responses (immediate or delayed; some unexpected)

Some fundamental steering mechanisms are species specific

”model” fish are not the same as target fish species

Level of biological organization analysed is important to level where result is applied

Transgenerational effects – -no single process determines outcome of metamorphosis