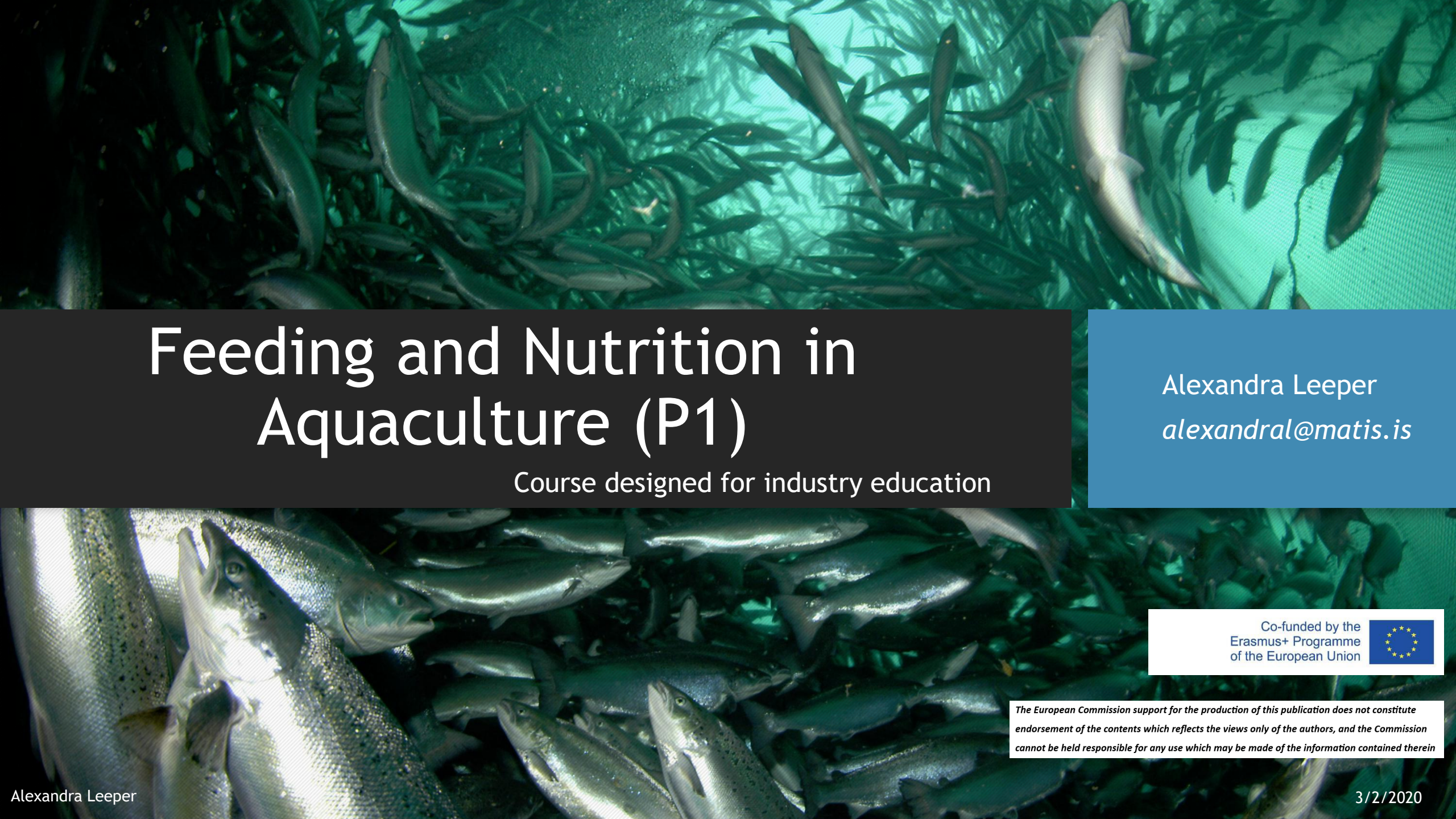


Feeding and Nutrition in Aquaculture (P1)

Course designed for industry education

Alexandra Leeper
alexandral@matis.is

Co-funded by the Erasmus+ Programme of the European Union

Course Outline

- Total of six modules.
- Taught over two teaching periods and one online session

<u>November 2-3</u>
Module 1: The digestive biology of fish.
Module 2: Key nutritional requirements of fish.
Module 3: Aquafeed formulation.
**Homework 1*

<u>Online Session</u>: Homework and question time.

<u>November 15-16(?)</u>
Module 4: Food production and storage.
Module 5: Feeding and feed intake.
Module 6: Feed additives and further knowledge.
**Homework 2*

Learning Outcomes

Aim of course: Provide students with a strong introduction of feeding and nutrition in aquaculture with reference to salmonids.

At the end of the course students will be able to:

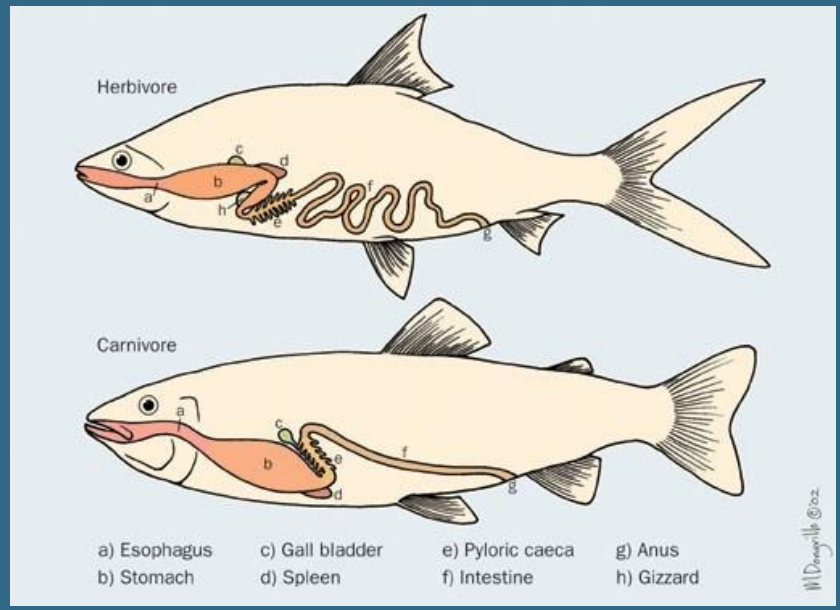
- List and describe basic **nutrients**.
- Describe the feeding **anatomy** and digestion of fish.
- Describe the different parameters that can impact **feed intake** in fish.
- Identify changes in **appetite** of farmed fish.
- Describe the **production of aquaculture feed**.
- Handle feed, understand labels and **storage** instructions.
- Explain the importance of **feed rations** and pellet size.
- Explain the consequences of **over-feeding/underfeeding**.

Alexandra Leeper

Day 1

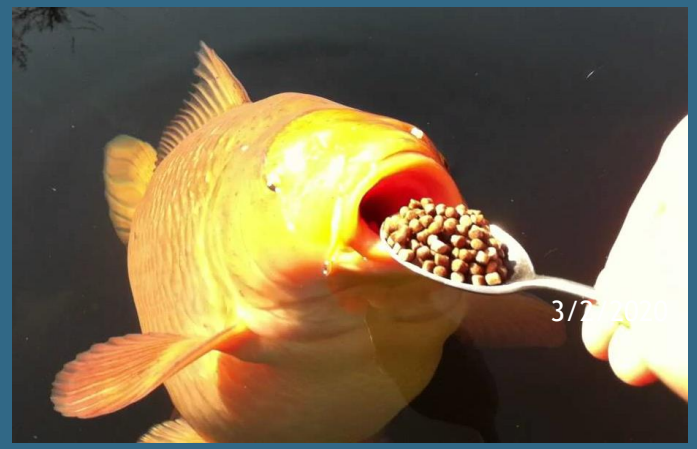
- Module 1: The digestive biology of fish.

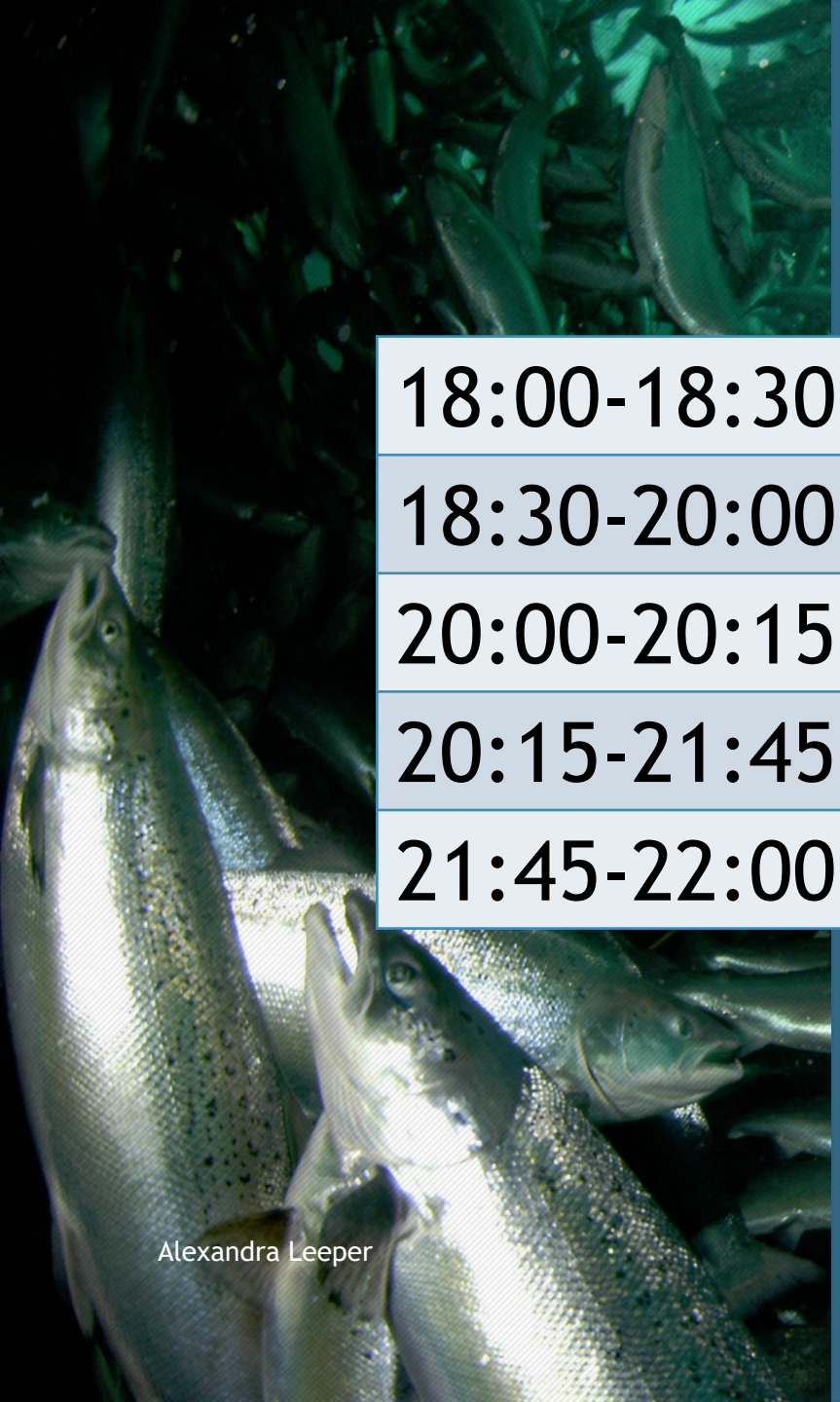
*Exercise 1.1



- Module 2 Part 1: Key nutritional requirements.

*Exercise 2.1





Day 1 Tuesday

18:00-18:30-Introduction and Course Outline
18:30-20:00 Lecture slides for Module 1 (S19)*
20:00-20:15 Coffee Break and Questions
20:15-21:45 Lecture slides for Module 1 & 2 (S35)*
21:45-22:00 Questions

Day 2 Wednesday

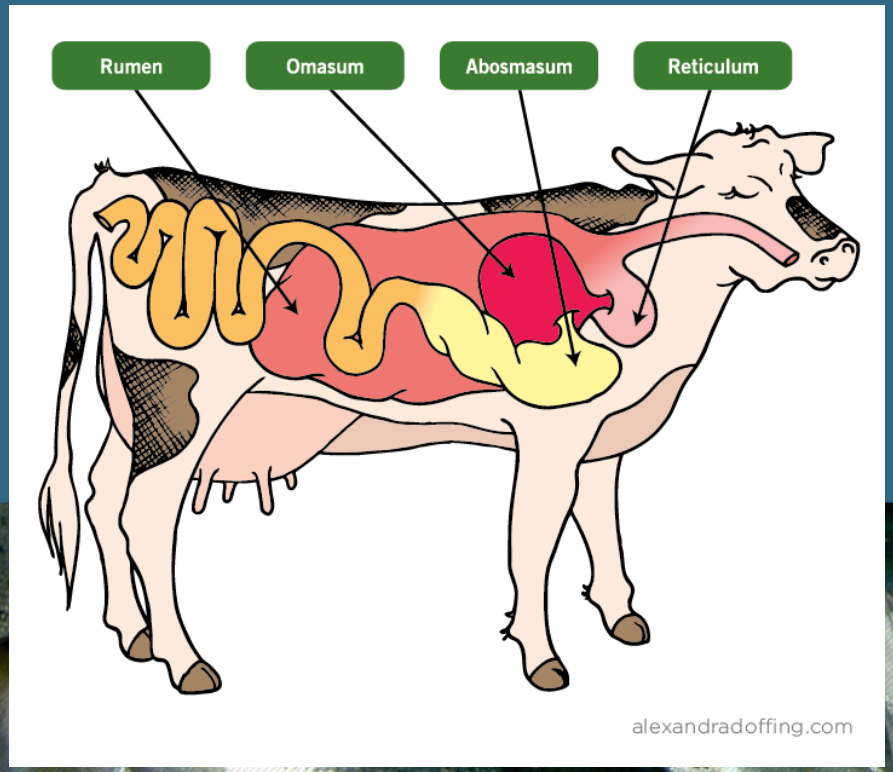
18:00-18:30-Re-cap of yesterday & Mini Quiz
18:30-20:00 Lecture slides for Module 2 (48)*
20:00-20:15 Coffee Break and Questions
20:15-20:30 Lecture slides for Module 1 (S48-53)*
20:30-21:30 lecture slides for Module 2 (S53-60)*
21:30-22:00 Review quiz & homework setting

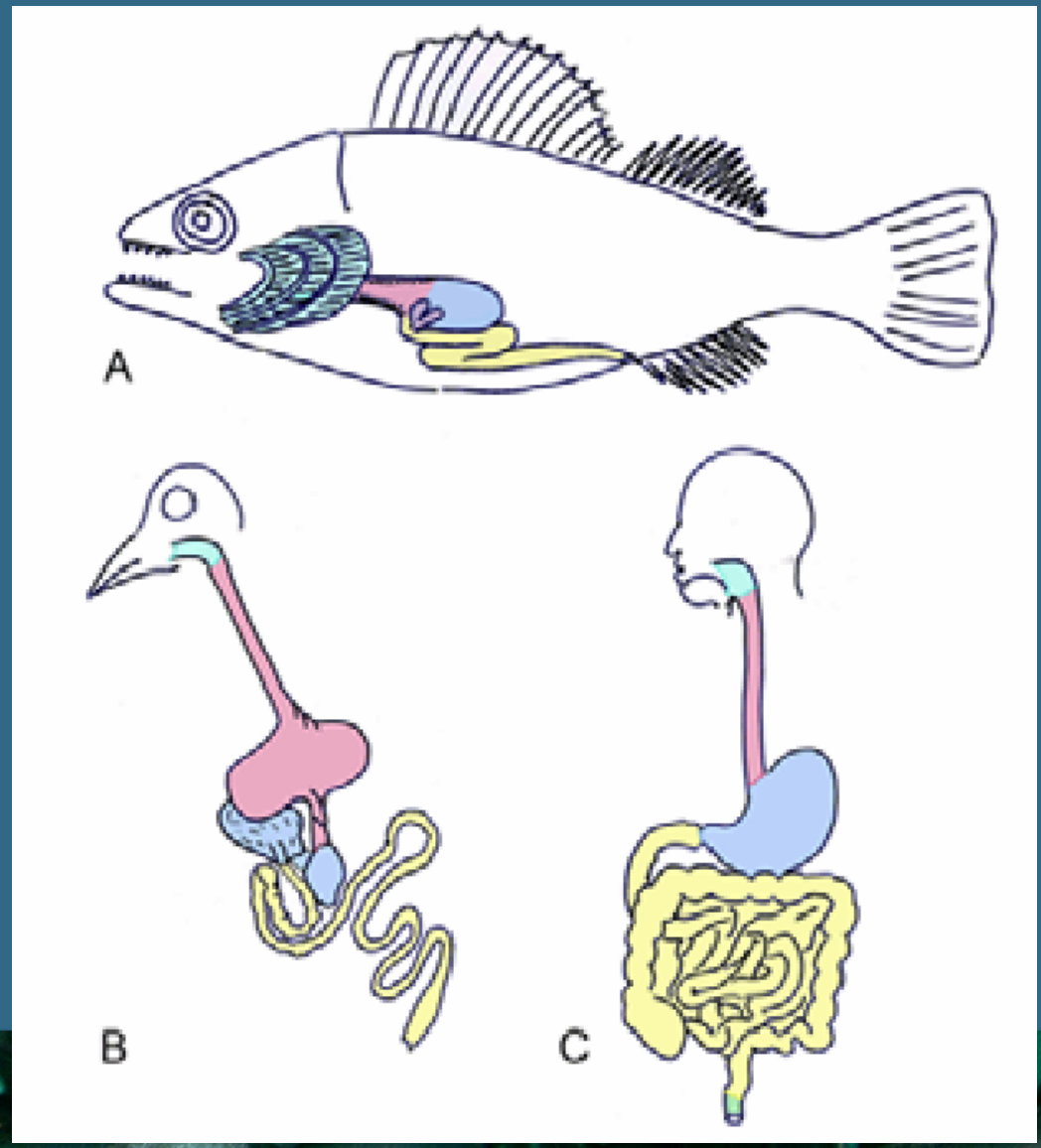
Digestive biology

Digestion = The process by which food is broken down into simple chemical compounds that can be absorbed and used as nutrients or eliminated by the body.

Mono-gastric = having a stomach with only a single compartment.

Ruminant= four stomachs and eat plant matter with the help of enzymes.





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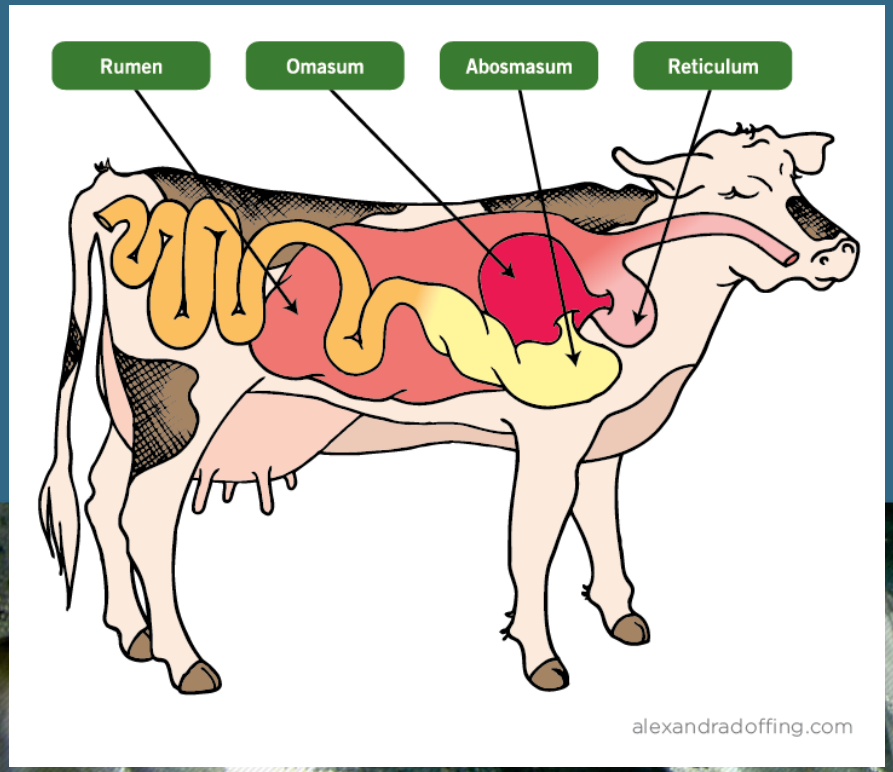
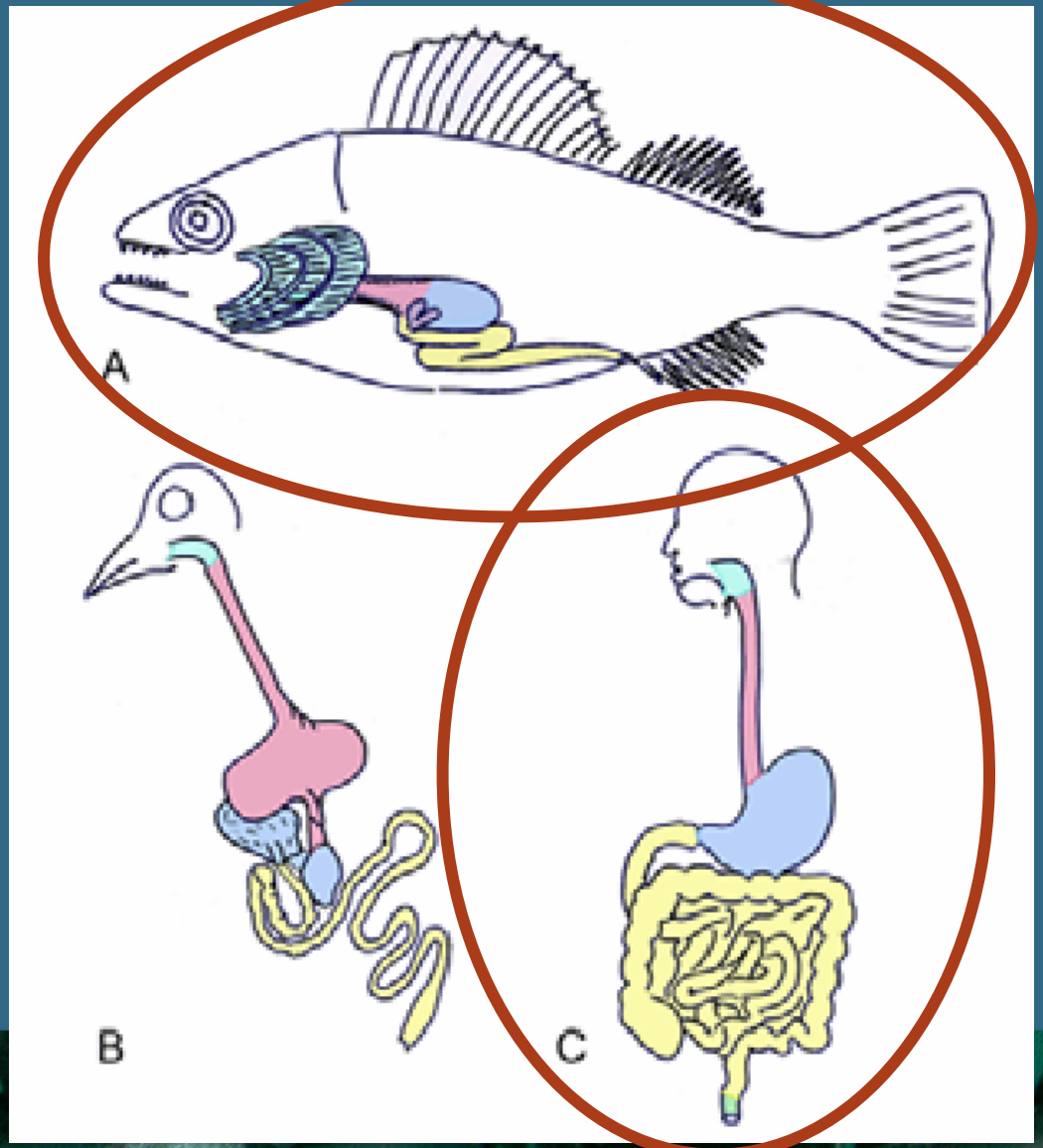


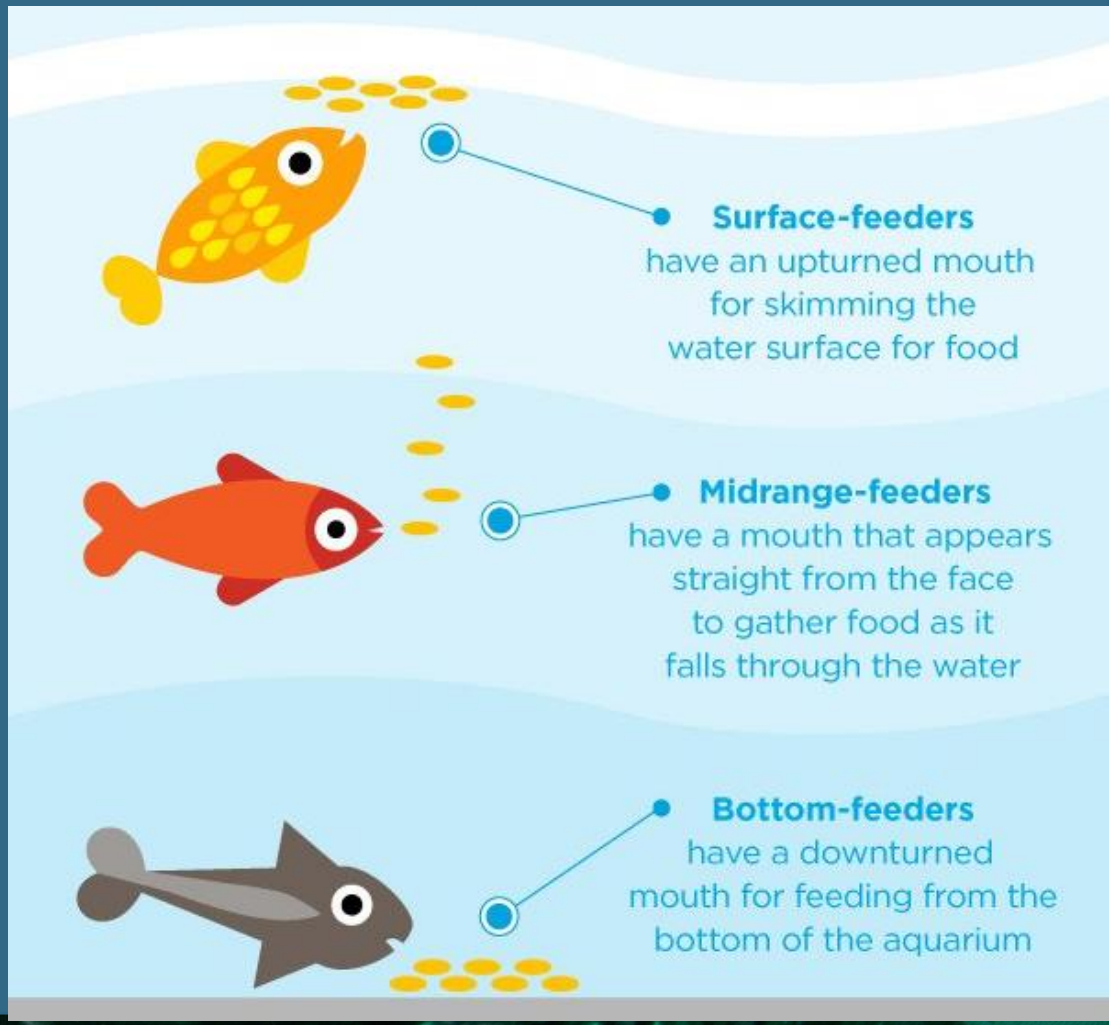


Digestive biology

- Even within the fish kingdom there is a huge difference in digestive biology.

- Factors affecting digestive biology:

  -Feeding strategy
  -Nutritional content
  -Size & structure of feed
  -How easy the food is to digest
  -Environmental factors



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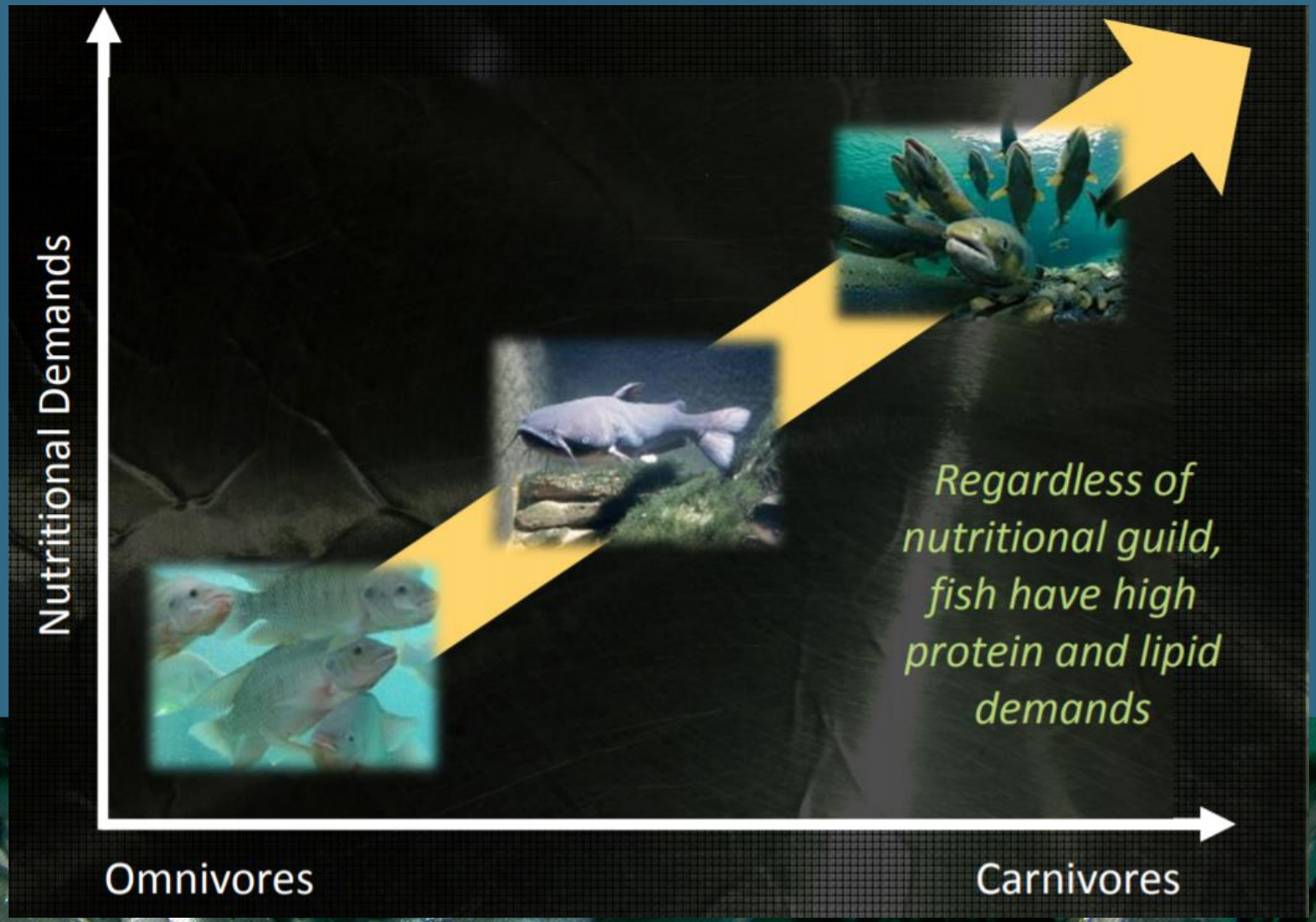


Digestive biology

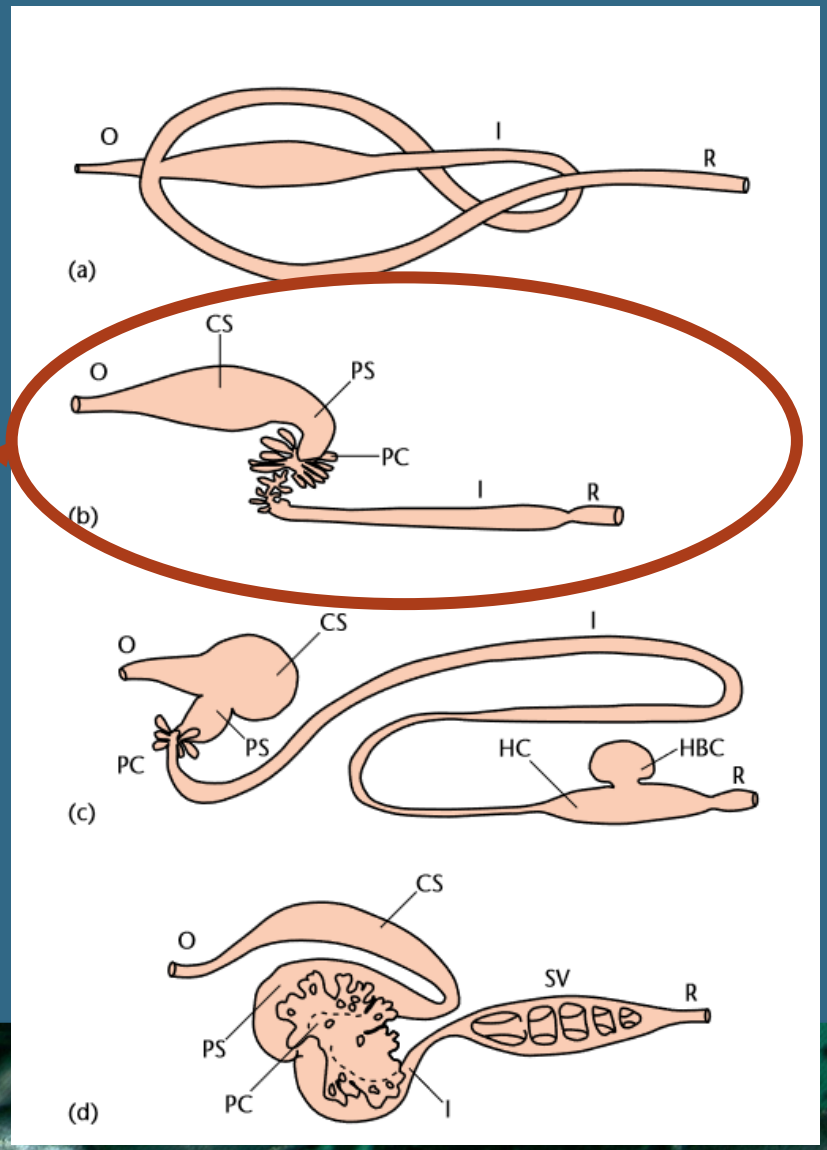
- These systems look different but have all the same function which is digestion but are designed for different environments, diets and nutritional needs.

B) is the digestive tract of a Rainbow Trout

- Rainbow trout is a salmonid




All from different types of fish



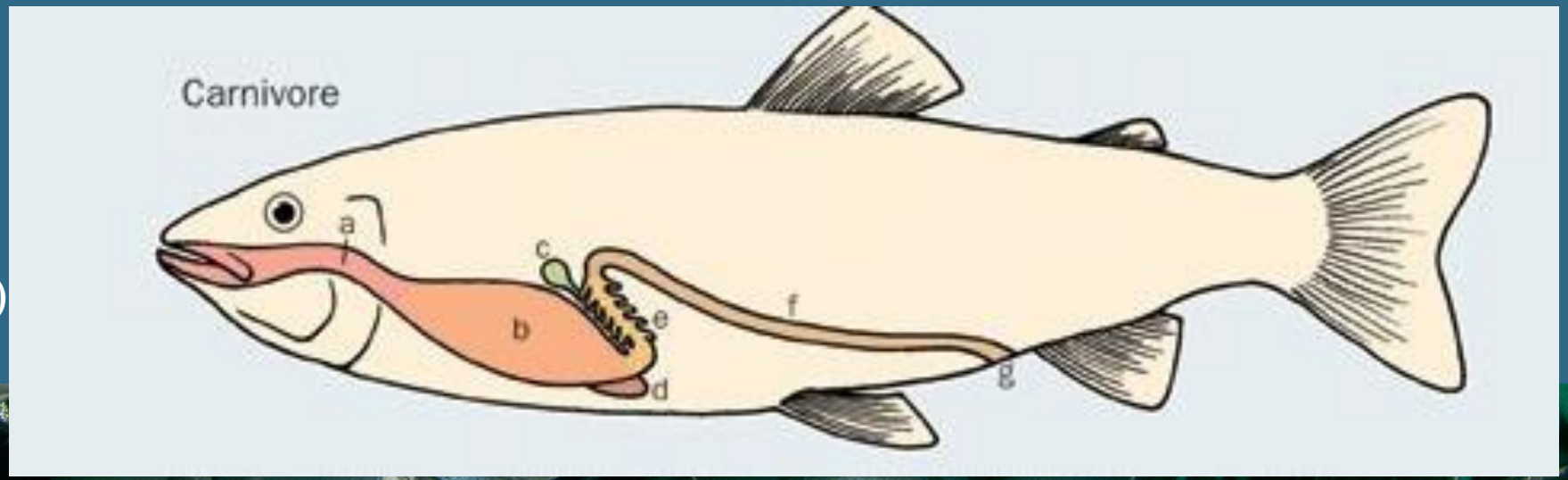
Digestive biology: Salmonids

Reminder: What is a salmonid?




Key parts of the digestive biology we will explore

a) Esophagus
b) Stomach
c) Gall bladder
d) Spleen
e) Pyloric ceaca
f) Intestine (mid and hind)
g) Anus



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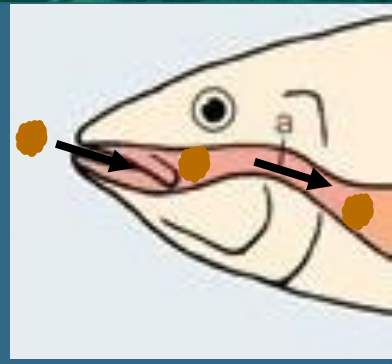
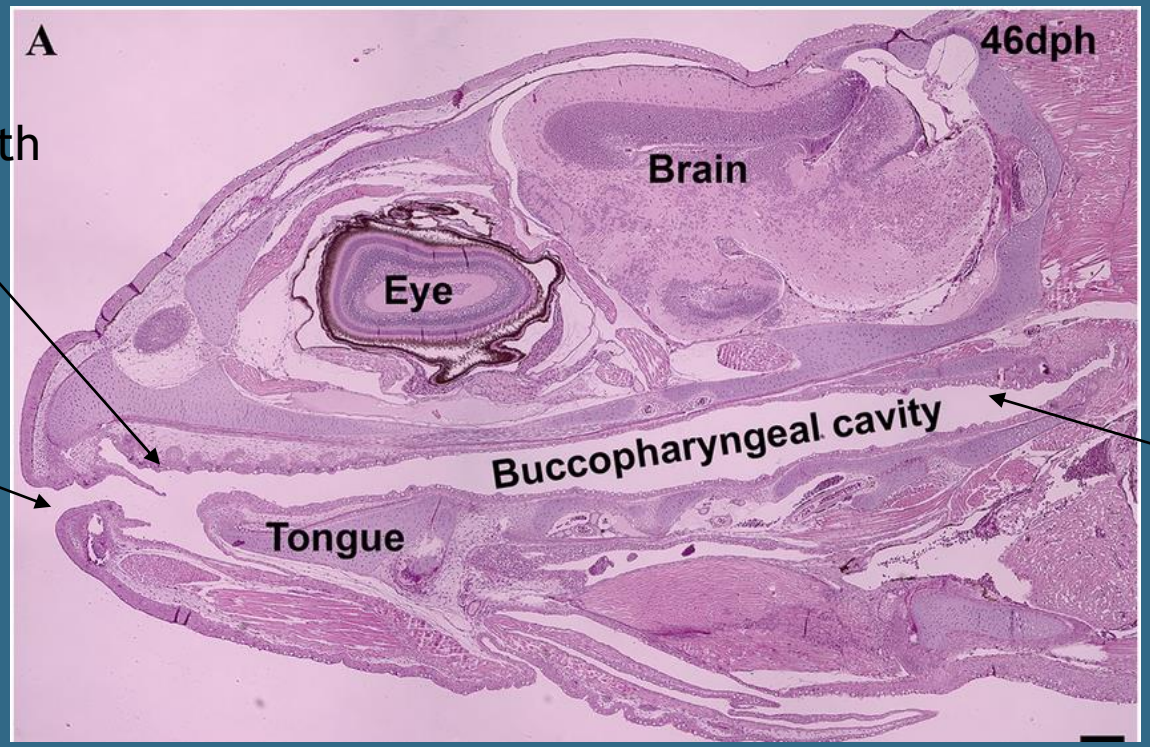
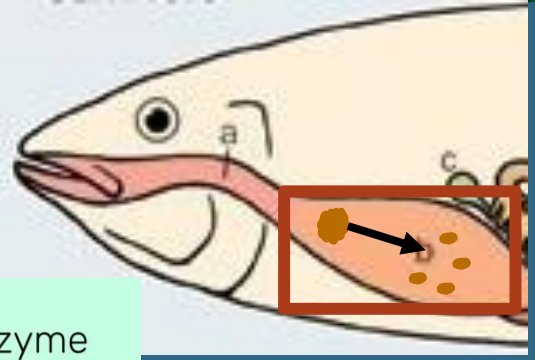
Digestive biology: Mouth and Esophagus



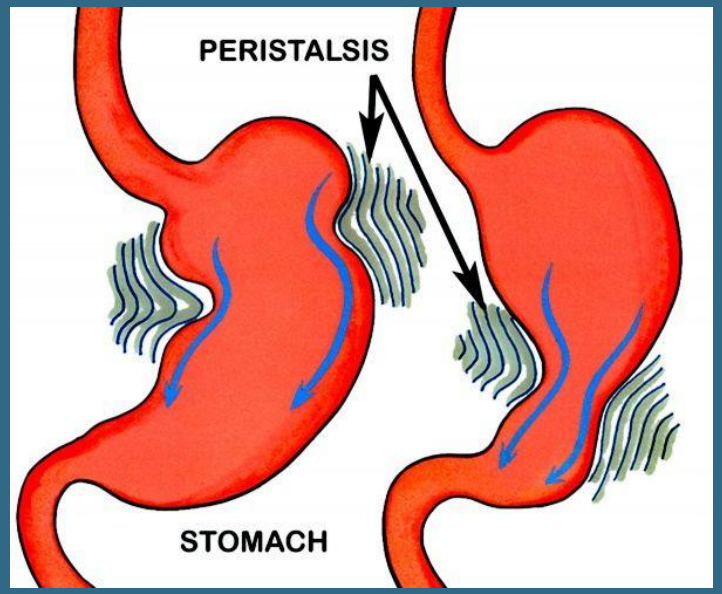


Function: The mouth acts as an opening for food and the esophagus facilitates food passing from the mouth to the stomach by muscle movement.

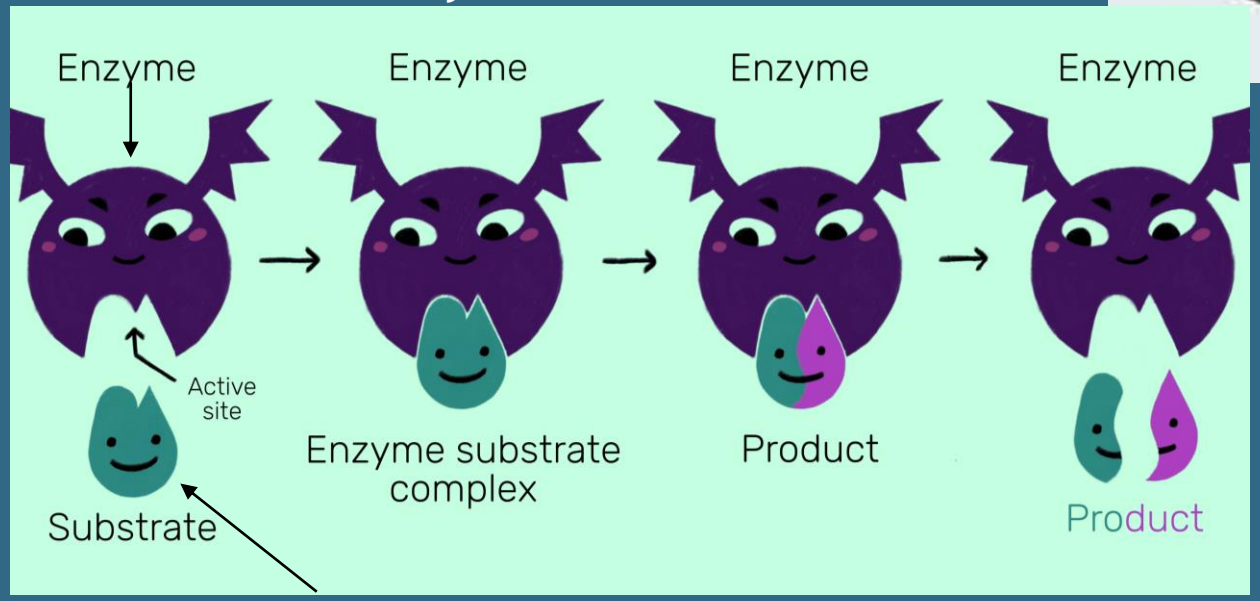
Digestive biology: Stomach



Muscle contraction



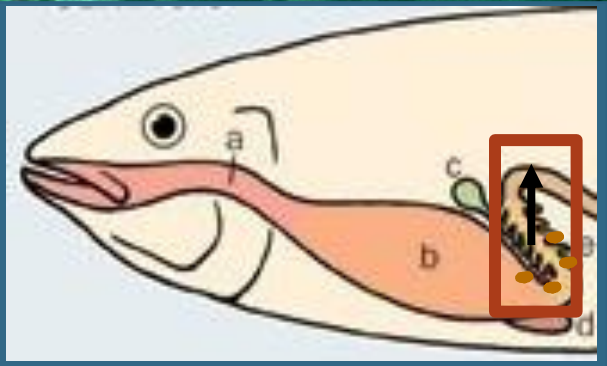
Enzyme Action



Protein

Function: Mechanical digestion of food from mixing and churning action of stomach muscles, breaking the food down into more manage particle sizes. Chemical digestion by enzymes called pepsins and breakdown by acidity.

Digestive biology: Pyloric caeca



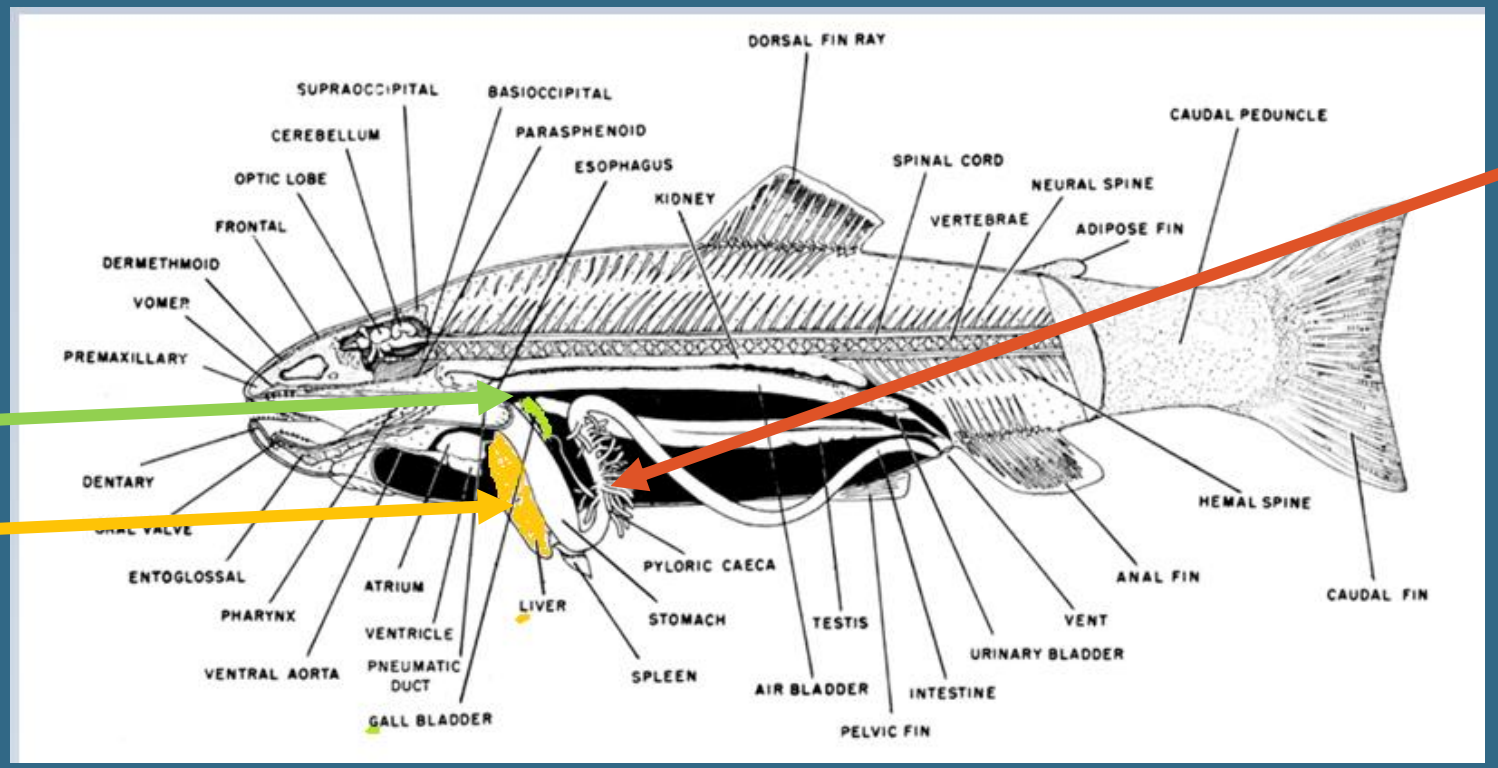
Digestive fluids: Bile, Pancreatic juices and mucus all reach the partially digested food here and help to break all the different components down to smaller and smaller sizes.

Bile from liver (made in gall bladder)

Pancreatic juices (containing enzymes) and mucus.

Function: Location where the bulk of the chemical digestion is taking place (especially for fat and carbohydrates but also further breakdown of proteins and small peptides). Absorption of nutrients from digested food also starts here.

Digestive biology: Pancreas, Liver, Gall Bladder



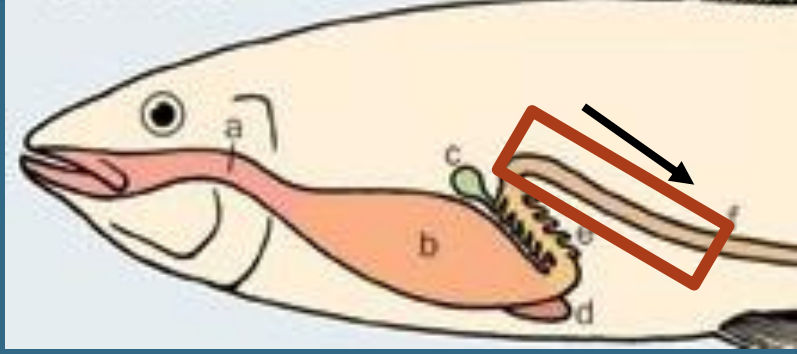
Gall bladder

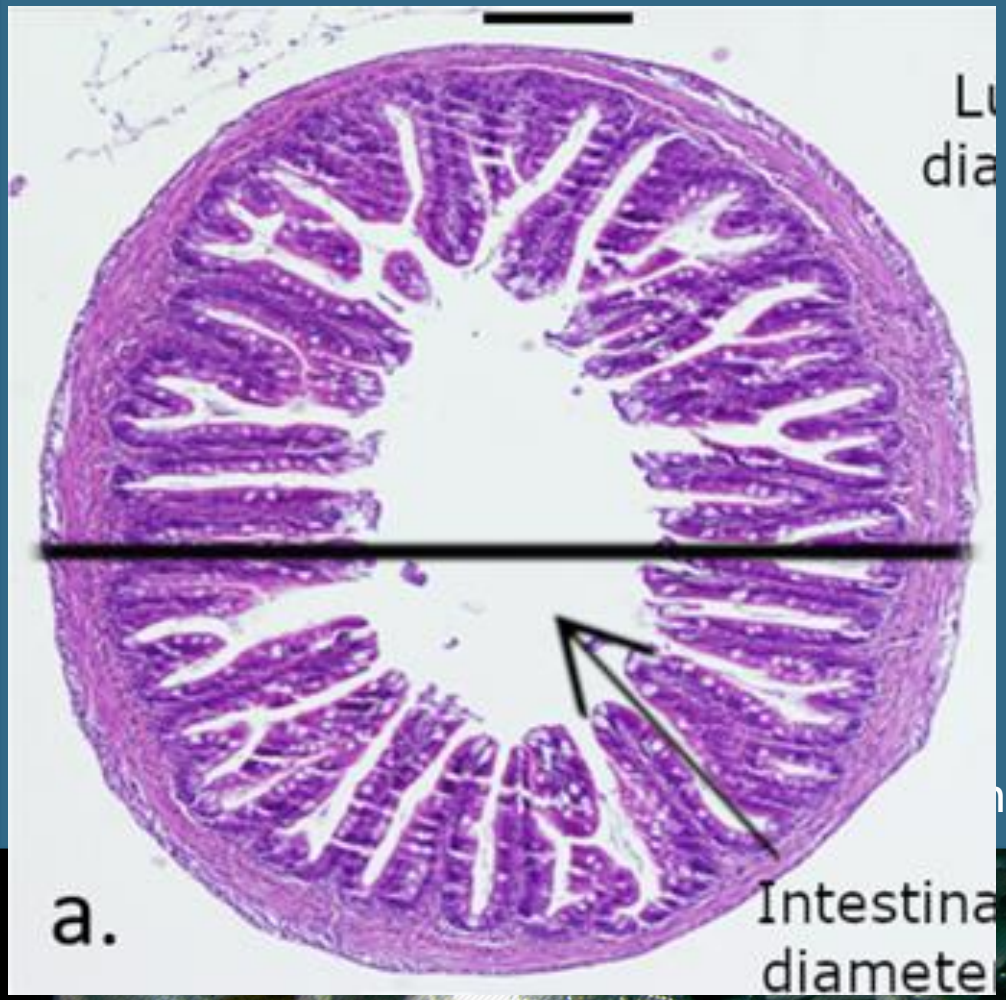
Liver

Pancreas found inside the pyloric caeca

Function: Production or transport of important fluids to the pyloric caeca and mid-intestine that aid facilitate chemical digestion.

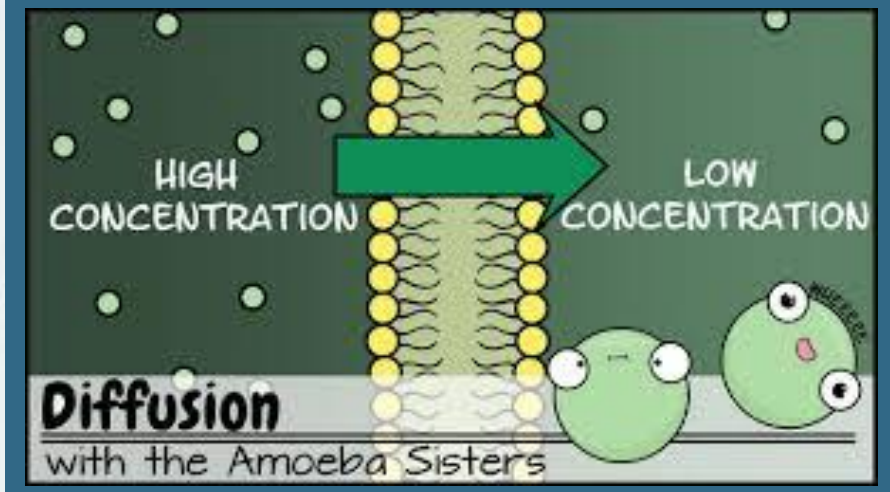
Digestive biology: mid-intestine





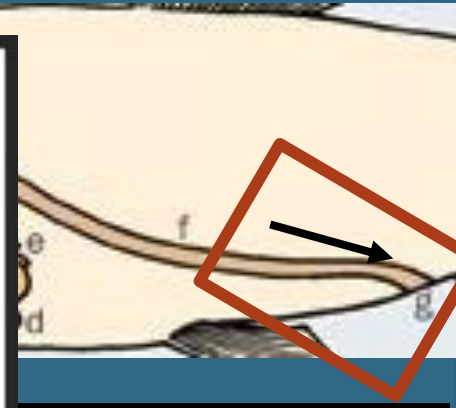
Inside the gut

In the blood stream.



and nutrient absorption through the intestinal wall.

Hind-inte



e intestines helps
n and absorption

Function: Final si
digestible materi

cretion of non-

Microbiome
IN NUMBERS

apc Microbiome Ireland
Interfacing Food & Medicine

100 Trillion
symbiotic microbes live in and on every person and make up the human microbiota

The human body has more microbes than there are stars in the milky way

95%
of our microbiota is located in the GI tract

150:1
The genes in your microbiome outnumber the genes in our genome by about 150 to one

The surface area of the **GI tract** is the same size as 2 tennis courts

>10,000
Number of different microbial species that researchers have identified living in and on the human body

You have **1.3X** more microbes than human cells

2kg
The gut microbiota can weigh up to 2Kg

The microbiome is more medically accessible and manipulable than the human genome

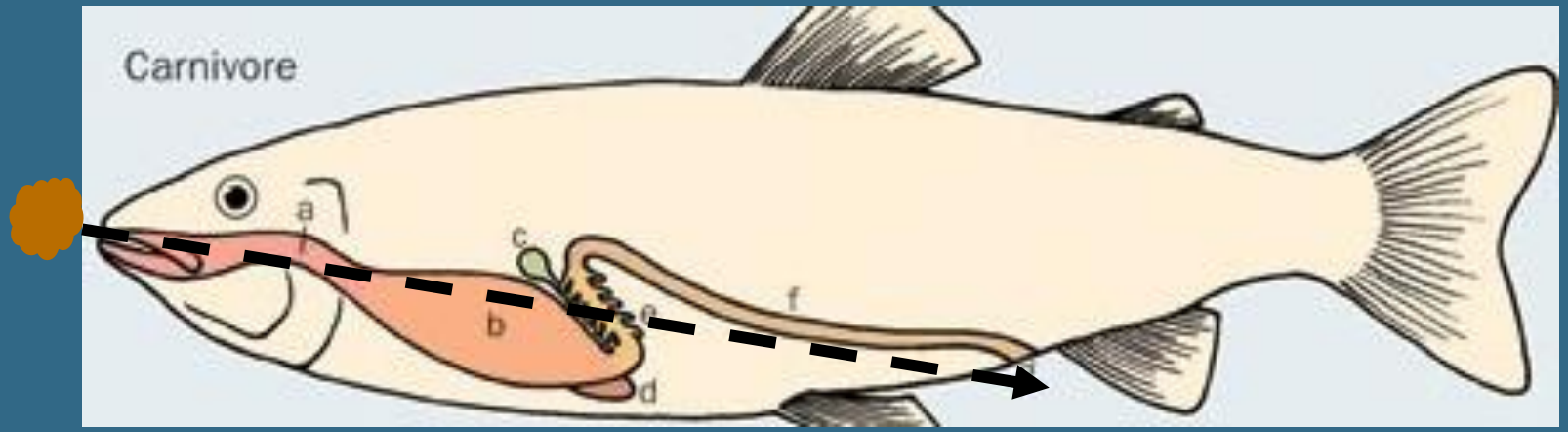
It is thought that **90%** of disease can be linked in some way back to the gut and health of the microbiome

5:1
Viruses:Bacteria in the gut microbiota

2.5
The number of times your body's microbes would circle the earth if positioned end to end

Each individual has a unique gut **microbiota**, as personal as a fingerprint

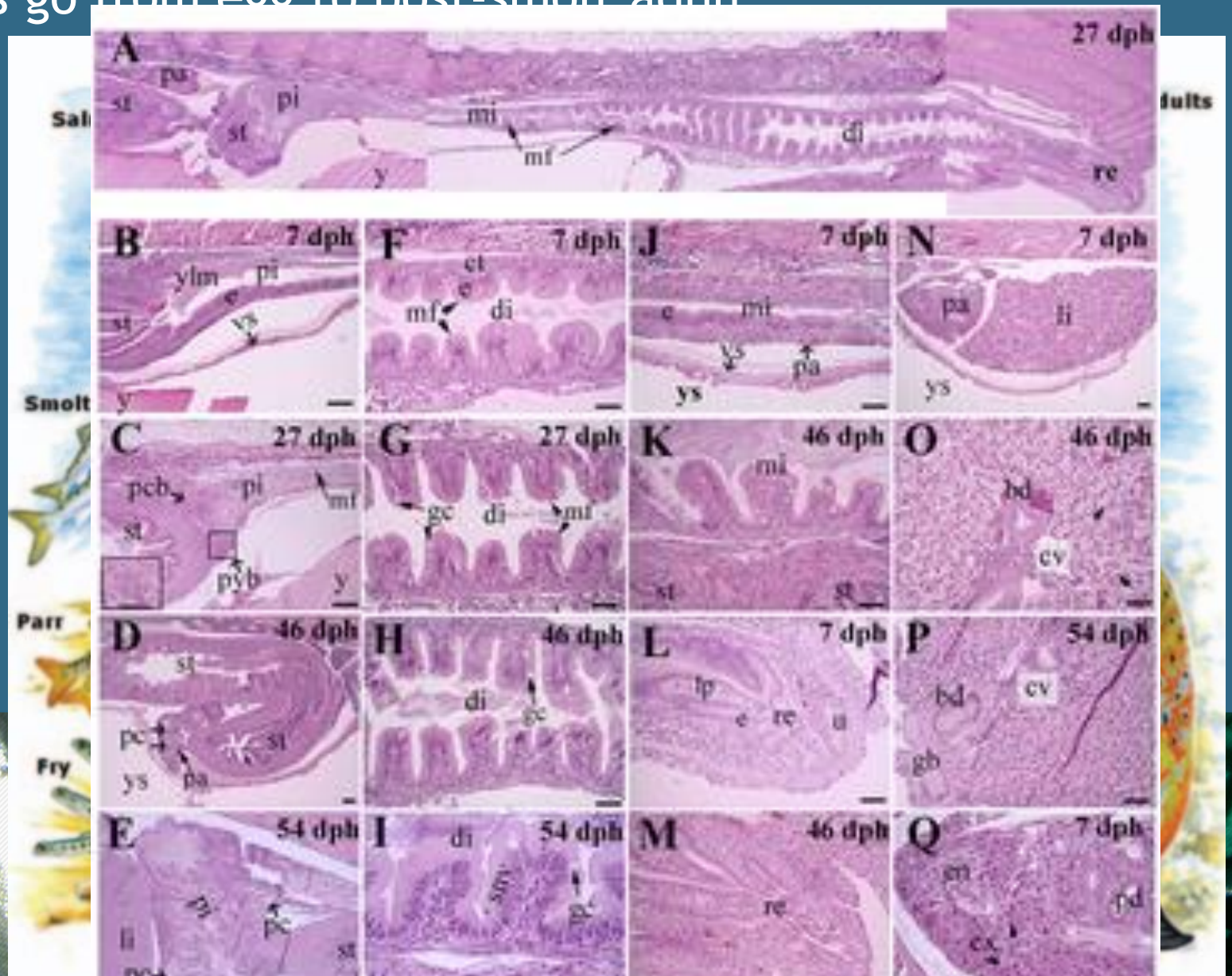
Transit of food: Summary



- How long does this take in an adult Atlantic Salmon?
- What factors effect transit time through the digestive tract?

Development of Digestive Tract

- As salmonids go from egg to post-smolt adult



Module 1: Exercise 1.1

This exercise will be to label key parts of a fish digestive tract diagram and a small multiple-choice quiz using an online application.

Day 1 part 2 & Day 2

- Module 2 Part 2: Key nutritional requirements.

*Exercise 2.2

- Module 3: Aquafeed Formulation.

*Exercise 3.1

Module 2 Key nutritional Requirements

Alexandra Leeper

We are what we eat……and so are fish

Just like us, fish need certain dietary requirements in order to be healthy and ultimately tasty for the consumer.

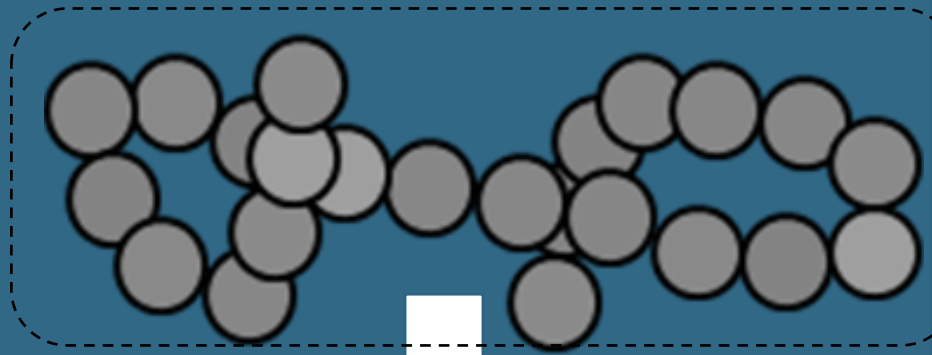
Proteins

Fats

Proteins

Key Functions

Providing the body with amino acids



Immune System
e.g. Antibodies that fight disease

Structure
e.g. Collagen found in ligaments/tendons

Hormones
e.g. insulin for blood sugar control

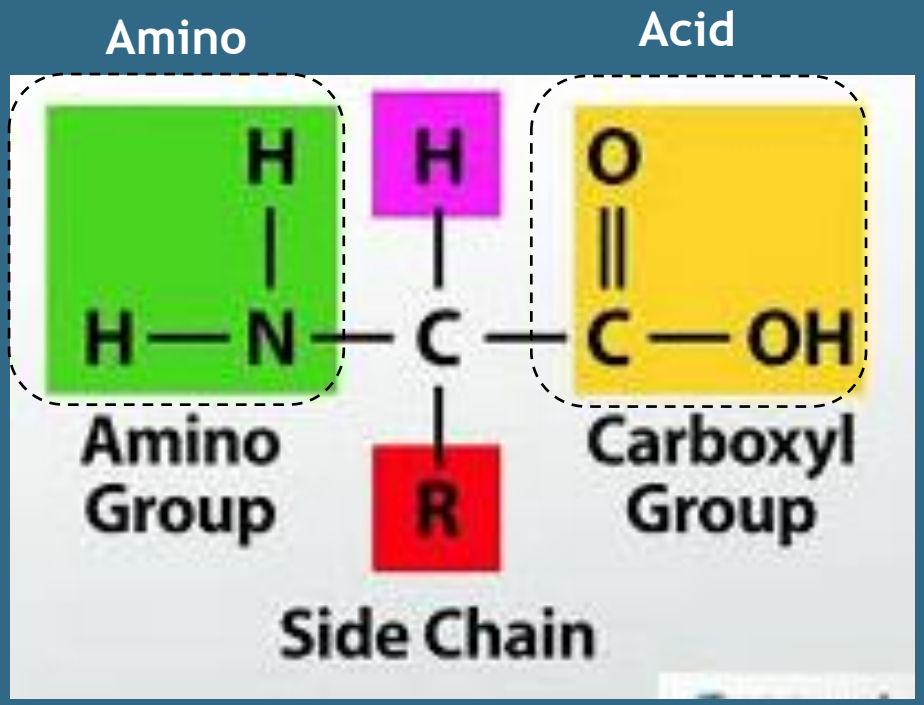
Muscle Building

Enzymes e.g. help in the break down of food

Proteins

Protein

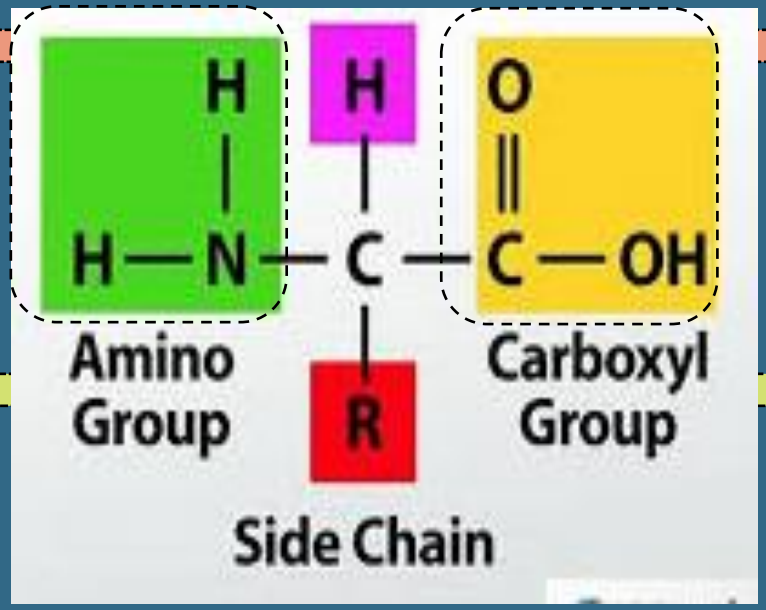
Different
Amino Acids



Essential Amino Acids

Different Amino Acids

- Arginine
- Histidine
- Isoleucine
- Lysine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine



Prevents cataracts

Increases cell survival

Reduces aggressive behaviour

Examples of AA deficiencies

Lysine deficiency
(Fin erosion)

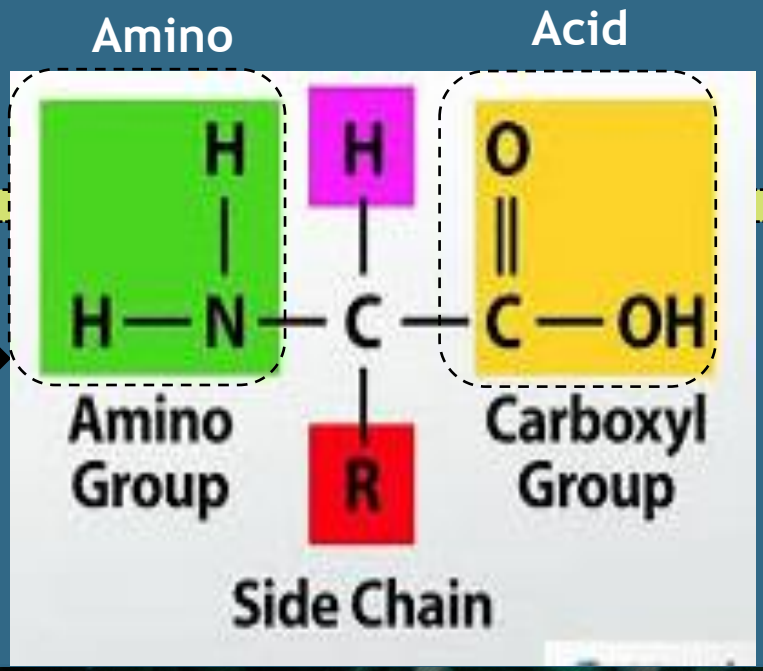
Leucine/Tryptophan/ Lysine
deficiency
(Spinal deformities)

Histidine deficiency
(Cataract)

Non-Essential Amino Acids

Different Amino Acids

- Alanine
- Aspartate
- Cysteine
- Glycine
- Glutamate
- Glutamine
- Proline
- Serine
- Tyrosine



Used to make an EAA

Used to make an EAA

Protein Sources in Fish Feed

Fish meal

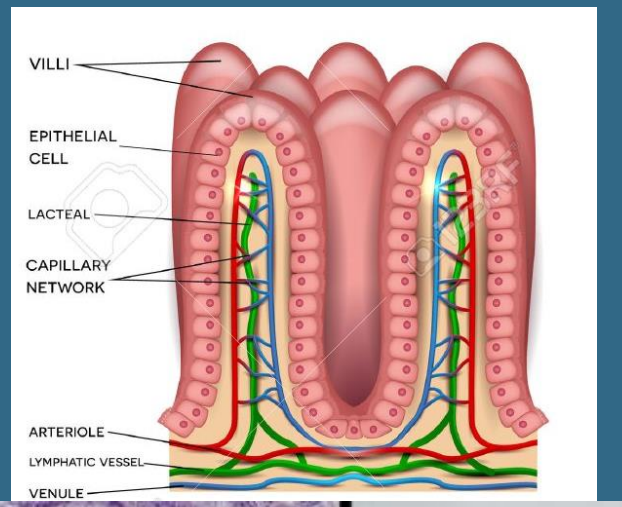
Rapeseed meal

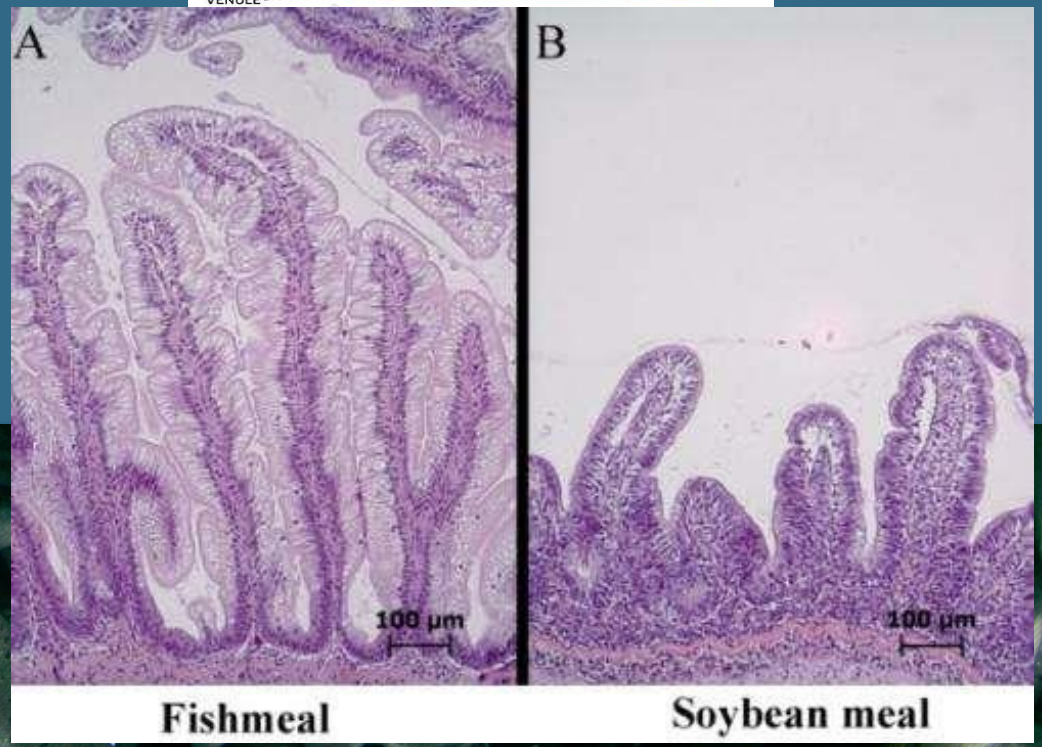
Soybean meal

Protein Sources in Fish Feed

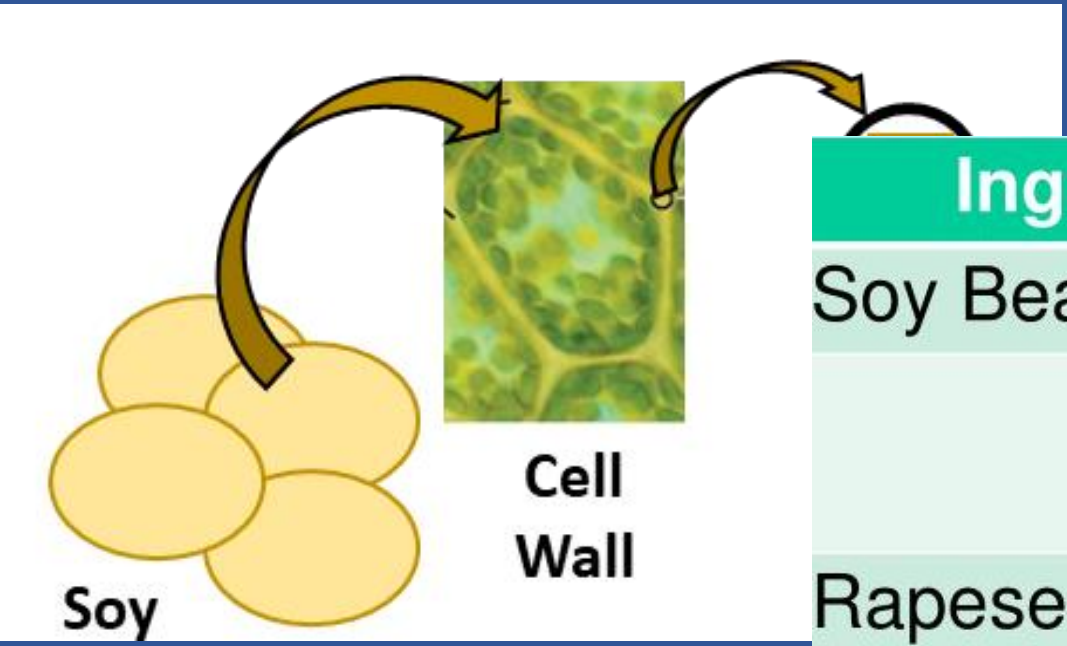
Rapeseed meal

Soybean meal





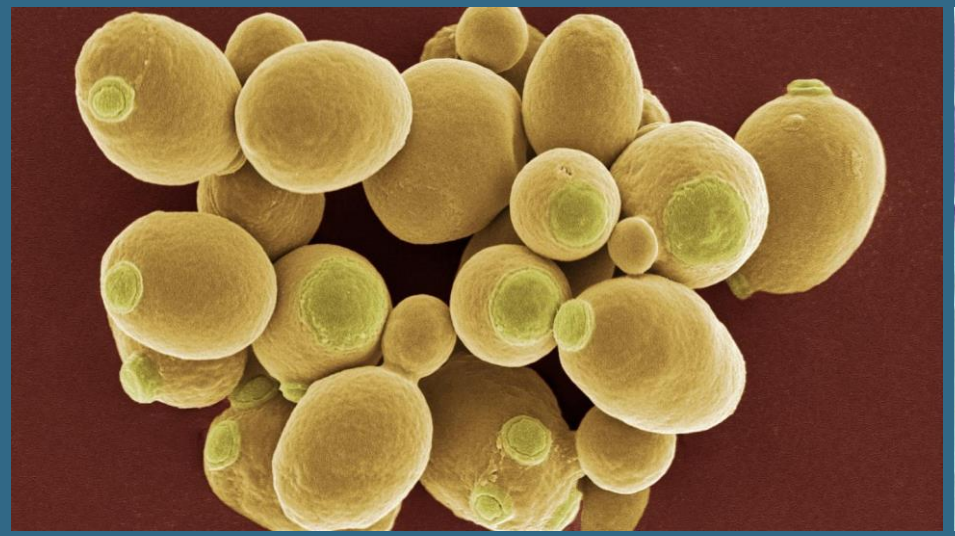
What makes soy problematic for salmon



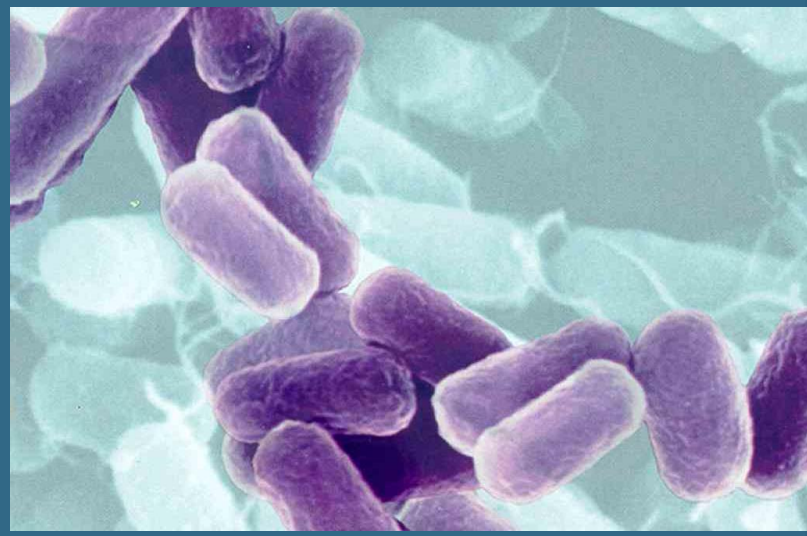
Ingredients	The Anti-Nutritional
Soy Bean Meal	Trypsin Inhibitor, Lectins,
	Saponins, Oligosaccharides (Raffinose, Stachyose)
Rapeseed Meal	Glucosinolates, Tannins, Phenolic acids, Fiber
Sunflower Meal	Fiber, Tannins

Novel Protein Sources in Fish Feed

Insect Proteins



Fungal Proteins



Bacterial Proteins

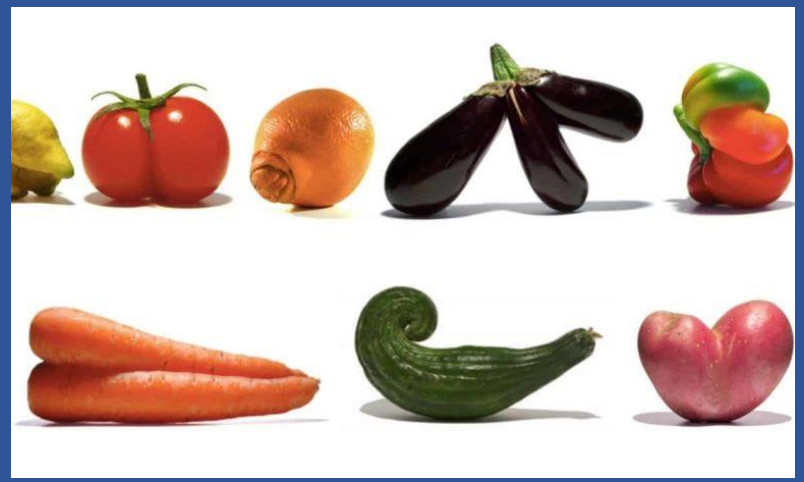
Alternatives: Insects

Pros

- Low water usage.
- Can be produced independent of location and climate.
- Very efficient converters of low value organic waste.
- Wide range of potential substrates
- Nutritional content linked to substrate grown on*.
- Can be produced in high density.
- Less competition with human market.

Cons

- Chitin (?).
- Strict European laws.
- Potential vectors for disease and transfer of pollutants.
- Lower protein content 40-45%.
- Scale of production is low.
- Cost of production is high.
- Lower palatability.



Alternatives: fungal proteins

Pros

- Low water usage.
- Independent of location and climate.
- Substrates can be sourced from a wide range of industries*
- Can be produced in high density.
- Less competition with human market.
- Highly palatable to fish.
- Potential immuno-stimulant properties.

Cons

- Access to substrates at scale.
- Limit volume production and high volumes struggle for protein content.
- Cost of production is high.
- Some species or strains are pathogenic.
- Production and processing not yet optimised.
- Protein content (40-60%)
- Still a fairly new concept for fish.

We are what we eat……and so are fish

Just like us, fish need certain dietary requirements in order to be healthy and ultimately tasty for the consumer.

Fats & Oils = Lipids

Lipids (Fats & Oils)

Key Functions

Energy **storage**

Dietary Energy

Insulation

Structural
e.g. in cell membranes

Hormone
They are the building blocks

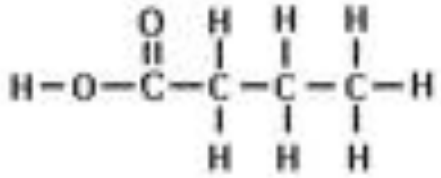
Communication

Lipids
(Fats & Oils)

Fatty Acid

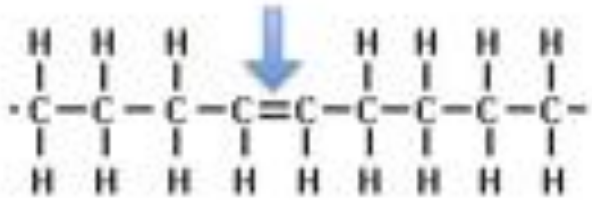
Saturated Fat

In animal fats



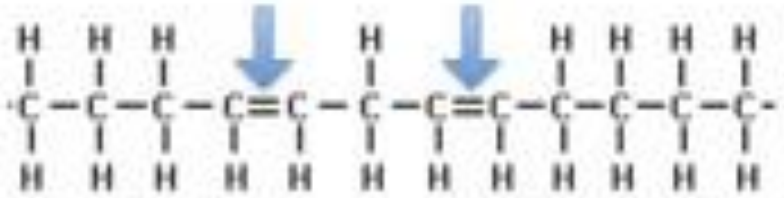
Monounsaturated Fat

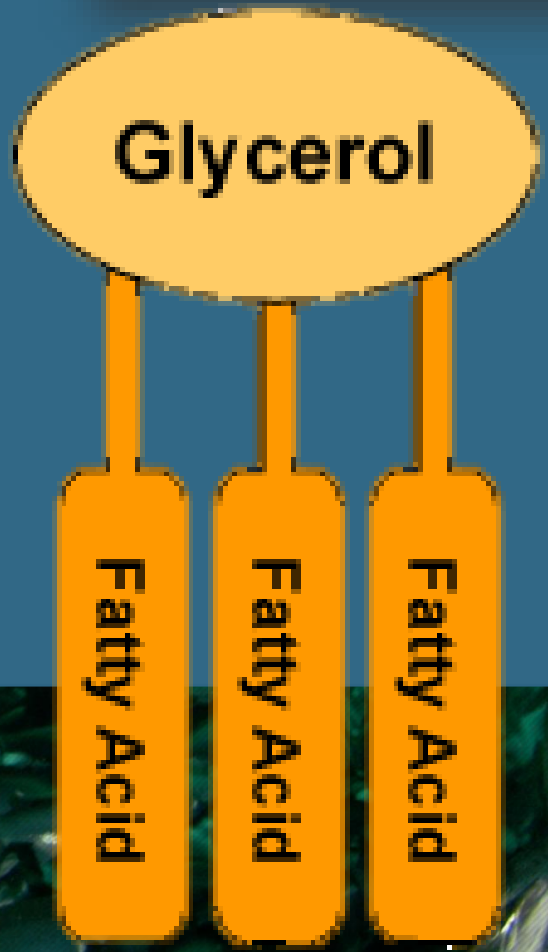
In plant fats



Polyunsaturated Fat

In fish/plants/seed fats

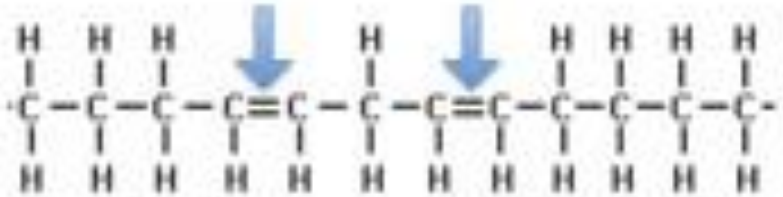




Lipids
Essential Fatty Acids

Fatty Acid

Polyunsaturated Fat



In fish/plants/seed fats

Omega-3

EPA

Eicosapentenoic acid

DHA

Docosahexaenoic acid

Sources
Essential Fatty Acids

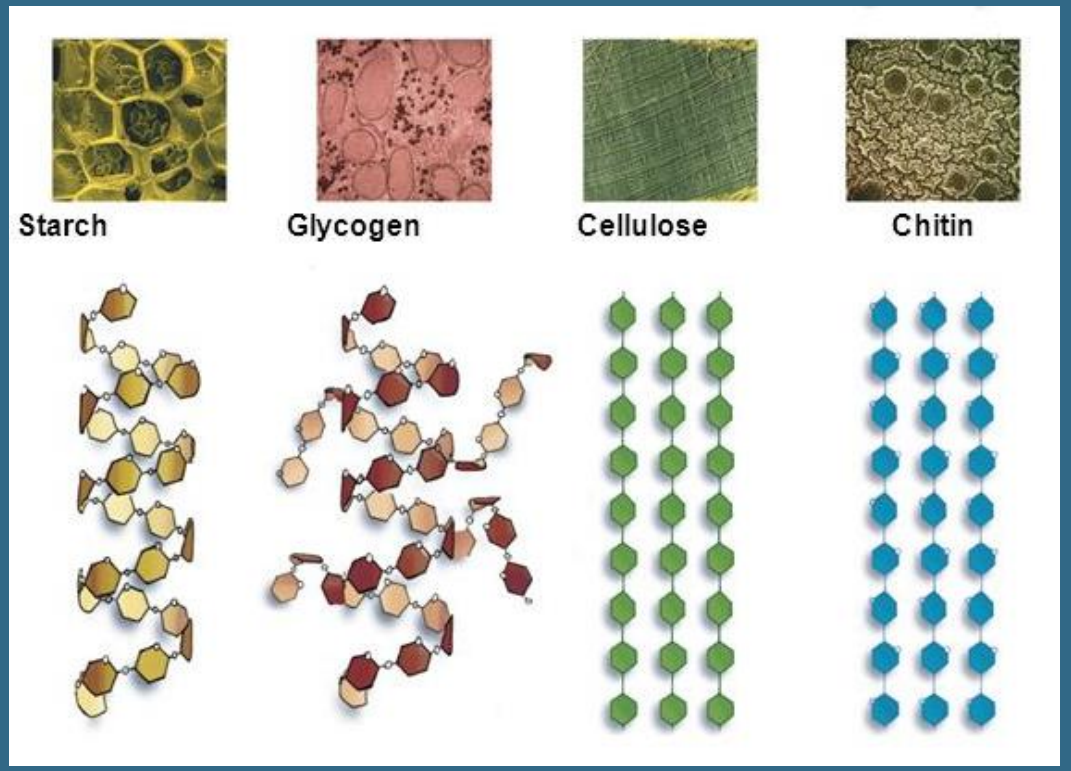
Fish Oil

Rapeseed Oil

Canola Oil

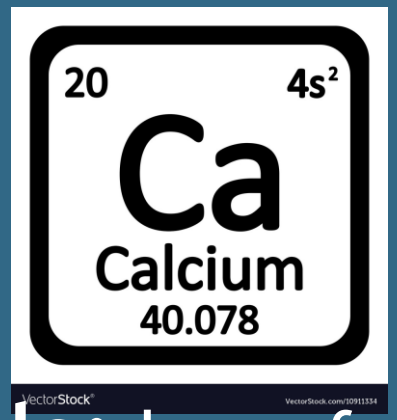
Microalgae Oil

Carbohydrates

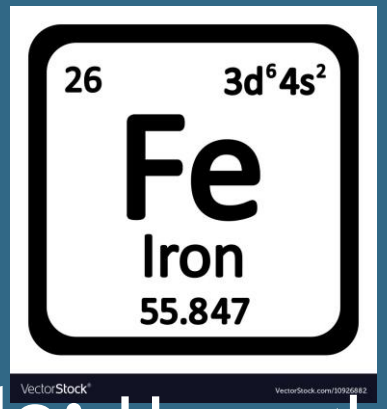


Role: Energy source & binding agent

Minerals, Vitamins & Pigments



Role: bone formation



Role: Hemoglobin (O2 transport)

Vitamin C

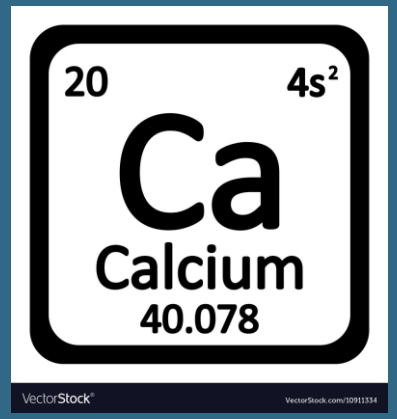
Role: Skeletal growth

Vitamin K

Role: Blood clotting

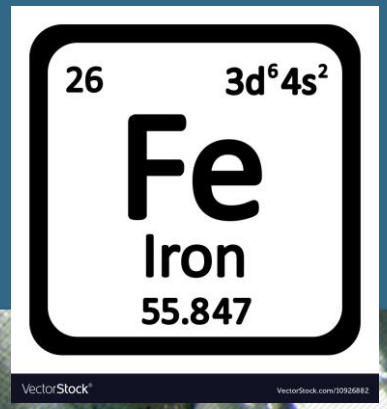
Role: Health, Vit A (precursor), anti-oxidant

Minerals, Vitamins & Pigments



Vitamin C

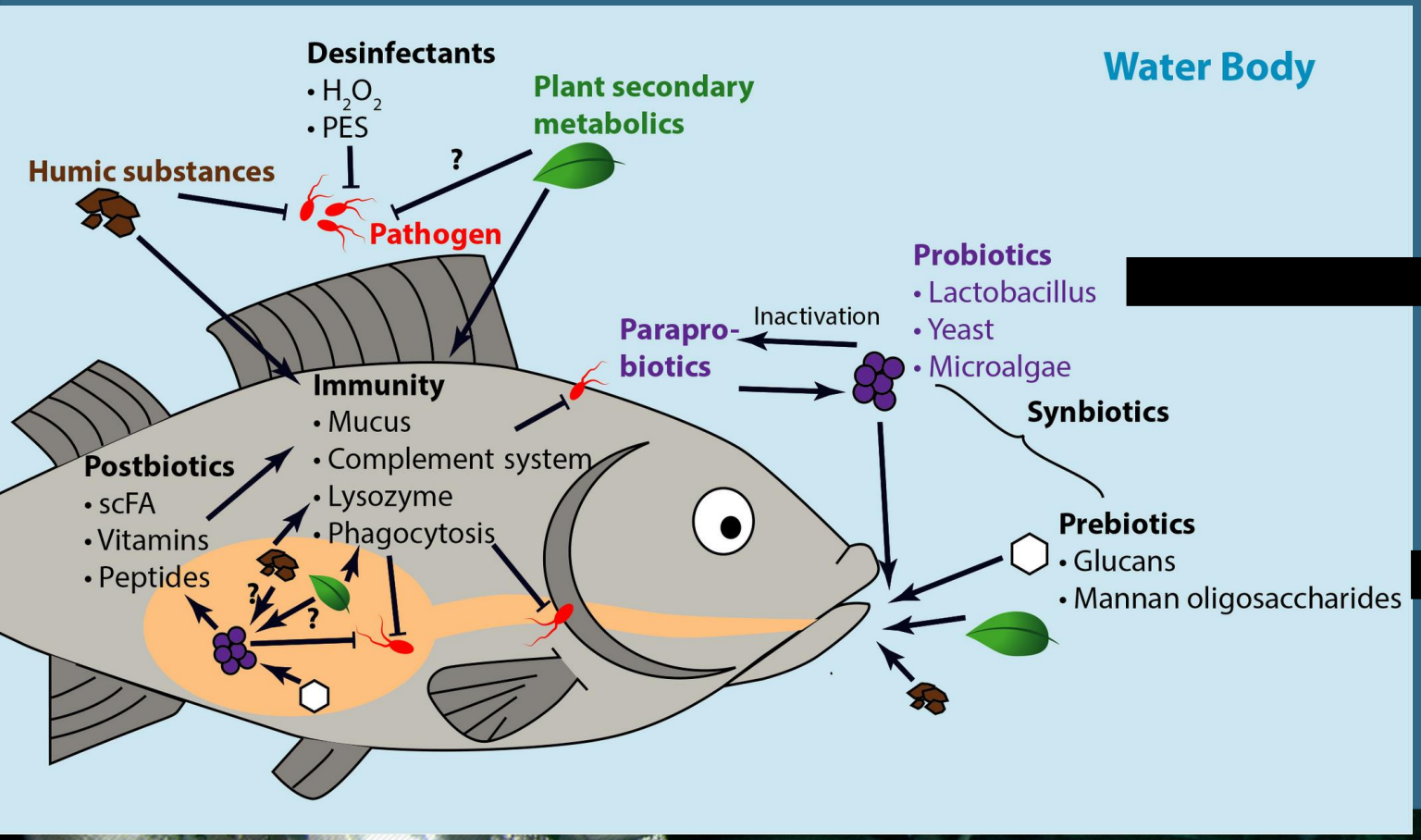
Source: Vitamin and mineral premix



Vitamin K

Source: natural prey (wild) from krill or red microalgae.

Probiotics and Prebiotics



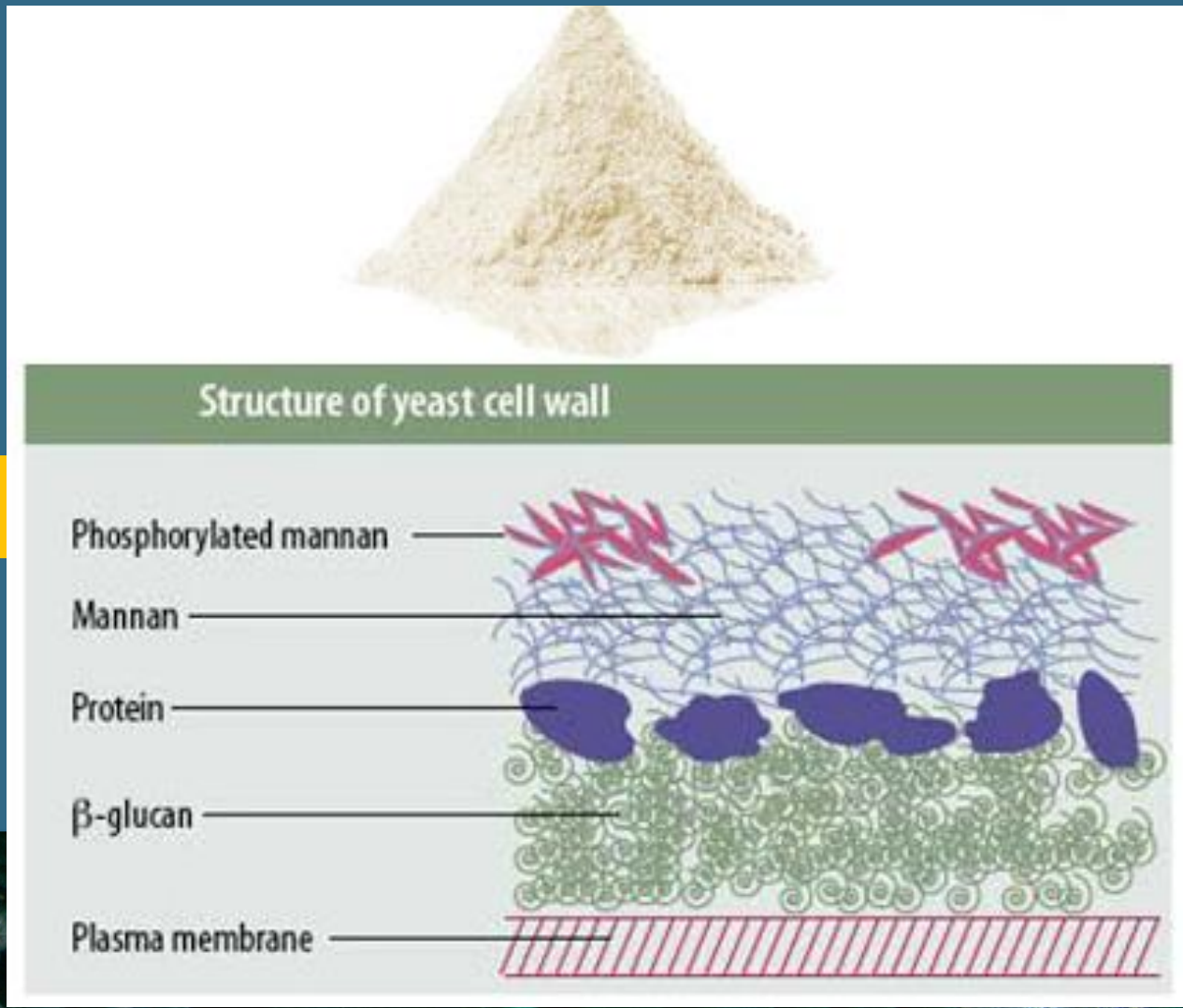
Live organisms that directly alter the gut microbiome that play a role in digestion and immuno-support.

Non-digestible and benefit the fish by supporting beneficial bacteria in the gut and support of growth and metabolism.

Non-nutritional Ingredients

Immunostimulants

- β glucans
- Peptidoglycans
- Lipopolysaccharides



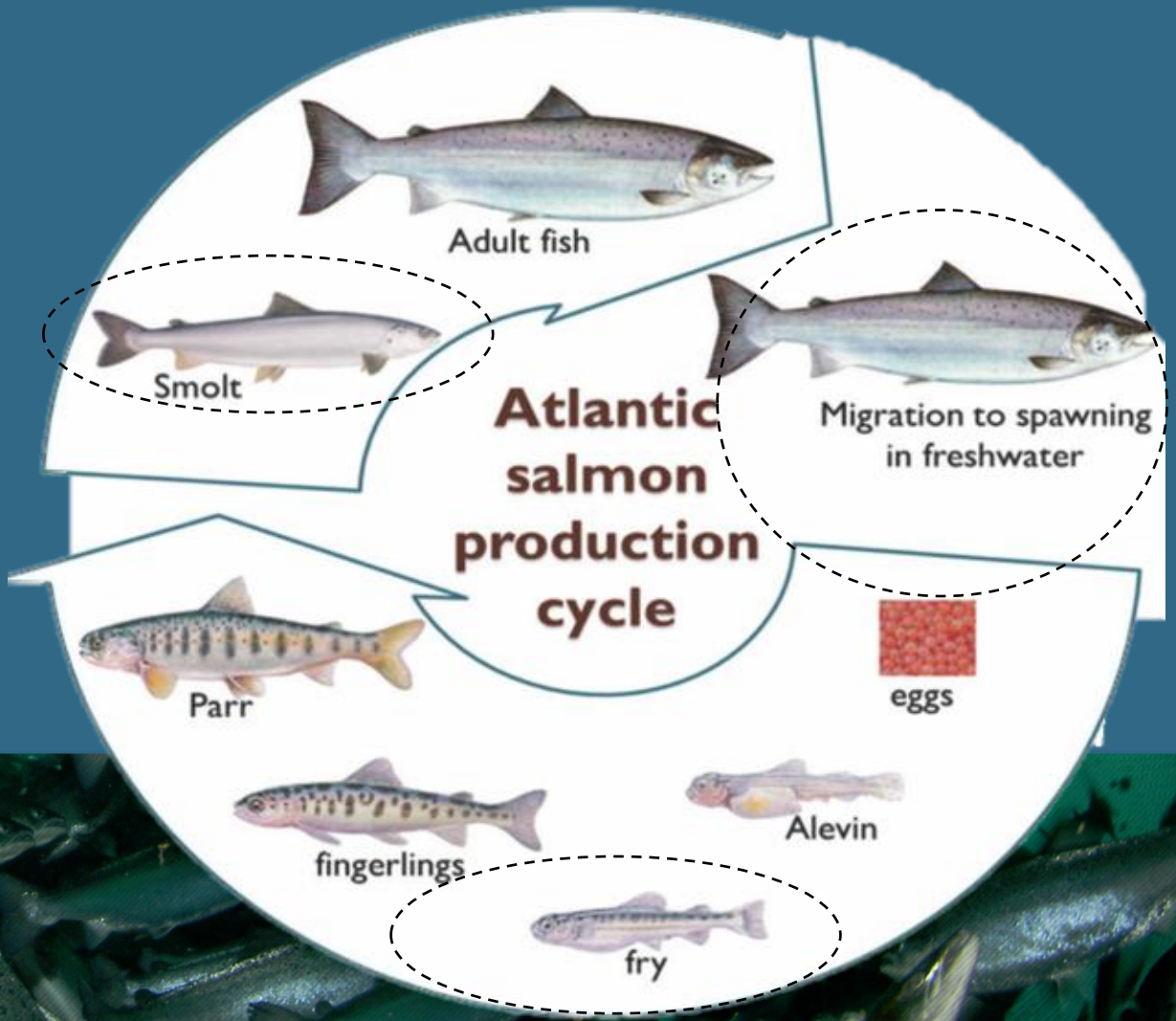
Nutritional Requirement Varies

Different species

Omnivores

Carnivores

Different developmental period



Nutrition Summary

Macro Nutrient	Key Roles
Protein	Enzymes, muscle building, hormones, structural proteins (collagen), immune support (anti-bodies), amino acid source.
Lipids	Dietary energy, insulation, cell membrane structure, hormone structure, energy storage, immune support.
*Carbohydrates**	Energy Sources (herbivores/omnivores), binding agent (carnivores)

Micro-Nutrient	Key Roles
Minerals	e.g. bone formation and hemoglobin
Vitamins	e.g. skeletal growth and blood clotting
Pigments	Vitamin A production & Antioxidants, protecting fatty acids in eggs.

Source Summary

Macro Nutrient	Traditional Sources	Emerging sources
Protein	Fish meal, Soybean Meal, (some other plant meals)	Bacterial meals, fungal meals, Insect meals.
Lipids	Fish oil, rapeseed oil, canola oil*	Microalgae oils
Carbohydrates	Wheat	

Micro-Nutrient	Sources
Minerals	Mineral premix
Vitamins	Vitamin premix
Pigments	Crustacean material and red-microalgae

Module 2: Exercise 2.1 & Exercise 2.2

Fill in a blank table about the sources and roles of nutrients and a small multiple-choice quiz using an online application.

Alexandra Leeper

3/2/2020

Module 3 Aquafeed Formulation

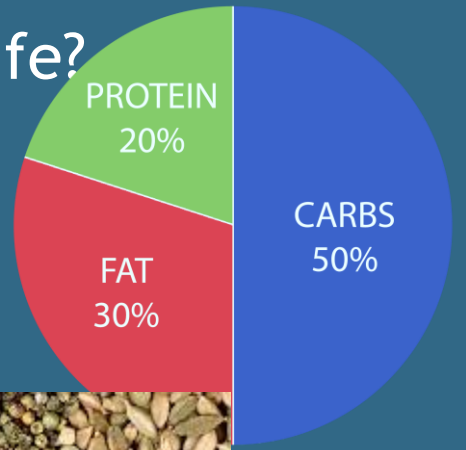
Alexandra Leeper

Feed formulation

- What is the species of interest?

- What is the developmental stage of the fish?

- What are the nutritional needs of that fish at that stage of its life?
- What ingredients are available and what are the nutritional compositions of those ingredients?
- Cost (?)



Formulation for different species

Omnivores

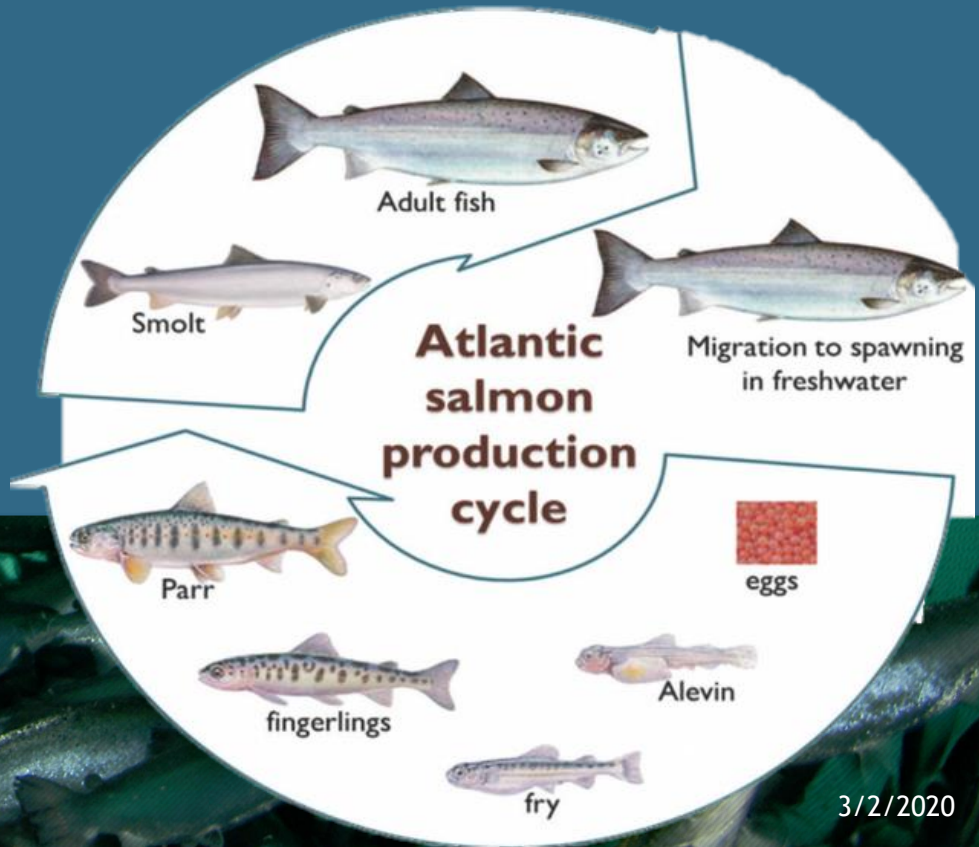
Carnivores

Macro-nutrient	Common Carp	Nile Tilapia	Atlantic Salmon
Protein %	28	26	34
Lipid	5-15(omega3 & 6)	10-15(omega-6)	24 (Omega-3)
Carbohydrate	38.5	40	Not required for nutrition*

Examples from adult diets (non-broodstock)-FAO

Formulation for different stages

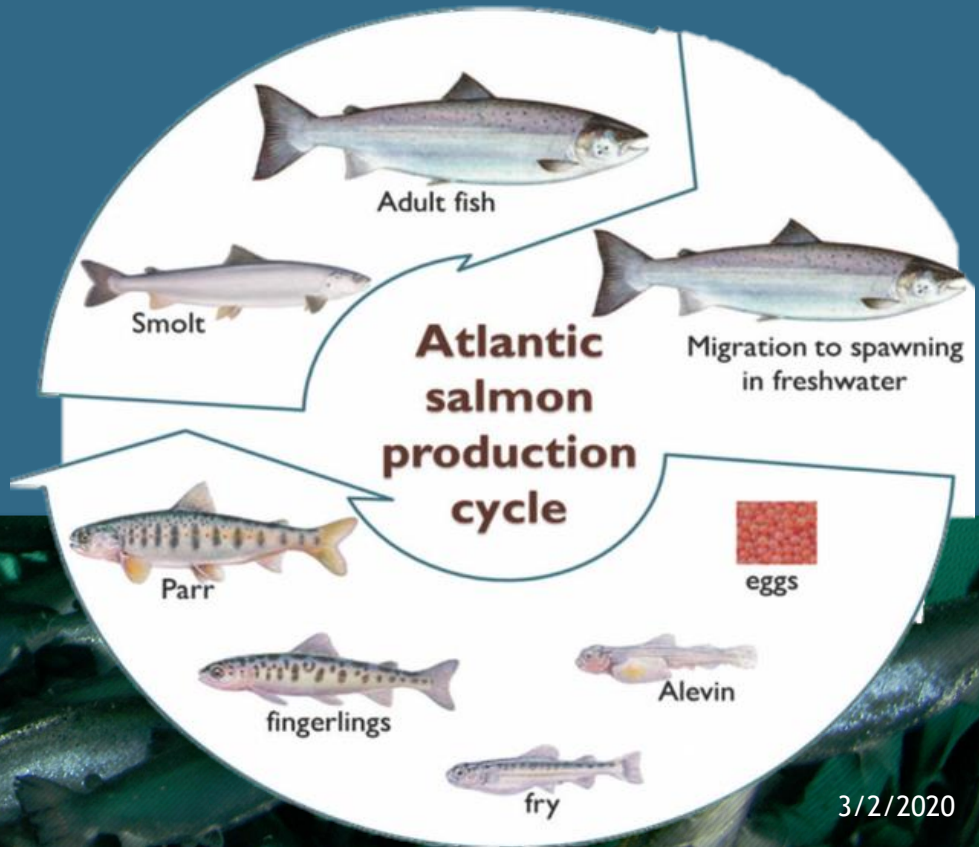
Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34



Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34

Ingredient	Diet R1	Diet R2	Diet R3	Diet R4
Fishmeal	40	30	18	18
Soybean protein concentrate	0	5	10	10
Terrestrial Animal Protein	12	19	29	29
Fish Oil	9.6	9.8	10	10
Poultry Oil	9.6	9.8	10	10
Mannan oligosaccharide	0.2	0.2	0.2	0
Proximate analysis				
Digestible protein	39	39	39	39
Digestive energy	20	20	20	20



Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34

	FM[b]	CU[c]	KM[c]	SC[c]
Dry matter	918	937	939	968
Crude protein	735	560	511	460
Nucleic acids	13	93	102	58
Crude lipid	114	3	8	2
Starch	10	37	8	11
Ash	139	54	76	64
Ca	26	2.7	0.5	0.7
P	20	15	15	11
Se, mg kg^{-1}	2.7	< 0.04	< 0.04	0.12
Gross energy, MJ kg^{-1}	22.3	21.4	20.5	19.6

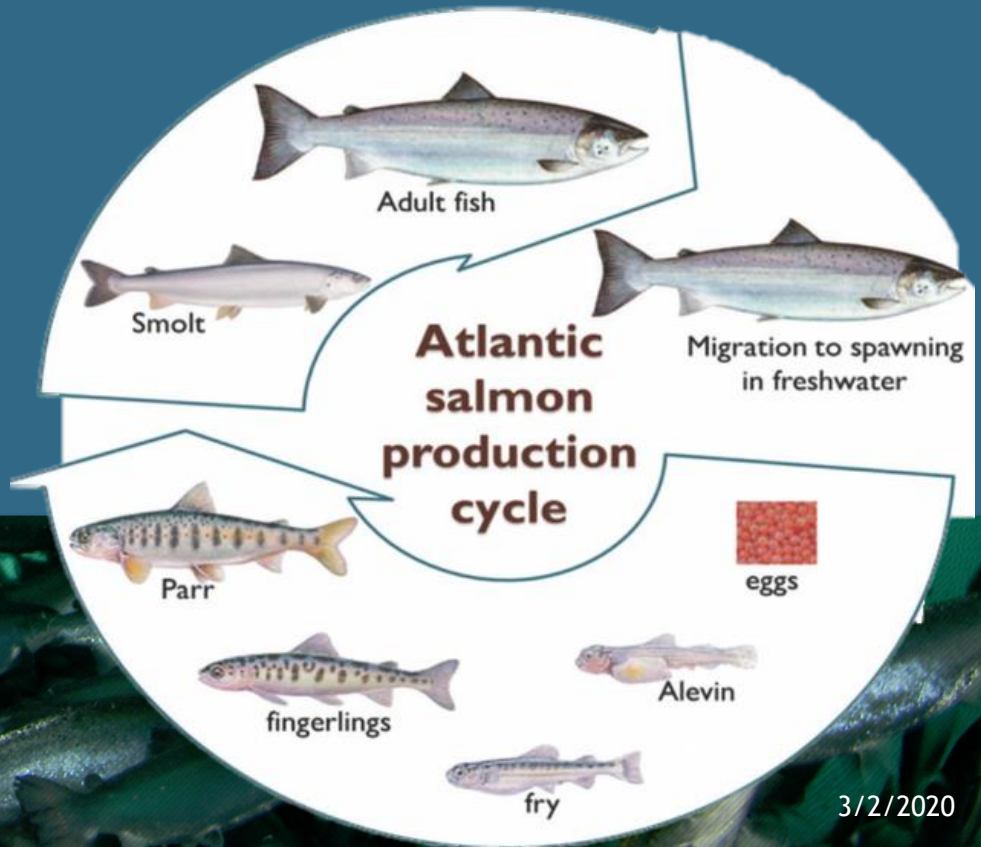
	FM diet	CU diet	KM diet	SC diet
Formulation, g kg^{-1}				
Fish meal	579	347	347	347
Candida utilis	0	283	0	0
Kluyveromyces marxianus	0	0	302	0
Saccharomyces cerevisiae	0	0	0	345
Gelatinized potato starch[a]	126	118	100	56
Fish oil[b]	137	162	161	161
Gelatin[c]	80	80	80	80
Cellulose[d]	67	0	0	0
Premix[e]	9.9	9.9	9.9	9.9
Y_2O_3[f]	0.1	0.1	0.1	0.1

Formulation for different stages

Requirement	Start-feed (fry)	Fingerlings	Parr	Smolt	Post-smolt adult	Broodstock
Protein %	48	48-44	44-40	38	34	34

Table 1. Formulation, proximate composition and fatty acid composition of the high marine diet (Diet $M^{stimulus}$) and low fishmeal/fish oil diets (Diet $V^{stimulus}$ and Diet $V^{challenge}$) used in the respective feeding phases

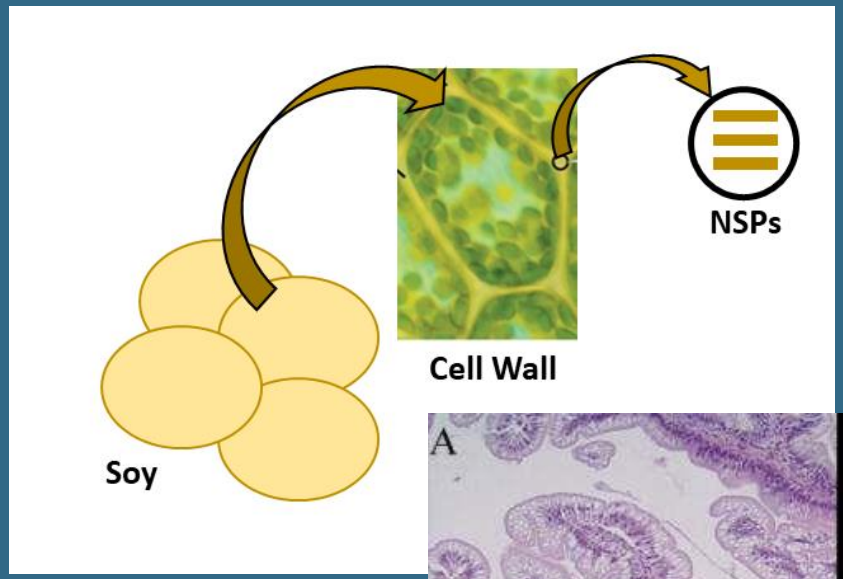
Experimental phases...	Stimulus phase		Challenge phase
Diets...	$M^{stimulus}$	$V^{stimulus}$	$V^{challenge}$
Ingredients (g/kg)			
Fishmeal*	648·4	50·0	50·0
Crustacean and fish peptones†	146·0	50·0	50·0
SPC‡	–	163·7	90·2
Wheat gluten§	–	214·0	181·7
PPC‖	–	210·0	245·7
Wheat¶	135·9	139·9	134·4
Fish oil**	40·0	·	·
Rapeseed oil§	–	60·0	170·6
Vitamins and minerals††	22·7	54·8	52·5
Amino acids‡‡	7·0	57·6	25·0
Analysed proximate composition			
Lipid – crude (%)	13·3	11·3	21·6
Protein – crude (%)	57·1	56·6	49·6
Energy – gross (MJ/kg)	20·5	20·6	22·7
All fatty acids (% total fatty acids)			
PUFA	40·6	37·6	33·3
LA (18:2*n*-6)	4·8	25·8	22·9
ALA (18:3*n*-3)	1·3	8·2	8·9
EPA (20:5*n*-3)	13·0	1·4	0·6
DHA (22:6*n*-3)	12·1	1·4	0·6

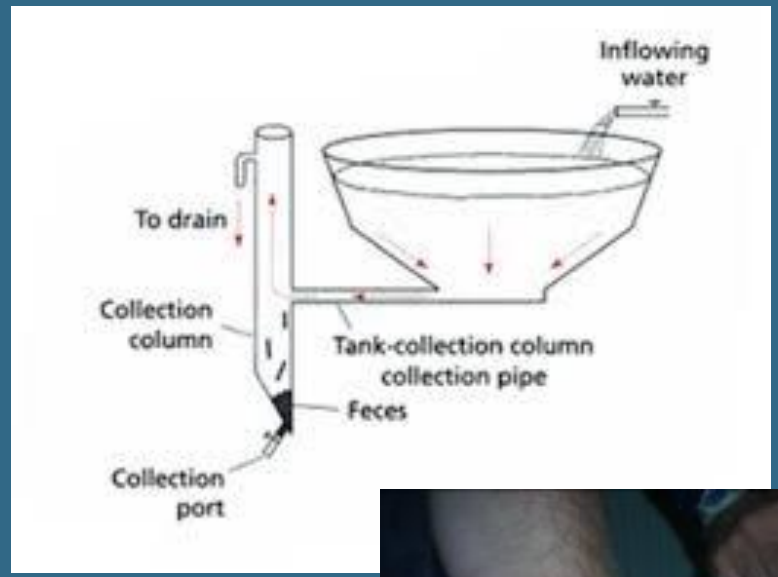


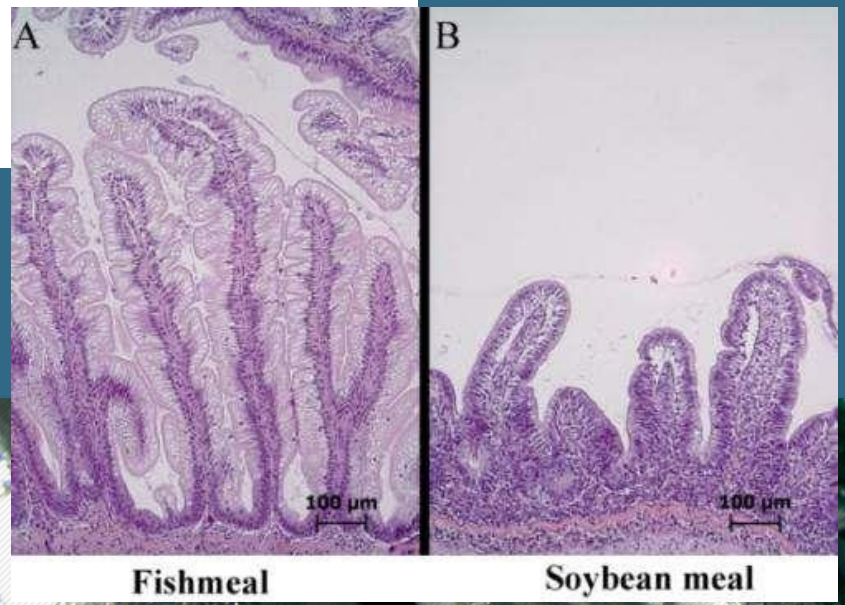
Additional Feed formulation considerations

- Digestibility & biological availability of feed ingredients
- Palatability & attractability of feed ingredients
- Compatibility with the pellet production process
- Anti-nutritional Factors & Toxins

Digestibility & availability





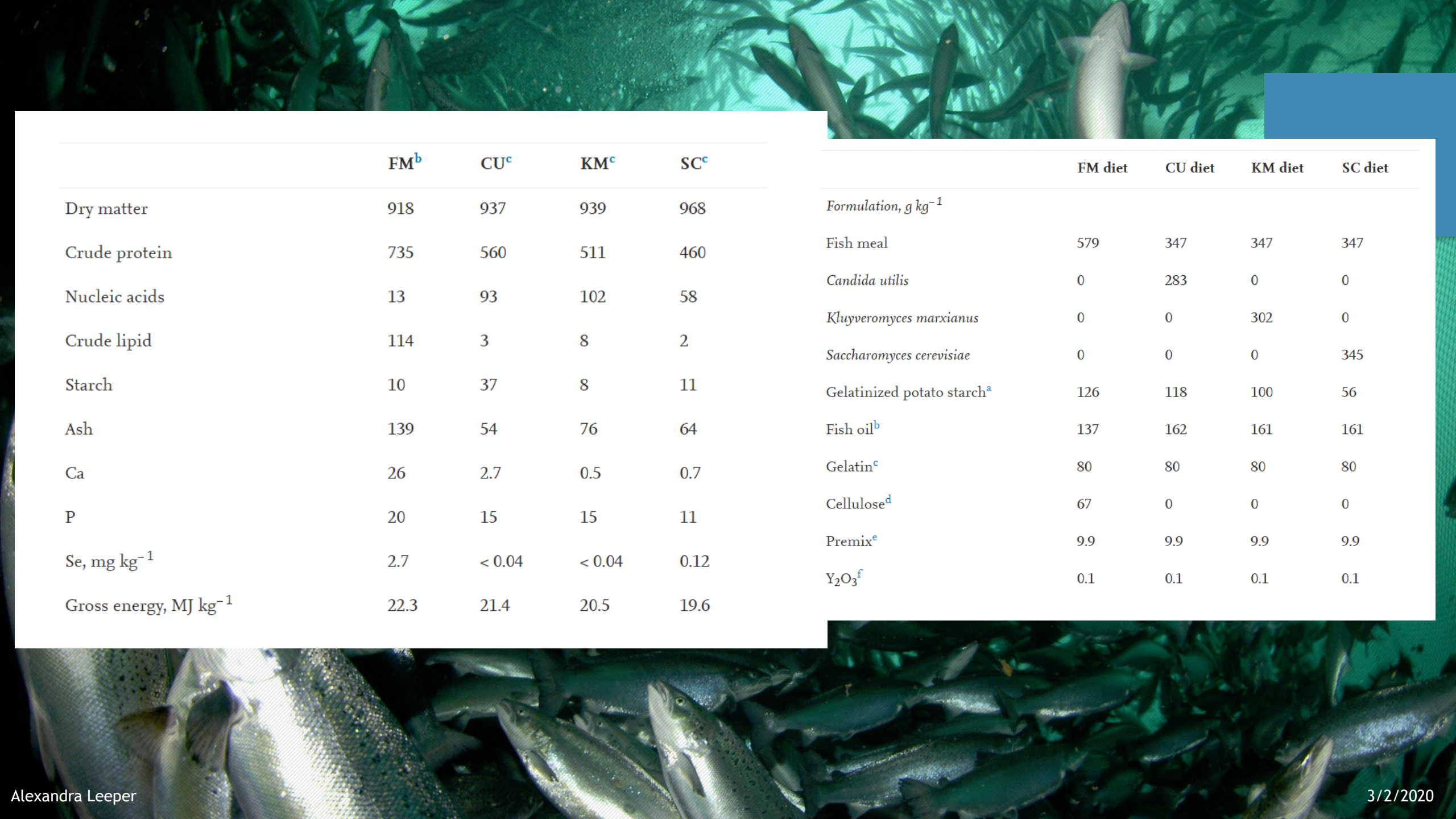


Anti-nutritional factors

Palatability & Attractability

Module 3: Exercise 3.1

Match the formulation with the species and the developmental stage and justify answer. Explore the feed ingredients and info from diets fed on farms. Small question and answer session to review any material from the first three modules.



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Ingredient	Diet R1	Diet R2	Diet R3	Diet R4
Fishmeal	40	30	18	18
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Fish Oil	9.6	9.8	10	10
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Mannan oligosaccharide	0.2	0.2	0.2	0
Proximate analysis				
Digestible protein	39	39	39	39
Digestive energy	20	20	20	20

Ingredients:	Unit	FM 0
Fish meal	g/kg	676,8
Fish oil	g/kg	103,5
Wheat	g/kg	209,7
Plant protein mix	g/kg	0,0
Corn gluten meal	g/kg	0,0
Soy protein concentrate	g/kg	0,0
Wheat gluten meal	g/kg	0,0
SYLPRO ®	g/kg	0,0
Lysine	g/kg	0,0
Methionine	g/kg	0,0
Premix	g/kg	10,0
		1000,0
Nutrient composition, calculated as is:		
Dry matter	g/kg	923,3
Crude protein	g/kg	500,0
Crude lipid	g/kg	160,0
Crude fiber	g/kg	4,6
Crude ash	g/kg	100,0
NFE	g/kg	144,5
Starch	g/kg	124,6
Phosphor	g/kg	14,6
Lysine	g/kg	35,1
Cystine	g/kg	4,7
Methionine	g/kg	13,1
Methionine + Cystein	g/kg	17,9
Histidin	g/kg	11,1
GE (Calculated)	MJ/kg	20,7

Ingredients:	Unit	FM 0
Fish meal	g/kg	401,8
Fish oil	g/kg	38,3
Wheat	g/kg	549,9
Plant protein mix	g/kg	0,0
Corn gluten meal	g/kg	0,0
Soy protein concentrate	g/kg	0,0
Wheat gluten meal	g/kg	0,0
SYLPRO ®	g/kg	0,0
Lysine	g/kg	0,0
Methionine	g/kg	0,0
Premix	g/kg	10,0
Nutrient composition, calculated as is:		
Dry matter	g/kg	895,3
Crude protein	g/kg	350,0
Crude lipid	g/kg	80,0
Crude fiber	g/kg	12,1
Crude ash	g/kg	69,9
NFE	g/kg	398,9
Starch	g/kg	326,6
Phosphor	g/kg	10,1
Lysine	g/kg	22,3
Cystine	g/kg	4,0
Methionine	g/kg	8,6
Methionine + Cystein	g/kg	12,6
Histidin	g/kg	7,8
GE (Calculated)	MJ/kg	18,3

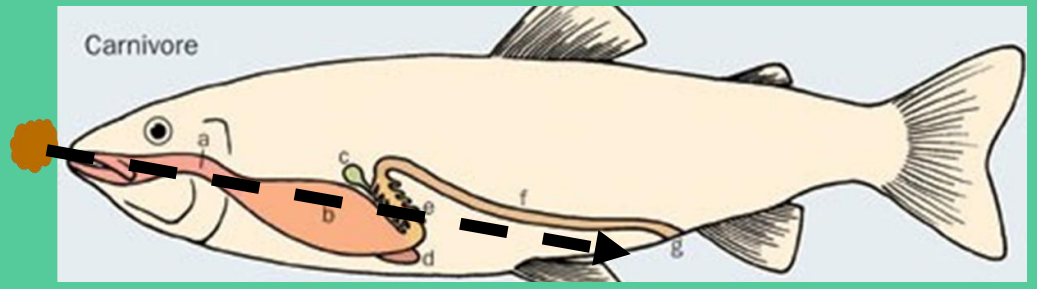
Table 1
Dietary formulation and proximate composition of the diets

Feed formula	%	Proximate composition	%
Fish meal [a]	56.0	Crude protein (N×6.25)	49.1
Fish oil [b]	12.5	Lipid	14.4
Extruded wheat	28.0	Nitrogen free extract	16.9
Binder (Tylose)	2.0	Moisture	9.3
Vitamin premix [c]	1.0	Ash	10.3
Mineral premix [c]	0.5		
Carophyll Pink (5% astax.)	(0 or 2 g kg^{-1})		

[a] Norse LT, Norsildmel, Bergen, Norway.
[b] Refined sardine oil (canning oil) and cod-liver oil (medicine oil) (1:1), JC Martens a.s, Bergen, Norway.
[c] Standard proprietary premixes (Ewos Aqua, Sweden).

Homework module 1-3

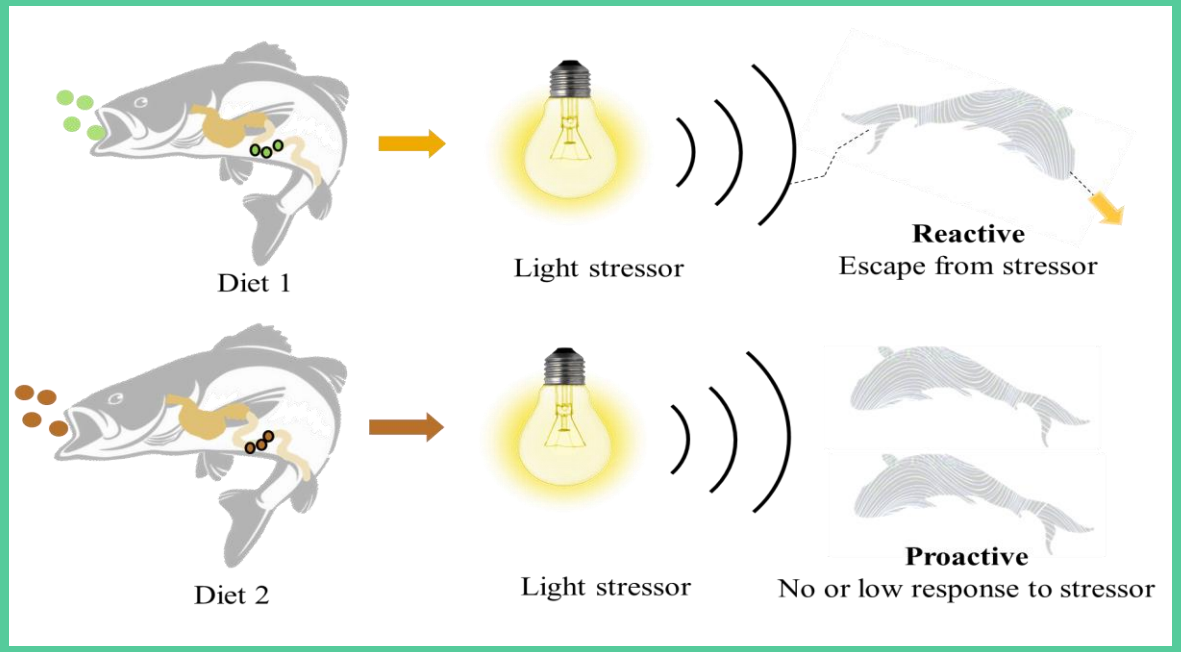
To be set



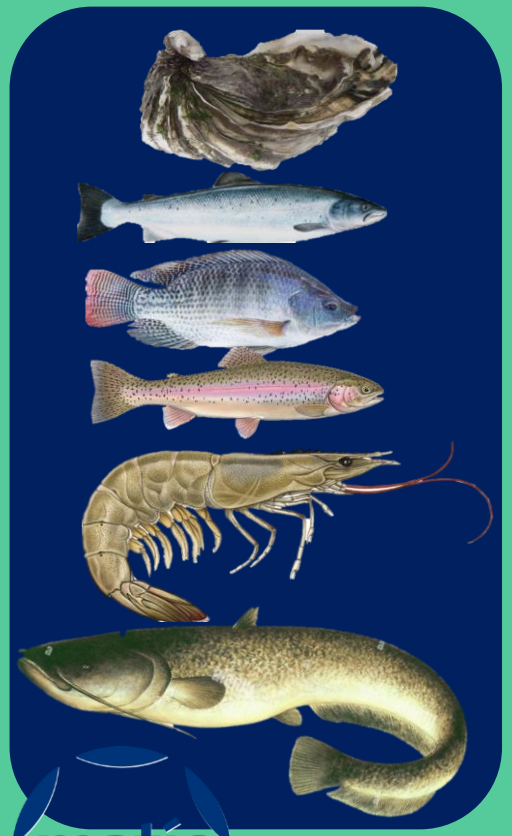
Factors to consider in feeding

Gut microbiome (gut-brain-axis)

Behaviour and welfare



Ice and fire and aquaculture



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