
TRAINING
Aquaponic
Arkades

TRAINING

Procedures for integrated fish and plant production

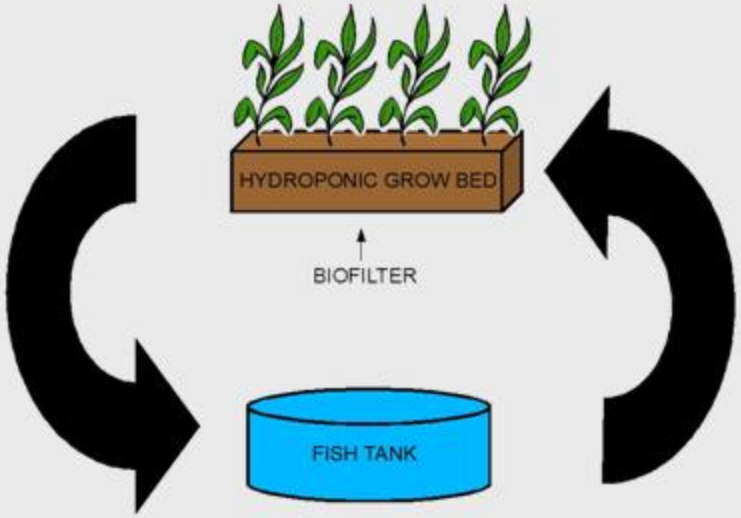
Theory

Aquaponic =

ecologically worthwhile combination of fish farming and plant cultivation in a closed water cycle

Topics of the TRAINING:

- **FISH**
- **WATER**
- **PLANTS**



1. Topic: FISH

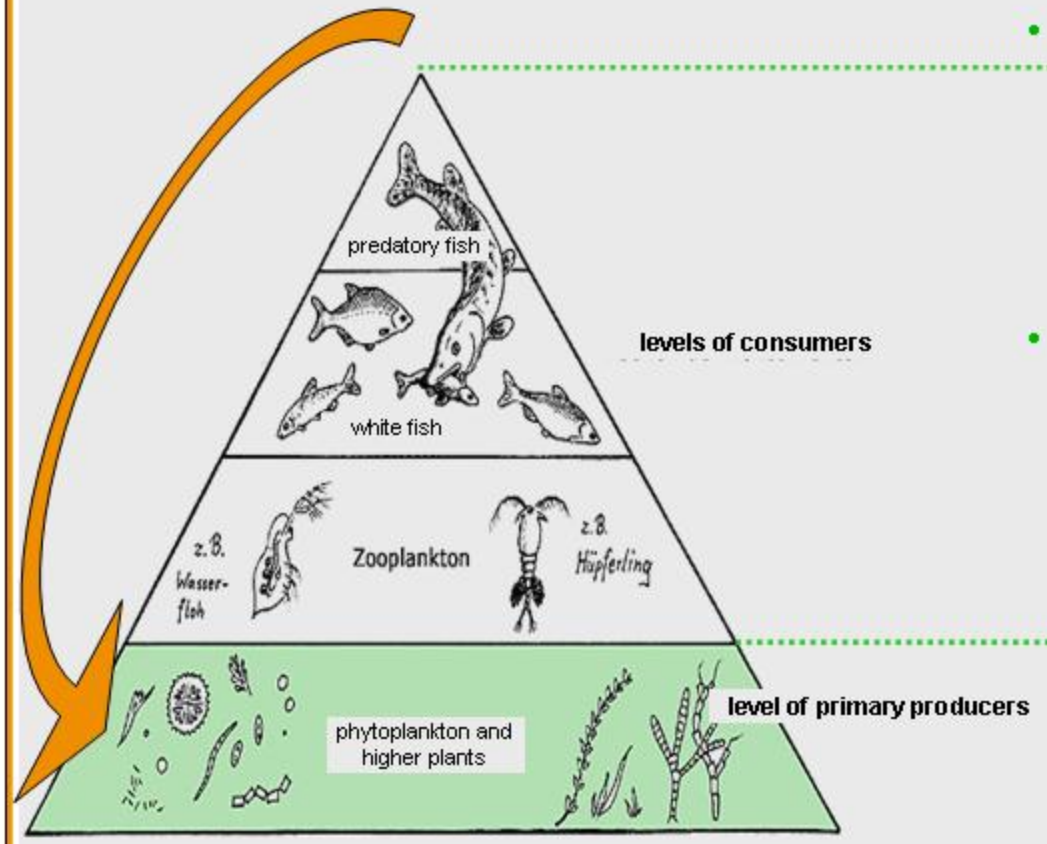
1.1 Relevance of Fish (I)

- **habitat: water (71 % of the earth's surface)**
- **major vertebrate group with approx. 25.000 various species**
  - 1/5 live in freshwater and
  - 4/5 in saltwater
- **classification of fish to 3 subgroups**

jawless fish (Agnathans)	**jaw fish**	
	cartilaginous fish	**bony fish**
Their long eel like body has no limbs, scales, skull, bones and jaw.	They have a cartilaginous skeleton, rough skin, gills without protective flaps and no swim bladder.	Their bodies have a bone skeleton, scales, gills with protecting bony cutaneous flap and a swim bladder.
e.g.: lamprey	e.g.: sharks, rays	most species e.g.: eel, salmon, catfish, perch, carps, whitings

1.1 Relevance of Fish (II)

Fish is an essential element of aquatic ecosystems within the framework of food chains and webs.



- for reducers dead biomass is food
- classification of fish/animals in different levels of consumers depending on the rank of the food chain

biomass formation particular by plants as primary producers

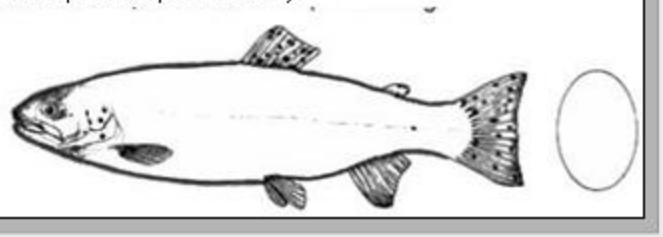
1.1 Relevance if Fish (III)

- **Fish is an essential part of human nutrition, because their meat is rich in …**
  - valuable protein,
  - unsaturated fatty acids,
  - vitamins and minerals (trace elements)

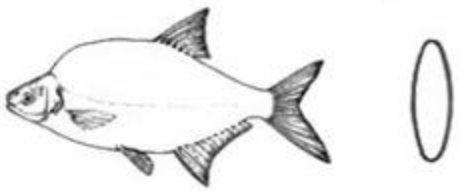
1.2 Body Structure (I)

- **Due to the influence of various habitats and forms of behavior body structures were developed.**

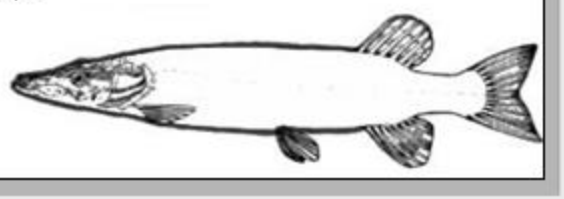
spindle-shaped or torpedo-like body



high backs, laterally compressed

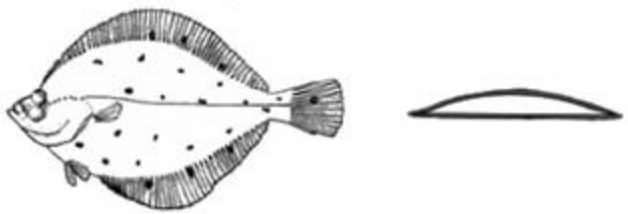


arrow-shaped



flattened from top to bottom

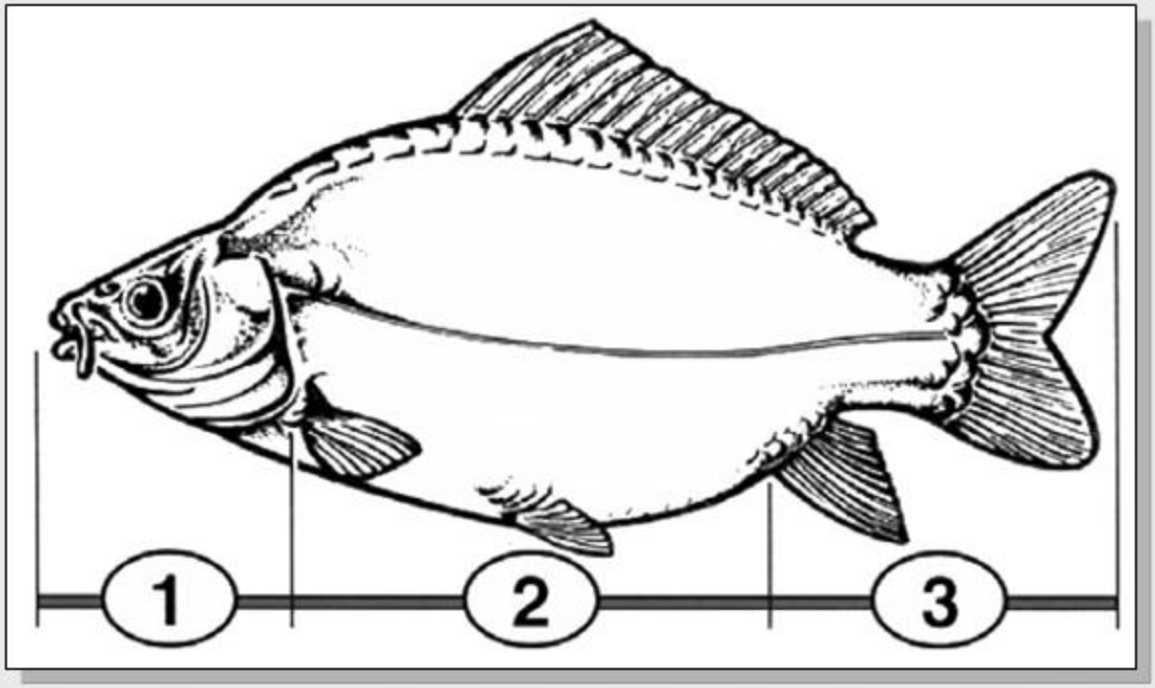
disc-shaped



snake-shaped

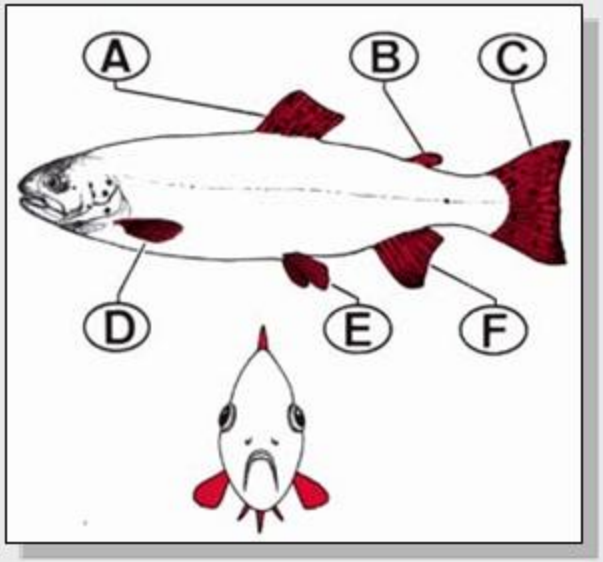
1.2 Body Structure (II)

- **division into**
  - 1 head (snout to the end of gill covers)
  - 2 torso (end of gill covers to anus)
  - 3 tail (anus to the end of caudal fin)



1.2 Body Structure (III)

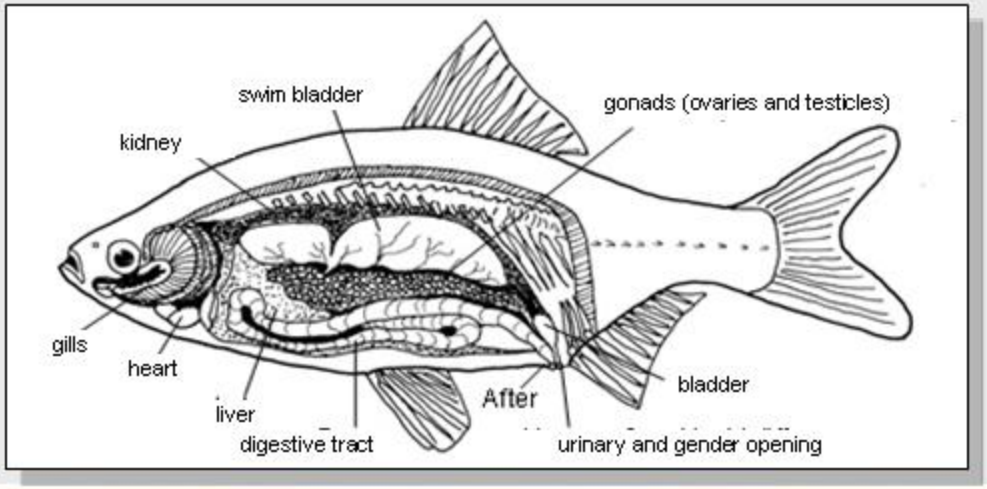
- **paired and unpaired fins for swimming and steerage**
  - unpaired (a) dorsal fin (steer)
    (b) bold fin
    (c) caudal fin (impetus)
    (f) anal fin (steerage)
  - paired (d) pectoral fin (control, movement, braking, balance, tactile perception)
    (e) ventral fin (steerage)



- **musculature amounts to about 30 … 50 % of body mass = edible part**

1.3 Internal Organs

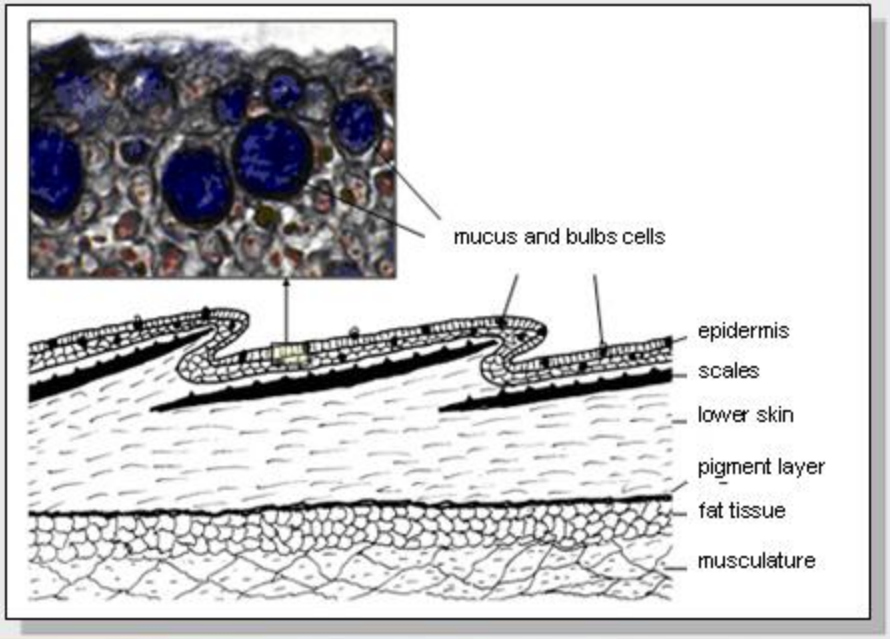
- **behind the head and beneath the spine the body cavity contains…**
  - heart (bloodstream)
  - liver (digestive gland and storage organ)
  - digestive tract (digestion)
  - genitalia (reproduction)
  - swim bladder (balanced state)
  - kidney (blood-forming organ, secretion of waste products)
  - spleen (degradation and conservation of blood components)



1.4 Fish Skin (I)

- **major organ**
- **surrounds entire body and partly enables oxygen uptake**

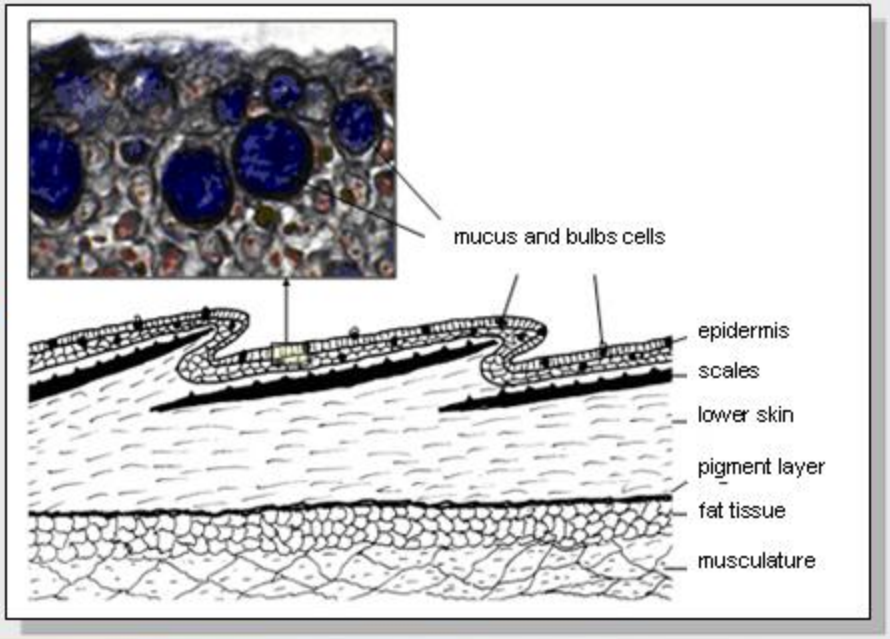
- **lower skin layer = cutis**
  - nerves and blood vessels
  - anchorages for the scales
  - pigment cells
  - lateral line
    (perception of currents and water pressure changes)



1.4 Fish Skin (II)

- **epidermis = with mucous glands for the formation of the mucosa:**
  - mucosa forms the barrier layer to the surrounding water
  - reduction of friction
  - quick wound closure
  - protection from parasites, bacteria and chemical influences
  - delivery of kind's scent, repellents

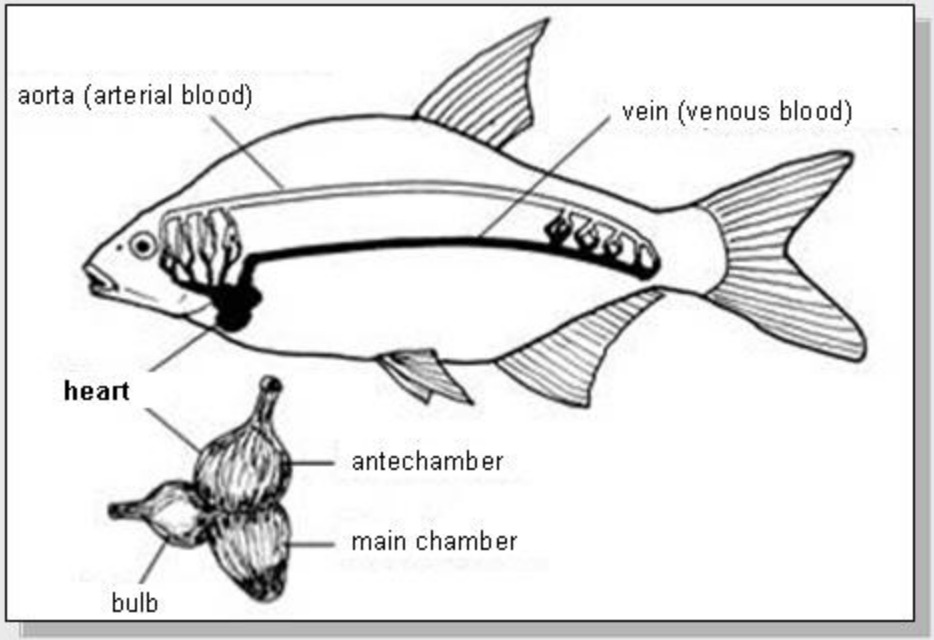
Only touch live fish with wet hands or wet clothes!



1.5 Bloodstream

- **closed blood circulation**
- **fine veins run through the whole body**
- **by the pumping action of the heart the circulation is maintained**

- **blood = transportation**
  - bonding and distribution of O_2 on the basis of gills
  - bonding and transport of waste products of metabolism (CO_2, NH_4^+) to the gills

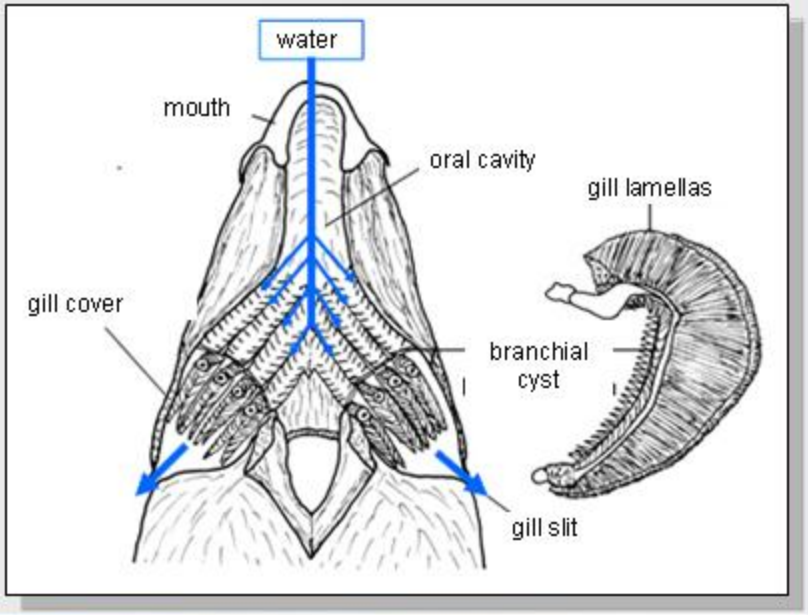


- **Before being eaten, fish have to bleed by spearing through the heart or severing veins between heart and gill!**

1.6 Respiration of Fish (I)

- **forms of respiration: gill breathing, cutaneous respiration, intestinal respiration**
- **gill = most important respiratory organ**
  - located on both sides at the end of the head under the gill covers
  - each side with 4 branchial cysts, on each 2 rows with many gill lamellas (skin flap: large-surface, well supplied with blood)
- **gill breathing**
  - 1. sucking of respiratory water: mouth open, gill slit closed

    (O_2 is bound to blood in gill lamellas)
  - 2. emitting of respiratory water: water is pressed along the gill lamellas trough gill slit (emission of metabolic waste products to water)



1.7 Respiration of Fish (II)

- **gills are very sensitive to dirt and damage**
  - in healthy fish:
    - gills are colored bright red

  - in sick fish or in case of bad water quality:
    - swollen gills
    - increased mucus secretion
    - yellow or grey discoloration

1.8 Nutrition and Feeding (I)

- **an adequate nutrition of the fish is the basic requirement for health and healthy growth**
  - usage of dry food for nutrition / feeding in intensive fish-farming
  - dry fish food contains proteins, fat, carbohydrates, vitamins and minerals → quality of raw material is crucial for digestibility and water quality

1.8 Nutrition and Feeding (II)

- **for weight gain per kg 1,0 … 1,2 kg food is required**
- **cool and dry storage of the feedstuff; in case of mold growth feedstuff can not be reused**
- **only as much can feeding as fish are able to take up immediately (otherwise it spoils the water quality)**

- **best: automatic pendulum feeder**
  - fish learn to nudge pendulum
  - fish only eat in case of appetite
  - no waste of feedstuff

2. Topic: WATER

2.1 Significance of Water in Aquaponics

- **water = fish habitat**
- **property of water: solution of salts**
  - significant to the nutrition of plants (nitrogen, phosphorus and potassium are attached to salts)
- **property of water: solution of gases**
  - dependent on temperature, pressure and pH-value
- **pH-value: acidic, neutral or basic reaction of water**
- **water polluted with waste water is very turbid and contains many bacteria → inadequate O_2-supply to fish!**

2.2 Determining the Temperature

- **as the temperature increases, the metabolic activity and thereby the O_2-need of fish increases**
- **conditions:**
  - best conditions for Tilapia in the range of 24 … 30 °C
  - requirements: O_2-supply and accurate feeding
  - avoidance of sudden temperature changes: approximation of max. 2 °C per day
  - water temperature influences life processes, effects of other environmental factors as well as resistance of fish to stress and pathogens
  - significantly increased or decreased water temperature or extreme temperature changes can cause stress, damages and even lead to fish's death
- **determining the temperature by thermometer**

2.3 Determining the Oxygen Content (I)

- **oxygen (O_2) = principal respiratory gas for fishes**
- **O_2 for plants**
  - plants need O_2 for radical respiration
  - a good O_2 supply is increasing the ionic and nutrient uptake of the roots
- **amount of oxygen is dissolved in dependence of temperature (mg/l)**
- **if lack of O_2 in water:**
  - fish grow badly and sicken rapidly or suffocate

- **O_2 on 2 different ways in water:**
  - photosynthesis of the water plants (nutrients and CO_2 from water to O_2 and biomass) → direct solution of O_2 in water
  - O_2 via contact of air with water
    - additional injection of air
    - spraying water by pumping
    - the greater the contact area or longer the contact time, the greater the O_2 –yield

2.3 Determining the Oxygen Content (II)

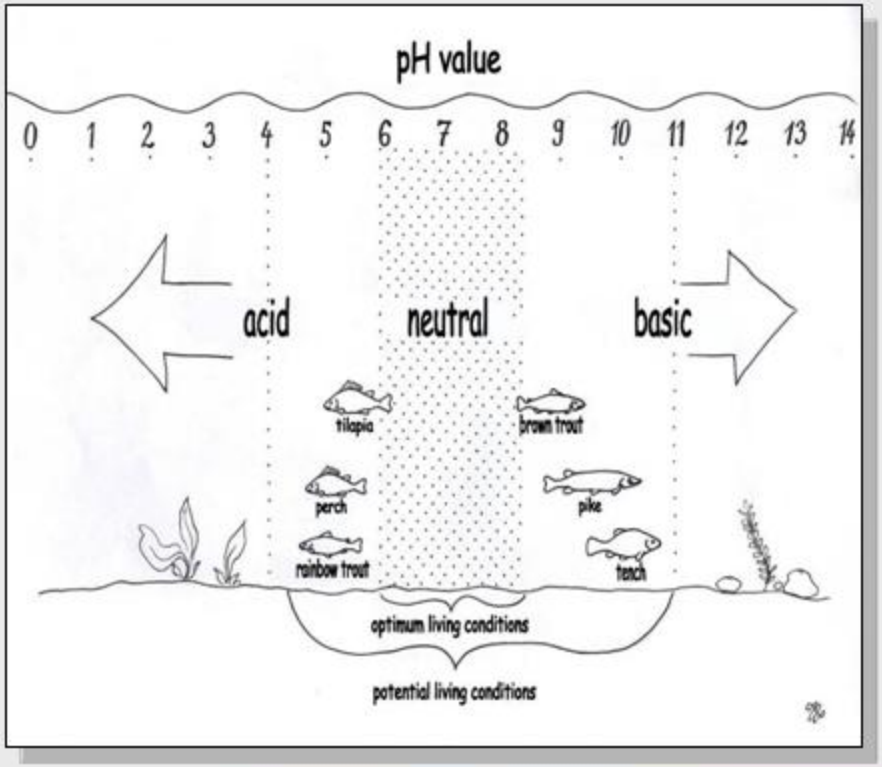
- **detection with rapid test**
  - **optimal**: values **around 7 mg/l** (O_2 – content in the upper part of solvency → optimal O_2 –supply of fish)
  - **critical**: values **below 2 mg/l**

- **in case of inadequate O_2–content fish come to the water surface and practice "emergency respiration"!**

- **activity in case of O_2-deficiency:**
  - discontinue feeding
  - aeration of water
  - supply of fresh water

2.4 Determining the pH-Value

- optimum conditions for development and growth of fish is in a pH-value range from 6,0 to 8,5

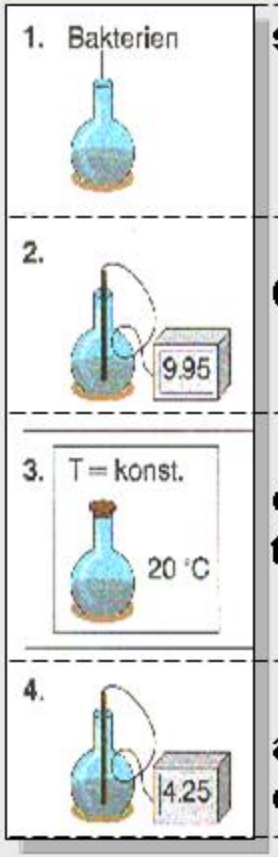


- pH-value detection by rapid test

2.5 Determining the BOD_5

- BOD = biological oxygen demand
- BOD_5 = amount of O_2 in mg/l, which is consumed in 5 days by bacteria and other water organisms at a temperature of 20 °C
- the higher the value, the more the water is polluted
- good conditions for Tilapia at values **lower than 15 mg/l**

For improving the conditions use fresh water!



sampling

O_2 -determining

closed keeping at a constant temperature of 20 °C for 5 days

after 5 days renewed determination of O_2-content

→ **difference of the values results in the BOD_5**

2.6 Determining the Ammonium (I)

- **ammonium (NH_4^+) = waste product of the digestion, dissolved in water**

conversion of nitrogen

food remains, digestion products, dead organisms

$$NH_4^+ + OH^- = NH_3 + H_2O$$

< pH 7 >

  - NH_4^+ **higher than 5 mg/l**: harmful to fish
  - NH_3 = ammonia = fish toxic: optimal < 0,01 mg/l

- **attention:** **as NH_3-content in water increases the excretion of metabolic waste products via the gills is blocked**

  → ammonia toxicity!

  → heavy damages of gills!

  (toxicity increases with high pH-values)

2.6 Determining the Ammonium (II)

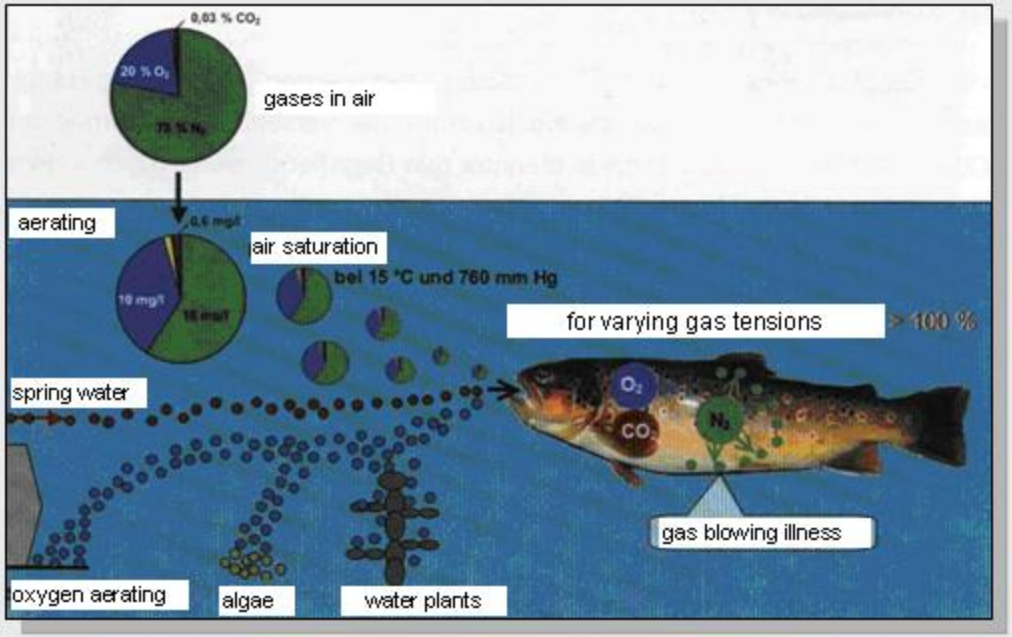
- **determining by rapid test**
  (NH_4^+, nitrite and nitrate)

- **critical values of NH_4^+ induce:**
  - decline of food uptake
  - swelling of the gills and high mucus secretion
  - several gill lamellas become white and die!

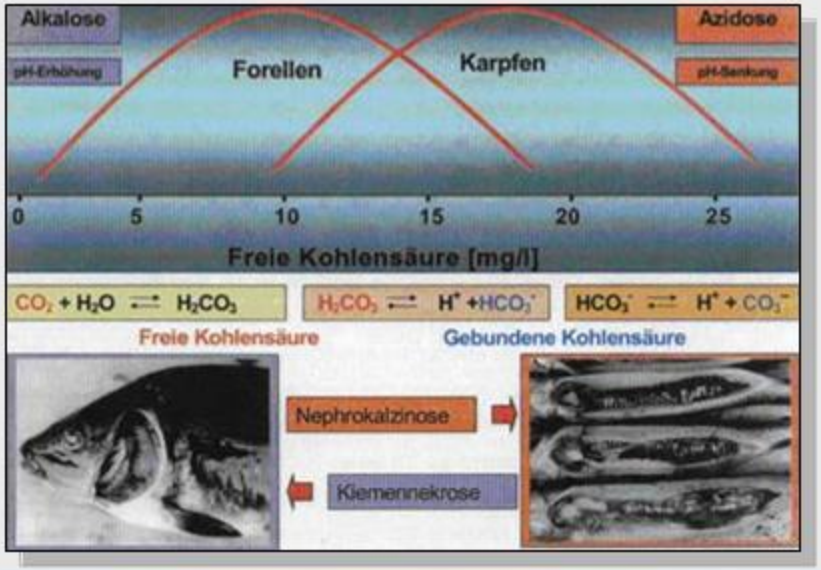
- **counter measure:**
  - interrupt feeding
  - offering fresh water
  - increase of the admission water flow of the hydroponic

2.7 Fish Hygiene (I)

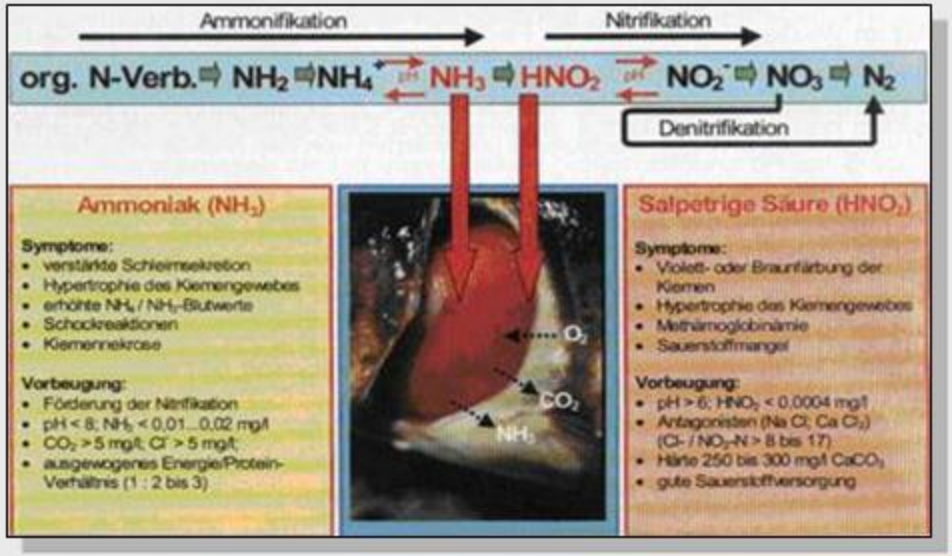
- **environmental-related diseases**
  - gas blowing illness:
    - to much air can be entered in water (e.g. by pumping) in case of aerating the water (keep air injection depths below 1,5 m)
    - in case of gas over saturation: lot of gas, esp. nitrogen intrudes into fish
    - in case of gas surge decompression sickness



- **environmental-related diseases**
  - effect of carbonic acid and pH-value:
    - large deviations of the neutral range (pH 7) may induce heavy damages, especially of the gills
    - acid disease: from pH < 5 greyish membrane and browning of the gills
    - alkali disease: from pH > 9,5 heavy mucus secretion and alkali burn of the gills



- **environmental-related diseases**
  - intoxication due to nitrogen compounds
    - in particular by ammonia (NH_3) and nitrous acid (HNO_2)
    - as the NH_3-content in the water increases, the excretion of metabolic waste products over the gills is blocked → ammonia toxicity! → heavy damage of the gills! (toxicity is increased by high pH-values)
    - as the pH-values decreases, HNO_2 increases → interrupts the oxygen transport in the blood → shortness of breath!



threshold values:

NH_3 = < 0,01 mg/l

HNO_2 = < 0,0002 mg/l

2.7 Fish Hygiene (IV)

- damage of the biological epidemic balance
- pollution with organic substances
- toxicity and pollution arising from impurities (heavy metals, insecticides, hormones)

3. Topic: PLANTS

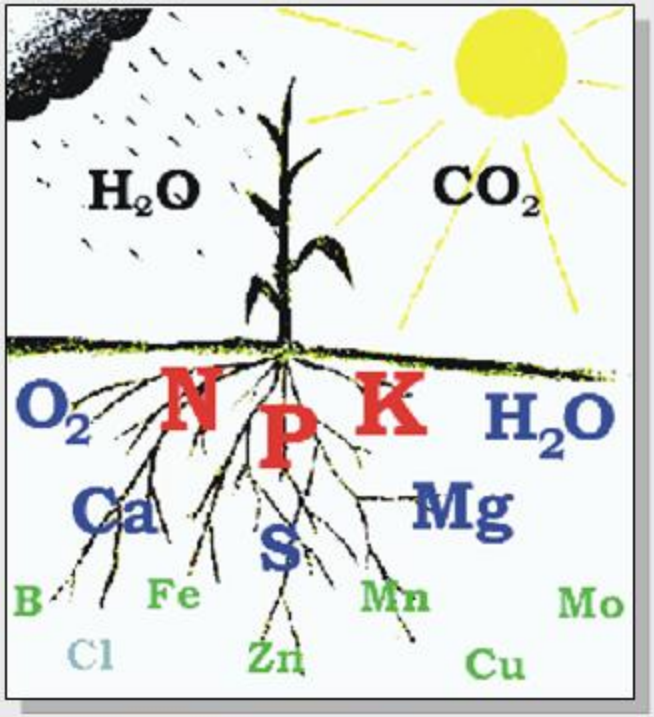
3.1 Crop Requirements

3.2 Hydroponic

3.3 Plant Cultivation

3.1 Crop Requirements (I)

- utilization of nutrients of the fish waste water (nitrate, phosphate, …) to build up biomass
- biomass = proteins, fats, carbohydrates, fibers
  = food basis to all animals
- plant growth mostly depends on light, temperature, CO_2 and water supply
- the plants are fed with water and nutrients by roots



3.1 Crop Requirements (II)

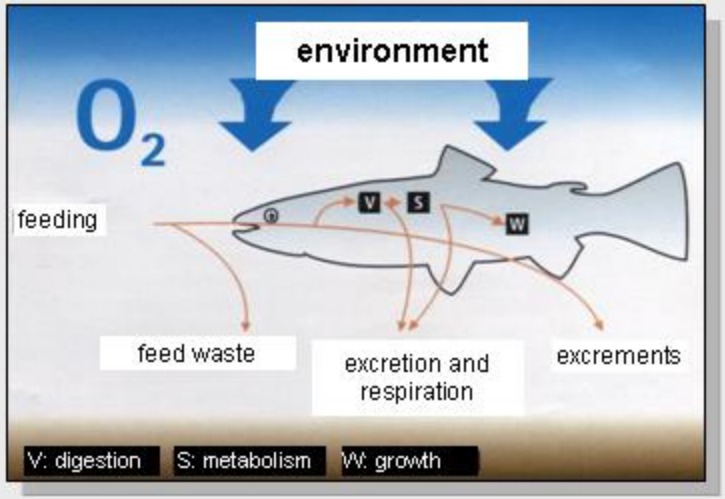
- plant production is possible without ground / soil / substrates
- for plant cultivation plants are supplied with nutrient solution on a sealed bed (with sheet)

→ *HYDROPONIC*

- to achieve a fertilization, the nitrogen-content effect of the fish waste water has to be among 50 mg/l

3.2 Hydroponic (I)

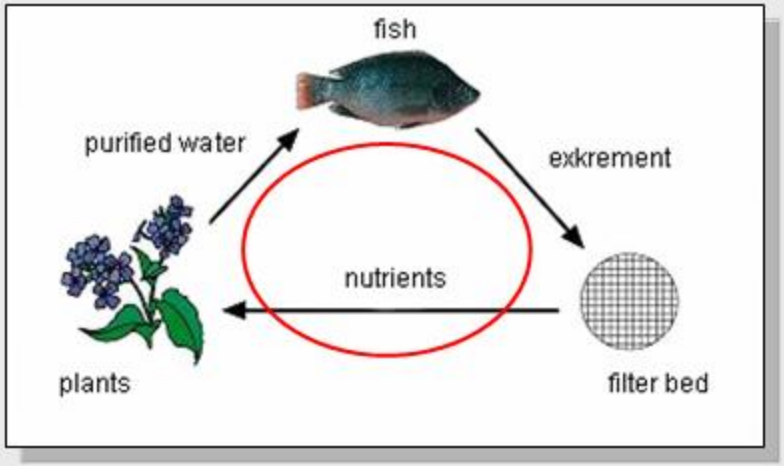
- fish food contains N und P
- only half of the feeding is bound in fish's own substances → the remainder reaches the water and deteriorates the water quality



combination of aquaculture (fish farming)
and hydroponic (plant cultivation in water without ground)

3.2 Hydroponic (II)

- useful plants planted in a filter bed detract enriched and converted nutrients from water (recycling of nutrients of the fish waste water)



- 1 water circulation combines fish farming with cultivation of useful plants
- saving valuable water
- no formation of waste water and pollutants
- effective nutrient recycling, no eutrophication of waterbodies

3.3 Plant Cultivation (I)

- preparation of seedlings of the desired sort in a free-of-ground cultivation (equipment is available on the market)
- put into sealed plant beds

3.3 Plant Cultivation (II)

- **use of granulated lava on the sheet**
  - for protecting the sheet
  - Support of plant roots
  - improvement to water quality (natural filter)

3.3 Plant Cultivation (III)

- **examples of plant species**

ผักคาวตอง
(Houttuynia Cordata Thumb)

ผักแผว
Globe Amaranth

ผักแขยง
Finger grass

ผักกาดหอม
Lactuca sativa

B. r. chinensis

Roses

Lilies


Thank you!
PRO Arkades