Introduction to anatomy and physiology of fish

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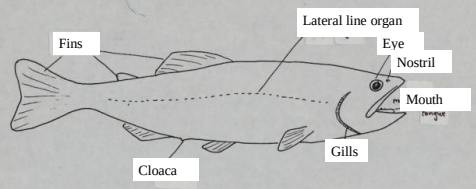
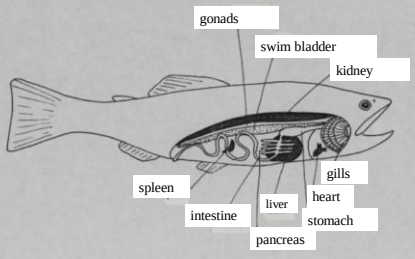
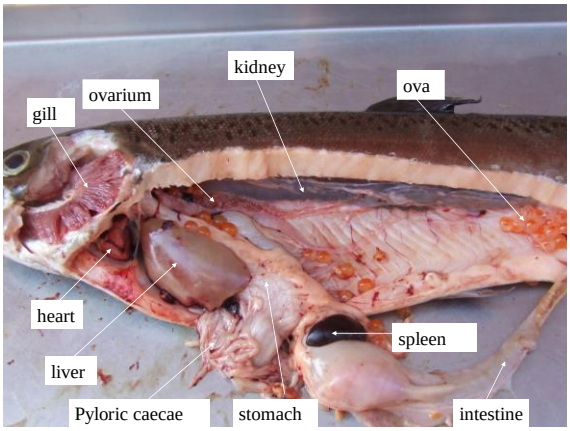
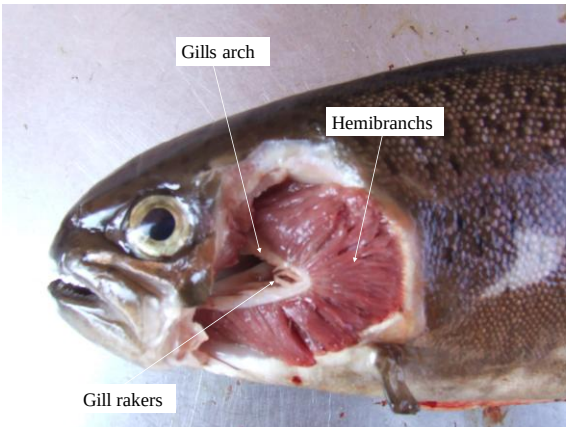
TROUT ANATOMY

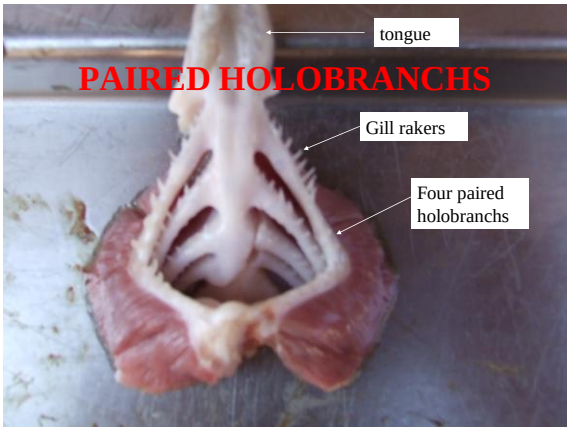


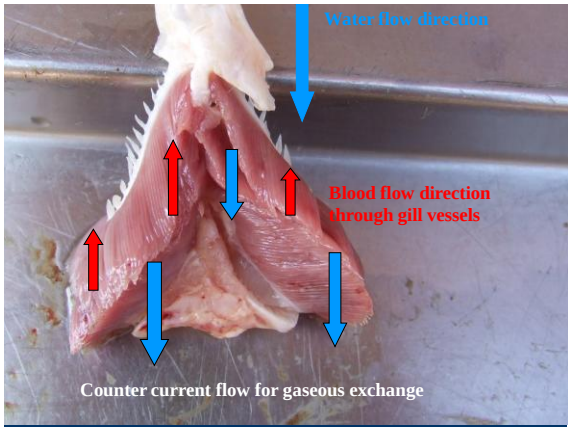
TROUT INTERNAL ANATOMY

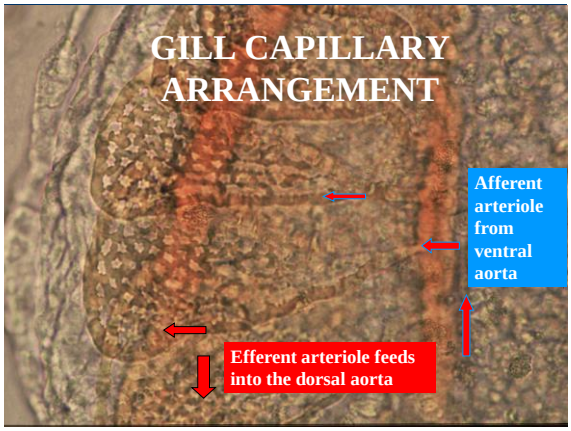












Skin - protection against environment, osmotic barrier, defence against disease.

Comprised of:

- cuticle
- epidermis - non-keratinising, living, stratified squamous epithelium,
- dermis (connective tissue incl. pigment cells/chromatophores and scales),
- hypodermis (well vascularised adipose layer).

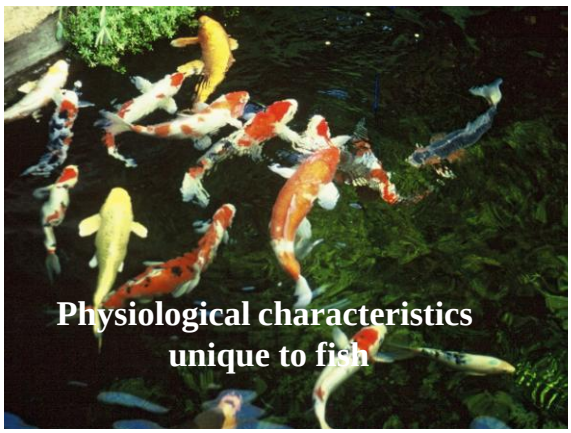
Swim bladder

- maintenance of buoyancy,
- variable other functions; in some species sound reception and production, pressure reception and respiration.

- A variable structure that develops as a diverticulum of the fore-gut.
- Physostomes have a patent pneumatic duct, physoclists have a closed duct.
- Gas secretion, through the gas gland, and absorptive functions are under vagal nerve control.

Skeletal muscles

- White muscle fibres are poorly vascularised, dependant on lymph circulation. They are anaerobic, used for sudden bursts of movement, and are rapidly exhausted.
- Red muscle fibres are located as a wedge beneath the lateral line and beneath the skin, are well vascularised and used for sustained slow swimming movement.



Respiration

- Water carries approximately 5% of the oxygen in the air.
- Gills are designed to optimise the exchange of dissolved gases between the water and the blood of the fish.
- The double pump action involving the mouth, buccal cavity and opercula, requires a much higher energy expenditure than the tidal respiration in mammals.
- Unidirectional flow with counter current exchange .
- Autonomic control.
  - acetylcholine.
  - adrenaline.

Bohr effect

- The very large Bohr effect in fish results in loading and unloading of oxygen from haemoglobin being sensitive to very small changes in carbon dioxide.
- elevated carbon dioxide plasma level has almost no effect on the respiratory rate in fish. Fish directly sense changes in dissolved oxygen.

Heart

- sinus venosus, atrium, ventricle and bulbus arteriosus.
- Blood enters the ventral aorta feeding the gills via afferent branchial arteries.
- Oxygenated blood leaves the gills via efferent branchial arteries that converge into the dorsal aorta that in turn distributes blood to the rest of the body.
- Deoxygenated blood is collected by the venous system and is returned to the sinus venosus.
- The atrium and to a lesser extent the ventricle is lined by phagocytic cells making up part of the reticuloendothelial system of fish.

Circulation

- lymph volume in fish is four times larger than blood volume
- capillaries have a high permeability to protein
- small changes in lymph formation can lead to large changes in blood composition.

Digestion

- 1. **stomach and intestines** – modified according to feeding habits and diet

. 2. **liver** – relatively large in most species. In some species forms a composite organ with the pancreas (hepatopancreas). Glycogen and fats stored in hepatocytes resulting in a variable histological appearance. Absence of functional Kupfer cells. Haemopoietic tissue, including melanomacrophage centres may be present around the larger vessels of the liver.

3 . **pancreas** – exocrine and endocrine, either interspersed among mesenteric fat cells between the pyloric caecae or as hepatopancreas within the liver, or subcapsular in the spleen

Digestion

- Fish are poikilothermic or cold blooded
- Within limits metabolic functions are dependant on the temperature of the surrounding water.
- oxygen requirement to digest and absorb feed increases dramatically after feed intake
- Post feeding asphyxia may occur when DO is low.

Excretion

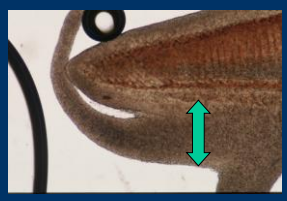
- 1. kidney – composite organ consisting of haemopoietic, reticuloendothelial, endocrine and excretory tissues. Many species have melanomacrophage centres within the kidney
- 2. Gills – main site of excretion of nitrogenous waste

Excretion

- Most fish are **ammoneotelic**
- AMMONIA - the main waste product of digestion and is excreted mainly through the gills. Large amounts of ammonia can be rapidly excreted following feeding or stressful episodes.
- Teleost fish produce only small amounts of urea and this not from ammonia
- urea is produced from metabolism of exogenous and endogenous amino acids
- Urea is a poor indicator of GFR in fish
- Salinity determines GFR in fish

CLINICAL SIGNIFICANCE

- Elevated blood urea nitrogen (BUN) in fish is more likely associated with gill and liver disease than renal disease
- **Urea is a poor indicator of GFR in fish**
- **ammonia auto-intoxication** occurs at high pH despite adequate fresh water



Hyperplastic changes in the gill epithelium

Osmotic regulation

- **constant energy drain**
- **impermeable skin**
- gills permeable
- **chloride cells in gills** actively take up salts in fresh water and excrete salts in sea water
- Large amounts of **dilute urine** produced in **FW**
- Small amounts of **concentrated urine** produced in **SW**

CLINICAL SIGNIFICANCE

- damage to either the gills, skin or kidneys can severely impair the fluid balance
  1. a bulging belly
  2. exophthalmos
  3. a bulging vent
  4. rough looking surface of the skin

Immune system

- Fish possess both granulocyte and mononuclear phagocytic cells and are capable of mounting both a cell mediated and humoral immune response.
- Fish lack both bone marrow and lymph nodes.

Immune system

Lipofuscin, melanin and haemosiderin

- Melanomacrophage centers represent forerunners of germinal centers of mammalian lymph nodes and spleen
- MM centres contain reticular cells, lymphocytes, macrophages and plasma cells

Fish have no lymph nodes and the spleen is the most important filter for the circulatory system. The pulp sinusoids contain predominantly lymphopoietic tissue

Thymus

- paired organ found subcutaneously in the dorsal branchial cavity, responsible for the production of lymphocytes.

Leukocytes

- Monocytes
- restricted to peripheral circulation
- Macrophages linked to tissues

- Granular leukocytes
- Heterophils
- Eosinophils
- Basophils

Heterophils predominate

Extracellular function through release of hydrolytic and oxidative enzymes

Clinical significance

- **Bacterial infections in fish lead to haemorrhagic liquefaction**

(rather than suppuration as seen in mammals)

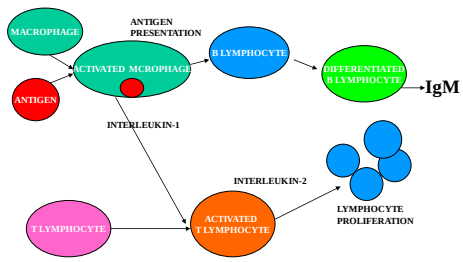
Non-specific immunity

- Skin – non-keratinized living cells,
  - migration of Malpighian cells across wounds,
  - lymphocytes and macrophages able to migrate into the epidermis
- Mucus – antibodies,
  - lysozyme and
  - bacteriolysins

Non specific immunity

- Complement
- C-reactive protein
- A-antiprotease
- Non-specific cytotoxic leukocytes
- Type I, II and III hypersensitivity

IMMUNE RESPONSE STOSKOPF 1993



Humoral immunity

- Fish synthesize only one type of immunoglubulin equivalent to IgM, the primary immunoglobulin of the mammalian immune response.
- Despite absence of IgG, fish are able to mount protective immune responses

Ig M

- Complement activation
- Opsonization
- Neutralization of viruses
- Agglutination

Clinical significance

- The immune response of many fish species becomes retarded during the cold winter months.
- The activity of many aquatic disease causing organisms is also temperature dependant.
- In contrast to the rapid multiplication of many pathogens and parasites once water warms in spring, the immune system of fish lags behind taking up to three weeks to become fully active

Gonads

- paired organs suspended by the mesentery from the dorsal abdomen.
- Oestrogens and androgens are released under control of pituitary gonadotropins.

Reproduction

- Gonadal development is dependant on
  - adequate nutrition
  - climatic and seasonal factors
  - day length
- Phenotypic expression can be altered by exposure of fry to sex hormones during early life. Used in tilapia and salmonid culture.

Breeding patterns

- variation is illustrated in the highly sophisticated hatchery technology required to artificially breed aquaculture species.

Practical application in the commercial production of Nile tilapia

- Male Nile tilapia are faster growing than female fish
- Sex reversal of fry by feeding of methyl testosterone in early life to produce phenotypic male fish is standard commercial practice.

Practical application in commercial salmonid production

- Sex reversal of fry by feeding methyl testosterone in early life to produce phenotypic male brood fish.
- Sex reversed female fish (phenotypic males) produce only X chromosome carrying spermatozoa.
- When milt from sex reversed female fish is used to fertilize normal female eggs only female offspring are produced.
- Female ova can be exposed to hyperbaric pressure to induce triploidy. Triploid fish are sterile and can be grown to large sizes.

Grass carp

- The grass carp is a potentially invasive species of fish outside of its natural distribution.
- Triploidy can be used to produce sterile grass carp.
- In South Africa triploid grass carp have been released into natural water bodies for aquatic weed control