# Histology of Fish

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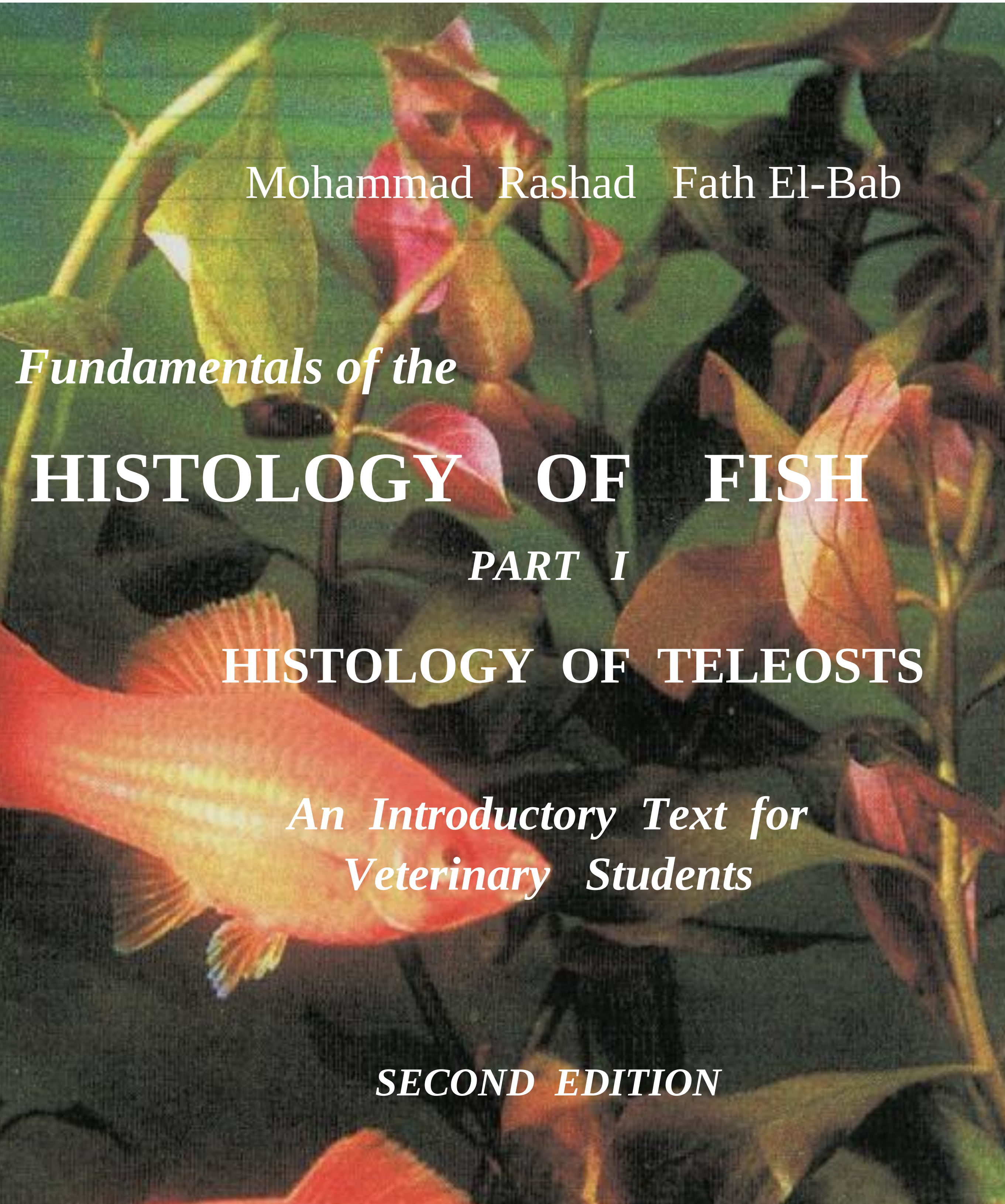

Mohammad Rashad Fath El-Bab

*Fundamentals of the*

# HISTOLOGY OF FISH

***PART I***

## HISTOLOGY OF TELEOSTS

***An Introductory Text for Veterinary Students***

***SECOND EDITION***

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# HISTOLOGY OF FISH

## *PART I*

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*An Introductory Text for Veterinary Students*

*SECOND EDITION*

بسم الله الرحمن الرحيم

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# *PREFACE*

Many institutes include a course in fish histology either an introductory course for biology, agriculture and veterinary medical students or as a part of a combined course.

It is recognized that a study of fish histology can provide a unifying background to physiology and pathology. In this edition the structure of tissues and organs of teleosts is described into an introductory text seeming to be helpful for both veterinary medical students and those interested in farm sciences.

**April, 2006**

رقم الإيداع بدار الكتب المصرية
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# CHAPTER 1

## *THE SKIN*

**The skin is composed of:**

**A) Epidermis:**

The epidermis covers the body surface and invests the tail and fins.

In adults the epidermis consists of stratified squamous epithelium, namely the fibrous Malpighian cells.

Unlike its mammalian counterpart, it is living and capable of mitotic division at all levels, even at the outermost squamous layer.

The fibrous Malpighian cells are rounded in shape, however they are horizontal and flattened at the superficial layers. Their cytoplasm is composed largely of an accumulation of elongated vesicles, degenerating mitochondria and some dense bundles of fibers, instead of the normally widely distributed bundles of fibers and mitochondria around the ovoid nucleus.

A fingerprint - like structure has been observed by electron microscope on the free surface of the cells in the outermost layer, but its significance is not known.

The epidermis is covered by a mucopolysaccharide layer (about 1 micron thick), namely, the cuticle. It is normally secreted by the epithelial surface cells rather than by goblet mucous cells.

The cuticular layer contains specific immunoglobulins, lysozymes and free fatty acids, all of which are believed to have antipathogen activity.

**Specific accessory organs are present:**

**1) Mucous gland cells or goblet cells:**

They are usually found in the middle layers of the epidermis. Although in a very thin epidermis a mucous cell may be seen to have its base on the basement membrane. They increase in size and elaborate secretions (mainly glycoprotein) as they approach the surface.

**2) Club cells (Leydig cells) :**

They are large rounded cells, found in the lower and middle layers of the epidermis. These cells secrete a potent alarm substance into the water when the skin of the fish is injured, and this substance may serve as a warning of possible danger to the other fish.

**3) Granule cells:**

They contain a substance in the form of oil droplets. This substance is thought to be poisonous in nature and secreted from the skin into the water.

**4) Other cells:**

They include lymphocytes, macrophages and large, clear cyst-like structures of putatively cellular origin.

**B) Dermis:**

**The dermis consists of:**

**1) Stratum spongiosum:**

It is a loose network of collagenous and reticular fibers contiguous with the epidermal basement membrane and contains the pigment cells (Chromatophores), mast cells, cells of the scale beds and the scales.

**2) Stratum compactum:**

It consists of collagenous dense matrix, which provides the structural strength of the skin.

The capacity for colour change to match the environment or due to sexual activity is very highly developed in many teleosts and is induced by chromophores, e.g.

(1) Melanophores (melanin-pigment containing cells).

(2) Lipophores (organic - solvent - soluble pigment containing cells):

a) Erythrophores (containing red pigments).

b) Xanthophores (containing yellow pigments).

**The Scales:**

**The scale consists of:**

**1) Outer osseous layer:**

It is formed by the cells which resemble osteoblasts.

**Inner fibrous layer:**

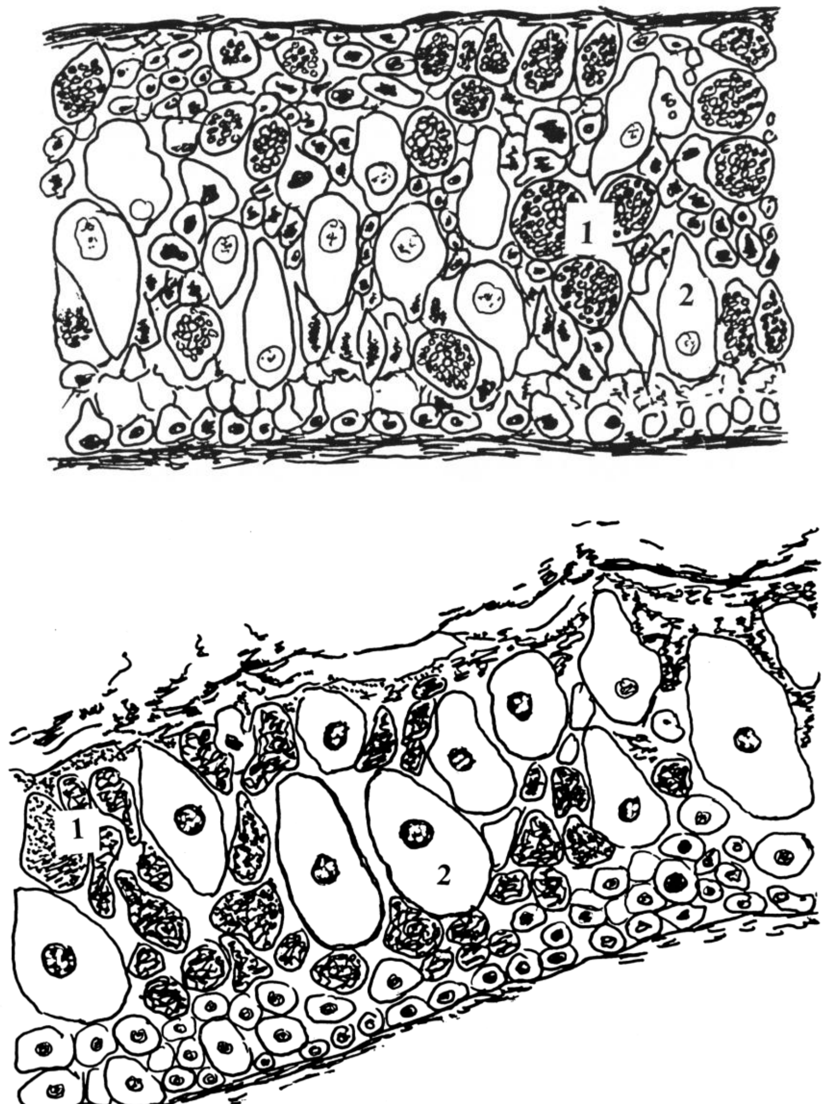
It is composed of collagenous fibers which are produced by fibroblasts.

The marginal portion of the scale is called growth - ridge. It is consisted of osteoid tissue.

Osteoblasts accumulated periodically at the growth ridge to form osseous substance. Thus the circuli (growth rings) are formed. The growth rings allow determination of the individual's age.

**Hypodermis:**

It consists of loose c. t. containing fat cells and abundant blood vessels.

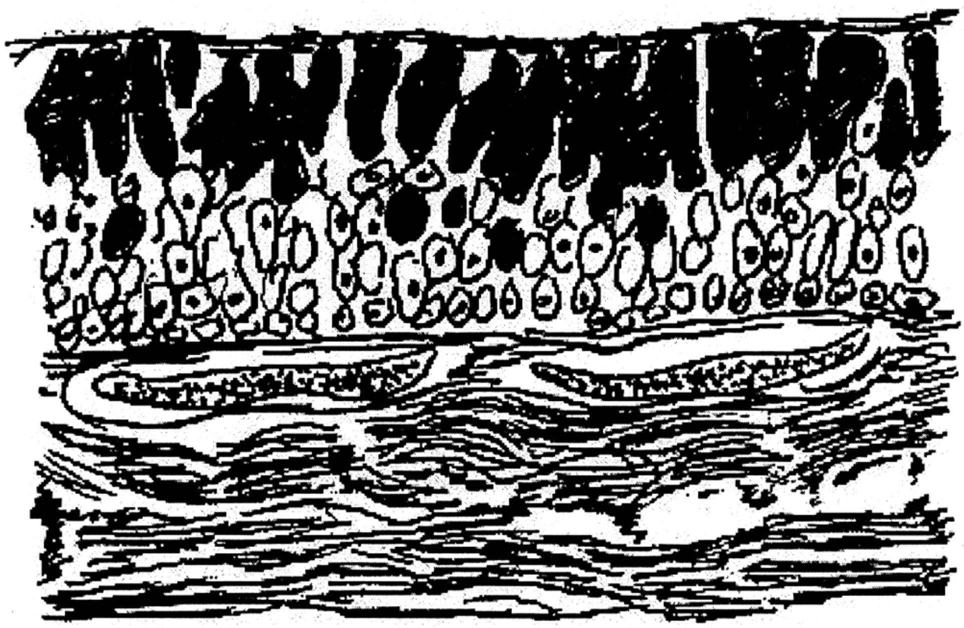



**THE EPIDERMIS OF TELEOSTS**

(Alcian blue / PAS technique)

1- Mucous cells.

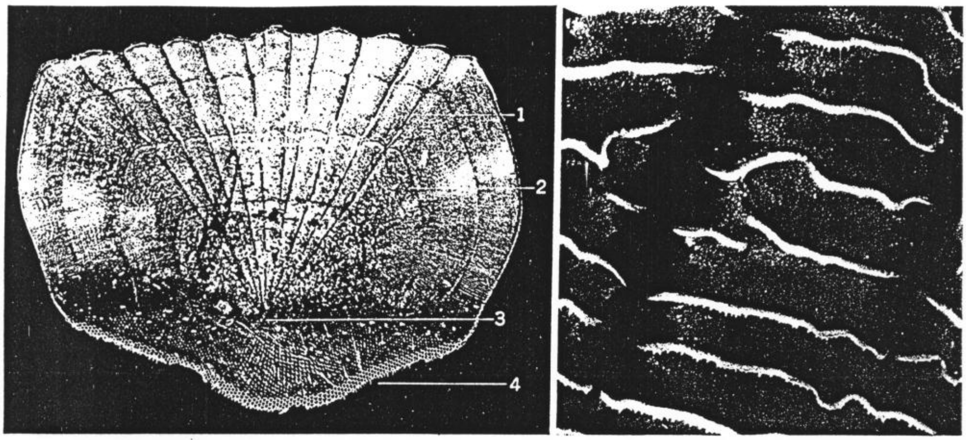
2- Club cells.



**THE SKIN OF EEL**

(PAS technique)
Mucous cells ( black) manifest strong PAS –positive reaction.

**FINGERPRINT-LIKE PATTERN ON THE SURFACE OF THE SUPERFICIAL EPIDERMAL CELLS OF TELEOSTS.**




**Left: SCALE OF TELEOSTS**

1- Groove
2- Annuli.
3- Focus.
4- Teeth.

**Right: Circuli ( Growth rings ).**

# CHAPTER 2

## *THE RESPIRATORY SYSTEM*

The gills of a typical teleost comprise two sets of four holobranches, forming the sides of the pharynx.

Each holobranch consists of two hemibranches projecting from the posterior edge of the branchial arch or *gill arch* in such a way that the free edges diverge and touch those of the adjacent holobranches.

Close examination of the hemibranches shows that they consist of a row of long thin filaments, *the primary lamellae*, which project from the arch like the teeth of a comb.

The surface area of the primary lamellae is increased further by the formation of regular semilunar folds across its dorsal and ventral surface - *the secondary lamellae*. The dorsal and ventral rows of secondary lamellae on each primary lamella are staggered so that they complement the spaces in the rows of lamellae of adjacent filaments. This arrangement of arches and lamellae forms the sides of the pharynx into two sets of corrugated sieves through which the water must flow.

**The gill arch:**

It is a curved cartilagenous or osseous structure from which radiate the bony supports (the gill rays) of the primary lamellae.

The gill arch contains the afferent branchial arteries from the ventral aorta and the efferent branchial arteries serving the dorsal aorta.

The ventral aorta divides into numerous fine branches as it passes up through the holobranch. Each branch runs along the opercular edge of the primary lamella to serve the secondary lamellae joining the branch of the efferent branchial artery running down the buccal edge of the primary lamellae. Thus the deoxygenated blood circulates through the secondary lamellae in a direction opposite to that of the water flow over the gills.

The gill arch is covered by epidermal tissue (stratified epithelium) well endowed with mucous cells. Below the epidermal tissue there is usually a lymphocytic infiltration.

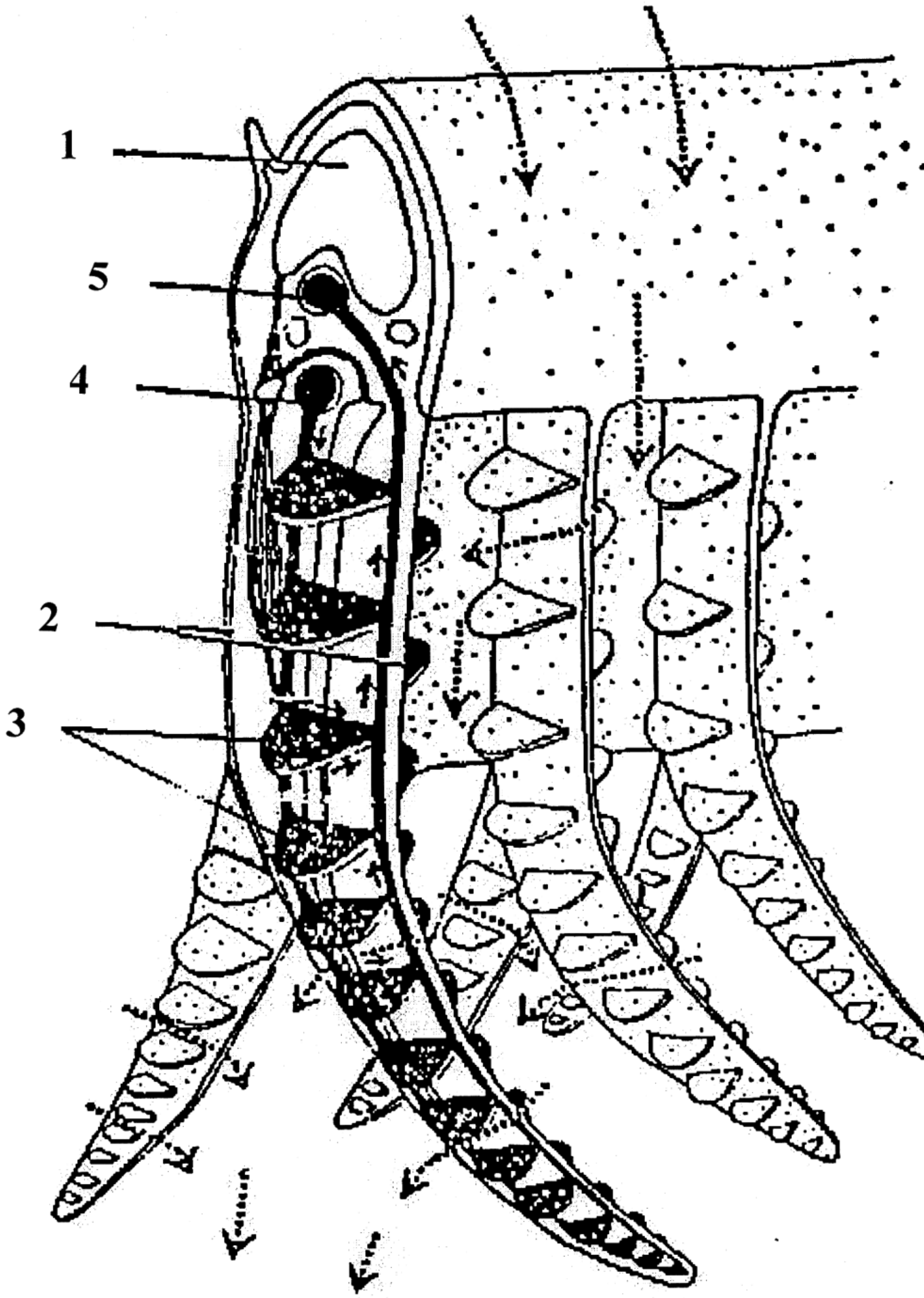
The primary lamella is an osseous structure covered by epidermal tissue (stratified epithelium) containing mucous cells. The covering epithelium contains pale - staining saline, or salt secreting cells. Below the epidermis there is a varying number of lymphocytes, eosinophils and phagocytic cells.

The secondary lamellae (site of gaseous exchange) are covered by simple squamous epithelium supported and separated by pillar cells, which are arranged in rows 9 - 10 microns apart. The pillar cells spread to form flanges, which coalesce with those of neighboring pillar cells to complete the lining of the lamellar blood channels, which contact the afferent and efferent lamellar arteries. The pillar cells have been shown to contain columns of contractile protein similar to that found in amoebae. Since the blood entering the lamellar blood spaces (comes directly from the ventral aorta) is of high pressure, the presence of contractile elements in the support of these spaces will serve to resist their distension under normal circumstances. Also, contraction of pillar cells can be used to control blood flow rate through the gaseous exchange surfaces.

The surface of the lamellar epithelium is thrown into microvilli. These serve to aid attachment of the cuticular mucus, which in addition to its role in reducing infection and abrasion has a significant role in regulating the exchange of gas, water and ions.

The combined thickness of cuticle, respiratory epithelium and flanges of the pillar cells ranges from 0.5 to 4 microns and represents the total diffusion distance for respiratory exchange, since the diameter of the lamellar blood channel is virtually the same as the diameter of the teleost erythrocyte.

Chloride cells are seen on the basement of the secondary gill lamella. These cells are acidophilic and exist generally in marine fishes and rarely in fresh water fishes.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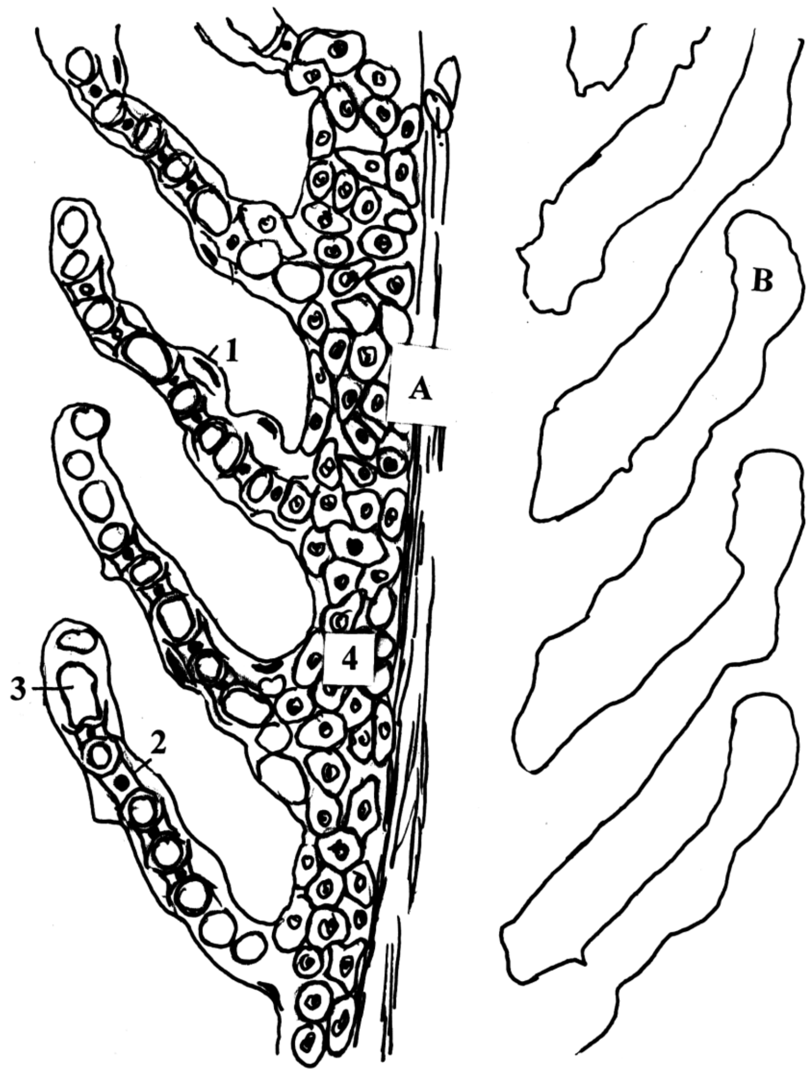
**DIAGRAMMATIC ILLUSTRATION SHOWING THE RRANGEMENT OF A GILL HOLOBRANCH**

1- Gill arch.
2- Primary lamellae.
   (arranged into 2 hemibranches)
3- Secondary lamellae.
4- Afferent branchial artery.
5- Efferent branchial artery.
——→ Blood flow .
----------→ Water flow.




**GILL LAMELLAE OF TELEOSTS**

A- Primary lamella.

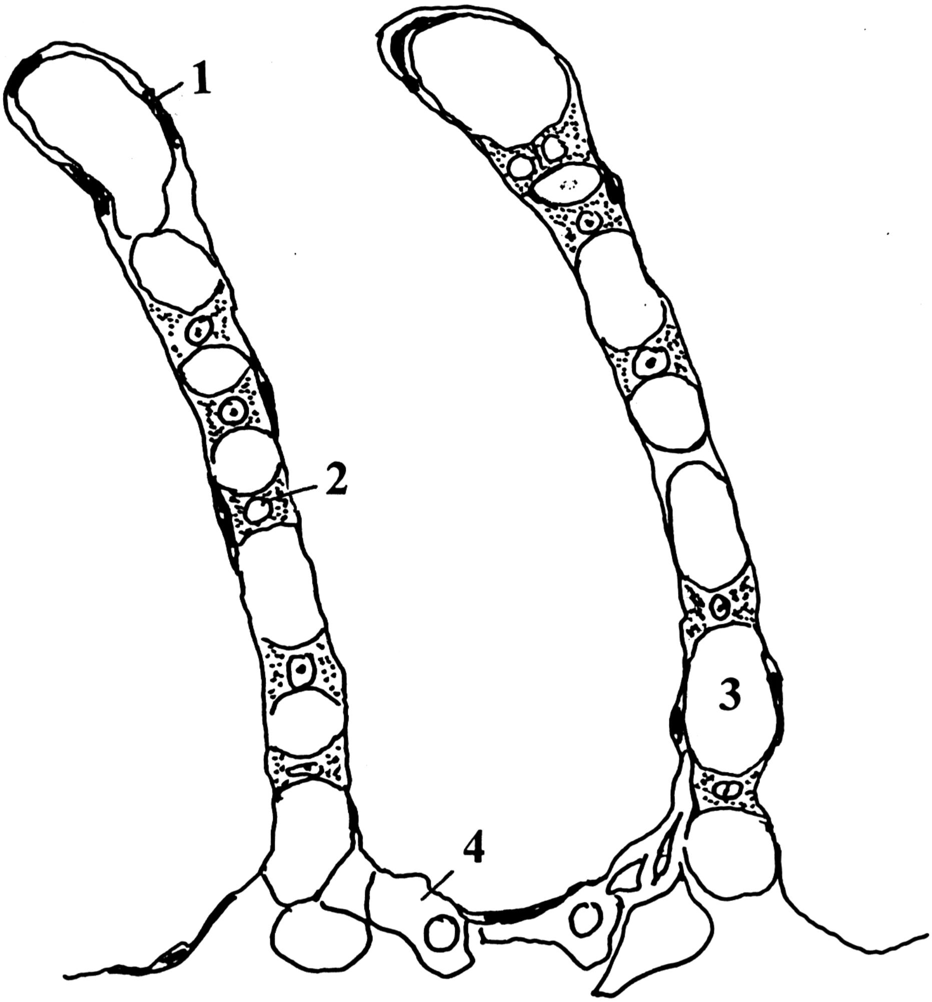
B- Secondary lamella:

1-Epithelial cell.

2- Pillar cell.

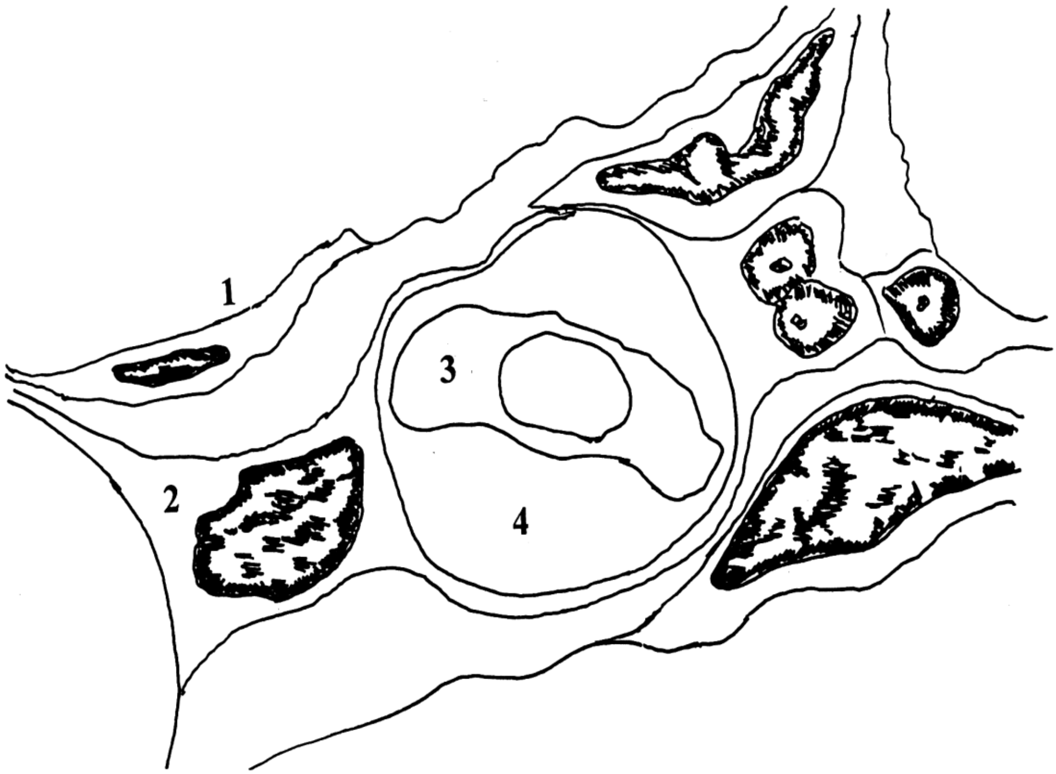
3- Blood capillary.

4- Interlamellar cells.




**SECONDARY LAMELLAE**

1- Epithelial cell.
2- Pillar cell.
3- Blood capillary.
4- Chloride cell.




**C.S. OF A SECONDARY GILL LAMELLA**

1- Epithelial cell.
2- Pillar cell.
3- Erythrocyte.
4- Capillary lumen.

# CHAPTER 3

# *THE VASCULAR SYSTEM*

## THE HEART

The fish heart consists of an atrium and a ventricle. Blood flows into the sinus venosus and passes through the atrium, ventricle and bulbus arteriosus.

The wall of all parts of the heart is composed of an internal membrane, an intermediate layer and an external membrane.

1) The endocardium lines the internal surface of the heart and is composed of epithelial cells and connective tissue.
2) The intermediate layer is composed of cardiac muscle fibers in the atrium and ventricle, but of connective tissue in the sinus venosus.
3) The external membrane of the heart is the epicardium, which is composed of simple flat epithelium and an underlying layer of connective tissue.

## THE BLOOD VESSELS

Three layers can be distinguished in the wall of arteries; an inner coat, tunica intima, an intermediate coat, tunica media, and outer coat, tunica externa. The tunica intima is composed of endothelial cells followed by connective tissue. This connective tissue contains collagenous and elastic fibers, and the elastic fibers form a layer called the tunica elastica. The tunica media is composed of circular smooth muscle and is the thickest layer of the wall. The tunica externa is composed of connective tissue, which consists mostly of collagen fibers. Between the tunica media and the tunica externa, there is a thinner tunica elastica externa.

Basically, veins are similar in structure to arteries: they are composed of tunica intima, media and externa. However, the tunica media, i.e., the muscle layer, of the vein is less developed and thinner than that of the artery of the same size, and sometimes is absent. However, the tunica externa of veins is thicker than that of arteries.

Blood capillaries are composed of endothelial cells, basement membrane and pericytes. The capillaries are classified into several types depending on the form and position of the endothelial cells and pericytes. There are two types of capillaries: continuous capillaries and fenestrated capillaries. Capillaries of the muscle and retina belong to the former type, while those of glomeruli and pancreas to the latter.

## THE SPLEEN

Although usually single, it may in some species be divided into two or more smaller spleens.

The spleen is surrounded by a fibrous capsule devoid of muscle.

The surface of the spleen is covered with a serous membrane. A part of this capsule extends inward forming a net-like trabecula. The artery, which enters the spleen gradually, branches into smaller vessels and eventually forms a capillary network. The spleen is composed of these two networks (connective tissue and capillary), and of the cells filling up the spaces within the networks. These cells are erythroblast, mature and immature erythrocytes, lymphocytes, monocytes and macrophages. In the spleen of Osteichthyes, there is no clear distinction between the red pulp and the white pulp, as there is in mammalian spleen. The parts rich in erythrocytes and those rich in lymphocytes are intermingled.

## BLOOD

Blood volumes of teleosts are small, being about 5 % of body weight.

## 1- Erythrocytes:

These cells are ovoid in shape and possess a centrally located nucleus. Mature erythrocytes contain abundant hemoglobin and are pink or yellowish on preparations stained with Giemsa. The size and number of erythrocytes show considerable variation by species and, depending on the physiological condition, may vary markedly even within the same species. The number ranges between 1.05-3.0 $\times 10^6$ / $mm^3$.

## 2- Leukocytes:

Lymphocytes and neutrophils are two representative leukocytes commonly found in the blood of carp, ayu, rainbow trout, eels and crucian carp.

### A) Lymphocytes:

The size of lymphocytes is one third to one half that of erythrocytes (4.5 - 8.2 microns). The centrally located nucleus is round or oval in shape, rich in chromatin. The scanty cytoplasm, which sometimes is not evident at all, is basophilic and exhibits a deep blue color. It contains few mitochondria and ribosomes.

A pale perinuclear zone is often detected in the cytoplasm. Lymphocytes are the most numerous types of leukocytes, constituting 70 to 90 % of total leukocytes (48 $\times 10^3$ / $mm^3$).

**B) Neutrophils:**

Neutrophils in fish are present in about the same numbers as in mammals (3 - 6 × $10^3$/$mm^{3)}$ but they comprise a much smaller proportion of the blood leukocytic population (6 - 8 %). In blood smears, neutrophils are round or oval in shape and are usually larger than erythrocytes. The eccentric nucleus is normally shaped like the human kidney, but in mature cells two - or three-lobed nuclei may be recognized. Neutrophils show peroxides and Sudan black positive reaction.

**Other types of leukocytes:**

**a) Monocytes:**

Monocytes are partially differentiated end cells.

Under appropriate circumstances they develop into mature cells of the mononuclear phagocyte system (Macrophages).

They form about 0.1 % of total leukocyte population.

They are similar to mammalian monocytes. The cytoplasm is thrown into pseudopodia. The chromatin of the eccentric nucleus is dispersed marginally. The lysosomes are very electron-dense. The Golgi apparatus is well-developed.

**b) Eosinophils:**

The presence and nature of eosinophils in fishes is notoriously confused, with many claims, both of their presence and absence.

**c) Basophils and Mast cells:**

The presence of basophils in fishes is, like that of eosinophils, claimed by some workers and disputed by others. They resemble those of mammals in their morphology and staining reaction.

Mast cells in fishes are identified on the bases of their similarity to those of mammals (c.t. habitat and metachromatic cytoplasmic granules).

The presence of both eosinophils and mast cells in fishes is disputed.

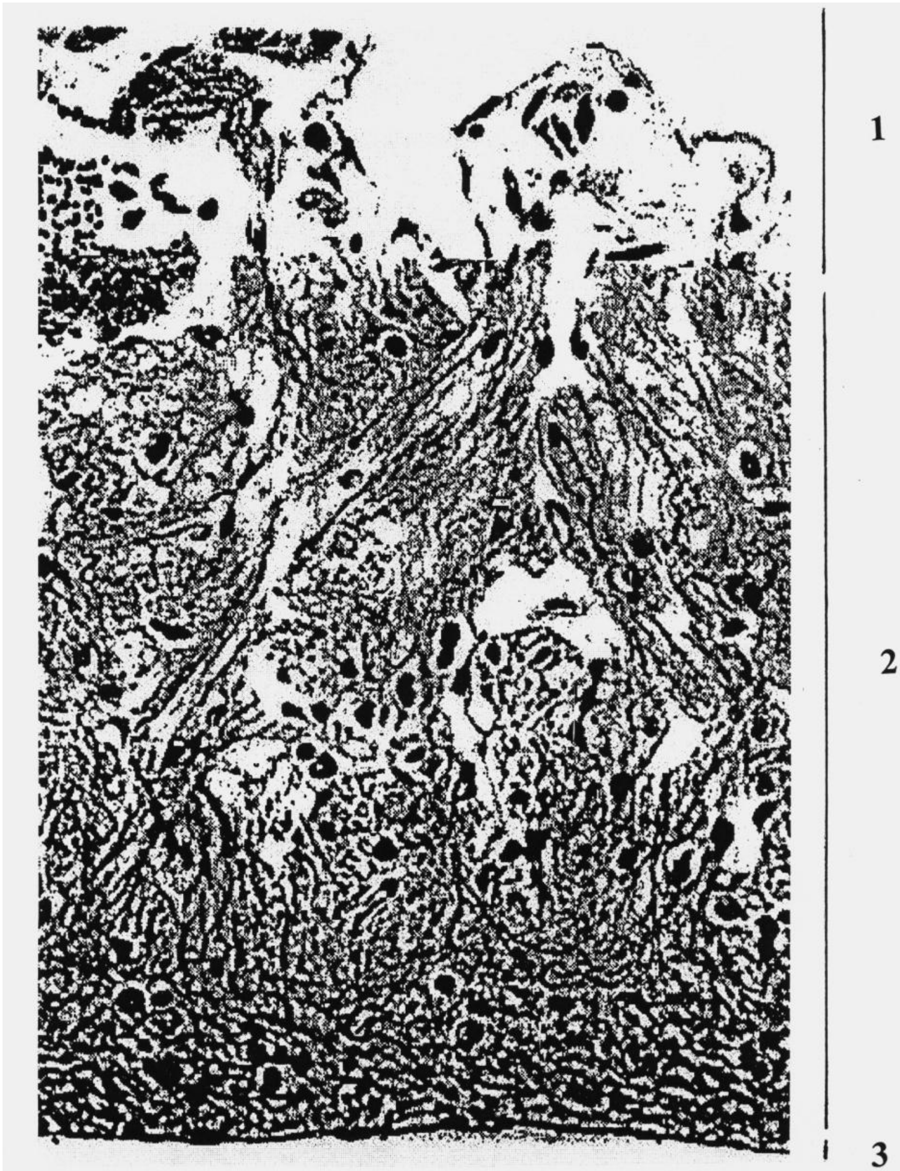
**3- Thrombocytes:**

These cells are also known as spindle cells and are commonly seen in the blood of birds, reptiles and lower vertebrates. In blood smears, thrombocytes are spindle or ellipsoidal in shape, and the length of their long axis is similar to or somewhat shorter than that of erythrocytes. On Giemsa stained preparations, the chromatin-rich nucleus exhibits a dark blue or dark violet color. The cytoplasm is extremely scant and usually has a light blue area adjacent to one of the poles of the spindle-shaped nucleus. It is believed that fish thrombocytes are functionally homologous to the platelets of higher vertebrates.

The ultrastructure of the cytoplasm of the teleost thrombocyte is similar to that of mammalian platelets. A labyrinth of interconnecting vacuoles ramifies through the cytoplasm and opens via fenestrae to the exterior. The total number of thrombocytes ranges from 60000 to 70000 / $mm^3$

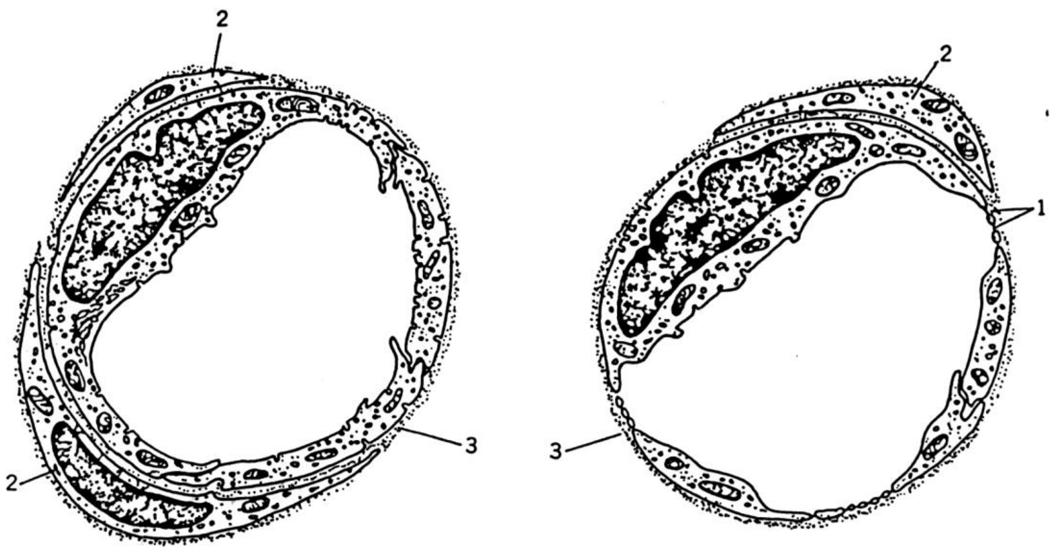
## LYMPH

Lymph is the liquid from blood, which has filtered through the capillary wall. Although it contains a smaller amount of soluble protein and white blood cells than blood, it has more lymphocytes. The lymph volume is about four times the blood volume. A lymphatic heart with fibers is recognized in the tail of the eel and Atlantic salmon.




**THE WALL OF THE HEART OF TELEOSTS**

1- Endocardium.
2- Myocardium.
3- Epicardium.

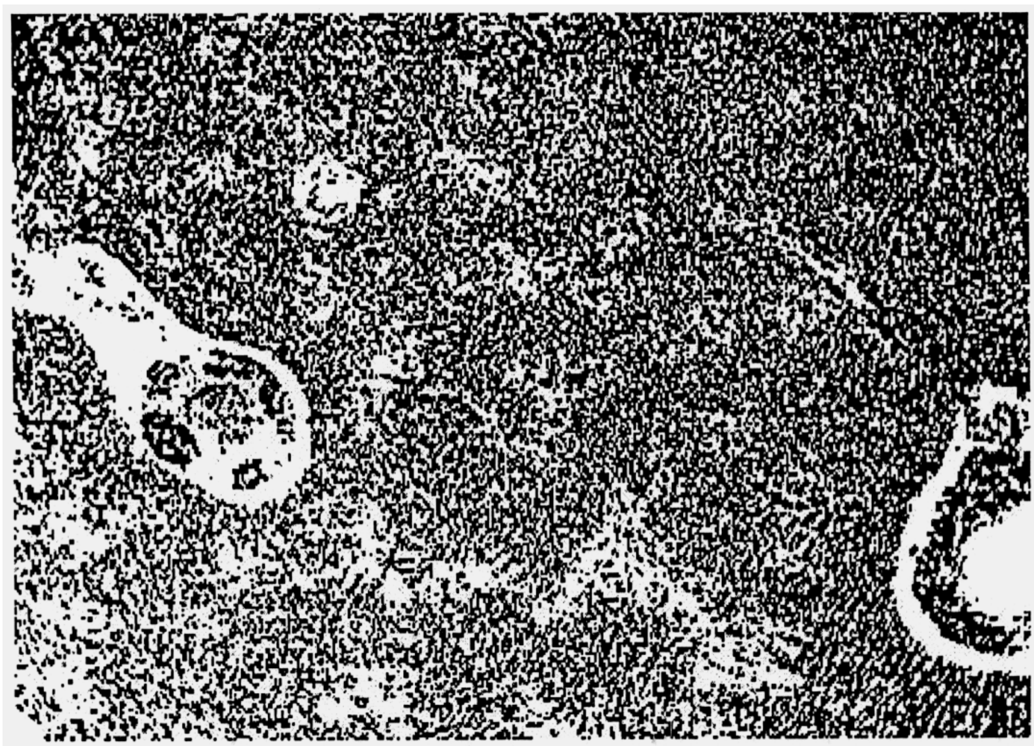



**BLOOD CAPILLARIES OF TELEOSTS**

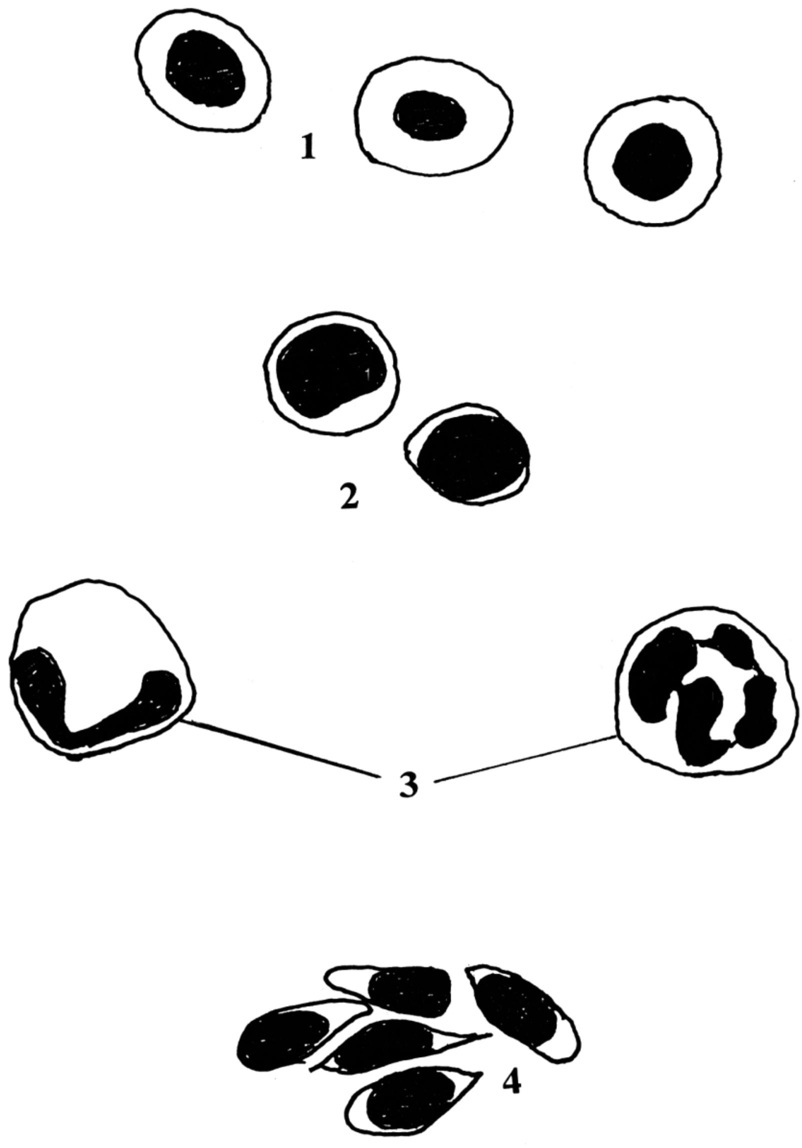
**Left: Continuous type.**

**Right: Fenestrated type :**

1- Pore.
2- Pericyte.
3- Basement membrane.



# THE SPLEEN OF TELEOSTS




**BLOOD CELLS OF TELEOSTS**

1- Erythrocytes.
2- Lymphocytes.
3- Neutrophils.
4- Thrombocytes.

# CHAPTER 4

## *THE DIGESTIVE SYSTEM*

## I - THE ALIMENTARY TRACT

### A)The oral cavity:

The mouth and oral cavity are shared by the respiratory and digestive systems.

The oral mucosa consists of:

**1 - Lamina epithelialis:**

Stratified epithelium containing many mucous cells and taste buds.

**2 - Lamina propria:**

Dense c.t.

**The tongue:**

The tongue consists of a c.t. core covered by stratified epithelium containing many goblet cells.

Sometimes the core contains smooth muscle fibers.

**The teeth:**

The tooth consists of:

**1 - The pulp:**

The pulp is composed mainly of connective tissue and occupies the center of the tooth. The odontoblasts are arranged at the outermost region of the pulp and secrete dentin.

**2 - The dentin:**

Dentin is composed mainly of collagen fibers, and is very similar to bone. This part of the tooth contains calcium salts. Protoplasmic projections from the odontoblasts enter the dentin through the dentinal tubules.

**3 - The enamel:**

The surface of the dentine is usually covered with enamel (or enameloid substance). The structure of the enamel is very complex. Ground sections of the teeth exhibit fiber-like striations extending from the dentinal tubules, which are arranged radially from the superficial layer to the intermediate layer. Enamel is secreted by the enamel organ, which is composed of two layers of epithelial cells, while the tooth is still in the tooth germ.

**B) The pharynx:**

**The pharyngeal wall consists of:**

**1 - Mucosa: folded**

**a - Lamina epithelialis**

Stratified squamous epithelium with numerous mucous cells.

**b - Lamina propria:**

Dense connective tissue.

**2 - Muscularis:**

a - Thin inner longitudinal layer.

b - Thick outer circular layer of striated muscle fibers.

**Pharyngeal pads:**

They substitute the salivary glands. The pharyngeal pad consists of:

A core of connective tissue covered by stratified epithelium containing many goblet cells and taste buds.

**C) The oesophagus:**

**The wall of the oesophagus consists of:**

**1 - Mucosa**: folded

**a - Lamina epithelialis:**

Stratified squamous epithelium (anteriorly).

Simple columnar ciliated epithelium (posteriorly).

The lamina epithelialis contains mucous cells and taste buds

**b - Lamina propria:**

Dense connective tissue.

**2 - Submucosa:**

Dense connective tissue.

**3 - Muscularis:**

a - Thin inner longitudinal layer.

b - Thick outer circular layer of striated muscle fibers.

**4 - Serosa**

**D) The stomach:**

**The wall of the stomach consists of:**

**1 - Mucosa**: folded

**a - Lamina epithelialis:**

Simple cuboidal epithelium (cardiac region).

Simple columnar epithelium (other regions), containing mucus-like substance within the cytoplasm.

**b - Lamina propria:**

It is made up of loose connective tissue containing the gastric glands.

The gastric glands are few at the cardiac portion, numerous at the blind sac (fundus) and absent at the pyloric portion.

The cells that compose the gastric glands are polygonal in shape and contain granules stained by Haematoxylin or azocarmin.

They produce a secretion analogous to the chief cells of mammals.

**c - Muscularis mucosa:**

Thick connective tissue layer at the blind sac (fundus).

**2 - Submucosa:**

a - Stratum compactum.

b - Stratum granulosum.

These strata are thick at the fundus and pyloric region.

**3 - Muscularis:**

a - Thick inner longitudinal layer.

b - Thin outer circular layer of smooth or striated muscle fibers.

**1 - Serosa.**

N.B.: The structure of the pyloric caeca resembles the intestine.

**E) The Intestine:** (duodenum, anterior intestine, posterior intestine and rectum)

The wall of the intestine consists of:

**1 - Mucosa**: folded

**a - Lamina epithelialis:**

Simple columnar epithelium (showing microvilli at the anterior intestine) and numerous goblet cells. Entero-chromaffin cells may be recognized among the epithelial cells.

**b - Lamina propria:**

Loose connective tissue.

No muscularis mucosa.

No submucosa.

**2 - Muscularis:**

a - Inner circular layer.

b - Outer longitudinal layer of smooth muscle fibers.

**3 – Serosa:**

**Anus:**

The anus is the terminal opening of the alimentary tract. The internal surface of the region near the rectum is covered with an epithelium rich in mucous cells. The muscularis is composed of an inner circular and an outer longitudinal muscle layer. The circular muscle is thickly developed forming a sphincter. In the region of the anus facing the exterior, the epithelium is continuous with the skin epidermis. The epidermis in the transitional region gradually transforms from simple to stratified.

## II- THE DIGESTIVE GLANDS

### 1 - The liver:

The surface of the liver is covered with serous membrane, and some connective tissue from this capsule extends inward into the parenchyma. Lobular structures containing a small vein in the center are present in the liver of higher vertebrates. In fishes, however, these structures vary depending on the species and are generally obscure.

The histology of fish liver differs from the mammalian in that there is far less tendency for disposition of the hepatocytes in cords or lobules.

Sinusoids, which are irregularly distributed between the polygonal hepatocytes, are fewer in number and are lined by endothelial cells with very prominent nuclei. Functional Kupffer cells are not found in the lining of the sinusoid. The sinusoidal lining cells are fenestrated and overlie the space of Disse, which is the zone between sinusoid cells and hepatocytes, and contains microvilli from both, as well as numbers of fat-storage cells, the cells of Ito.

The hepatic cell has a roundish polygonal cell body containing a clear spherical nucleus with usually one nucleolus. Mitochondria, Golgi apparatus, endoplasmic reticulum and other basic organelles are present in the cytoplasm. Fairly large quantities of lipid and glycogen are observed in the cytoplasm of fish. Therefore, the usual paraffin embedding and staining (Haematoxylin and eosin) methods cause the appearance of many vacuolar structures in these cells. The presence of lipid or glycogen can be determined by the shape of the vacuoles. PAS stain, however, imparts a purplish red color to glycogen vacuoles. Lipids can be easily recognized by staining cryostat-sections with Sudan III, IV or Sudan black B, or fixing the samples in fixatives containing Osmic acid and subsequent embedding in paraffin.

The function of the liver as a digestive gland is to secrete bile. Bile is secreted by the hepatic cells into the intracellular bile canaliculi from which it is carried into the extracellular bile canaliculi. Bile canaliculi join to form the bile duct, which subsequently joins with the hepatic duct. The latter leaves the liver and opens into the duodenum. In stomachless fishes such as carp and goldfish, the bile duct opens into the anterior portion of the intestinal bulb.

In many fishes, the hepatic duct has a branch, the ductus cysticus, leading into the gall bladder, which stores bile juice.

The walls of the bile and hepatic ducts consists of a single layer of low or high columnar epithelial cells over an underlying layer of connective tissue. The histological structure of the bile duct is similar to that of the hepatic duct, but the former possesses a layer of smooth muscle. Three layers are distinguished in the gall bladder: the inner layer, which is composed of a simple epithelium of columnar cells and connective tissue, the intermediate layer, which consists of smooth muscle, and the outer layer, which is the serous membrane. The walls of the gall bladder are contractile and shrink if the food, especially fatty food, passes through the duodenum in order to secrete bile juice.

**2 - The pancreas:**

The pancreas consists of an exocrine portion, which secretes pancreatic juices, and an endocrine portion, the islets of Langerhans, which secretes hormones such as insulin and glucagon.

The pancreas of teleosts lies scattered around the initial portion of the intestine, as mass tissue of varying size. Some teleosts such as carp and Sillago form a hepatopancreas. In some species the pancreas is located as a subcapsular layer to the spleen.

The pancreas of chondrostei forms an independent organ within which the endocrine portion is included.

The exocrine portion is composed of the compound acinus gland in which numerous glandular cells are clustered. There is a duct, which opens into the initial portion of the intestine.

The cytoplasm of glandular cells is strongly basophilic, except for the spherical and acidophilic substances (zymogen granules) found within the apical portion of the glandular cells. When very few zymogen granules are present, the cytoplasm appears almost purple with HE staining. Consequently, pancreas tissue appears dark purple except for the endocrine portion. When the glandular cell contains numerous zymogen granules, the cell itself is larger and basophilic only in the basal part of the cell, so the pancreas appears pale purple as a whole. The nucleus, which is spherical, rich in chromatin and for the most part has one nucleolus, is found in the basal part of the cell.

The small duct is composed of simple epithelial cells and as it increases gradually in size, the connective tissue become thicker, so that in the case of a large duct, a considerably thick layer of connective tissue surrounds the epithelial cells.

The endocrine portion is quite different in staining properties from the exocrine portion. It does not have a duct, and in some fishes the islets of Langerhans exist isolated apart from the exocrine portion.

## Swim Bladder

The wall of the (gas filled) swim bladder consists of:

**A) Tunica interna:**

**a - Lamina epithelialis:**

* Flat epithelium or * Transitional epithelium.

* Columnar epithelium or * Cuboidal (ciliated).

**b - Muscularis mucosae:**

Smooth muscle fibers

**c - Submucosa:**

L.c.t. with blood vessels.

**B) Tunica externa:**

a - Tough fibrous layer containing smooth muscle fibers and elastic fibers.

b - Serosa.

**Gas Glands:**

-Found into the wall of the swim bladder.

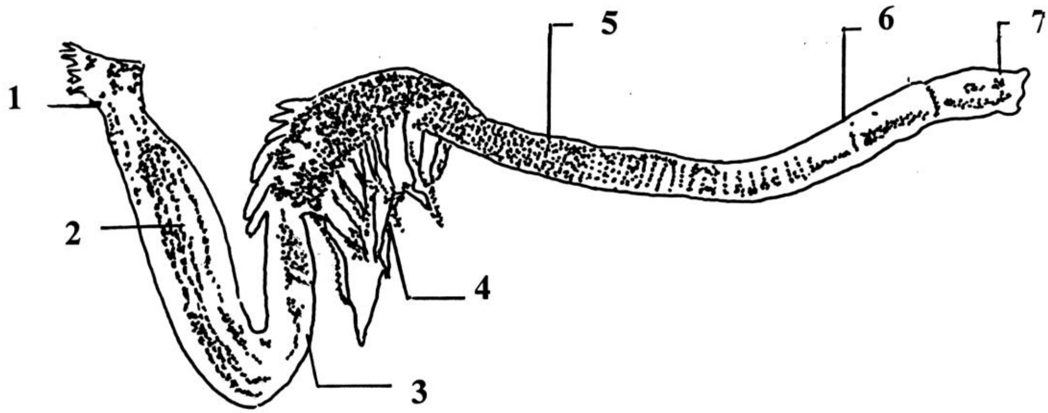
-They are highly vascular organ.

-They consist of:

Parallel venous and arterial rete merabile, which are arranged into a counter-current fashion.

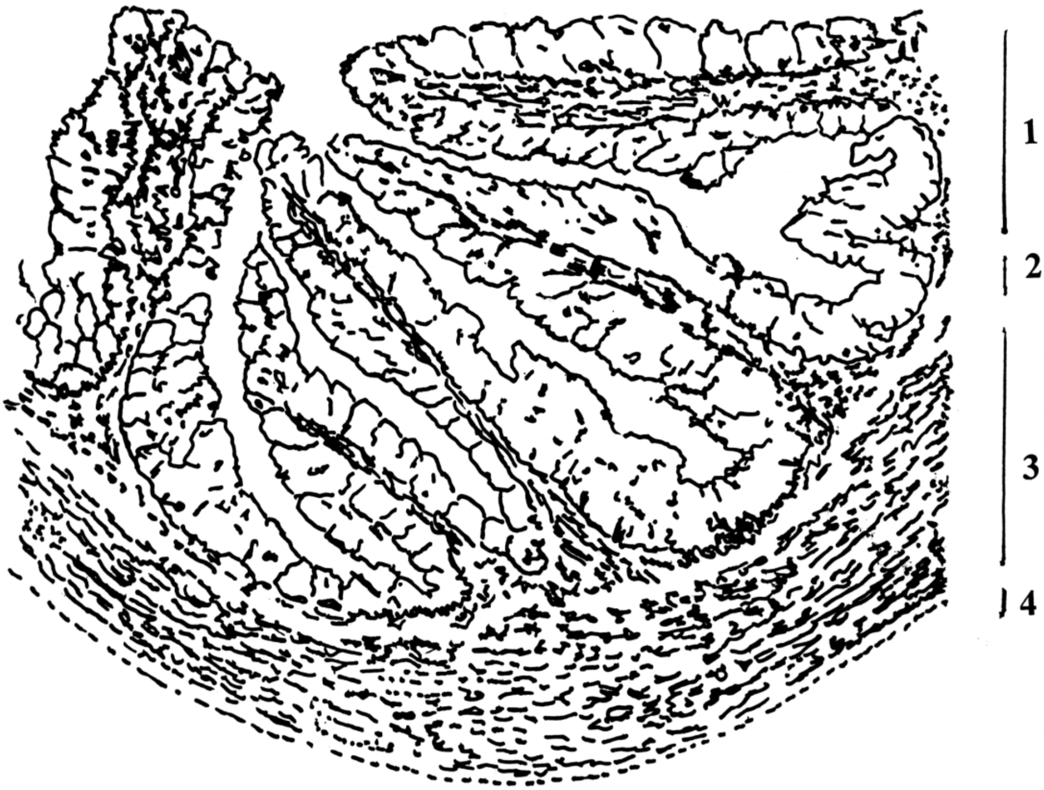

**TOOTH OF TELEOSTS**

1-Dentin.
2-Pulp.
3-Bone.



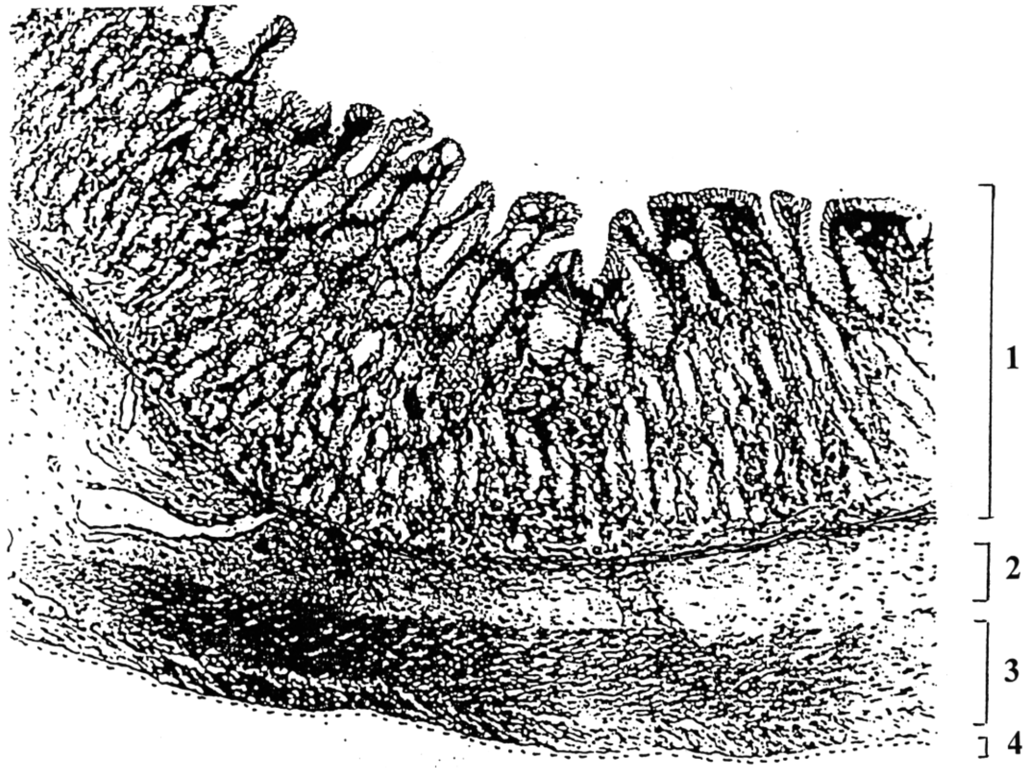

**THE ALIMENTARY TRACT OF TELEOSTS**

1-Oesophagus.
2-Stomach ( cardiac portion ) .
3-Stomach ( pyloric portion ).
4-Pyloric caeca.
5-Anterior intestine.
6-Posterior intestine.
7-Rectum.



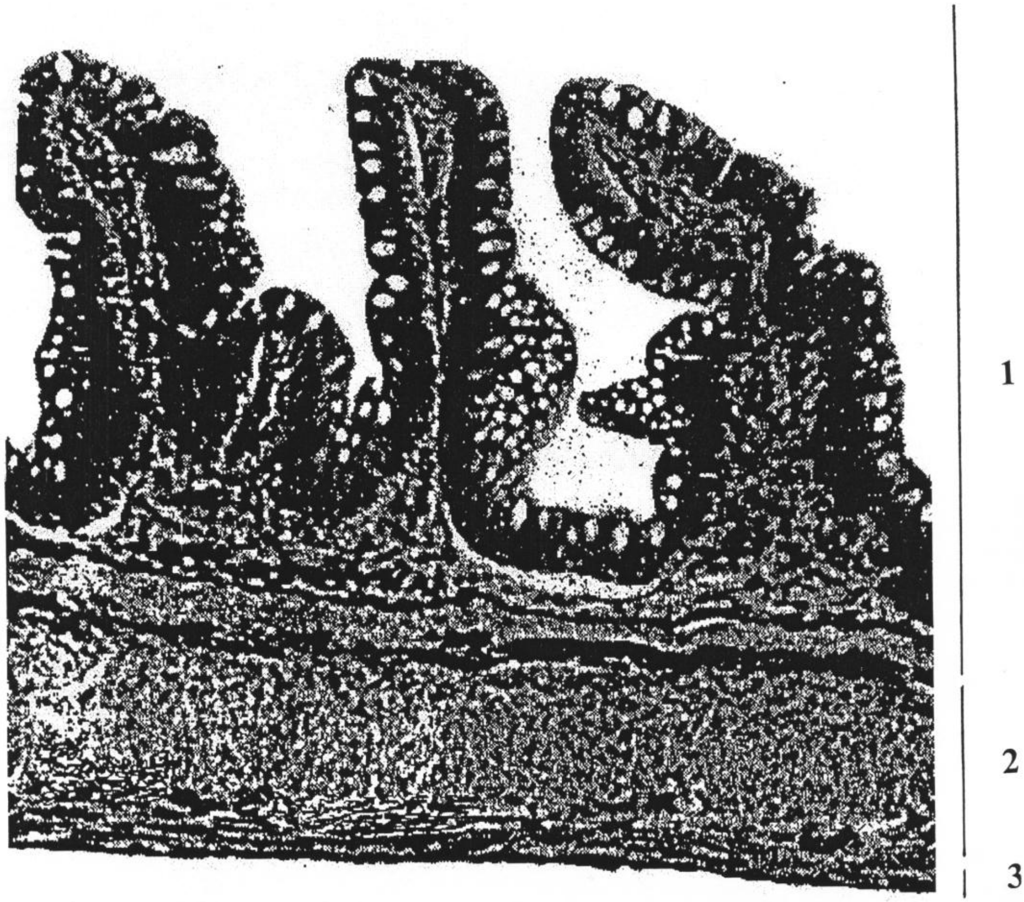

**THE OESOPHAGUS OF TELEOSTS**

1- mucosa.
2- Submucosa.
3- Muscularis.
4- Serosa.



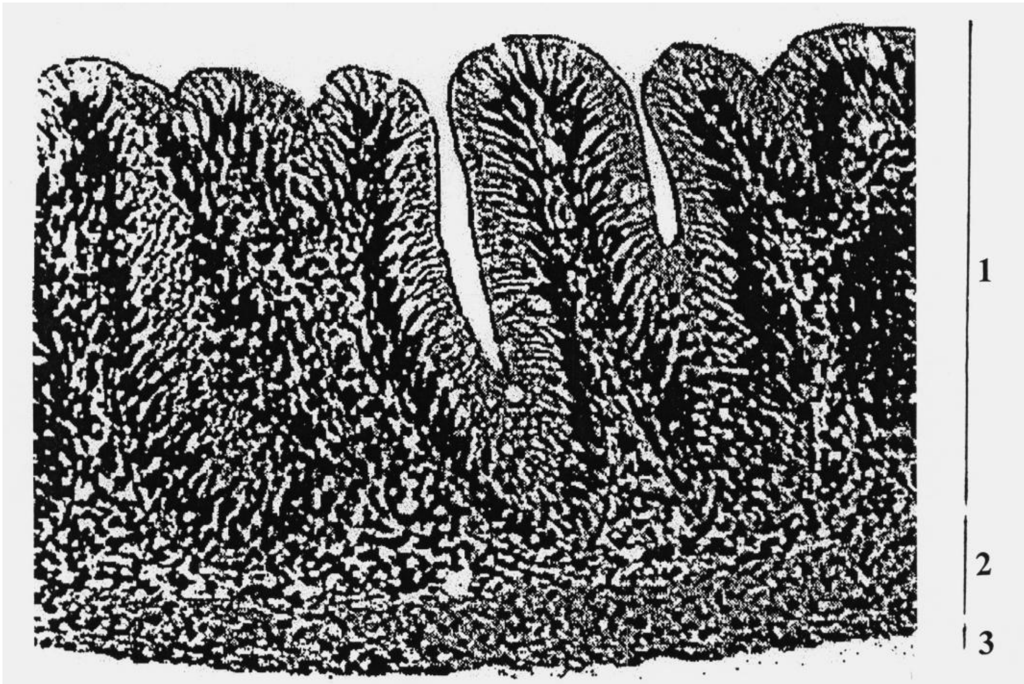

**THE STOMACH OF TELEOSTS**

1- Mucosa.
2- Submucosa.
3- Muscularis.
4- Serosa.



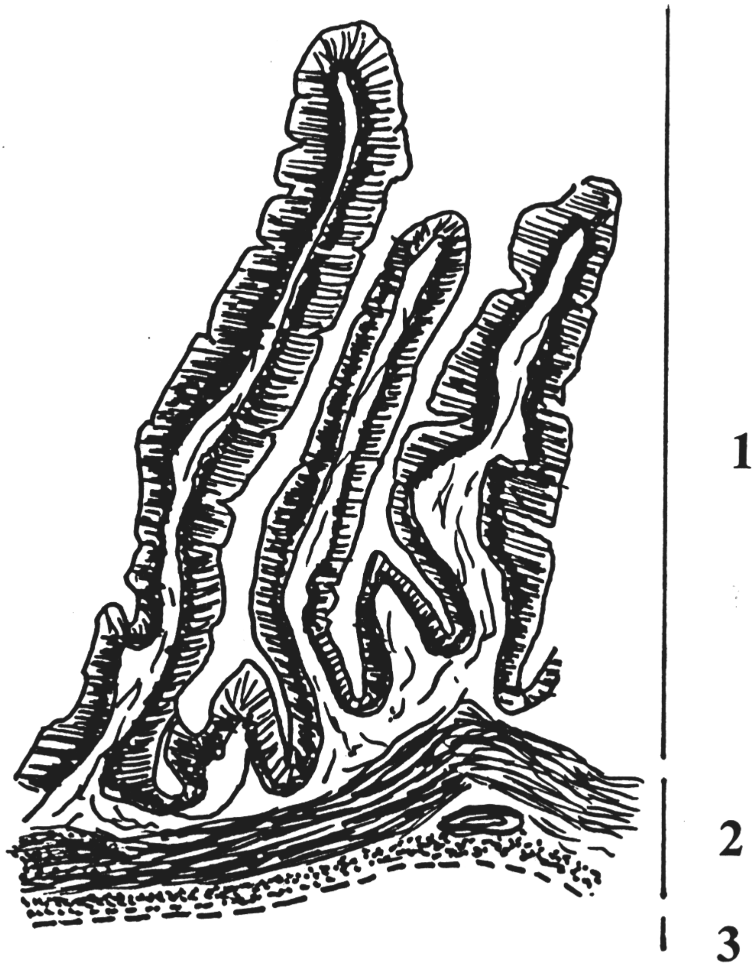

**THE ANTERIOR INTESTINE OF TELEOSTS**

1- Mucosa.
2- Muscularis.
3- Serosa.



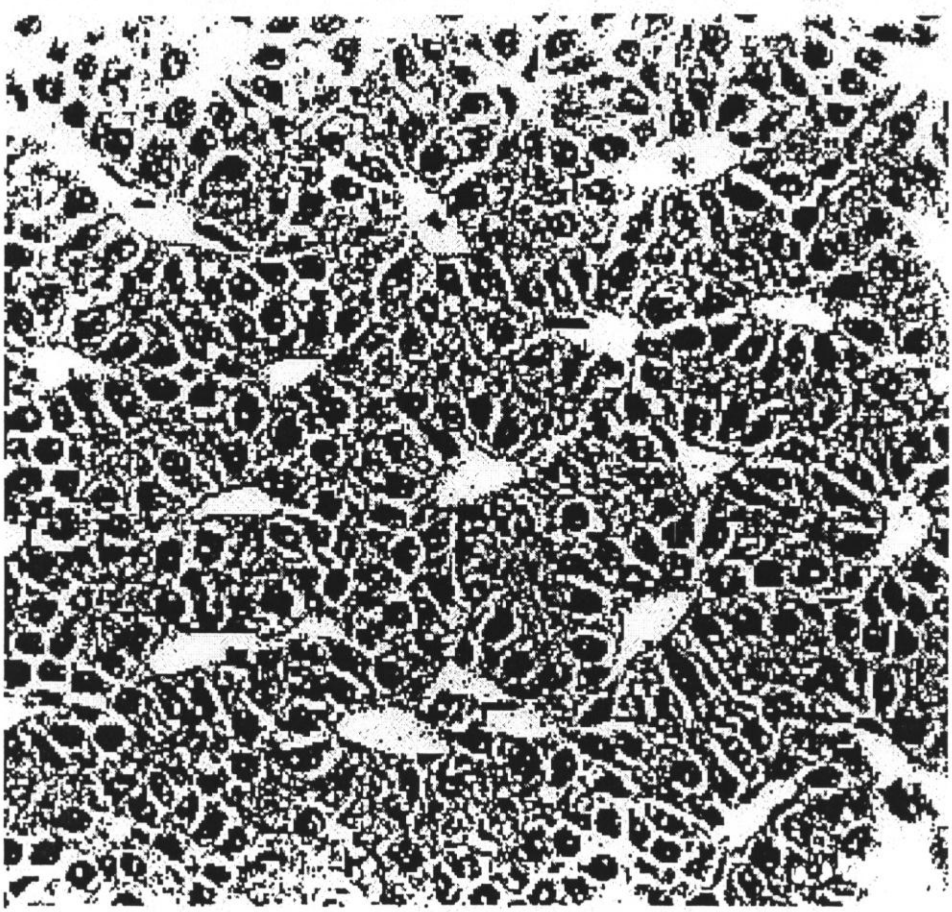

**THE ANTERIOR INTESTINE OF TELEOSTS**

1- Mucosa.
2- Muscularis.
3- Serosa.



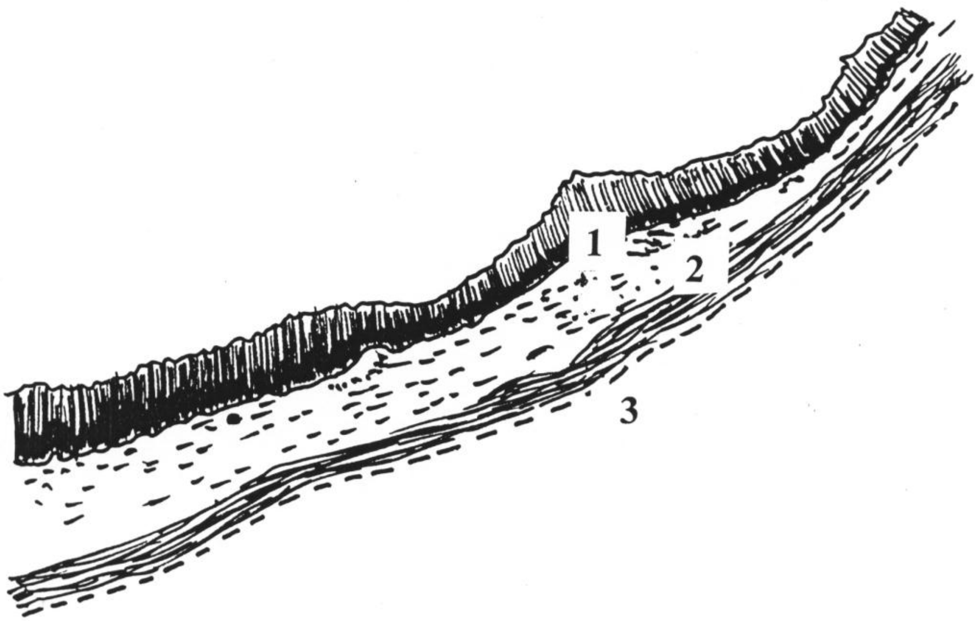

**THE POSTERIOR INTESTINE OF TELEOSTS**

1- Mucosa.
2- Muscularis.
3- Serosa.



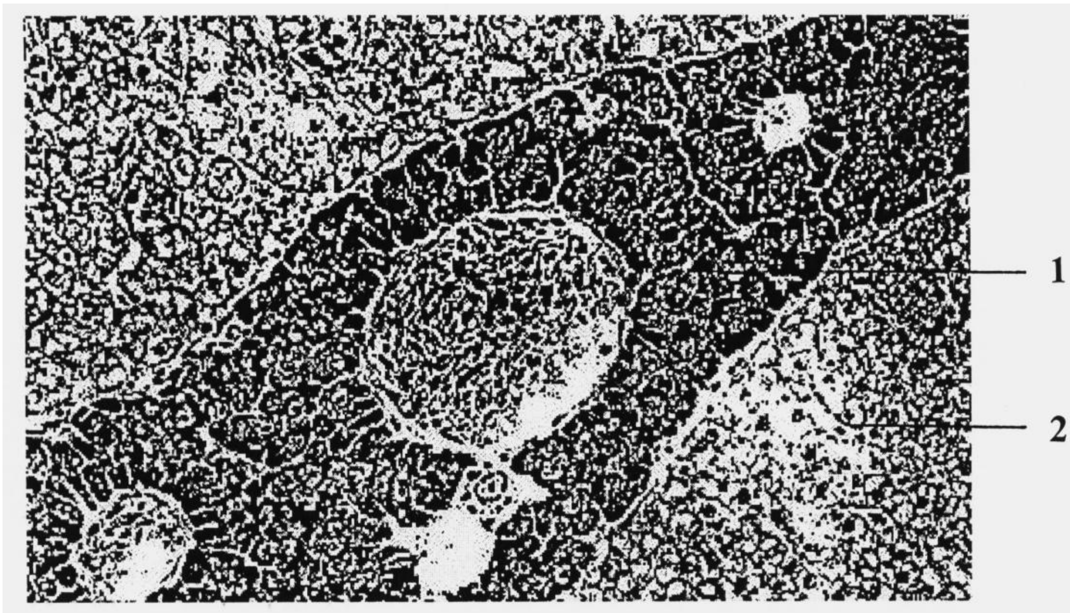
**THE LIVER OF TELEOSTS**

Showing the hepatic cords and the hepatic sinusoids(*)



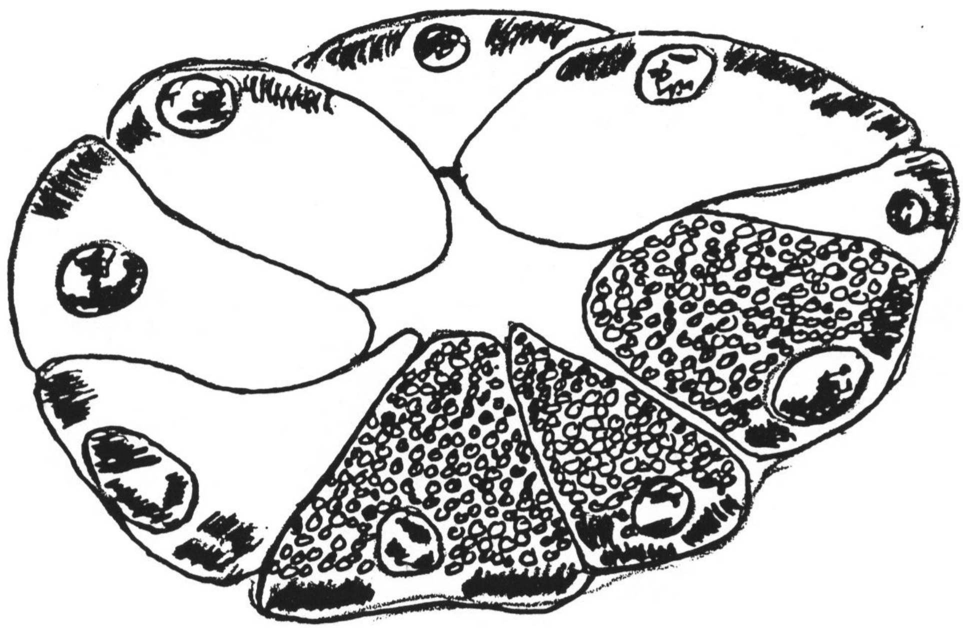

**THE WALL OF THE GALL BLADDER**

1- Inner layer.
2- Intermediate layer.
3- Outer layer.



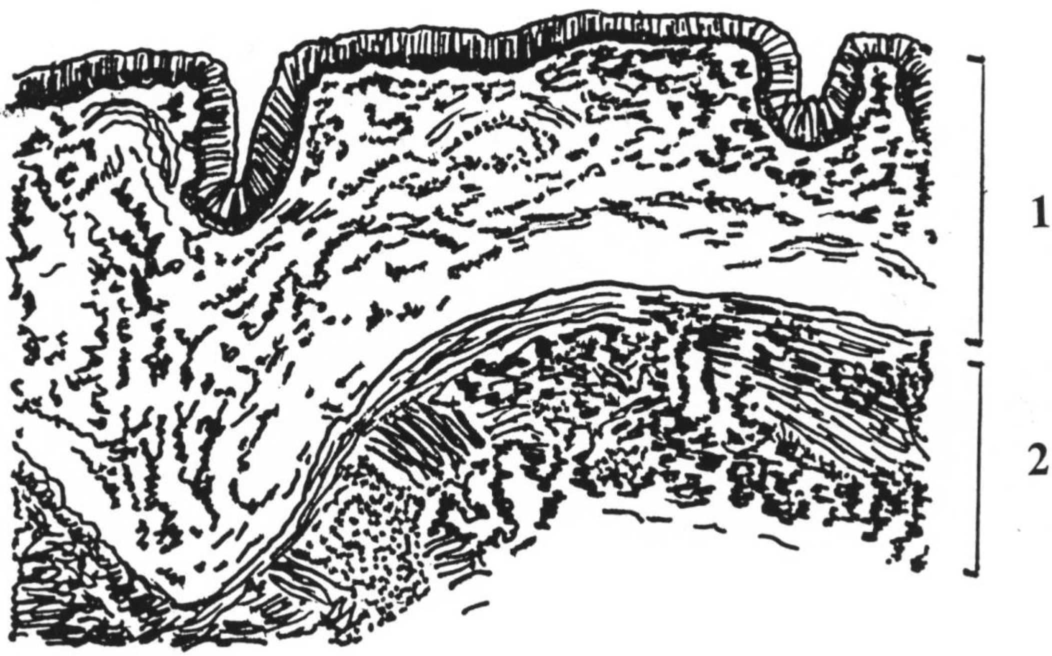

**THE HEPATOPANCREAS OF TELEOSTS**

Notice the pancreatic acini (1) within the hepatic tissue (2).



**THE PANCREATIC ACINUS OF TELEOSTS.**

Notice the zymogen granules within the pancreatic acinar cells.




**THE WALL OF THE SWIM BLADDER OF TELEOSTS**

1- Tunica interna.

2- Tunica externa.

# CHAPTER 5

## *THE RENAL AND EXCRETORY SYSTEM*

### THE EXCRETORY KIDNEY

The kidney of teleost fish is a mixed organ comprising haemopoietic, reticuloendothelial, endocrine and excretory elements.

**The kidney of teleosts is usually divided into:**

**a - Anterior kidney:**

Which is composed of haemopoietic elements.

**b - Posterior kidney:**

Which performs excretory function.

**The Nephron:**

**Two types:**

**A) In fresh water fishes the nephron is composed of:**

**1 - Renal corpuscle (Malpighian body):**

a - Glomerulus

b - Bowman's capsule

**2 - Renal tubule (urinary tubule):**

a - Neck segment.

b - Proximal convoluted segment.

i-Segment I ($P_I$)

ii-Segment II ($P_{II}$)

c - Intermediate segment.

d - Distal convoluted segment.

Fish nephron is devoid of the thin segment of Henle found in the nephron of higher vertebrates.

**I - The renal corpuscle:**

The renal corpuscle is composed of a glomerulus and its capsule. Just before entering the glomerular capsule, the afferent arteriole divides into several capillary loops, which form the glomerulus. These loops reunite and leave the capsule as the efferent arteriole. Mesangium fills the space between the loops of glomerular capillaries. The glomerular capsule consists of inner and outer layers of single flattened epithelia. The glomerular capillaries are covered with podocytes, which are the epithelial cells of the inner layer. Also, in teleost juxtaglomerular cells are detectable in the walls of the afferent arterioles. These cells contain secretory granules stainable with Bowie's method and PAS reagent. The hormone renin is said to be secreted from these cells.

**II - The renal tubules:**

**1 - The neck segment:**

Renal tubules are thin and short in the neck segment and consist of a single layer of low epithelial cells with long cilia.

**2 - The proximal convoluted segment:**

**Two parts:**

**a - Segment I:**

In segment I the renal tubules are composed of cuboidal epithelial cells with cilia and densely arranged microvilli in the tubular lumen. These microvilli are recognized as a brush border under light microscopy. The nuclei of these epithelial cells are large and round or oval. They are situated in the central or basal region of the cells. The cytoplasm of these cells contains mitochondria and many secretory granules. When fixed in Zenker-formol fluid, these organelles stain black with iron-hematoxylin and red with Mallory's triple stain.

**b- Segment II:**

In segment II the renal tubules are composed of cuboidal epithelial cells. Cilia and microvilli are found in the tubular lumen. The diameters of the tubules and tubular lumen are similar or a little larger than those of segment I.

The epithelial cells contain numerous mitochondria. Enfolding of the basal membrane is also noted in these cells. This segment occupies a considerable portion of the nephron and seems to be an active metabolic region.

**3 - The intermediate segment:**

The intermediate segment seems to be a specialized portion of segment II of the proximal convoluted segment. This segment is well developed in carp kidney but absent in several species of fishes.

**4 - The distal convoluted segment:**

In the distal convoluted segment, a brush border is not recognizable in the epithelial cells because these cells have almost no microvilli. The cells of this segment are stained with eosin more faintly than those of the proximal convoluted segment, due to the fact that there are few coarse granules in the cytoplasm. Thus under light microscopy, it is easy to distinguish between the proximal and distal convoluted segments.

**B) In marine fishes:**

The distal convoluted segment is absent in the kidney of marine fishes. Furthermore, glomeruli of freshwater teleosts are numerous and large in size. In marine teleosts, glomeruli are reduced in size and number. In extreme cases, the glomeruli disappear completely from the kidney of some marine fishes. These are called aglomerular fishes, and include seahorse , pipefish and frogfish.

The lymphoid tissue of the anterior kidney and the interstitial tissue of the posterior kidney are hematopoietic tissues of teleosts. These tissues are composed of reticular tissue containing reticular cells, abundant capillaries ,blast cells and mature blood cells.

**The function of the excretory kidney:**

In freshwater teleosts the main function of the kidney is to excrete the large amounts of water, which enter the fish body through the gills. Thus urine of freshwater fishes is copious and very low in the concentration of electrolytes. On the other hand, the gills are the main outlet for nitrogenous end products, ammonia and urea. In marine teleosts, there is the constant danger of water deprivation through the gills. Thus water retention is necessary and urinary volume must be reduced. The scanty urine excreted by marine teleosts contains various constituents: di-and tri-valent electrolytes such as $Ca^{2+}$ , $Mg^{2+}$ and $SO_4^{2-}$ as well as nitrogenous end-products such as creatine, creatinine and trimethylamine oxide (TMAO). Ammonia, urea and monovalent electrolytes ($Na^+$ , $Cl^-$), however, are excreted mainly through the gills.

## THE URETER AND URINARY BLADDER

The wall of the ureter and urinary bladder consists of:

**1 - Inner layer:**

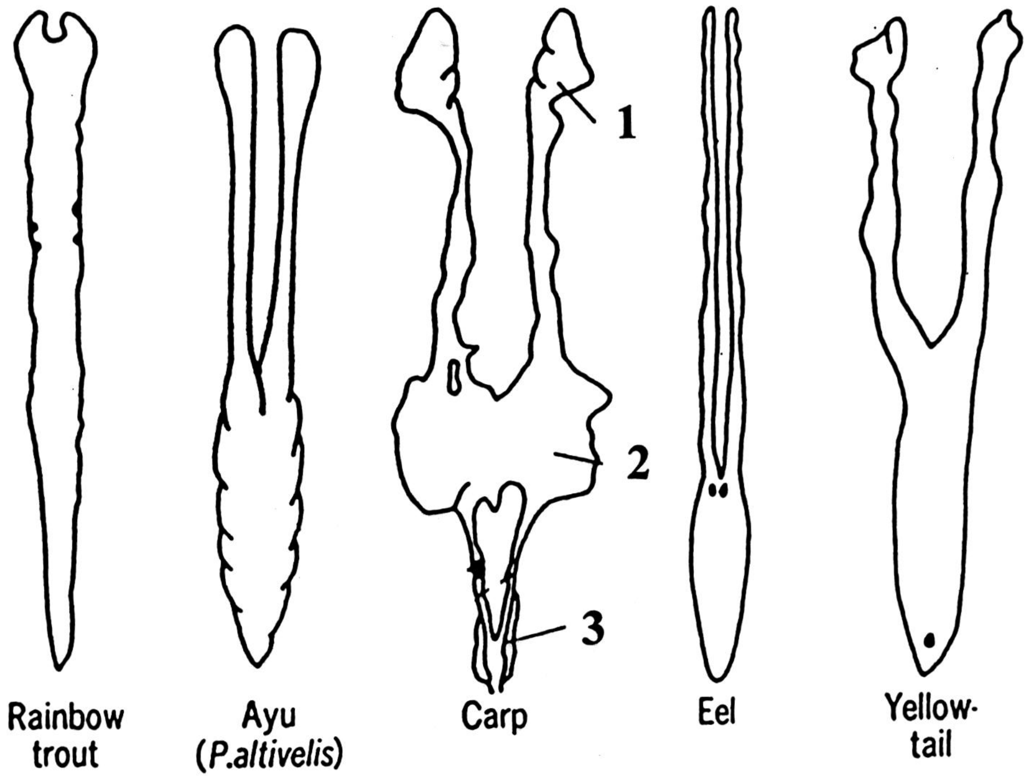
Simple columnar epithelium.

**2 - Middle layer:**

a - Connective tissue lamina propria.

b - Circulatory arranged smooth muscle fibers.

**3 - Adventitia.**




**THE FORMS OF TELEOSTEAN KIDNEY.**

1-Head.

2-Body.

3-Tail.

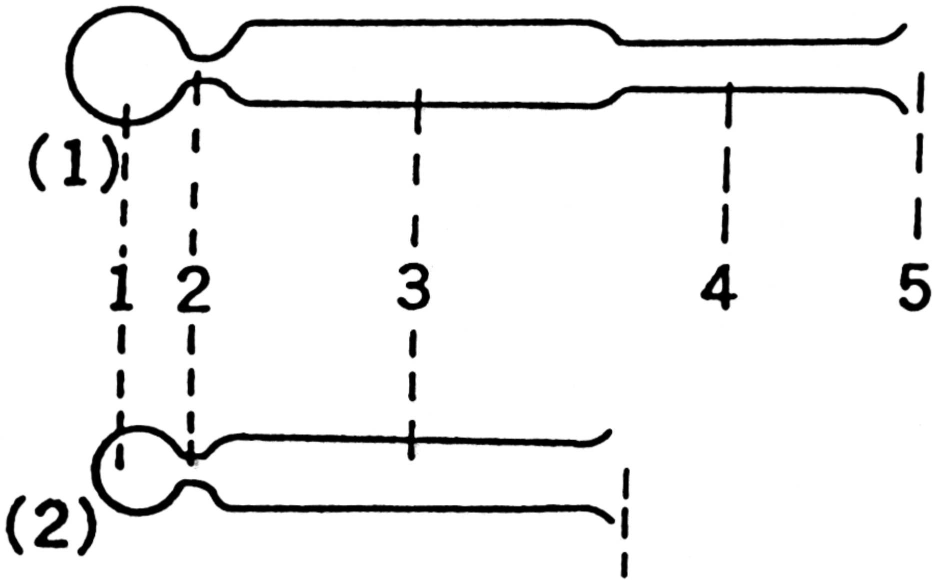



**DIAGRAM OF TELEOSTEAN NEPHRON**

(1) Fresh water fish.

(2) Marine fish.

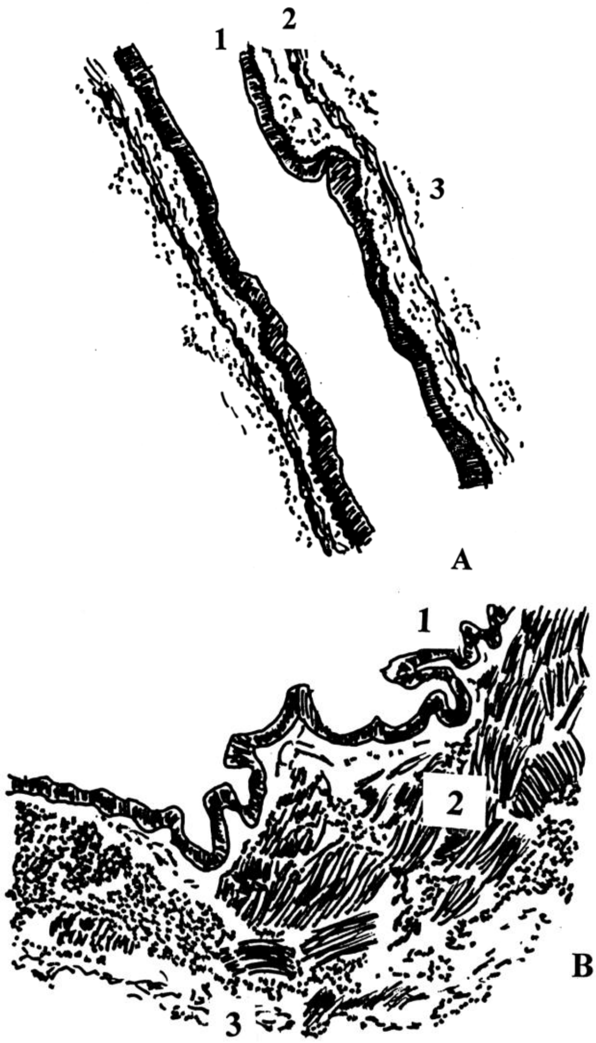
1- Renal corpuscle.

2- Neck segment.

3- Proximal convoluted segment.

4- Distal convoluted segment.

5- Collecting duct.




**THE URETER (A) and THE URINARY BLADDER (B) OF TELEOSTS.**

1- Inner layer.

2- Middle layer.

3- Outer layer.

# CHAPTER 6

## *THE REPRODUCTIVE SYSTEM*

### THE TESTIS

**The testis consists of:**

**A) Framework:**

a- Capsule.

b- Septa.

They divide the testis into lobules.

**B) Parenchyma:**

**The parenchyma is composed of:**

a) A series of tubules or blind sacs, the seminiferous tubules, which are lined with spermatogenic (or seminiferous) epithelium and Sertoli's cells.

The seminiferous tubule is different from that of higher vertebrates in which a permanent germinal epithelium exists. In fishes the spermatogonium in the resting stage is located at the blind end of the seminiferous tubule but it moves to the wall of the seminiferous tubule in the maturing season.

**Spermatogenesis:**

The spermatogonium in the early stage is a large oval cell with one large round nucleolus. In the latter stage of proliferation it is small and round. After the proliferation stage the spermatogonium develops into the primary spermatocyte. The primary spermatocyte develops into the secondary spermatocyte by maturation (or meiotic) division and then undergoes a second maturation division to develop into a spermatid. The spermatid then develops into a spermatozoon with a head, middle piece and long tail. The head is rounded and contains a large deeply stained nucleus. The latter presents a nuclear fossa at the side facing the middle piece. The nucleus is surrounded by some irregular membranes. The middle piece contains 6-10 circularly arranged mitochondria. The tail presents 9 pairs of peripheral and a central pair of microtubules, all of which run in the direction of the long axis of the tail. The tail shows two lateral cytoplasmic processes at each side.

**Sertoli's cells:**

They exist between the germinal cells and are believed to play a role in supplying of nutrients.

b**) Interstitial cells**: (or Leydig's cells)

They exist into the connective tissue of the testis and secrete sex steroids.

**Note:**

In fishes, the transport route of spermatozoa is basically the same as in the higher vertebrates, but fishes can be classified into two groups according to the length of the sperm duct. Namely, the testis of fishes having a short sperm duct gives the appearance of a lobular structure divided by connective tissue, and the fusion and enlargement of the lobules, which occur during the division and multiplication of the germinal cells in the lobules, cause them to come in contact with the small sperm duct. On the other hand, in fishes with long sperm ducts, the structure of the seminiferous tubule is visible and the sperm duct connects with a network of seminiferous tubules, which extends almost completely throughout the peripheral portion of the testis.

## THE OVARY

The ovary of fish is generally a pair of sac-shaped organs covered with an ovarian wall and consisting of an ovarian cavity (ovarian lumen) and numerous ovarian lamellae (ovigerous lamellae) where oogenesis takes place.

The ovarian cavity connects with the oviduct, and the oviducts from each bilateral ovary join together to lead to the genital pore. An ovary with such a structure is called the cyst ovarian type and after a mature oocyte, within a follicle on the lamella, is released by ovulation to the ovarian lumen it leaves the body through the oviduct and genital pore.

The ovary of most teleosts is generally of the cyst ovarian type, but salmon and trout have a pocket-like structure that opens to the body lumen and in place of oviducts, possess a funnel-shaped transporting groove leading to the genital pore. Such an ovary is of the semicyst-ovarian type.

The structure of the eel ovary is the most simple; the ovary hangs down like curtain and after the ovulated eggs are released in body cavity, they are discharged from the body. Such an ovary is of the gym ovarian type.

**Oogenesis:**

**Oogenesis comprises the following stages:**

1- **Proliferation stage**: (multiplication stage)

Oogenesis starts with the proliferation of oogonium on the ovarian lamella. The proliferation period varies from species to species. The oogonium in the early stages is a large cell with a large nucleus including one nucleolus and later, after multiplication, they become considerably smaller.

**2 - Leptotene stage**:

The oogonium after the multiplication stage develops into the primary oocyte. The size of the cell is not so different but the chromosomes at first appear thread-like and are distributed throughout the nucleus.

**3 - Zygotene stage**:

The chromosomes then assemble at one side of the nucleus and the nucleolus adjacent to the nuclear membrane localized at the opposite end of the nucleus.

**4 - Pachytene stage**:

The primary oocyte enters the pachytene stage in which the nucleolus moves to the central part of the nucleus and the bivalents to the edge of the nucleus; at the same time, the nucleus increases in size to become the germinal vesicle. The chromosomes become somewhat slender and distributed throughout the nucleus, and many chromatin nucleoli begin to appear.

**5 - Diplotene stage**:

The nucleoli become smaller, move to the periphery of the nucleus and arrange themselves in order on the inner side of the nuclear membrane. The cell body becomes large and the cytoplasm becomes strongly basophilic. Furthermore, the follicle cells surrounding the oocyte become clearly distinguishable constituting a single layer in bony fishes.

**Vitellogenesis:**

Vitellogenesis means the process of accumulation of yolk substances within the cytoplasm. The cytoplasm, basophilic up to this time, becomes acidophilic.

The essential yolk substances are of three kinds, i.e., yolk vesicles, yolk globules and oil droplets.

**a) The yolk vesicles**:

The yolk vesicles contain glycoprotein and stain very slightly red with eosin but exhibit a strong positive reaction to PAS, staining deep red. The quantity and properties of the yolk vesicles differ among species. The yolk vesicles later become the cortical alveoli and take part in the formation of the perivitelline space.

**b) The yolk globules**:

The yolk globule consists mainly of lipoprotein with some carbohydrate and other substances. It is eosinophilic with HE staining and weakly positive to PAS.

**c) The oil droplets**:

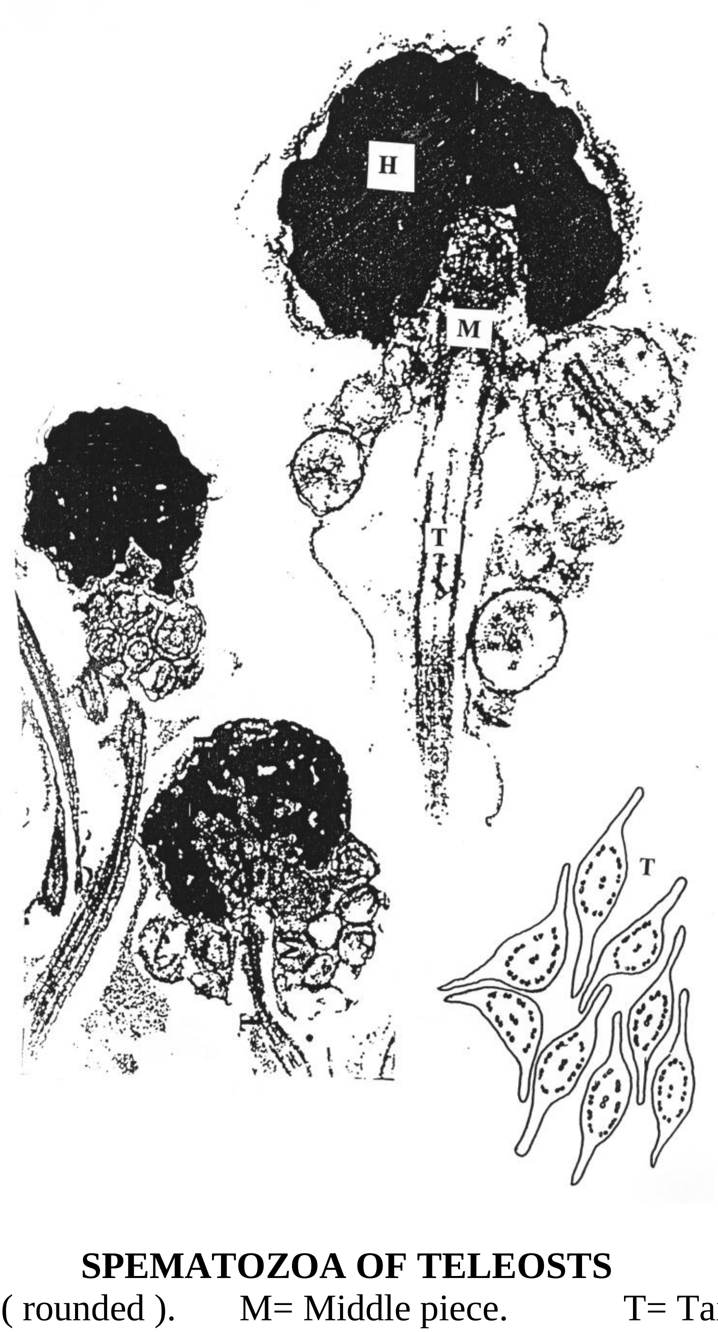
The oil droplets are generally recognized to contain glycerides and a small amount of cholesterol. The oil droplets stain black by Osmic acid .

When the accumulation of yolk substances becomes conspicuous, hyperplasia of follicle cells is recognized, and the squamous theca cells line up in two layers to form an outer and inner theca membrane outside the follicle cell layer.

When vitellogenesis begins, the egg membrane becomes clear and PAS-positive, and in the course of vitellogenosis becomes hyperplastic and differentiates to form inner and outer layers. Moreover, radial striation also becomes clear and this stratum is called the zona radiata. The thickness of the egg membrane decreases just before full maturation.

With the completion of vitellogenesis, movement of the germinal vesicle, fusion of yolk globules and grouping of oil droplets occur and, especially in marine fishes, the egg diameter increases sharply. Marked increase in body weight occurs due to water absorption. The degree of fusion of yolk globules differs among species.

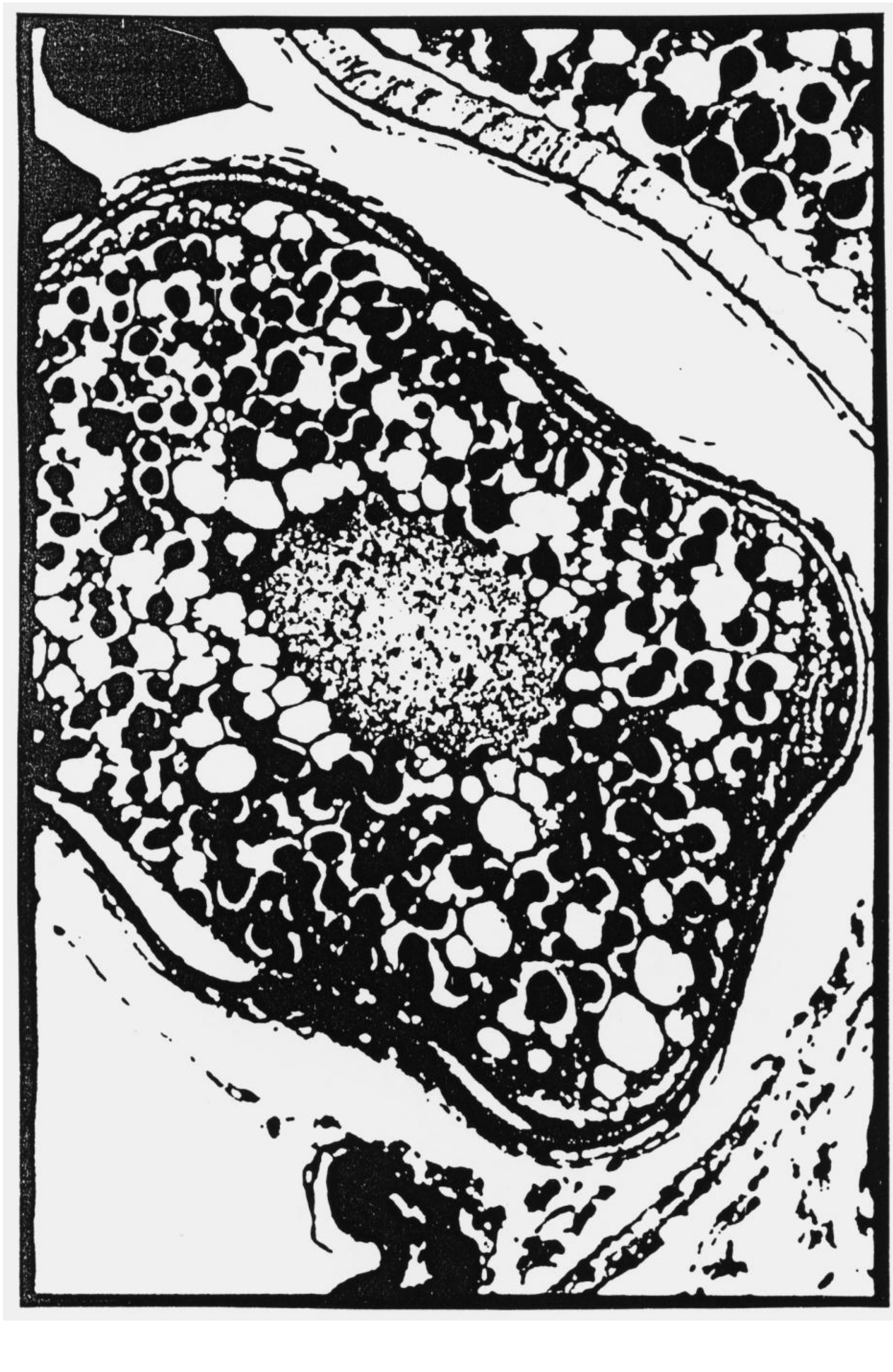
After movement of the germinal vesicle to an animal pole, the first meiotic division occurs and the first polar body is released. Subsequently, the second meiotic division starts and an egg in which division arrested at the metaphase is ovulated.




**SPEMATOZOA OF TELEOSTS**

H= Head ( rounded ). M= Middle piece. T= Tail.
Notice the lateral process on each side of the tail (bottom, right).

**PRIMARY OOCYTE AT THE YOLK VESICLE STAGE**



**PRIMARY OOCYTE AT THE YOLK GLOBULE STAGE**

# CHAPTER 7

## *THE ENDOCRINE SYSTEM*

### THE PITUITARY

**The pituitary of fish is divided into two parts:**

**I - The adenohypophysis:**

The adenohypophysis is subdivided into three parts. The organization and nomenclature of the pituitary gland are as follows.

I - Adenohypophysis

a - pro-adenohypophysis.

b - meso-adenohypophysis.

c - meta-adenohypophysis.

II - Neurohypophysis

**I-Adenohypophysis:**

**A) Pro-adenohypophysis:**

Three cell types are recognized in the pro-adenohypophysis.

**1 - Prolactin cells:**

In eel and rainbow trout most of the pro-adenohypophysis consists of prolactin cells in follicular arrangement. Prolactin cells are acidophilic and contain many secretory granules stainable with acid fuchsin or erythrosine. However, these granules do not stain with periodic acid-Schiff (PAS) or aldehyde fuchsin (AF).

**2 - Corticotrops** (ACTH-cells):

These cells are located in the dorsal region of the pro-adenohypophysis, forming two or three layers at the border of the neurophypophysis and contain many secretory granules stainable with MacConaill's lead-hematoxylin. However, ACTH cells do not stain with PAS or Alcian blue.

**3 - Thyrotrops** (TSH cells):

In eel, TSH cells are found in the pro-adenohypophysis. They are stained among the follicles of prolactin cells, occasionally appearing as larger cell cords. In most other species of fishes, TSH-cells are located singly or in clusters in the meso-adenohypophysis. These cells are basophilic and contain many secretory granules stainable with PAS, chromehematoxylin (CH), or AF.

**B) Meso-adenohypophysis**

Two cell types are distinguished in the meso-adenohypophysis.

1) **Growth hormone cells** (Somatotrops, STH cells) STH cells occupy a considerable portion of the meso-adenohypophysis. STH cells are acidophilic and not stainable with PAS or AF.

2) **Gonadotrops** (GTH cells) GTH cells are not numerous in eels with immature gonads, but increase considerably in mature eels. They sometimes invade the pro-adenohypophysis and are found there in eel and rainbow trout with mature gonads. GTH cells are basophilic and contain many secretory granules stainable with PAS or AF.

**C) Meta-adenohypophysis:**

The meta-adenohypophysis is composed of two types of cells. One type does not stain with PAS. The other type is PAS-positive. These cells are intermingled in the meta-adenohypophysis. In ell, the PAS -negative cells seem to secrete a melanophores-stimulating hormone (MSH), which expands the granules in melanophores.

**II – Neurohypophysis:**

The adenohypophysis is composed of glandular tissue, but the neurohypophysis is composed of nervous tissue containing many unmyelinated nerve fibers from the hypothalamus and large scattered glia cells called pituicytes. Most of the nerve fibers contain secretory granules stainable with CH or AF. The granules are called Herring bodies if they are detected as being massive in the neurohypophysis. In fishes, the majority of these nerve fibers are the axons of the neurosecretory cells belonging to the preoptic nucleus of the hypothalamus. The terminals of these nerve fibers contact with the pituicytes or the capillary walls in the neurohypophysis, or the cells of the meta-adenohypophysis.

The neurohypophysis of teleosts secretes two kinds of octapeptide hormones, arginine vasotocin and isotocin (ichthyo-tocin). They are produced in the neurosecretory cells of the preoptic nucleus, carried along the axon and released in the blood capillaries of the neurohypophysis.

## THE EPIPHYSIS

The epiphysis is composed of a pineal vesicle and stalk. The pineal lumen of the vesicular portion varies in size according to species.

Epiphyseal parenchyma consists of photoreceptor, supporting and ganglion cells, as well as neuropile, which is the aggregation of the cytoplasmic processes of these cells.

**1) The photoreceptor cells**:

The photoreceptor cells of the epiphysis are sensory cells showing fundamentally the same morphological features as the visual cone cells of eye retina. Electron-microscopic observation reveals that the photoreceptor cell is composed of inner and outer segments, cell body and basal processes. The inner and outer segments consist of aggregated mitochondria and numerous lamellae, respectively.

**2) The ganglion cells**:

The presence of ganglion cells in the epiphysis has been confirmed in rainbow trout and ayu, but compared with photoreceptor cells, they are few in number. The ganglion cells are detectable in the central region of the epiphyseal epithelium and compared with photoreceptor and supporting cells, are larger in size. The ganglion cells contain large nuclei and prominent nuclei, but Nissl's substance in the cells is not abundant. Supporting cells fill in the spaces among the photoreceptor and ganglion cells.

**3) The neuropile**:

Electron microscopic observations have revealed that this portion is an aggregation of the basal processes of numerous photoreceptor cells and dendrites of ganglion cells. This aggregation is called the neuropile and here the dendrites of ganglion cells form synapses with the basal processes of photoreceptor cells. Unmyelinated axons of ganglion cells assemble and form the pineal tract, which extends to the posterior commissure via the pineal stalk.

## THE UROPHYSIS

In teleosts a small-distended body called the urophysis is recognized in the terminal region of the spinal cord. This organ releases materials produced in the neurosecretory cells located in the spinal cord. These cells together with the urophysis are called the caudal neurosecretory system. This neurosecretory system is recognized only in teleosts and elasmobranches, but it is very similar in structural organization to the hypothalamo-neurosecretory system present in vertebrates.

In the caudal neurosecretory system, neurosecretory cells are diffusely located in the terminal region of the spinal cord. Axon terminals of these cells assemble at the ventral side of the region and form the urophysis with blood capillaries. The axon terminals end at the walls of these capillaries in the urophysis. The neurosecretory cell is a large nerve cell containing a polymorphic nucleus, and its cytoplasm is basophilic.

The urophysis is composed of the following: spinal cord elements such as neurosecretory axons, glia, and ependymal and glia fibers and meningeal derivatives such as vascular reticulum and reticular fibers.

Many granular neurosecretory materials are observable in the urophysis. These materials of the caudal neurosecretory system are stained with azocarmine, iron-hematoxylin or phloxine, which are employed as counter staining.

## THE THYROID GLAND

The thyroid follicles in many teleosts, unlike in other vertebrates, disperse individually or in clusters into the connective tissue around the diverging part of the afferent branchial artery and do not involve into a compact organ.

The follicles are of varying size, lined by simple cuboidal epithelium and filled with colloid in the lumen. The follicle activity takes in iodine from the blood and produces the thyroid hormones.

When the thyroid gland is active, the epithelial cells are cuboidal and there is little colloid. Thus many vacuoles are frequently recognized in the colloid adjacent to the epithelium. On the other hand, when the gland is inactive, the epithelial cells are squamous and the follicular lumen is filled with much colloid.

## THE THYMUS

The thymus is located on the dorsolateral wall of the pharynx from the first to the fourth branchial arches. Its ventral surface is covered with mucosal epithelium. There is a layer of connective tissue adjacent to its dorsal side and subsequently a layer of muscle. The parenchyma consists of lymphoid tissue, which is almost entirely composed of lymphocytes. The thymus is clear in the fry, but becomes less prominent in the adult fish. It is reported that the size of the thymus changes with the reproductive cycle in some gobies. Depending on the species, structures resembling Hassal's corpuscles may be present.

## THE ULTIMOBRANCHIAL GLAND

The ultimobranchial gland is also called suprapericardial body or subesophageal gland. In most teleosts, the gland is located in the transverse septum between the pericardial and peritoneal cavities, just under the esophagus. The ultimobranchial gland of eel and rainbow trout is a pair of left and right tissue masses, but the gland of carp consists of only a single mass.

In carp the ultimobranchial tissue is well-developed and composed of many densely packed follicles. The nuclei of glandular cells are round or oval and contain little chromatin. Secretory granules are not visible under light microscopy. A central cavity is seen in the ultimobranchial tissue of eel and rainbow trout. Also, enfolding protruding into the cavity is observed in the gland of rainbow trout. In these species, the parenchyma of the ultimobranchial gland is not follicular in arrangement, but consists of pseudostratified epithelia. The nucleus is located in the basal portion of the cytoplasm and is oval in shape. In rainbow trout, goblet cells are seen singly or in clusters among the ultimo-branchial cells.

## THE INTERRENAL GLAND AND CHROMAFFIN CELLS

The interrenal gland of fish is homologous to the adrenal cortex of mammals. Usually, it is distributed in the anterior kidney and surrounds the postcardinal vein and its branches. In fishes, the tissue homologous to the adrenal medulla of mammals is called chromaffin cells and they are closely related to the interrenal gland.

Identification of interrenal and chromaffin cells is not difficult because the cytoplasm of interrenal cells stain deeply with eosin. Chromaffin cells are almost colorless in preparations fixed in Bouin's fluid and stained with hematoxylin and eosin. If the chromaffin cells are fixed in dichromate-containing fluid such as Zenker-formol and stained with H-E, minute yellow-brownish granules appear in the cytoplasm (chromaffin reaction). The identification of chromaffin cells can be made easily by this reaction.

The nucleus of the interrenal cell is usually round, contains little chromatin, and has a distinct nucleolus. The nucleus of the chromaffin cells is oval or irregular in shape and also contains little chromatin. The nucleolus is obscured in the chromaffin nucleus. Accordingly, the identification of interrenal and chromaffin cells is possible from these features of their nuclei.

Teleostean interrenal cells are stainable with Sudan black B. Histochemical examination of teleostean interrenal cells reveals the presence of the enzymes, 3β-hydroxysteroid dehydrogenase and glucose-6-phosphate dehydrogenase, important in the biosynthesis of steroid hormones.

## THE ISLETS OF LANGERHANS

The islets of Langerhans are of endodermal origin, and in most teleosts are found as small bodies scattered in the exocrine portion of the pancreas.

In teleosts, three types of cells can be distinguished in the islets of Langerhans under the light microscope: A, B and D cells.

**1) A cells:**

They are normally numerous at the periphery of the islets. The size and shape of these cells show marked variation according to species. Particularly in carp, they exhibit irregular size and shape. The nucleus shows invagination at one side. A cell granules are readily stained with acidic dyes such as phloxine and azocarmine if the samples are previously fixed in ZF. However, other fixatives cannot obtain satisfactory results. It has been shown by many investigators that A cells produce and secrete glucagon, one of the several hormones that promote elevation of blood glucose levels.

**2) B cells:**

These cells produce, store and secrete insulin, a hypoglycemic hormone. In the small islets, they tend to gather in the center, and in the large islets, they are arranged in cords and show a rather complicated pattern of distribution. B cells granules stain well with AF, and CH, hence B cells are easily distinguished from the other cells in the islet. In general, B cells are ovoid or spindle-shaped, and their size is similar or somewhat smaller than the A cells.

**3) D cells:**

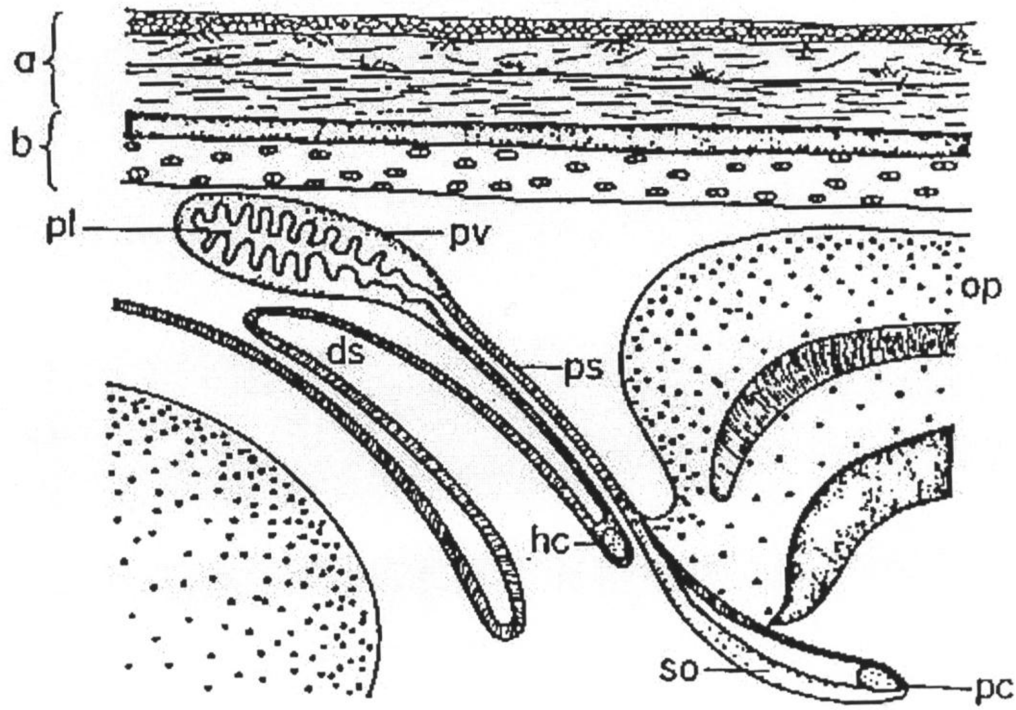
These cells are frequently found isolated among the B cells. Their shape is generally rounded or ovoid, but their size shows marked interspecific variation. They are smaller than A or B cells. D cell granules are slightly stained with phloxine in samples previously fixed in Zenker formol, but not in samples treated with other fixatives. These granules have strong argyrophilic properties; hence silver staining techniques are useful for identifying D cells.

## THE CORPUSCLES OF STANNIUS

The corpuscles of Stannius are small white-yellowish bodies in the kidney region of teleosts.

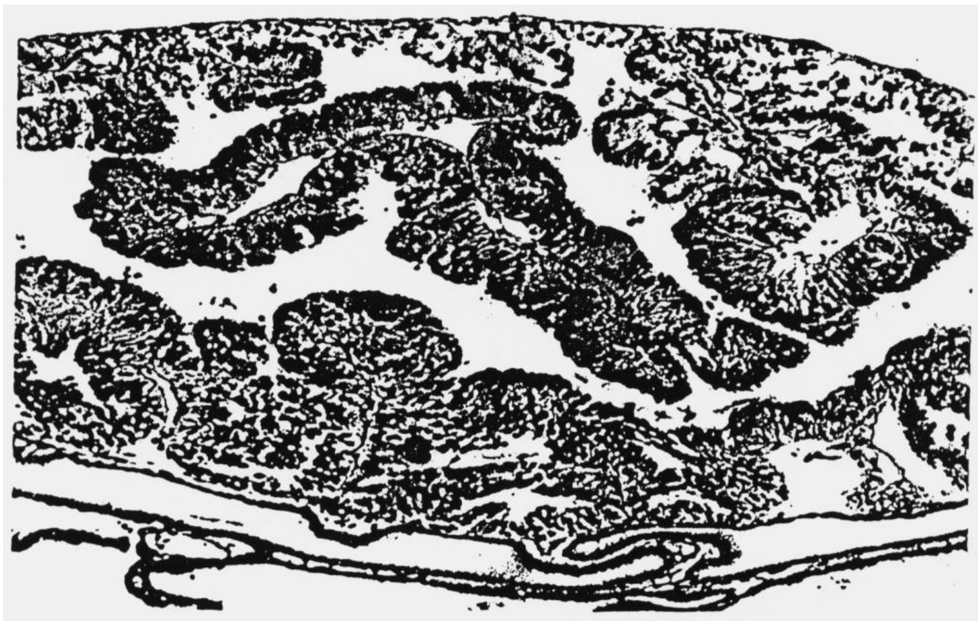
The corpuscles of Stannius are enveloped by capsular connective tissue, and their parenchyma is divided into many lobules. Each lobule is composed of many glandular cells containing numerous coarse secretory granules in the basal portion. Moreover, a central cavity or pseudolumen is detectable in the lobules of some fishes. The secretory granules of Stannius corpuscle are deeply stainable with eosin (HE stain), iron-hematoxylin (Heidenhain's stain), acid fuchsin (Mallory's triple stain).

The presences of steroid hormones such as cortisol, corticosterone and sex hormones were detected in the Stannius corpuscles of Atlantic salmon. Besides a renin-like substance was found in the Stannius corpuscles of European eel, carp and anglerfish.

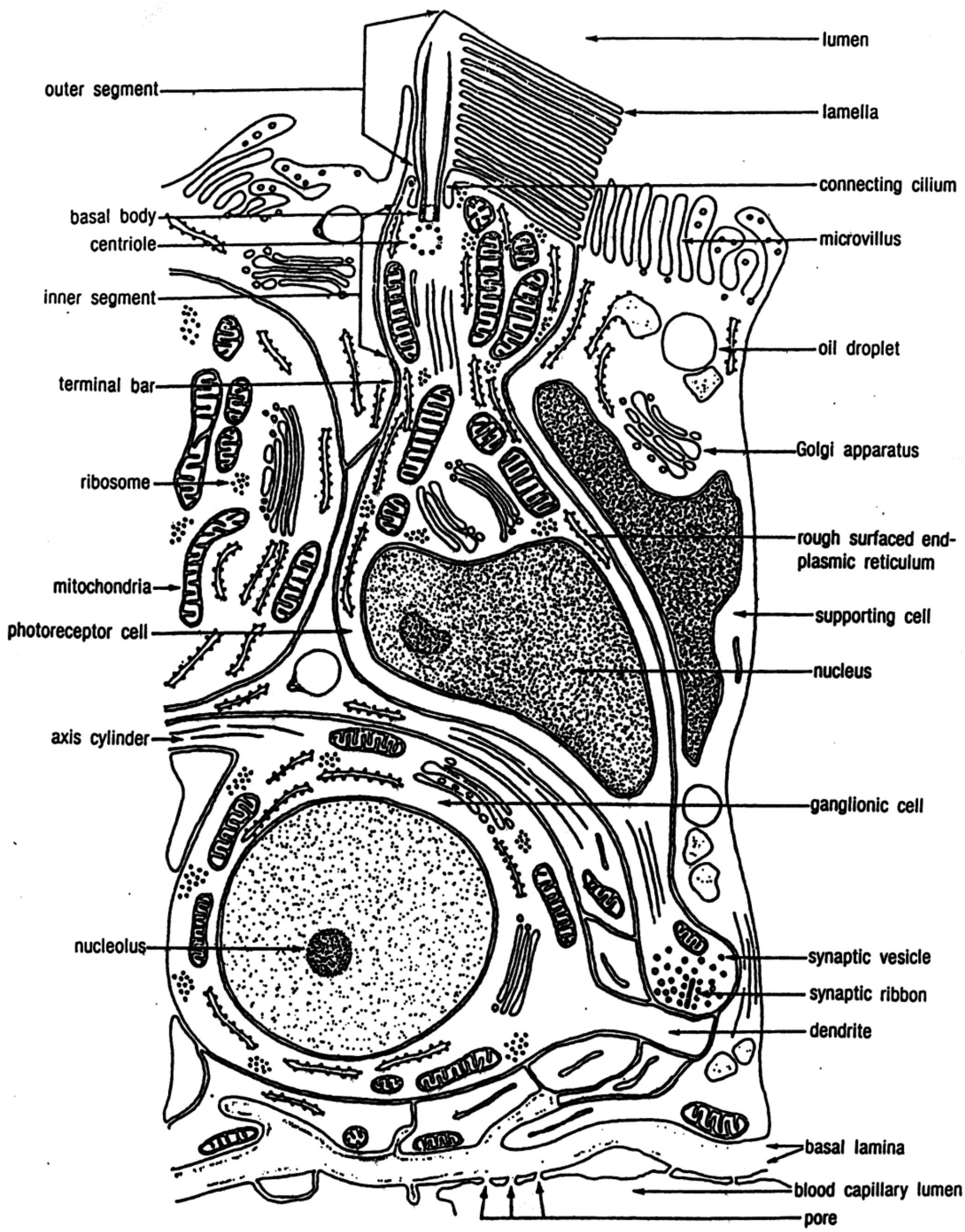



**DIAGRAMMATIC ILLUSTRATION SHOWING THE STRUCTURE OF TELEOSTEAN EPIPHYSIS ( pineal gland )**

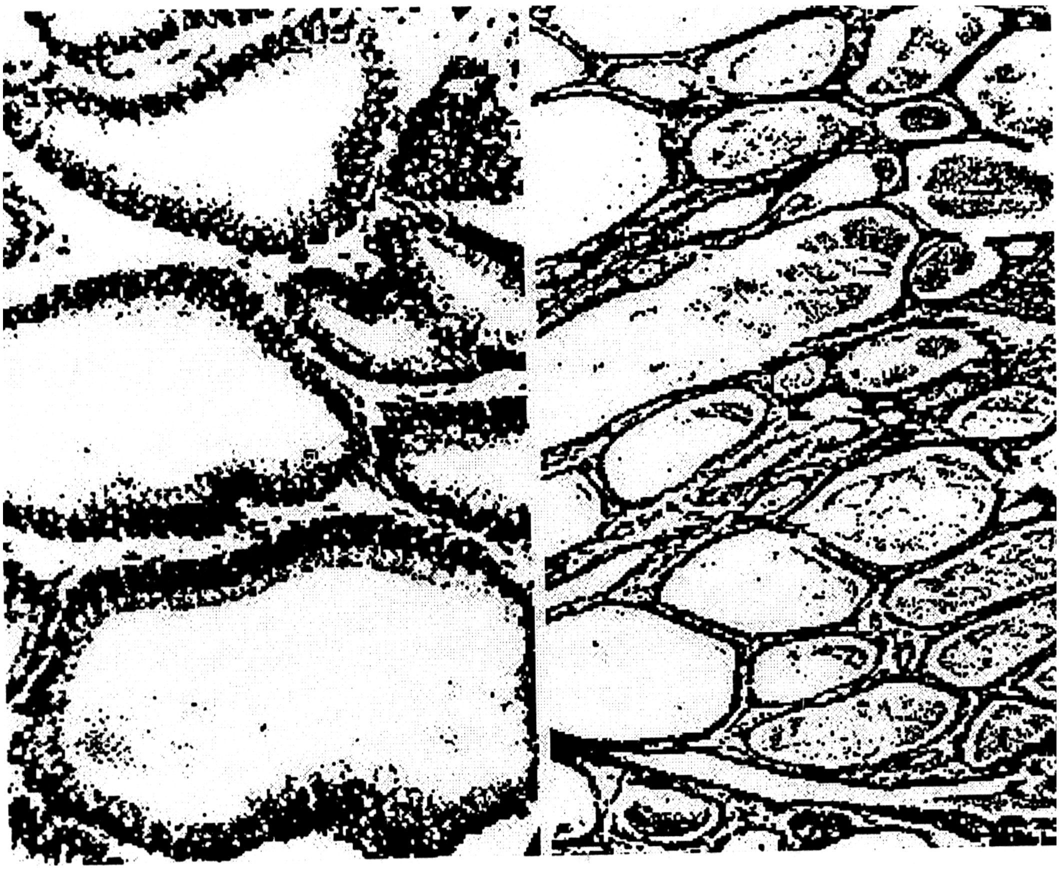
a- Skin.
b- Bone.
pv- Pineal vesicle.
pi- pineal lumen.
ps-pineal stalk.
ds-dorsal sacculus.
hc-habenularum commissure.
so-subcommissural organ.
pc-posterior commissure.
op-optic tectum.



**VESICULAR PORTION OF EPIPHYSIS OF TELEOSTS**



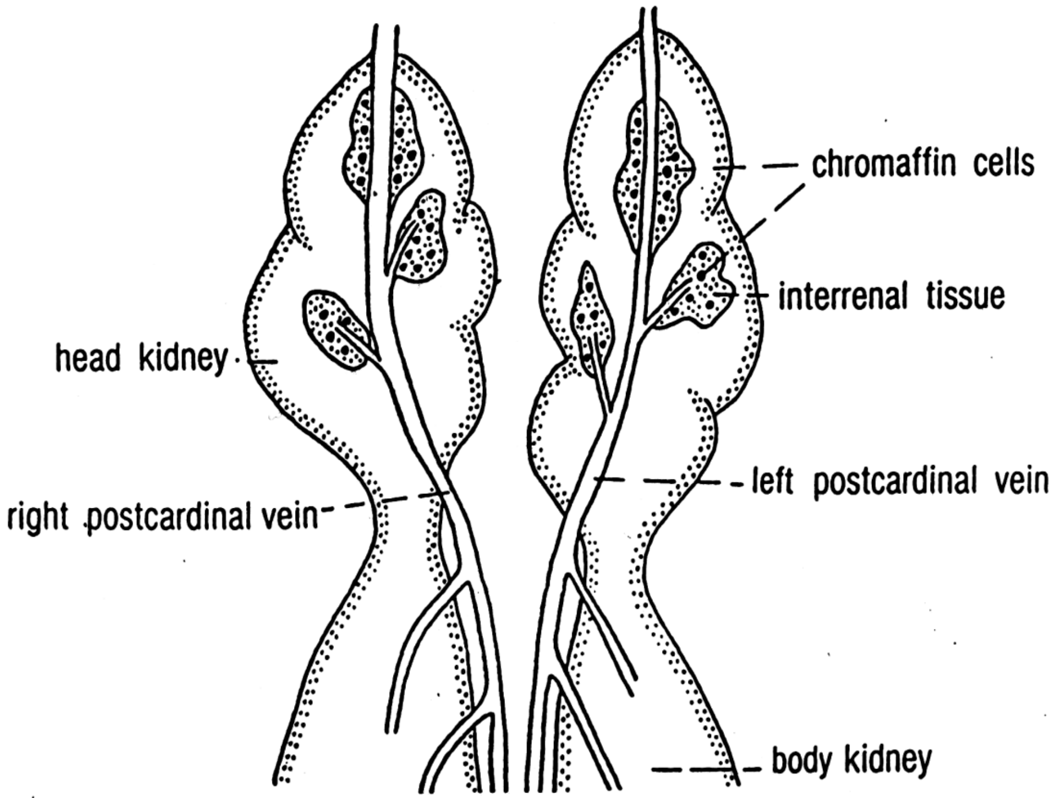

**ULTRASTRUCTURE OF EPIPHYSIS PARENCHYMA**



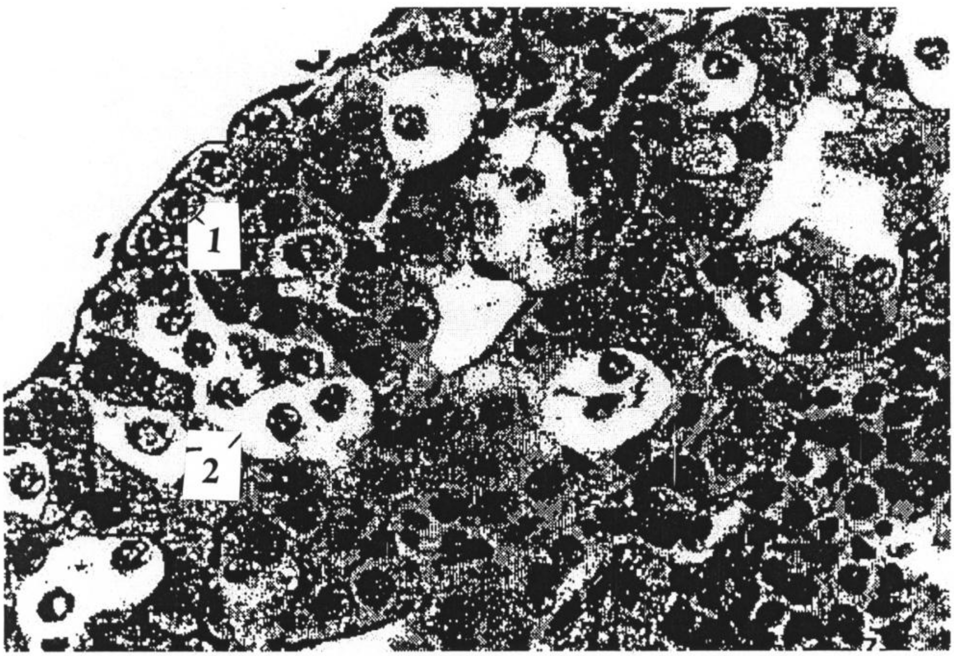
**THE THYROID GLAND**

Left: Active.

Right: Inactive.



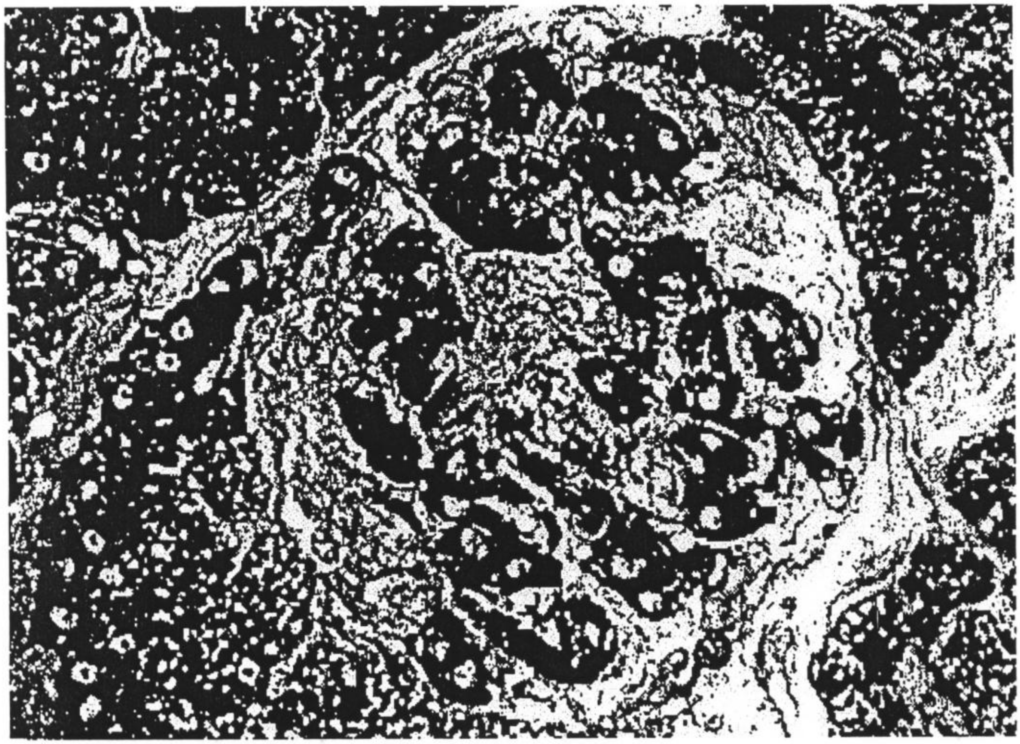

**Diagrammatic illustration showing, the arrangement of the interrenal gland and chromaffin cells in the anterior kidney ( Head kidney) of teleosts .**




**Interrenal gland and chromaffin cells of teleosts**

1- Interrenal cells.

2- Chromaffin cells.



**Islets of Langerhans of teleosts.**

B cells are deeply stained blue with aldehyde fuchsin.

# CHAPTER 8

## *THE RETICULOENDOTHELIAL SYSTEM (RES)*

**In teleost fishes, the cells comprising RES are:**

1- Promonocytes of Haemopoietic organs.

2- Monocytes of the blood and lymph.

3- Macrophages of loose connective tissue.

4- Macrophages (free and fixed) of the spleen and anterior kidney.

5- Macrophages (fixed) of the atrial lining of the heart.

**N.B**.:

a**)** The anterior kidney and the atrium are highly significant organs of the RES in fishes.

b) Lymph nodes do not occur in fish.

c) Kuppfer cells of the liver do not occur in fish.

# CHAPTER 9

## *THE NERVOUS SYSTEM*

### THE BRAIN

Five major regions are distinguished in the brain of fishes: telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon.

**1 - The telencephalon**:

The telencephalon is divided into the right and left cerebral hemispheres. The expended tip of each hemisphere is called the olfactory bulb. This bulb contains the cell bodies of olfactory nerve cells and is the primary center of the sense of smell.

In fishes, the roof plate of the telencephalon is covered with membranous tissue, and the lateral ventricles do not exist.

There are varying explanations regarding the structure of the telencephalon in fishes, and as a result, there are no standard terms for the centers in the cerebral hemispheres.

Dorsolaterally, each hemisphere consists of the olfactory area, and dorsomedially, of the septal area.

**2 - The diencephalon:**

The diencephalon is the region that contains the third ventricle and is composed of the epithalamus, thalamus and hypothalamus.

a) The roof of the epithalamus consists of a choroid plexus. The posterior part of the roof projects upward forming the pineal gland (epiphysis). The epithalamus contains the ends of the nerve fibers from the telencephalon and also the habenula, which connects with the thalamus, hypothalamus, and the olfactory areas of the telencephalon.

b) The thalamus, which consists of the lateral walls of the diencephalon, is believed to contain the center of autonomic functions.

c) The hypothalamus is the floor of the diencephalon, and its anterior portion includes the preoptic area. A pouch, the infundibulum, extends downward from the ventral part of the hypothalamus. The tip of this infundibulum becomes the neurohypophysis. The centers located in the hypothalamus have not yet been elucidated, but many investigations have been performed on two nuclei, nucleus preopticus and nucleus lateralis tuberis, which are composed of nerve cells with secretory capability.

The lower part of the hypothalamus in Osteichythes protrudes laterally and is called the inferior lobe. A structure containing many capillaries. The saccus vasculosus, is found at the back of the infundibulum in these fishes.

**3- The mesencephalon**:

The mesencephalon contains the center of the visual sense, as well as the integration center between this sense and the other senses and locomotion. The ventricle continues into the mesencephalon as a narrow cavity called the aqueductus mesencephali, or aqueduct of Sylvius, and its dorsal wall corresponds to the tectum opticum.

**Histology of tectum opticum:**

1) **Stratum opticum:**

This is the superficial layer and is supplied with optic nerve fibers.

2) **Stratum fibrosum and stratum griseum superficiale:**

Stratum fibrosum and stratum griseum superficial contains nerve fibers and nerve cells, and is the most important center of the visual sense in the tectum opticum.

3) **Stratum griseum centrale:**

Stratum griseum centrale contains the nerve cells of efferent nerves.

**4) Stratum album centrale:**

This layer contains the nerve fibers of efferent nerves and is connected with the oculomotor nerve and thalamus.

**5) Stratum griseum periventriculare:**

This layer consists of nerve cells, which receives the fibers of the periventricular system.

**6) Stratum fibrosum periventriculare:**

This layer faces the aqueductus mesencephali and contains numerous nerve fibers.

The ventromedial portion of the tectum opticum bears a protuberance called the Torus longitudinalis. It has been suggested that the torus longitudinalis contains a center that plays a role in the integration between the sense of equilibrium and the sense of vision.

**4 - The metencephalon**:

The metencephalon (cerebellum) occupies the anterior portion of the dorsal wall of the fourth ventricle and is composed of a cortex and medulla. The cortex in turn is composed of three layers, which are, in order from the surface: the molecular layer, the Pukinje's cell layer and the granular cell layer. The molecular layer consists of Purkinje cell dendrites and glia cells. The granular layer consists of small nerve cells called granular cells and also contains the Purkinje's cell axons.

**5- The Myelencephalon**:

The main part of the myelencephalon is the medulla oblongata.

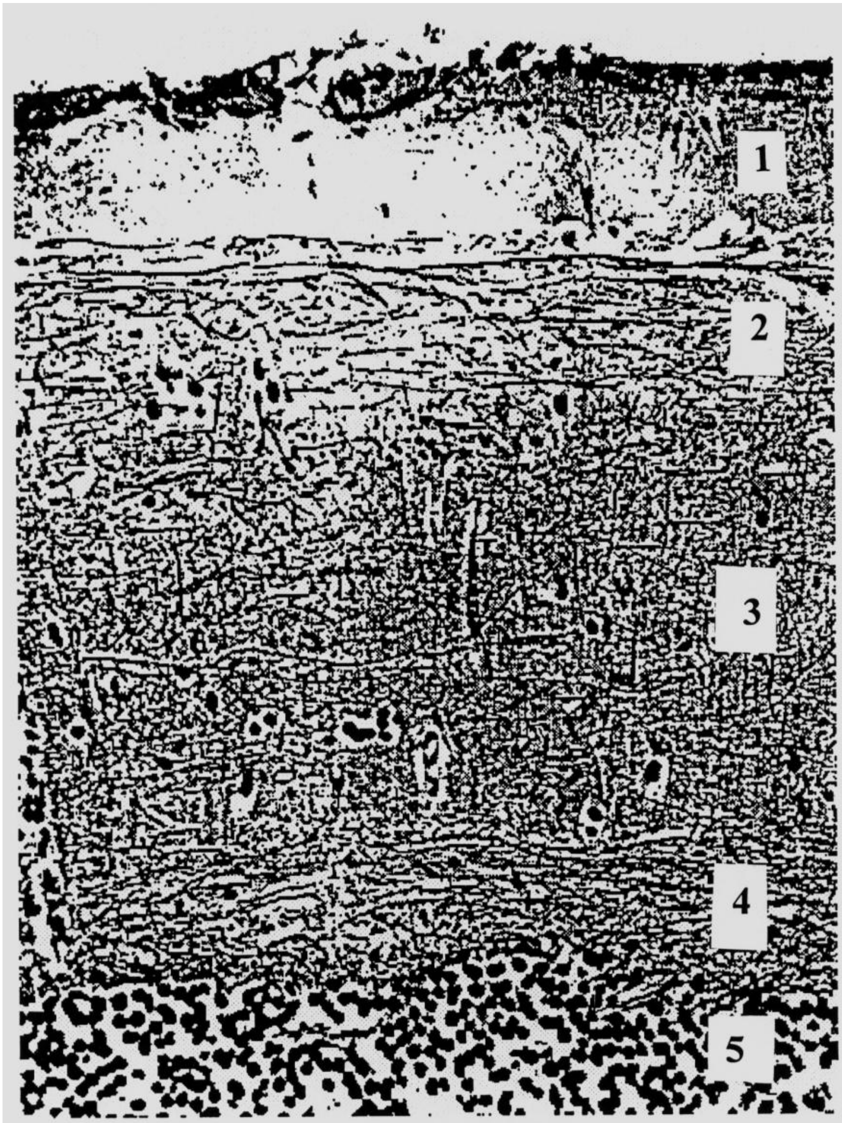
The medulla oblongata of Osteichythes contains two large nerve cells, the Mauthner cells. These cells are located on each side of the medulla between the sensory and motor areas. Mauthner cells are concerned with the rapid movements of the tail. It has been suggested that information from the lateral line system is conveyed to the posterior part of the spinal cord by the long axons of these cells.

## THE SPINAL CORD

The structure of the spinal cord in fishes is basically very similar to that in the higher vertebrates.

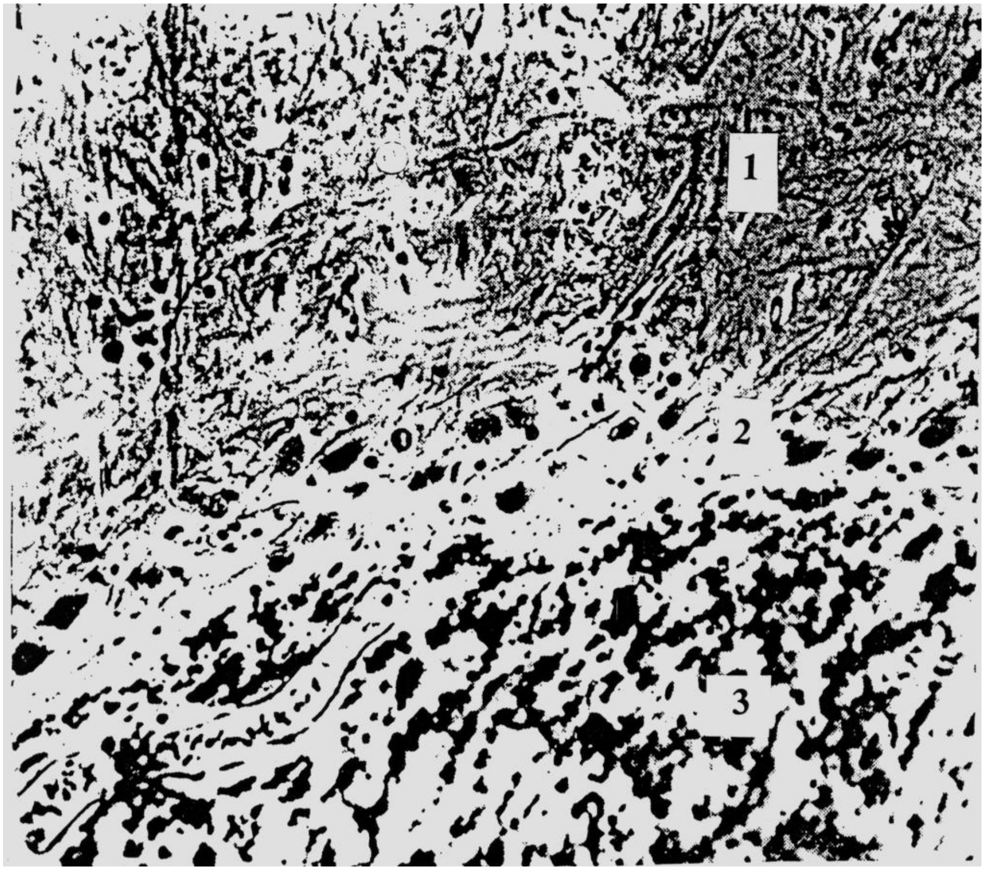
The transverse section of the spinal cord shows an inverted Y-shaped gray matter in the central region, where numerous nerve cells may be distinguished. Surrounding the gray matter is the white matter, which contains myelinated nerve fibers. The central canal in the center of the gray matter is filled with spinal fluid and lined with ependymal cells. This canal is an extension of the ventricles. The gray matter is divided into anterior, posterior and lateral columns, which serve as the entry or exist sites for the spinal nerve fibers. The anterior (or ventral) roots leave from the anterior columns to innervate somatic muscles or visceral organs.

In fishes, two large groups of cells may be distinguished in the gray matter of the spinal cord. The cells of the first group are located mostly in the dorsal region, and their function is to control the movements of the trunk musculature. The cells of the other group are located in the ventral region of the gray matter and control the movements of fins. The spinal nerve fibers have two roots: the posterior sensory root with its ganglion and the anterior motor root.




**SECTION INTO THE OPTIC TECTUM OF TELEOSTS**

1- Stratum opticum .
2- Stratum fibrosum and griseum superficial.
3- Stratum griseum central.
4- Stratum album central.
5- Stratum griseum periventricular.

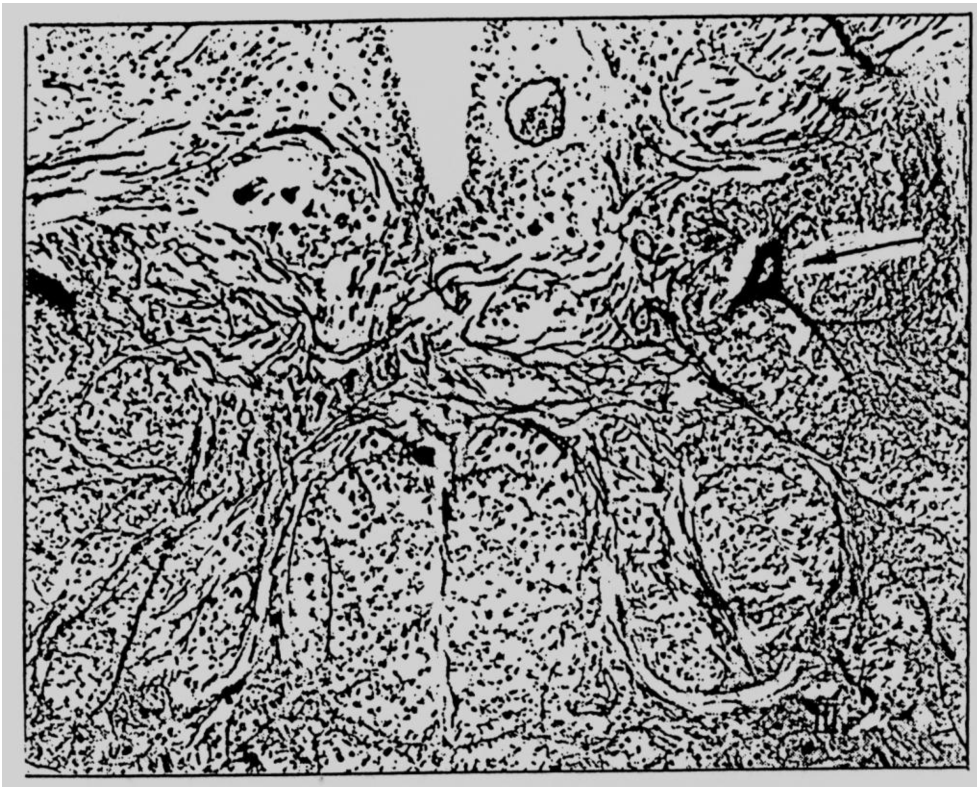



**SECTION INTO THE CEREBELLUM OF TELEOSTS**

1- Molecular layer.

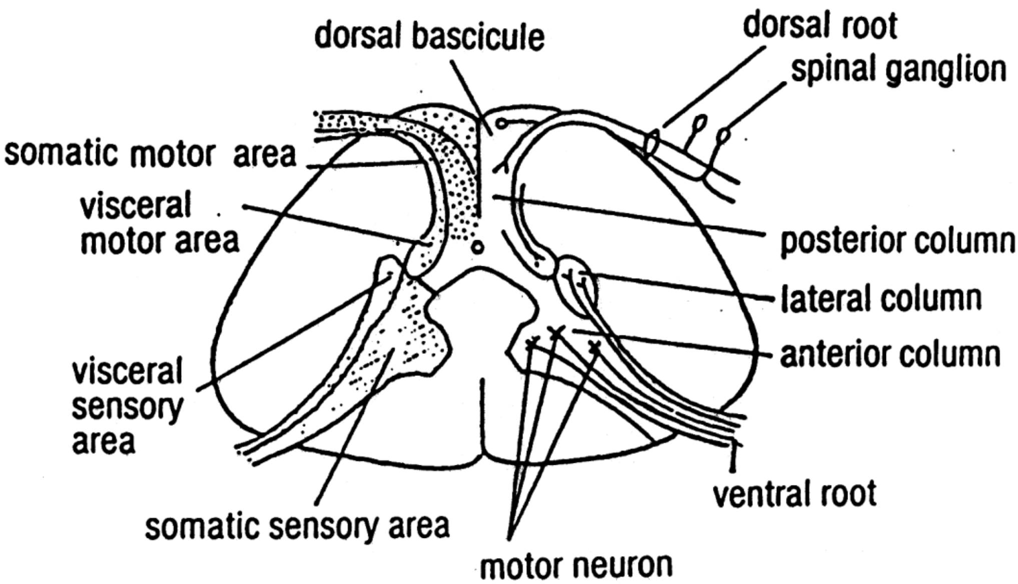
2- Purkinje cell layer.

3- Granular layer.



**MEDULLA OBLONGATA OF TELEOSTS**

Showing, Mauthner cells (arrow).




**C.S. INTO THE SPINAL CORD OF TELEOSTS**

# CHAPTER 10

# *THE SENSORY ORGANS*

## THE EYE

**1 - The cornea:**

The anterior segment of the eye is the cornea consisting of a corneal epithelium, corneal stroma and corneal endothelium.

**2 - The iris:**

The iris is a thin partition between the anterior and posterior chambers, projecting over the anterior surface of the lens with its free edge outlining the pupil. The cavity of the eyeball is filled with a transparent medium called hyaloid body.

**3 - The lens:**

In fishes, accommodation is usually achieved by altering the position of the lens rather than changing the lenticular shape. The lens is covered by the lens capsule, and its interior is occupied by the lens substance. Between them lies the lens epithelium, which plays an important role in the metabolic processes of the lens. The lens substance is composed of lens fibers arranged in flat hexagonal prisms. These lens fibers are highly modified epithelial cells.

**4 - The choroid:**

The choroid is the highly vascular portion underlying the retina. The degree of development of the choroid varies depending on the species. In carp, the plexus of blood capillaries is well developed and is known as the choroidal gland. In eel, however, the choroid is poorly supplied with blood capillaries, and no structure resembling a choroidal gland can be recognized. The sclera is the thick and firm layer surrounding the choroid. Some cartilage is present in this layer.

**5 - The retina:**

The retina is similar in structure in most vertebrates and functionally, is the most important component of the eye. It is made up of several layers which, from the outermost to the innermost, are as follows: pigment epithelium, layer of rods and cones, outer limiting membrane, outer nuclear layer, outer plexiform layer, inner nuclear layer, inner plexiform layer, ganglion cell layer, nerve fiber layer and inner limiting membrane. The retina presents some cells with marked specialized functions:

**1) Visual cells**

These are the rod and cone cells. The function of the rod cells is to detect the intensity of light, and that of the cone cells is to distinguish wave lengths, i.e., color.

**2) Horizontal cells**

These cells are located in the outer region of the inner nuclear layer. Some processes from these cells extend horizontally near the outer nuclear layer and serve as lines of communication between visual cells.

**3) Bipolar cells**

These nerve cells are located in the innermost region of the retina, and are the largest neurons observed within the retina. The axons from these cells form the optic nerve.

**4) Amacrine cells**

These cells are located between the inner granular and inner plexiform layers and serve as horizontal lines of communication for visual stimuli.

## THE INNER EAR

The inner ear of fishes is associated with two senses: hearing and equilibrium. The organ is composed of an upper portion, the pars superior, and a lower portion, the pars inferior.

The midportion of the pars superior is the utriculus, from which three semicircular canals arise, the anterior vertical, posterior vertical, and horizontal canals. Each canal bears an enlargement at one of its ends, the ampulla. Below the utriculus is the sacculus, which is connected with the utriculus through the recessus utriculus at its upper end. The sacculus forms the lagena at its posterior end. The cavity of the inner ear is filled with lymph.

The utriculus, sacculus and lagena contain lapillus, sagitta and asteriscus, respectively. Collectively they are called Otoliths. Otoliths are calcified structures of ectodermal origin and mainly composed of calcium carbonate, keratin like proteins and mucopolysaccharides. The center of the otolith is rather opaque and is surrounded by concentric rings (annuli). These rings are composed of alternating translucent and opaque zones, which form thin lamellae. The otolith in the sacculus is the largest of all and is often used for age determination.

The inner surfaces of the ampullae, utriculus, and sacculus of the inner ear are covered with sensory epithelium, and are supplied with VIII cranial nerve (acoustic nerve) terminals.

The sensory epithelium is simple and composed of hair cells and supporting cells. Hair cells bear sensory hairs on the apical surface and are receptors of vibratory stimuli.

Adjacent to and lying over the sensory epithelium is the tectorial membrane, which can mediate stimuli to the sensory hairs by vibration. This type of sensory apparatus of the ear is known as the Corti's organ.

Certain teleosts such as carp and catfish present a series of ossicles, the Weberian apparatus, between the air bladder and the inner ear. The Weberian apparatus is similar to the chain of auditory ossicles connecting the ear drum and the inner ear in the higher vertebrates, and serves to transmit vibrations from the air bladder to the inner ear.

## THE OLFACTORY ORGAN

In teleosts, a pair of olfactory pouches are present in the dorsal region of the head. Eels have specially well developed and large olfactory pouches. The bottom of each pouch bears a series of olfactory laminae which from a rosette (olfactory rosette). The rosette is covered with olfactory epithelium and is composed of olfactory cells, supporting cells (which sometimes include mucous cells) and basal cells. The olfactory cells are bipolar neurons. Their long and thin axons meet below the epidermis and form olfactory nerve fasciculi, which lead to the olfactory bulb.

## THE LATERAL LINE ORGAN

In fishes, the surface of the body has two kinds of sensory organ, chemical sensory and tactile organs. Neuromasts composing the lateral line organ belong to the latter. These receptors are innervated by branches from the facial, glosso-pharyngeal and vagus nerves. The receptor cells are sensory cells and are called hair cells since they have cilia on their apical surfaces. These cilia are embedded in the cupula, a component of the neuromast made up of mucopolysaccharides. The basal surface of the hair cell is supplied with nerve terminals.

There are two types of neuromasts: those distributed on the surface of the body, the free neuromasts or pit organs, and those enclosed within canals in the skin along both sides of the body, the canal organs. Many fishes possess both types of neuromasts, but the degree of development varies according to species. Since both the neuromasts of the lateral line system and the sensory cells of the inner ear lead from the ectoderm and perform similar functions, these two sensory systems are also collectively known as the acoustico-lateralis system. In the neuromast, movements of the cupula produced by physical stimuli from the environment (pressure, touch, vibration, water currents) strain the sensory hairs stimulating the hair cells. This stimulation is subsequently sensed by the nerve terminals of the hair cell. The receptors described above represent the ordinary types of lateral line organs present in fishes.

## THE TASTE BUDS

The pattern of distribution of gustatory receptors in fishes shows marked interspecific variation. In general, however, these receptors are numerous on the surface of the head, around the mouth, on the lips, oral mucosa and gill arches. They are also common in the barbels of carp, catfish and loach.

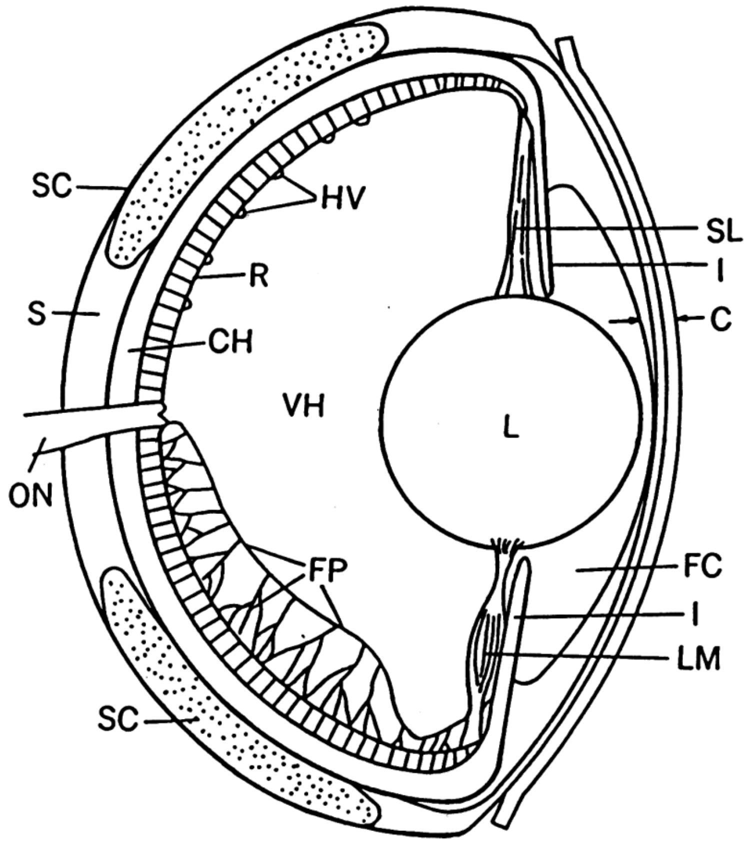
Taste buds in the skin or fins are sometimes also known as terminal buds.. The taste bud is composed of taste cells and basal cells. The apices of the taste cells have long and thin microvilli-like processes called taste hairs.

## THE BARBELS

Barbels consist of skin projections with histological features very similar to those of skin. They are composed of a dermis and epidermis. The dermis is composed mainly of connective tissue and contains many blood vessels and nerves.

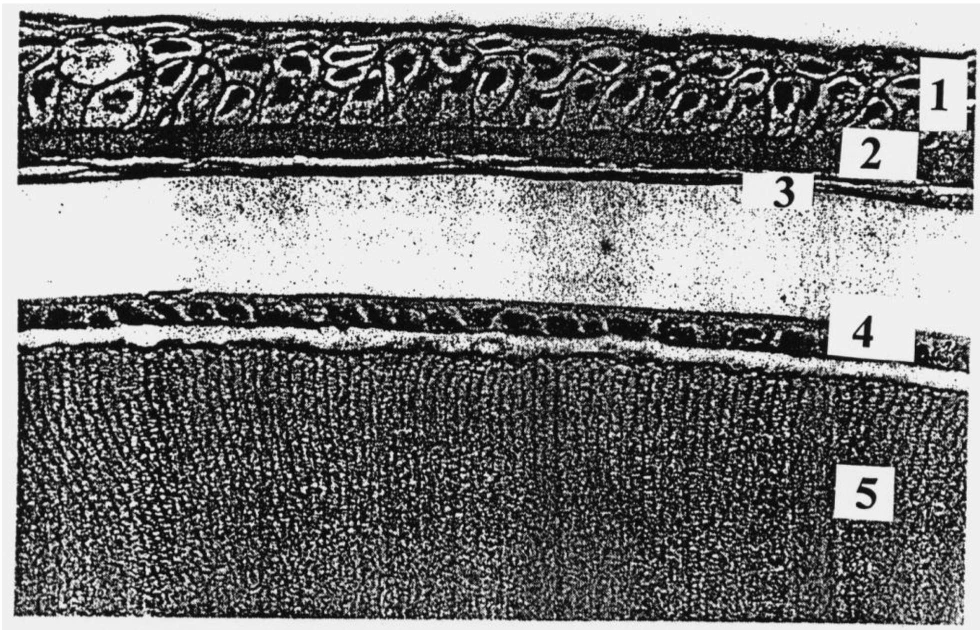
The epidermis contains mucous cells and many taste buds. In some species, cartilage is present in the center of the barbel.

Barbels are believed to aid senses of taste and touch.




**DIAGRAMMATIC ILLUSTRATION OF THE TELEOSTEAN EYE.**

C : Cornea.
FC: Anterior chamber.
HV: Blood capillaries.
L: Lens.
ON: Optic nerve.
S: Sclera.
VH: Vitreous body.
CH: Chorioidea.
FP: Falciform process.
I: Iris.
LM: Ciliary muscle.
R: Retina.
SC: Cartilage.




**CORNEA AND LENS OF TELEOSTS**

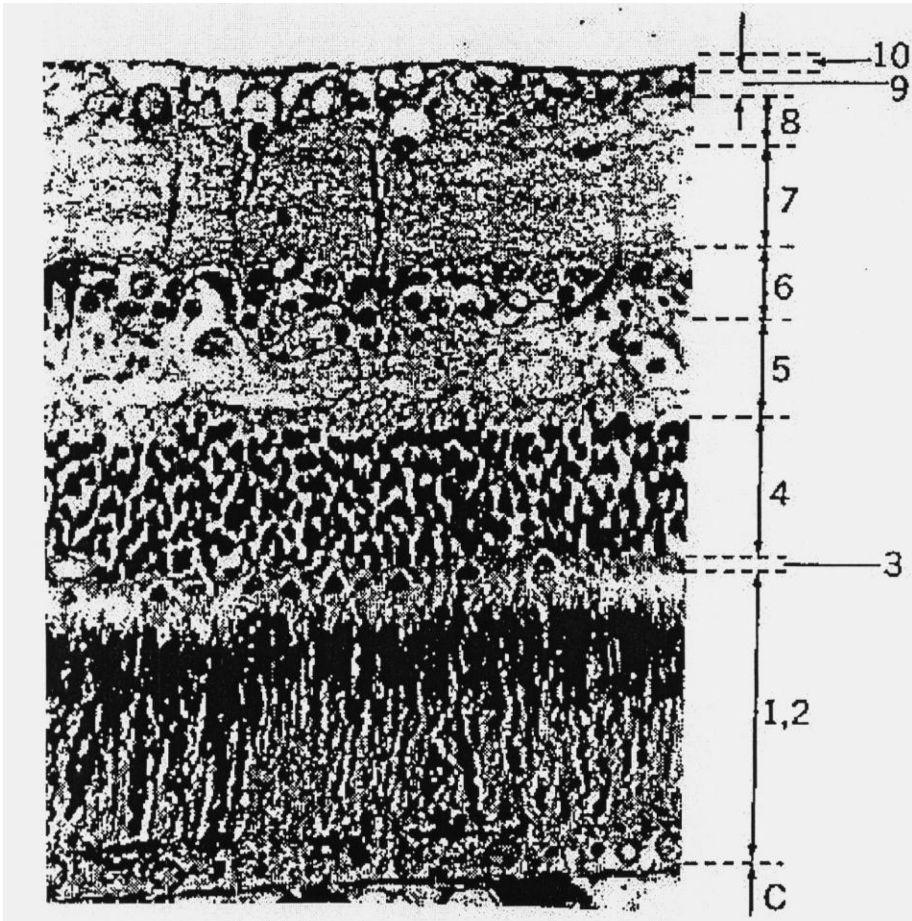
1- Corneal epithelium.

2- Stroma.

3- Endothelium.

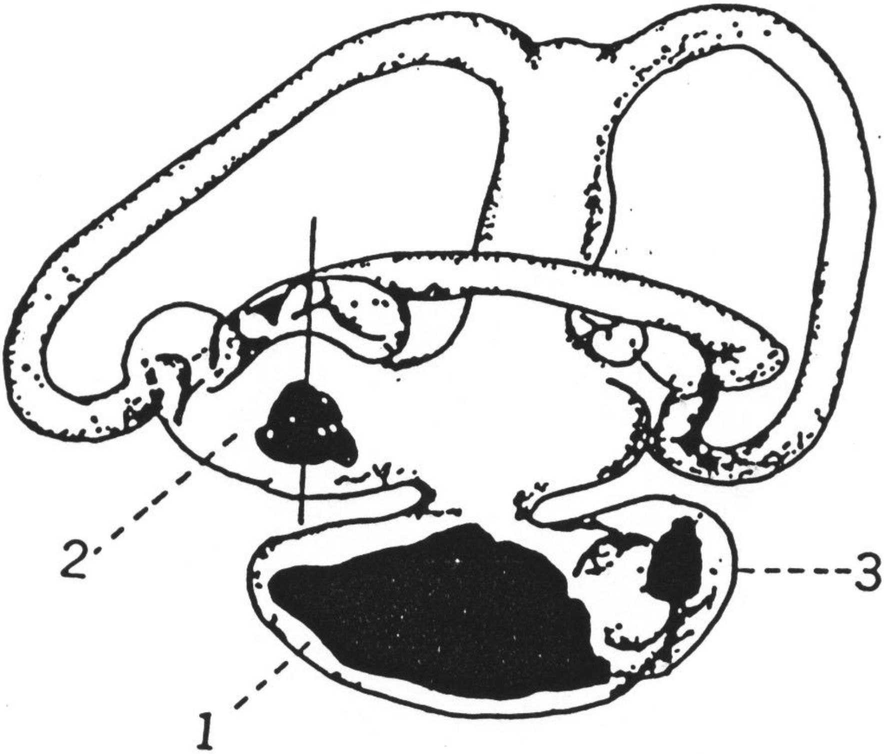
4- Lens capsule.

5- Lens fibers.




**THE RETINA OF TELEOSTS**

Pigment epithelium and pacillary layer.
Outer limiting membrane.
Outer nuclear layer.
Outer plexiform layer.
Inner nuclear layer.
Inner plexiform layer.
Layer of ganglion cells.
Layer of optic nerve fiber.
Inner limiting membrane.
Chorioidea.

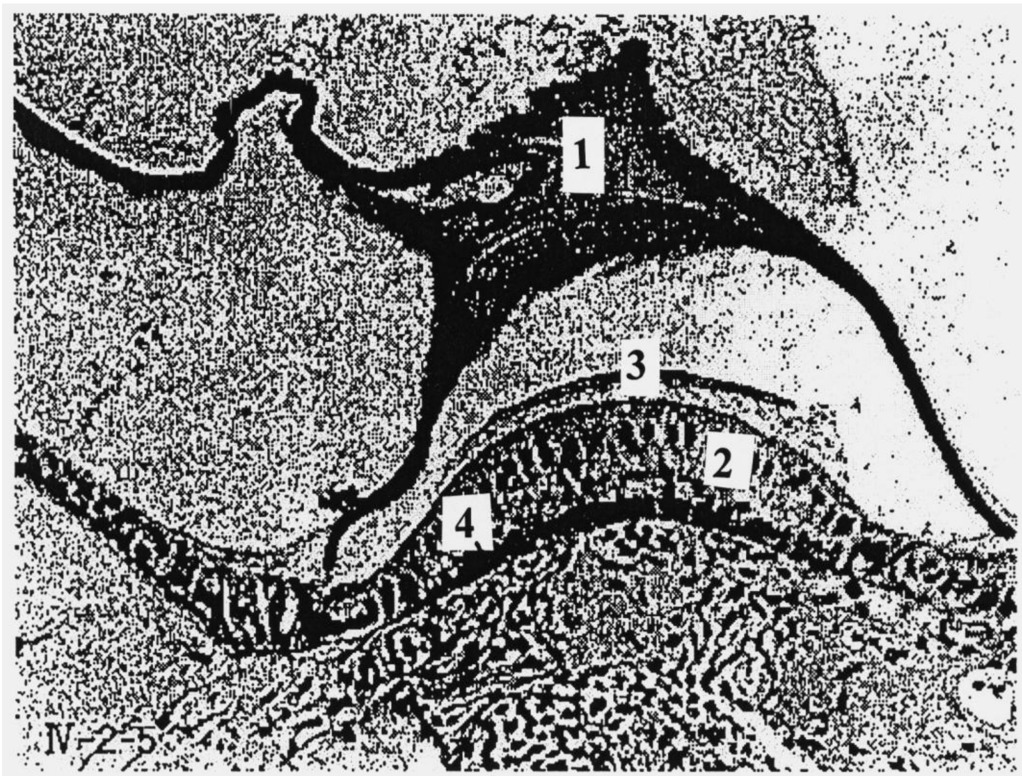



**DIAGRAMMATIC ILLUSTRRATION OF THE TELEOSTEAN INNER EAR**

1- Sacculus.

2- Utriculus.

3- Lagena.



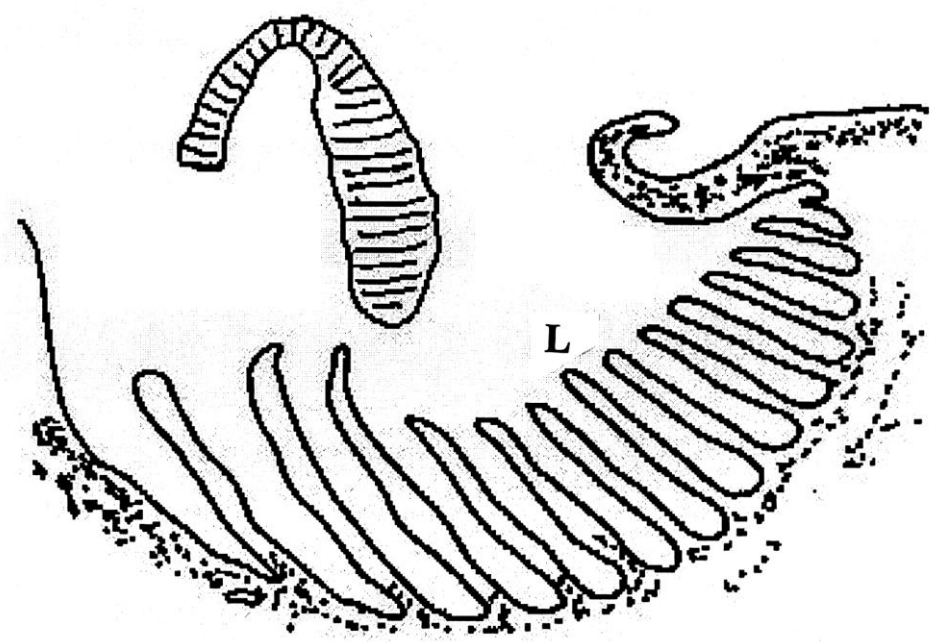

**THE CRISTA AMPULLARIS**

1- Tectorial membrane.

2- Sensory cells.

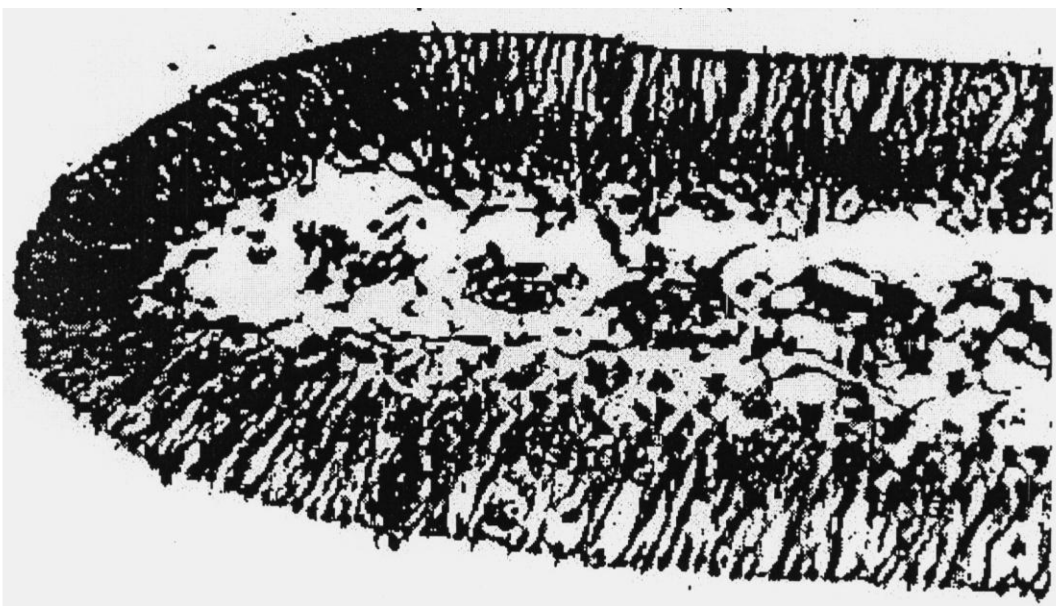
3- Sensory hair.

4- Supporting cells.




**L.S. OF THE OLFACTORY POUCH OF TELEOSTS**

showing, the olfactory lamellae (L)



**OLFACTORY LAMELLA OF TELEOSTS**

showing , the olfactory epithelium .

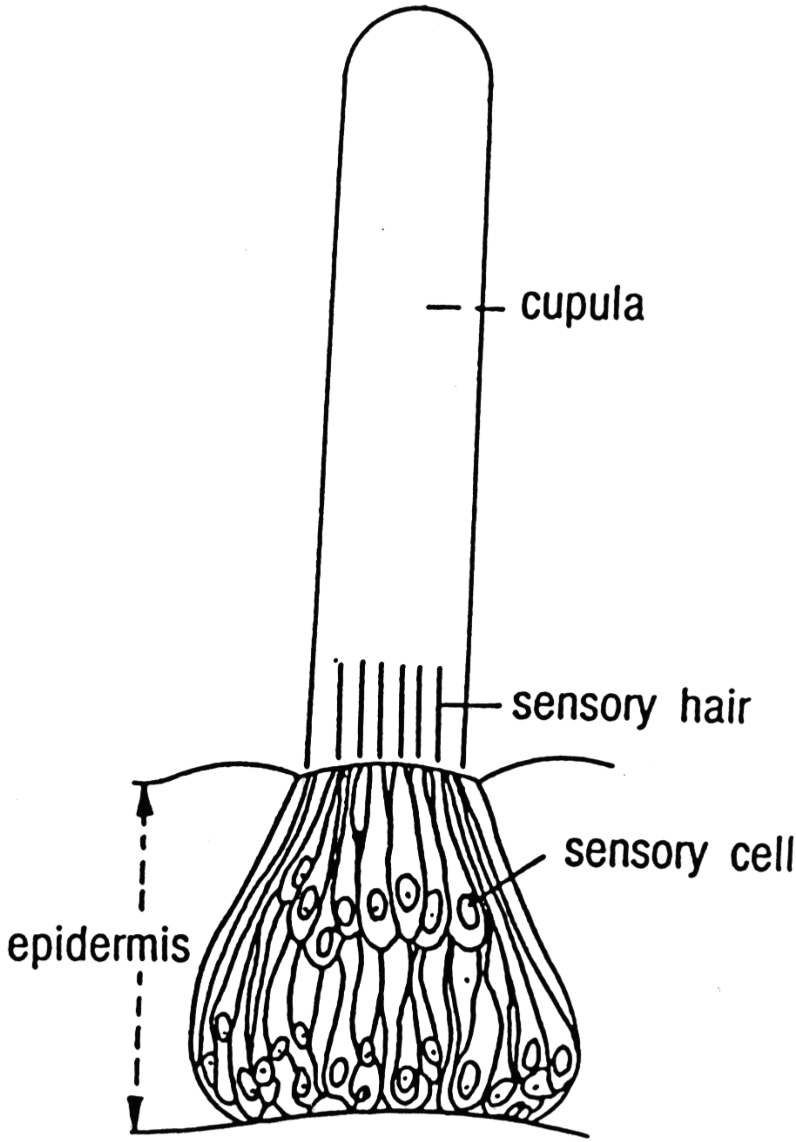



**DIAGRAM OF THE FREE NEUROMAST**

(in the acoustico-lateral system )

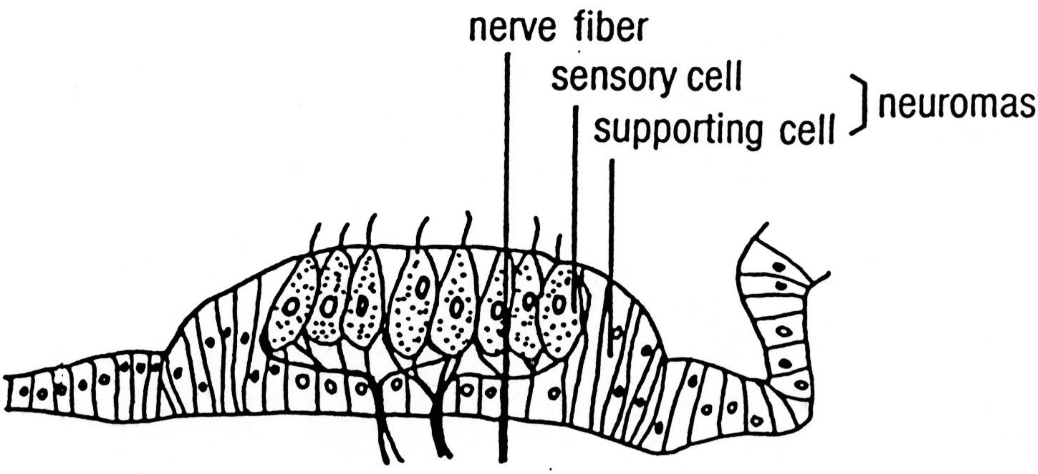
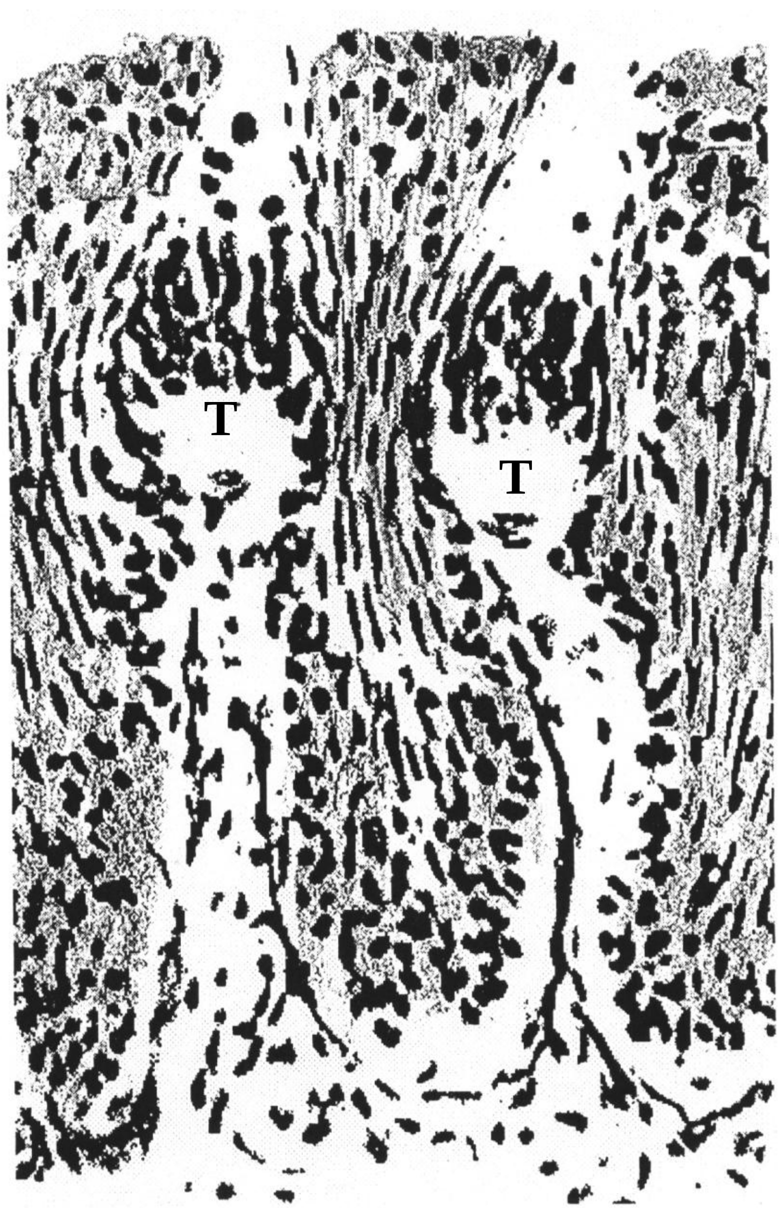
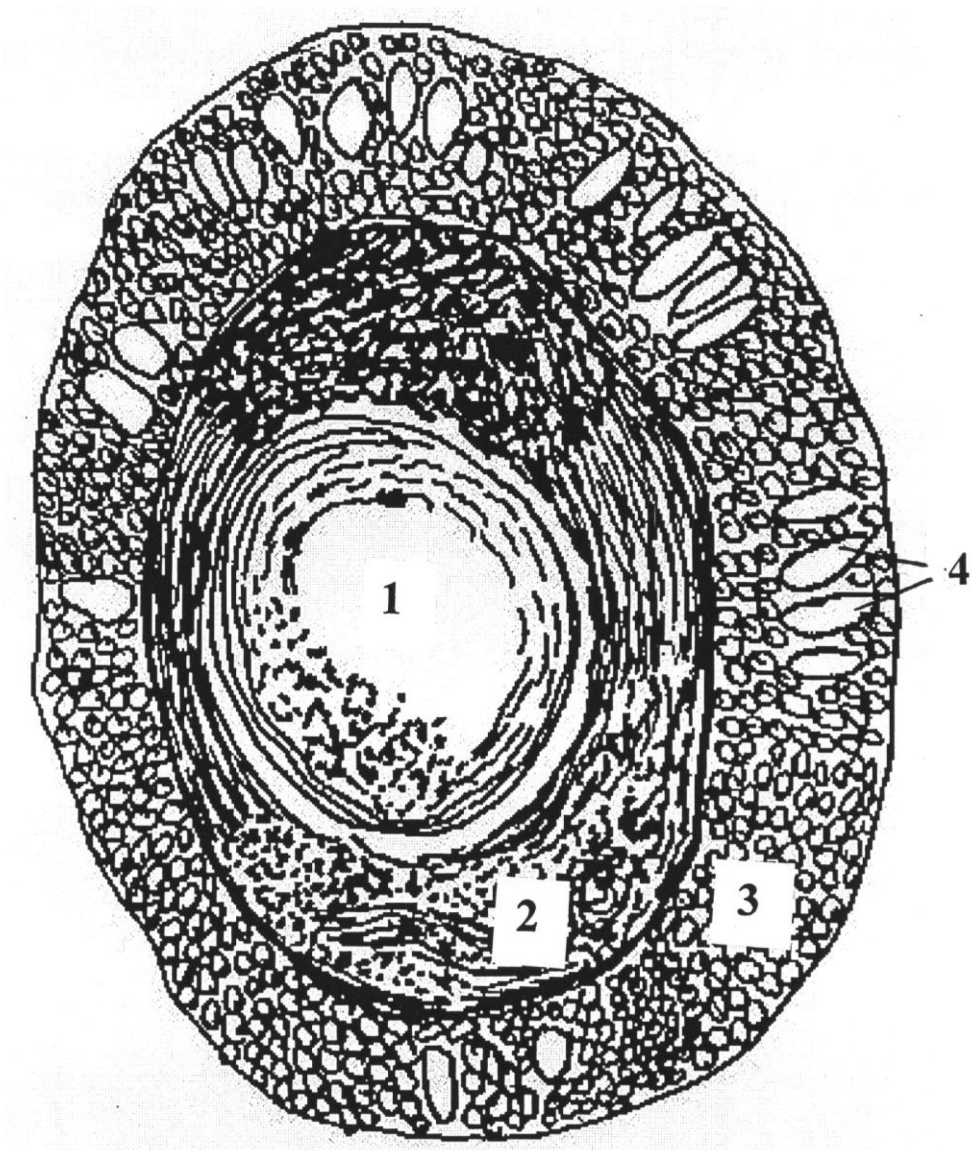



**DIAGRAM OF THE FREE NEUROMAST**

( in the pit organ )




**THE TASTE BUDS IN TELEOSTS (T)**




**C.S. of the barbel of teleosts**

1- Cartilage.

2- Dermis.

3- Epidermis.

4- Mucous cells.

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