

# Histology of the Atlantic Cod: The Atlas Series

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## Introduction

A series of four atlases has been produced. Originally atlases on supporting tissues (muscle, cartilage and bone), the urinary system, the brain and sensory organs and the circulatory system were planned, but these were not completed because of lack of funding and change in priorities. The first atlas was published in 1987, when cod was one of the most economically important fish in Canada (in 1985 the landed volume of cod for the east coast of Canada was 478,000 metric tonnes, having a value of \$187,000,000). Much effort had been expended on assessment of stocks of eggs, larval, juvenile and adult cod; but few histological studies had been done. The atlas series was started to provide a basic histology of the cod, so that the effects of factors such as disease, parasites, and pollutants could be properly evaluated. Given the slow return of the cod stocks, this baseline knowledge is also important to determine factors affecting the remaining cod. It was expected that the atlases could be used as a point of reference for similar tissues in other finfish species, and these atlases were aimed at scientists and veterinarians, technicians, hatchery managers and students specializing in finfish. Requests for the atlases have been received from veterinarians and scientists working on fish in this country and abroad; permission has been requested to photocopy parts of the atlases for teaching purposes at veterinary colleges; they have been used in presentations to fishermen on the reproductive stages of fish.

Work done for the cod larval atlas has been a basis for research on larvae of species of marine finfish that are being considered for use in aquaculture. These species include haddock, which is similar in its development to cod, winter flounder and halibut.

## The Atlases

The atlases are illustrated with figures showing gross morphology and light microscopy in both color and black and white, and ultrastructural features are illustrated using both scanning and transmission electron micrographs. This enables microscopic structure to be correlated with gross structure and function. Common parasites are illustrated. Existing atlases of fish histology use mainly light microscopy, but it was felt that electron microscopy was essential for an up-to-date description, as in textbooks of human histology. Work by other authors is discussed, and in many cases study of complete organ systems for the atlases enabled gaps in our knowledge to be filled. A detailed bibliography of pertinent work is included with each atlas.

## Atlas 1: Digestive Tract (Morrison 1987)

The first atlas describes the digestive tract and the organs associated with it; the gallbladder, liver, pancreas and swimbladder. During research for both this atlas and the second, "spines" were found



Figure 1: Projections on gill arch (ga), with teeth (t). Light micrograph of paraffin section stained with haematoxylin and eosin. Bar = 500mm.

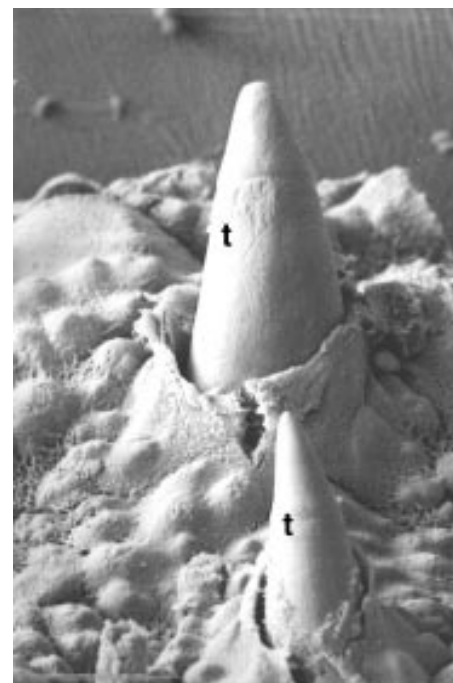


Figure 2: Teeth (t) on lower pharyngeal tooth plate. Scanning electron micrograph. Bar = 200mm.

on the gill arches. These have been described in several species of fish using scanning electron microscopy. After sectioning it was realized that these are in fact teeth (Fig. 1), which form a complete circle with those on the pharyngeal tooth plates (Fig. 2). This is of functional significance when it is considered that cod ingest live prey, which must be restrained until swallowed. In the rectum we found small parasites - probably amoebas- and bacteria attached to the epithelial surface. We also discovered flagellates (Fig. 3), found on further study to be a new species, *Spironucleus torosus* (Poynton and Morrison 1990). This species has a parasitic phase in which it is attached to the surface of the epithelial cells. The cod differs from salmonids since it is normal for the liver to contain a great deal of lipid except in the spring, when spawning. The cod is also unusual because most of the endocrine tissue of the pancreas is concentrated in a "principal islet" on the gallbladder. Attempts have been made to use this islet as a source of insulin. The coccidian protozoan parasite *Goussia gadi*, which had been reported in cod

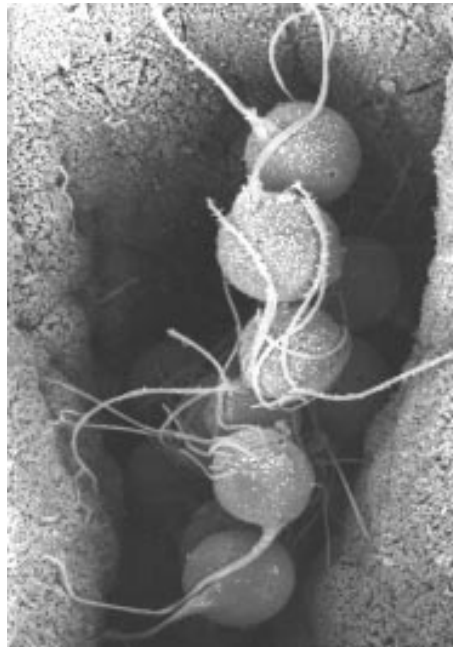


Figure 3: Flagellates in the rectum. Scanning electron micrograph. Bar = 5mm.

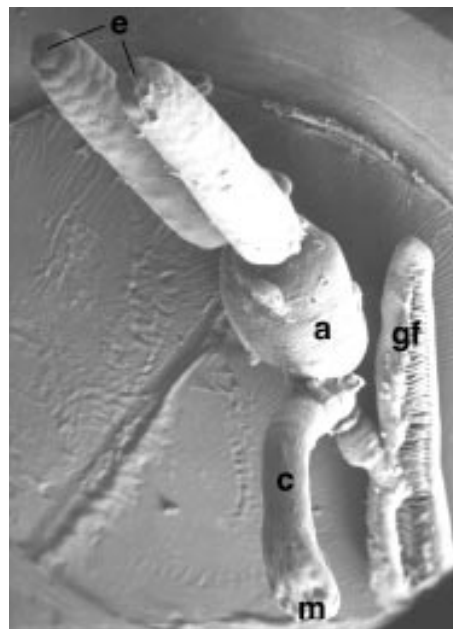


Figure 4: The copepod *Clavella adunca* on a gill filament (gf). Scanning electron micrograph. Mouth, m; cephalothorax, c; abdomen, a; egg sacs, e. Bar = 1mm.

swimbladders in Europe (Fiebiger 1913) was not present in the cod studied for the atlas, but has been found in further studies (Morrison and Marryatt 1990). This parasite can cause the swimbladder to be filled with pus, and may affect the ability of the host to control its buoyancy (Odense and Logan 1976).

### Atlas 2: Respiratory System (Morrison 1988)

The second atlas shows the structure of the gills and also the pseudobranch. Dr. R. Boutilier of Dalhousie University injected a cod with methyl methacrylate for this atlas. This resin polymerised in the blood vessels of the gills and the tissues were then removed, leaving a “corrosion cast” of the blood vessels (Fig. 5). Cysts of the microsporidian parasite *Loma branchialis* (Morrison and Sprague 1981) and the copepods *Lernaeocera branchialis* and *Clavella adunca* (Fig. 4) were commonly found on the gills. *L. branchialis* is usually near the base of the gills, and in many cases penetrates the blood system and sometimes the heart, producing loss in body weight (Khan *et al.* 1986). The enigmatic “nodule of unknown etiology” (MacLean *et al.* 1986) was also found in many gill filaments. This has been described in other species of fish, but its etiology is unknown.

The pseudobranch possesses lamellae like the gills, but they are fused and covered by connective tissue. The pseudobranch receives oxygenated blood and has no respiratory function. It consists of specialised cells with closely packed mitochondria and numerous smooth tubules, and it has been suggested that it may have an endocrine function. Removal of the pseudobranch causes darkening of the fish, so it appears to control the chromatophores; removal also reduces the ability of the swimbladder to secrete gas. Nodules of *Loma branchialis* were found in some pseudobranchs, and “pseudobranch tumors” were found in some cod (Morrison *et al.* 1982). The tumors consisted of rounded cells with a round nucleus and prominent nucleolus, which are believed to be protozoan parasites.

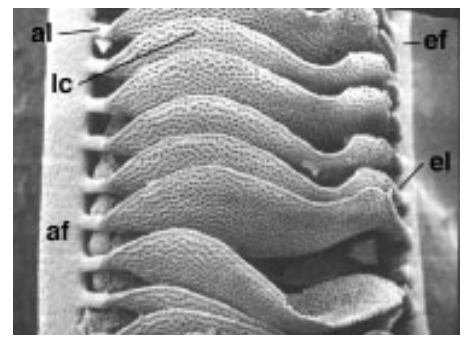


Figure 5: Corrosion cast of blood vessels of gill filament. Scanning electron micrograph. Afferent filament artery, af; efferent filament artery, ef; afferent lamellar arteriole, al; lamellar capillary sheet, lc; efferent lamellar arteriole, el. Bar = 500mm.

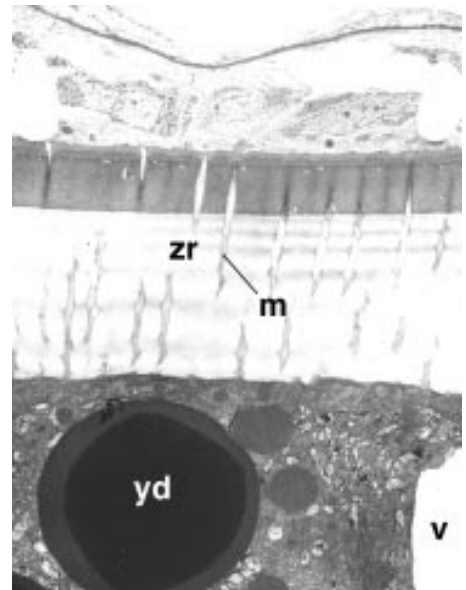


Figure 6: Periphery of developing oöcyte. Transmission electron micrograph. Zona radiata, zr; microvilli in pores in the zona radiata, m; vesicle, v; yolk droplet, yd. Bar = 2mm.

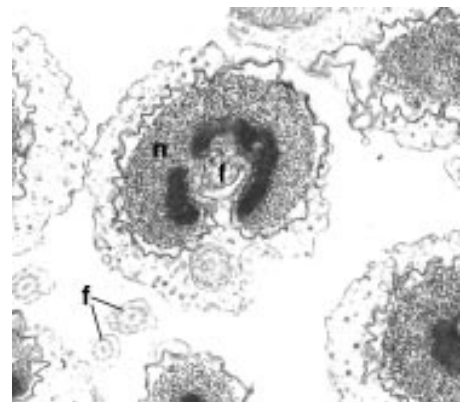


Figure 7: Maturing spermatozoa. Transmission electron micrograph. Nucleus, n; cross-section of flagellum, f. Bar = 500nm.

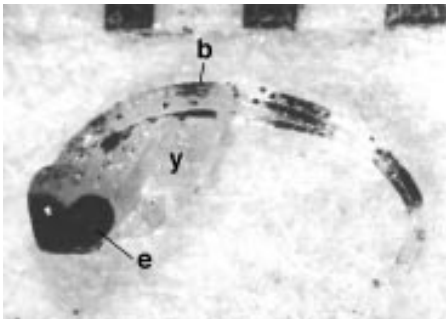


Figure 8: Peak-hatch cod larva. Bar of pigment on body, b; eye, e; yolk-sac, y. Bar = 0.5mm.



Figure 9: Three-day post-hatch cod larva, dark-field. Eye, e; Meckel's cartilage, M; liver, l; yolk-sac, y; fin-fold, f. Bar = 1.0mm.

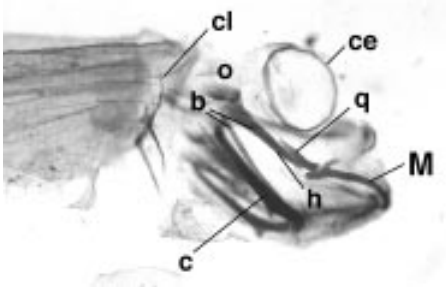


Figure 10: Nine day post-hatch larva stained for cartilage and bone. Cartilage around eye, ce; otic capsule, o; Meckel's cartilage, M; hyosymplecticum, h; quadrate, q; ceratohyal, c; branchial arch, b; cleithrum of pectoral girdle, cl. Bar = 500mm.

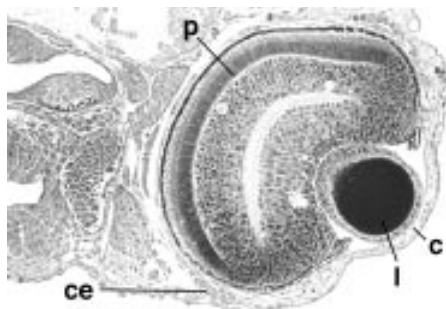


Figure 11: Section through the eye of a peak-hatch larva. Larva embedded in JB4 resin, sectioned at 1mm and stained with toluidine blue. Lens of eye, l; photoreceptors of retina, p; cornea, c; ring of cartilage around eye, ce. Bar = 50mm.

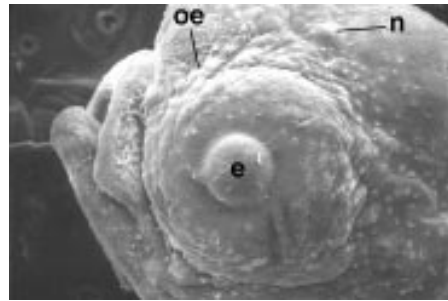


Figure 12: Head of 2 day post-hatch larva. Scanning electron micrograph. Eye, e; neuromast, n; olfactory epithelium, oe. Bar = 100mm.

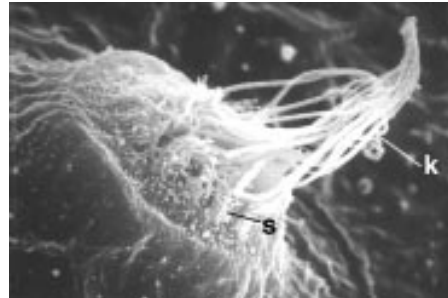


Figure 13: Neuromast on head of 44 day post-hatch larva. Scanning electron micrograph. Kinocilium, k; stereovillus, s. Bar = 2mm.

### Atlas 3: Reproductive System (Morrison 1990)

The gross appearance and histology of the various stages of maturity are illustrated in color and black and white, and the ultrastructure of the development of the oöcytes and spermatozoa is also illustrated (Fig. 6 and 7). Problems of staging, such as differentiating between a virgin and resting fish, are discussed, and a Table describing the stages is presented. The only abnormalities found in studies for the atlas were cysts of *Loma branchialis*, which spreads throughout the organs of some cod (Morrison 1983). We have since found *Ichthyophonus hoferi*, which is believed to be a fungus, in some cod gonads.

### Atlas 4: Histology of the Cod Larva (Morrison 1993)

The last atlas, on the histology of the cod larva is the largest and most ambitious. The organ systems are described at several stages of development, in as much detail as possible. Larvae grown at St. Andrews Biological Station by Dr. Neilson provided the samples for this atlas. The pigmentation (Fig. 8) and gross morphology (Fig. 9)

are shown, and a cartilage and bone stain modified from that used on larger animals was employed to reveal the developing skeleton (Fig. 10). Histological techniques were used to show the structure of the organs (Fig. 11). The surface of the larva was studied using scanning electron microscopy at both low magnifications (Fig. 12), and at higher magnifications to show details of such features as the neuromasts (Fig. 13). Transmission electron microscopy was used to study internal ultrastructure (Fig.14).

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