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Atlas of Lobster Anatomy and Histology

Jeffrey D. Shields  
*Virginia Institute of Marine Science*

Robert A. Boyd  
*Virginia Institute of Marine Science*

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Atlas of Lobster Anatomy and Histology

Jeffrey D. Shields, Robert A. Boyd
Virginia Institute of Marine Science
The College of William & Mary


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This web publication replaces an earlier atlas of lobster anatomy (Famiglietti & Shields 2002). The 2014 atlas has new photomicrographs, labeling and covers additional tissues, as well as an expanded set of photos on the lobster gross anatomy. The older atlas had some issues with the web presentation so we have removed it. The citation for the older version was:

Preface

This is a histological atlas of the most common organs and tissues found in the American lobster, *Homarus americanus*. The atlas contains photomicrographs from histological sections of healthy tissues. The sections were all cut at 5-6 µm and were all stained with hematoxylin and eosin as in Shields et al. 2012b. The atlas contains pictures of tissues that are readily observed in dissection and several that are commonly affected by diseases. It is not a complete atlas. Several organs are not covered, notably the central nervous system, ventral nerve ganglion, several sensory organs, and organs associated with molting.

The atlas may be useful to you for comparisons with other lobster species, or other crustaceans. Three other references offer similar anatomical or histological perspectives for model crustaceans: penaeid shrimp (Bell & Lightner, 1988), the American lobster (Factor, 1995), and the blue crab (Johnson, 1980). Herrick (1895, 1909) undertook histological descriptions of several tissues in the lobster. His classical works are now freely available online.

Our lobster atlas arose partially out of the “100 Lobster Project” and partially from an earlier atlas (Famiglietti & Shields 2002). The histological analysis for the “100 Lobster Project” offered an unparalleled perspective on tissues from normal, healthy lobsters and those affected by epizootic shell disease (Shields et al. 2012a,b). This presented an opportunity to revise, expand and rework the earlier atlas into a more comprehensive and accessible pictorial presentation.

The current atlas is a work in progress. We foresee possible expansions by adding other tissues, other staining methods, histopathology, and other imaging techniques. If you use the atlas, let us know what could be added or what improvements could be made. In addition, if you find errors, let us know, and we’ll make efforts to fix them.

Jeffrey D. Shields
Professor of Marine Science
Jeff@vims.edu

Robert A. Boyd

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**Acknowledgements**

**Bibliography**
The exterior gross anatomy of the lobster has been depicted by Hadley (1906), Herrick (1909) and is reviewed in Factor (1995).
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Heart

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Muscle

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Gill

Detail of lamellae demonstrating their tubular nature. One side of the lamella shows the thin epidermal layer, the other side shows an oblique epidermal layer, with a hemal sinus in the middle. from Lobster ME29C. D = epidermis, Lam = lamella, sin = hemal sinus, bar = 100 µm.
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Gill

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Hematopoietic tissue is the source of hemocytes, or blood cells, in the lobster. The tissue occurs as lobules of cells on the dorsal pyloric stomach, or foregut (Lobster ME24A). Note the nerve tract interspersed between the nodules of hematopoietic tissue. lob = lobule, n = nerve, bar = 100 µm.
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Antennal “Green” Gland

Antennal gland, or green gland, at the anterior end internally, ventral to the eyes, with a small piece of the bladder attached (arrow).
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Coelomsac showing squamous epithelial cells arranged in a complex pattern within the gland (lobster ME34A). Note the ducts within the coelomosac and the fibrous connective tissue around the organ. There is no connective tissue within the sac. 

d = duct, fcon = fibrous connective tissue, le = labyrinth epithelium, bar = 50 µm.
Antennal gland

Border between the labyrinth and coelomosac (lobster ME34A). Note the large duct within the coelomosac (arrow). This could be a connection with the bladder or an arteriole. ce = coelomosac, le = labyrinth, ly = labyrinth, po = podocyte, bar = 100 µm.
Podocytes in the coelomosac (lobster ME34A). These cells function in excretion and osmoregulation. Note the many brown granules present in the podocyte (arrow). An arteriole is also present. $aa =$ arteriole, $hsp =$ hemal space, $h =$ hemocyte, $po =$ podocyte, bar = 10 µm.
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Antennal gland

Interdigitation of the secretory labyrinth (lobster ME22A). Sloughed cells are components of the secretory labyrinth.

Bb = brush border, h = hemocyte, le = labyrinth epithelium, ss = sloughed epithelial cells, bar = 20 µm.
Eye and eyestalk

Lateral view of lobster eye.
Eye and eyestalk

Dorsal aspect of lobster eye. Note the cuticle that covers the eyestalk is thicker and has a cuticular pigmentation compared with the thin cuticle that covers the eye proper.

eyes = eyestalk.
Eye and eyestalk

Gross view of the lobster eyestalk in longitudinal section. The eyestalk was removed, fixed in z-fix, decalcified in formic acid – sodium citrate, then bisected with a razor. Note the increasing thickness of cuticle on the lateral margins of the eye. cut = cuticle, lm = lamina ganglionaris, m = retractor muscle, oma = ommatidia, on = optic nerve region, np = nerve plexus.
Low magnification of the lobster eyestalk in longitudinal section (lobster AM 65). The empty space between the cuticle and ommatidia is an artifact of fixation. Note the increasing thickness of cuticle on the lateral margins of the eye. bm = basement membrane of ommatidial region, cut = cuticle, lm = lamina ganglionaris, m = retractor muscle, me = medulla externalis, mi = medulla internalis, mt = medulla terminalis, np = nerve plexus, oma = ommatidia, tg = tegmental glands, bar = 900 µm.
Eye showing ommatidia (bracket) stretching from the cuticle to the basement membrane (lobster RI44). Note the separation of the premolt cuticle from the old cuticle. bm = basement membrane, cc = crystalline cone, cut = cuticle, om = ommatdium, pr = proximal retinula, rh = distal retinula and rhabdom, bar = 300 µm.
Eye and eyestalk

Ommatidia stretching from the cuticle to the basement membrane (lobster RI44). Accessory pigment cells have screening pigments (arrows) around the cones and at the base of the ommatidium. bm = basement membrane, cc = crystalline cone, cut = cuticle, pr = proximal retinula, rh = distal retinula and rhabdom, bar = 100 µm.
Cornea associated with individual ommatidia. Note the screening pigments in the accessory pigment cells (arrows). cr = cornea, cc = crystalline cone, cut = cuticle, om = ommatidia.

Higher magnification of corneal cells (lobster RI53). The open areas are artifacts introduced during processing. ch = corneal hypodermis, cc = crystalline cone, cut = cuticle, bar = 10 µm.
Juncture of the ommatidia with the basement membrane in the eye (lobster RI44?). Screening pigments (arrows) surround the proximal rhabdom. Note the vasculature around the basement membrane. bm = basement membrane, hc = vasculature of the hemocoel, pr = proximal retinula, on = optic nerves, bar = 50 µm.
Proximal retinula of the ommatidium (lobster RI44). Note the pigment granules extending above and around the rhabdom, as well as the pigment cell nucleus (arrow). prhc = proximal retinula, rh = rhabdom, bar = 20 µm.
Region of the basement membrane separating the ommatidia from the optic nerve fibers (lobster ME75E). Many pigment granules are present in accessory pigment cells (arrow) that extend into the underlying tissue. bm = basement membrane, g = granules, lc = lacuna of hemocoel, on = optic nerve, bar = 10 µm.
Eye and eyestalk

Optic nerve region between the ommatidia and the lamina ganglionaris (lobster AM65). Note the long optic nerve fibers attaching the ommatidia to the lamina ganglionaris and the highly vascular nature of the region. art = arteriole, bm = basement membrane, hs = hemal sinus, lg = lamina ganglionaris, on = optic nerve fibers, bar = 50 µm
Eye and eyestalk

Detail of lamina ganglionaris (lobster RI44). cr = rind of support cells, gl = glial cells, lg = lamina ganglionaris, mx = medulla externalis, onf = optic nerve fiber, bar = 20 µm.
Eye and eyestalk

Highly vascularized region of the medulla externalis showing optic nerve tracts from the lamina ganglionaris into the region. Specialized rind cells or secretory cells encase the optic nerves as they enter into the medulla internalis (not shown) (lobster AM65). art = arteriole, cr = rind cells, me = medulla externalis, on = optic nerve fibers, bar = 50 µm
Eye and eyestalk

Nerve plexus known as the medulla internalis showing optic nerves entering from the medulla externalis and exiting the medulla internalis (lobster AM65). The cell rind of the medulla internalis is thin and less organized than that of the other medullar ganglia. art = arteriole, cr = rind cells, mi = medulla internalis, on = optic nerve fibers, bar = 100 µm
Eye and eyestalk

Nerve plexus known as the medulla terminalis with individual optic nerves entering from the medulla internalis (lobster AM65). Neurosecretory cells (arrows) occur loosely around the outer margin of the medulla internalis and terminalis. The optic nerves continue from here on to the brain of the lobster. art = arteriole, fcon = fibrous connective tissues, cr = rind cells, mt= medulla terminalis, on = optic nerve fibers, bar = 100 µm
Eye and eyestalk

Dorsal to the medulla terminalis is the sinus gland which controls molting. The lumen of the gland is not shown in this micrograph. Note the numerous neurosecretory cells, the neurilemma and glial cells surrounding the medullae and sinus gland (lobster AM65). gl = fibrous glial cells, mt = medulla terminalis, nsc = neurosecretory cells, sg = sinus gland, bar = 100 µm
Dense grouping of tegmental glands near the proximal end of the eyestalk (lobster RI44). Inset shows more detail of a tegmental gland with a common duct. con = connective tissue, cut = cuticle, epi = columnar epithelial cells underlying the cuticle, gran = cuticularized granuloma, tg = tegmental gland, bar = 50 µm.
Midgut

Gross view of exposed thoracic cavity showing midgut (arrow) running between lobes of the hepatopancreas.
The food bolus of arthropods is encased in a peritrophic membrane secreted by the midgut. This low magnification view of the midgut shows the epithelium of the organ, the thin layer of supporting tissues around it, and a food bolus with a peritrophic membrane (arrows) around it (lobster RI92). bl = food bolus (gut contents), ec = epithelial cells, fcon = fibrous connective tissue with supporting cells, L = lumen, bar = 1200 µm.
The midgut epithelium is columnar with a brush border. Underlying it is a basement layer and a band of reserve inclusion cells interspersed among myofibrils of circular muscle (lobster RI92). bl = food bolus, bm = basement layer, ec = epithelial cell, pm = peritrophic membrane, RI = zone of reserve inclusion cells and myofibrils, bar = 50 µm.
The midgut epithelium is columnar with a brush border. The peritrophic membrane is a thin layer of cuticle that has separated (as an artifact) from the bolus (lobster RI92). bl = food bolus, ec = epithelial cell, L = lumen, pm = peritrophic membrane, bar = 50 µm.
The midgut has columnar epithelial cells supported on a basement membrane overlying small muscle fibrils and absorptive reserve inclusion cells (lobster RI92). Basal cells (arrows) can be seen among the epithelial cells. Their function is not known. bb = brush border, bm = basement membrane, fcon = fibrous connective tissue, ec = epithelial cells, L = lumen, m = muscle, RI = reserve inclusion cells, bar = 20 µm.
The hepatopancreas is comprised of a mass of individual tubules (arrow) connected through common absorptive ducts to the midgut gland.
Hepatopancreas

Gross view of hepatopancreas showing individual tubules in longitudinal and cross sections (lobster ME23A). It = longitudinal section of tubules, xt = cross section of tubule, bar = 600 µm.
Hepatopancreatic tissue showing two zones: the E-cell (Embryozellen) zone near the apical end of the tubule, and the digestion zone with B- (Blasenzellen), F- (Fibrillenzellen) and R-cells (Restzellen) near the basal end. bc = B-cell, ec = E-cell, fc = F-cell, fcon = fibrous connective tissue, L = lumen, rc = R-cell, s = B-cell secretion, bar = 100 µm.
Hepatopancreas

The stem E-cells in a cross section near the apical end of a hepatopancreatic tubule (lobster ME19). Note the brush border at the apical end of the cells (arrow). bm = basement membrane, ec = E-cell, L = lumen, s = B-cell secretion, bar = 10 µm.
Hepatopancreatic tubules in cross section (lobster ME19). Note the higher abundance of E-cells in tubules sectioned near the edge of the tissue. This is because the apical portions of these tubules cross the plane of section while tubules within the inner portion of the tissue were sectioned in a more basal region. bc = B-cell, ec = E-cell, L = lumen of tubule, bar = 100 µm.
Secretory B-cells in the hepatopancreatic tubule (lobster ME19). These are holocrine cells in that they secrete their entire contents into the lumen. The nucleus (arrow) is characteristically pushed to the side of the cell. $bc =$ B-cell, L = lumen, $s =$ B-cell secretion, bar = 10 µm.
F-cells and R-cells in a hepatopancreatic tubule (lobster ME19). The function of the F-cells is unknown; they may become B-cells. The R-cells function in storage of products. bb = brush border, bm = basement membrane, fc = F cells, L = lumen, rc = R cells, bar = 10 µm.
Fixed phagocytes surrounding an arteriole (arrow) in the hepatopancreas (lobster ME23A). The fixed phagocytes remove pathogens from the tubules. bm = basement membrane, fc = F-cell, ff = fixed phagocytes, hs = hemal sinus, rc = R-cell, RI = effete reserve inclusion cell, bar = 50 µm. Photo from Shields et al. 2012b.
Male Gonad: Testis

Thoracic cavity with the heart removed showing testes and hepatopancreas. t = testis, hep = hepatopancreas, m = thoracic muscle
Lobster testis is made up of many lobules (arrow) surrounding a seminiferous duct encased in a thin capsule of fibrous connective tissue cells.
Cross section of testis showing a lobules containing germinative centers in various stages of development (lobster ME23B). A capsule of fibrous connective tissues encases the testis, with thinner connective tissues supporting the lobules internally. l = lobules, f = fibrous capsule, sem = seminiferous duct bar = 300 µm
Male Gonad: Testis

Testis tissue from lobster ME23B showing non-flagellated mature sperm within a seminiferous epithelium. f = fibrous connective tissues, spg = spermatogonia, spM = mature sperm, s1 = primary spermatocytes, s2 = secondary spermatocytes, sem = seminiferous duct with spermatocytes, bar = 100 µm.
Non-flagellated mature sperm cells (arrow) in lumen of seminiferous duct of testis (lobster ME23B). spg = Spermatogonia, spM = mature sperm, sem = seminiferous duct wall, bar = 20 µm.
Spermatogonia in testis (lobster ME23B). f = fibrous connective tissues, s1 = primary spermatocytes, s2 = secondary spermatocytes, bar = 20 µm.
Testicular lobules within the testis (lobster ME23B). \( f = \) fibrous connective tissues, \( spg = \) spermatogonia, \( sem = \) seminiferous duct, \( s1 = \) Primary spermatocytes, \( s2 = \) Secondary spermatocytes, bar = 100 \( \mu m \).
Male Gonad: Ejaculatory Duct

Ventral view of lobster showing male gonopore (arrow) and specialized nature of the first pleopod.
Male Gonad: Ejaculatory Duct

Close up view of male gonopore (arrow) and male first pleopod.
Male Gonad: Ejaculatory Duct

Ejaculatory duct dissected from abdomen (circle).
Low magnification of the ejaculatory duct (lobster ME19). The duct is the posterior-most portion of the posterior vasa deferens. ec = epithelial cells, ms = skeletal muscle, tg = zone of tegmental glands, bar = 1500 µm.
Zone of tegmental glands associated with muscle laterally around the posterior ejaculatory duct (lobster ME19). These glands may provide additional lubrication to the duct or lubrication for molting. fcon = fibrous connective tissue, ms = skeletal muscle, tg = zone of tegmental glands, bar = 50 µm.
Male Gonads: Ejaculatory Duct

Cross section of ejaculatory duct containing mature sperm within a waxy spermatophore (lobster ME 12-1).

fcon = fibrous connective tissue, RI = reserve inclusion cell, spe = spermatophore, spm = mature sperm, scon = spongy connective tissue, bar = 50 µm.
Male Gonads: Ejaculatory Duct

Detail of ejaculatory duct with mature sperm in a waxy spermatophore (lobster ME 12-1). ec = columnar epithelial cells, fcon = fibrous connective tissue, RI = reserve inclusion cell, spe = spermatophore, spm = mature sperm, bar = 50 µm.
Male Gonads: Ejaculatory Duct

Columnar epithelium in the ejaculatory duct (lobster ME19). Note the brush border. cill = cilia, ec = epithelial cells, fcon = fibrous connective tissue, mS = skeletal muscle fibers, bar = 20 µm
Female Gonad: Ovary

Ovary showing ova in different stages of maturation (lobster ME44B).

fcon = fibrous connective tissue ‘rind’, ml = mature lobule of ovary, iml = immature lobule, pre = previtellogenic oocyte, vova = vitellogenic oocyte, bar = 1500 µm.
Female Gonad: Ovary

Detail of ovarian lobules showing maturing and immature lobules. acb = accessory cell border, fcon = fibrous connective tissue ‘rind’, ml = mature lobule of ovary, iml = immature lobule, pre = previtelligenic ooocyte, vova = vitellogenic oocyte, bar = 300 µm
Vitellogenic and previtellogenic oocytes in ovary (lobster ME46B). Note the large yolk (vitellogen) granules forming within the immature oocyte, the numerous granules within the adjacent vitellogenic oocyte, and the chorion (arrows). acb = accessory cell border, n = nucleus of oocyte, nu = nucleolus of oocyte, pre = previtellogenic oocyte, vova = vitellogenic oocyte, yg = yolk globule bar = 50 µm.
Female Gonad: Ovary

Detail of accessory cell border between two previtellogenic oocytes (lobster ME46B). acb = accessory cell border, yg= yolk globule, pre = previtellogenic oocyte, bar = 10 µm.
Yolk globules (vitellogenin) in vitellogenic oocyte (lobster ME46B). Note that some globules contain smaller globules inside them (arrow). \( yg \) = yolk globule, bar = 10 \( \mu m \).
Fibrous tissue around ovary (lobster ME46B). Note the border of accessory cells separating oocytes and the fibrous connective tissue delineating the ovary. acb = accessory cell border, fcon = fibrous connective tissue “rind” around ovary, pre = previtellogenic oocyte, vova = vitellogenic oocyte, yg = yolk globule, bar = 10 µm.
Bibliography
Bibliography


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