INTRODUCTION

The prevalence and severity of reef degradation due to coral disease has increased considerably over the last two decades. Emerging coral diseases have been linked to biotic and abiotic stressors and their synergistic interactions. Coral disease research is in its infancy and only beginning to take advantage of technologies and methodologies routinely used in epizootiology, clinical and diagnostic medicine, and pathology. This Coral Histopathology Workshop (and its predecessor) provided forums to begin adapting advances in biomedical and veterinary sciences, pathology, toxicology, and biotechnology to the study of coral disease and health; it also provided a foundation on which to build a framework for coral disease research that can interface with mainstream medical and veterinary research. The goals of this Workshop were to produce standards for (1) morphological descriptors based on accepted medical terminology, (2) consistent and concise descriptions of lesions in the field, as well as (3) clinical morphological diagnoses in the laboratory. Consensus reached during this workshop will be peer reviewed by the coral scientific community, both in public settings where the materials will be presented in workshop/discussion formats, directly soliciting review by others establishing terminology for the field, and through opinion papers in the peer-review literature to adopt specialized terminologies to facilitate communication among histopathologists. Once adopted, the terminology and microscopic descriptions will enable development of instructional materials and distance learning tools for coral histopathology.

E. Peters discusses coral pathology with R. Harley, T. Reynolds and V. Boschler. (Photo: Sylvia Galloway)

STUDY SETS OF HISTOLOGY SLIDES PROVIDED BY THE IRCP

An important facet of this workshop was the use of study sets of slides with serial sections from the same sample for independent individual microscopic review. Study sets for the workshop were provided by the International Registry of Coral Pathology at the NOAA/NOS/NCCOS/CCEHBR Cooperative Oxford Laboratory (COL) in Oxford, MD. Microslides were prepared from coral tissues accessioned by IRCP, from paraffin blocks provided by individual investigators, and the Registry of Tumors in Lower Animals (RTLA) in Sterling, VA. Contributors included Andy Bruckner, Margaret Miller, Esther Peters, Caroline Rogers, Debbie Santavy, Lou Sileo, Ernesto Weil, Dana Williams, Thierry Work, and Cheryl Woodley. COL staff who contributed to the preparation of the study sets included Kathy Price, Molly Billmyre, Dorothy Howard, Bob Bingaman and Shawn McLaughlin.

ANATOMY OF CORALS

(Note: Terms relevant to the description of coral histology are shown in blue at their first mention in the text, and are linked to the Glossary)

Gross anatomy of a scleractinian polyp from an imperforate coral (Fig. 1a)

Colonial scleractinian corals are composed of numerous interconnected polyps. The coenenchyme is the tissue between polyps and consists of a tubular network of gastrovascular canals that connect the gastrovascular cavity (gastric cavity) of adjacent polyps. At the oral end of the polyp are tentacles surrounding the oral disk; they have a bulbous structure at their tips, the acrosphere. The tentacles are studded with nematocysts/spirocysts, either scattered or clustered. Inside the ring of tentacles, within the oral disk, is a structure that surrounds the mouth and may be elevated, the peristome. Below the mouth is an invagination of the epidermis to form a short muscular tubular passageway to the gastric cavity, the actinopharynx. The area comprising the oral disk and actinopharynx is the column. The lower portion from the actinopharynx to the aboral end of the polyp is the coenosteum. Polyps and interconnecting tissues alike are made up of the same tissue layers. The surface body wall contains epidermis, mesoglea, gastrodermis and is found in the polyp and coenenchyme. The actinopharynx body wall lines the lumen of the actinopharynx. The basal body wall is the tissue apposed to skeleton, consists of calicodermis and gastrodermis separated by mesoglea, and is found in the aboral region of the polyp and lining the gastrovascular canals. Within the gastrovascular cavity are mesenteries, that provide structural support and increase the surface area of the gastrodermis to improve nutrient absorption, and the gonads develop within these structures.

Gross anatomy of a gorgonian polyp (Fig. 1b)

Colonial gorgonian polyps have some similarities in structure to scleractinian polyps but differ in significant aspects. The oral (distal) portion of the polyp, bearing the mouth and tentacles, is the anthocodia. Gorgonian polyp tentacles are characterized by two diametrically arrayed rows of short pinnules. The polyps are anchored to the axis at their aboral end and in some species the polyp is surrounded by a rigid structure, the anthostele, into which the anthocodia may be withdrawn. The axis has a central chord and is surrounded by an axial cortex and sheath. The axial sheath contains longitudinal canals characterized by sclerites that differ from those found in the coenenchyme. The coenenchyme is the tissue continuous between polyps, consisting of the surface body wall, gastrovascular canals and solenia, penetrating through the thick mesoglea stiffened with sclerites.

Skeletal features of a noncolonial scleractinian coral (Fig. 1c)

The skeleton deposited by an individual polyp within a colony is the corallite. The corallite is defined by three regions, the calice the columella, and the theca. The column-shaped skeletal projection of the central basal plate or modified inner septal edges is the columella. The calice includes the upper oral surface of a corallite, while the theca is the wall of the skeletal cup (corallite). The septa, vertical calcareous partitions, radiate from the corallite wall toward the central axis within the calice and provide support to the mesenteries. Extensions of the septa outside the calice onto the coenosteum are the costa.

Skeletal features of colonial scleractinians (Fig. 2)
The coral skeleton may be porous (perforate), with connections between the polyps through the skeleton **(Fig. 2a-b)**, or nonporous (imperforate) **(Fig. 2c-d).**

Mesentery features of a scleractinian polyp (Fig. 3)
Mesenteries are internal longitudinal partitions of tissue that provide structural support and increase surface area within the gastrovascular cavity. They are important in nutritional functions as well as fertility of anthozoans. A mesentery develops by infolding of the mesoglea and its lining gastrodermis from the body wall of the polyp. Multiple mesenteries are arranged radially within the gastrovascular cavity of the polyp (between the septa in scleractinian corals) and are attached to the oral disk. In the oral region, mesogleal pleats supporting the longitudinal retractor muscles are prominent; in the aboral region, gonads and loops of the mesenterial filament develop. Complete mesenteries attach to the polyp wall whereas incomplete mesenteries float free within the lumen of gastrovascular canals. The free edge of mesenteries consists of a cnidoglandular band with adjacent lobes.

Surface body wall organization of a scleractinian polyp; cell types associated with the epidermis, mesoglea, and gastrodermis (Fig. 4)
The generic cellular organization of coral tissue layers consists of an epidermis, the mesoglea and a gastrodermis. The epidermis may be either, located next to the external environment (surface body wall), located next to the skeleton (basal body wall) or located in the actinopharynx (actinopharynx body wall). The epidermis contains numerous cells including cnidae, mucocytes (mucosecretory cells), pigment cells, calicoblastic cells, epitheliomuscular cells and other supporting cells. The calicoblastic epithelium (calicodermis) is apposed to and secretes the calcium carbonate, aragonite, skeleton. The epidermis of the actinopharynx has more supporting cells than the surface body wall epidermis, with notably elongated cilia, that function to move food particles and fluid into and out of the gastrovascular cavity. The mesoglea is a homogenous connective tissue layer of variable thickness that may contain isolated cells. It is bordered either by epidermis and gastrodermis or by gastrodermis on both sides (as occurs in the mesentery, Fig. 3). The gastrodermis lines the digestive lumen, underlies the mesoglea, and contains zooxanthellae, or symbiotic algae, in membrane bound vacuoles. The gastrodermis may contain ciliated or flagellated support cells, cnidocytes, amoebocytes, sensory cells, mucocytes, granular gland cells and pigment cells. Neurons and epitheliomuscular cells are found in both epidermis and gastrodermis. The base of an epitheliomuscular cell contains a contractile portion within the plasma membrane, the myoneme, which attaches to the nucleus-containing portion of the cell by a peduncle and also attaches the cell to the mesoglea.

FIGURE LEGENDS FOR FIGURES 1-4.

Figure 1a. Gross anatomy of a scleractinian polyp from an imperforate coral.

Figure 1b. Gross anatomy of a gorgonian polyp.

Figure 1c. Diagram of skeletal features of a noncolonial scleractinian coral. Only those skeletal features included in the glossary are labeled. Additional features important in scleractinian taxonomy are not labeled here.

Figure 2a. Left, sagittal section through *Acropora* polyps, a perforate coral. Tissue fixed in Helly's solution and stained with azocarmine G. Below, tissue section from a different *Acropora* sample, stained with hematoxylin and eosin.

Figure 2b. Oblique section through *Acropora* polyps. The plane of the section passes through both oral (actinopharynx) and aboral (gonad) portions of polyps.

Figure 2c. Left, sagittal section through *Montastraea* polyps, an imperforate coral. Tissue fixed in Z-Fix solution and stained with azocarmine G. Below, tissue section from a different *Montastraea* sample, stained with hematoxylin and eosin.

Figure 2d. Oblique section through a *Montastraea* polyp. The plane of the section is from the oral region of a contracted polyp.

Figure 3. Three-dimensional diagram of the key features of a scleractinian polyp mesentery. In the oral region, mesogleal pleats supporting the longitudinal retractor muscles are prominent; in the aboral region, gonads and loops of the mesenterial filament develop.

Figure 4. Three-dimensional diagram of the surface body wall of a scleractinian polyp, showing cell types of the epidermis, mesoglea, and, gastrodermis.

Figure 1a.

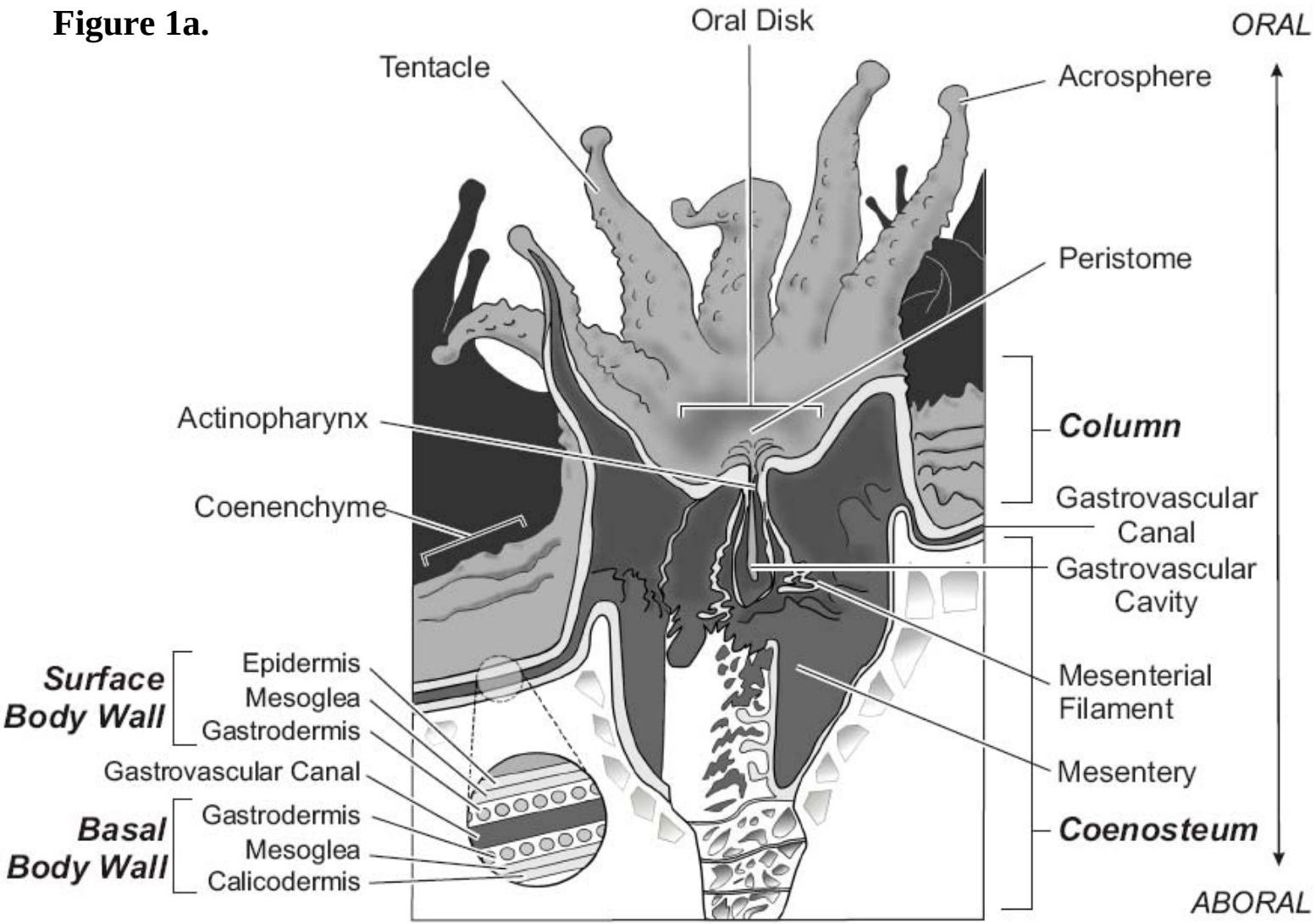
Oral Disk
ORAL
Tentacle
Acrosphere
Peristome
Actinopharynx
Column
Coenenchyme
Gastrovascular Canal
Gastrovascular Cavity
Mesenterial Filament
Mesentery
Coenosteum
Surface Body Wall
Epidermis
Mesoglea
Gastrodermis
Gastrovascular Canal
Basal Body Wall
Gastrodermis
Mesoglea
Calicodermis
ABORAL

Figure 1b.

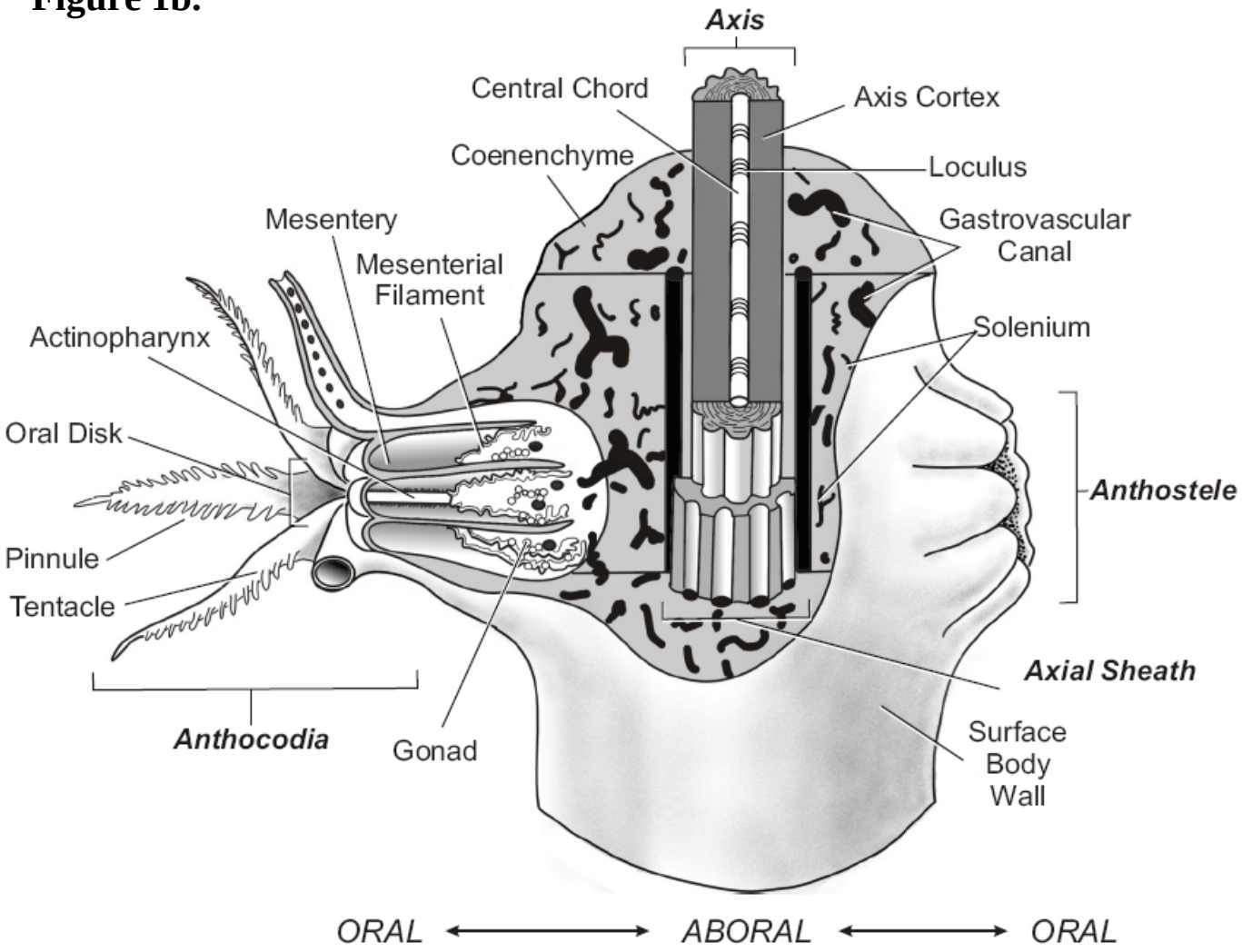
Axis
Central Chord
Axis Cortex
Coenenchyme
Loculus
Mesentery
Gastrovascular Canal
Mesenterial Filament
Actinopharynx
Solenium
Oral Disk
Anthostele
Pinnule
Tentacle
Axial Sheath
Anthocodia
Gonad
Surface Body Wall
ORAL
ABORAL
ORAL

Figure 1c.