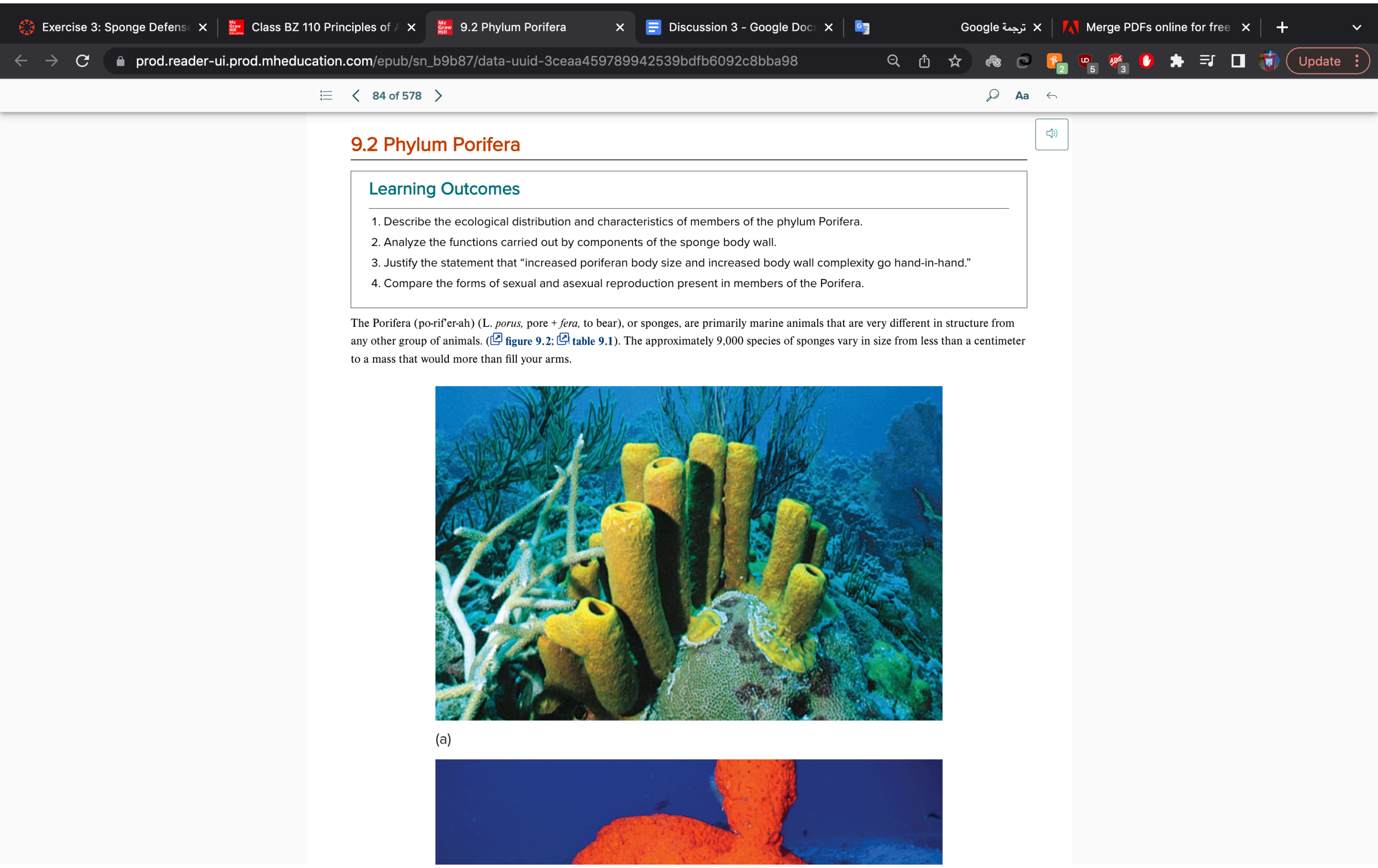


9.2 Phylum Porifera

Learning Outcomes

1. Describe the ecological distribution and characteristics of members of the phylum Porifera.
2. Analyze the functions carried out by components of the sponge body wall.
3. Justify the statement that “increased poriferan body size and increased body wall complexity go hand-in-hand.”
4. Compare the forms of sexual and asexual reproduction present in members of the Porifera.

The Porifera (po-rif'er-ah) (L. *porus,* pore + *fera,* to bear), or sponges, are primarily marine animals that are very different in structure from any other group of animals. (**figure 9.2**; **table 9.1**). The approximately 9,000 species of sponges vary in size from less than a centimeter to a mass that would more than fill your arms.

(a)

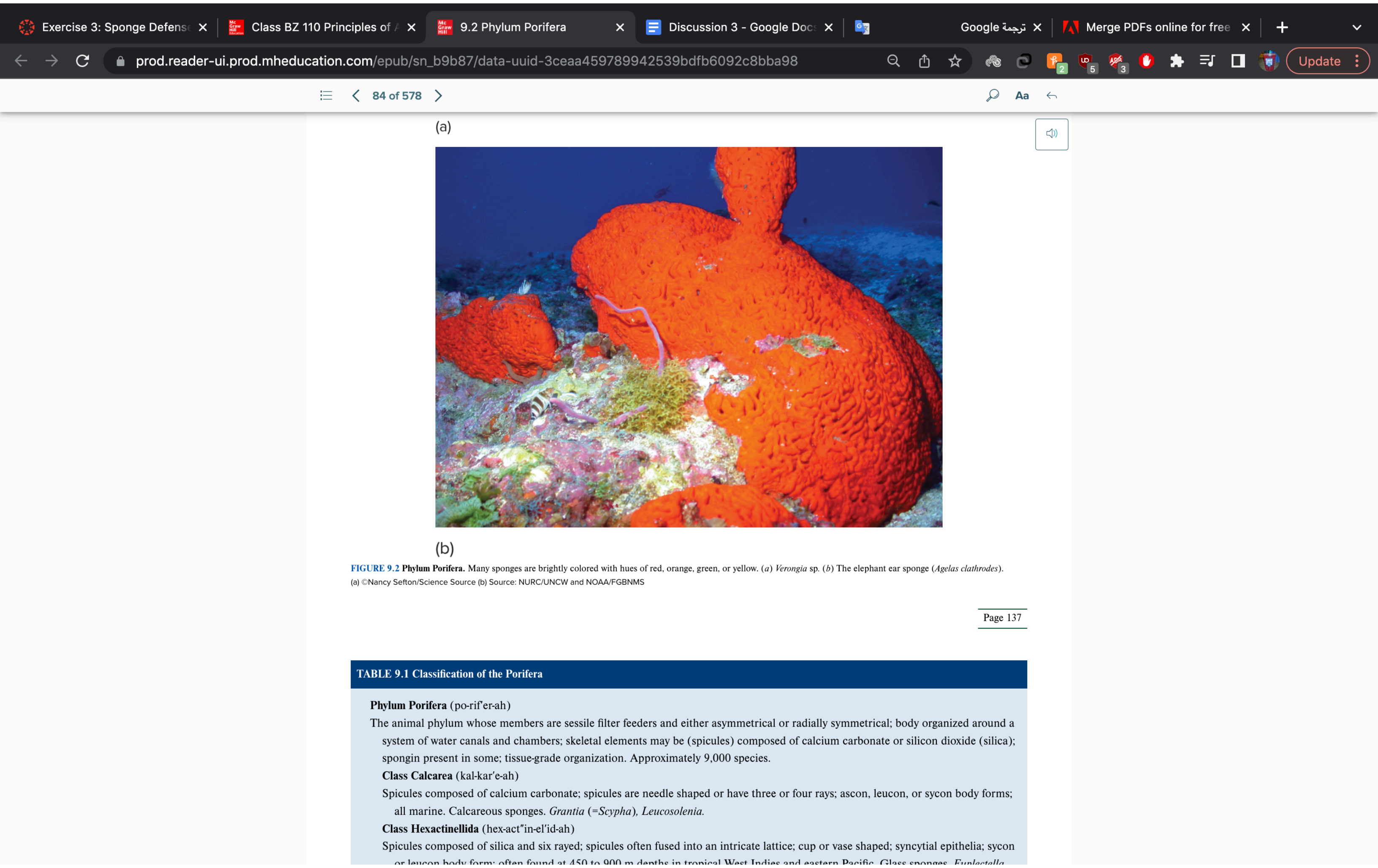


FIGURE 9.2 **Phylum Porifera.** Many sponges are brightly colored with hues of red, orange, green, or yellow. (*a*) *Verongia* sp. (*b*) The elephant ear sponge (*Agelas clathrodes*).

(a) ©Nancy Sefton/Science Source (b) Source: NURC/UNCW and NOAA/FGBNMS

TABLE 9.1 Classification of the Porifera

Phylum Porifera (po-rif′er-ah)

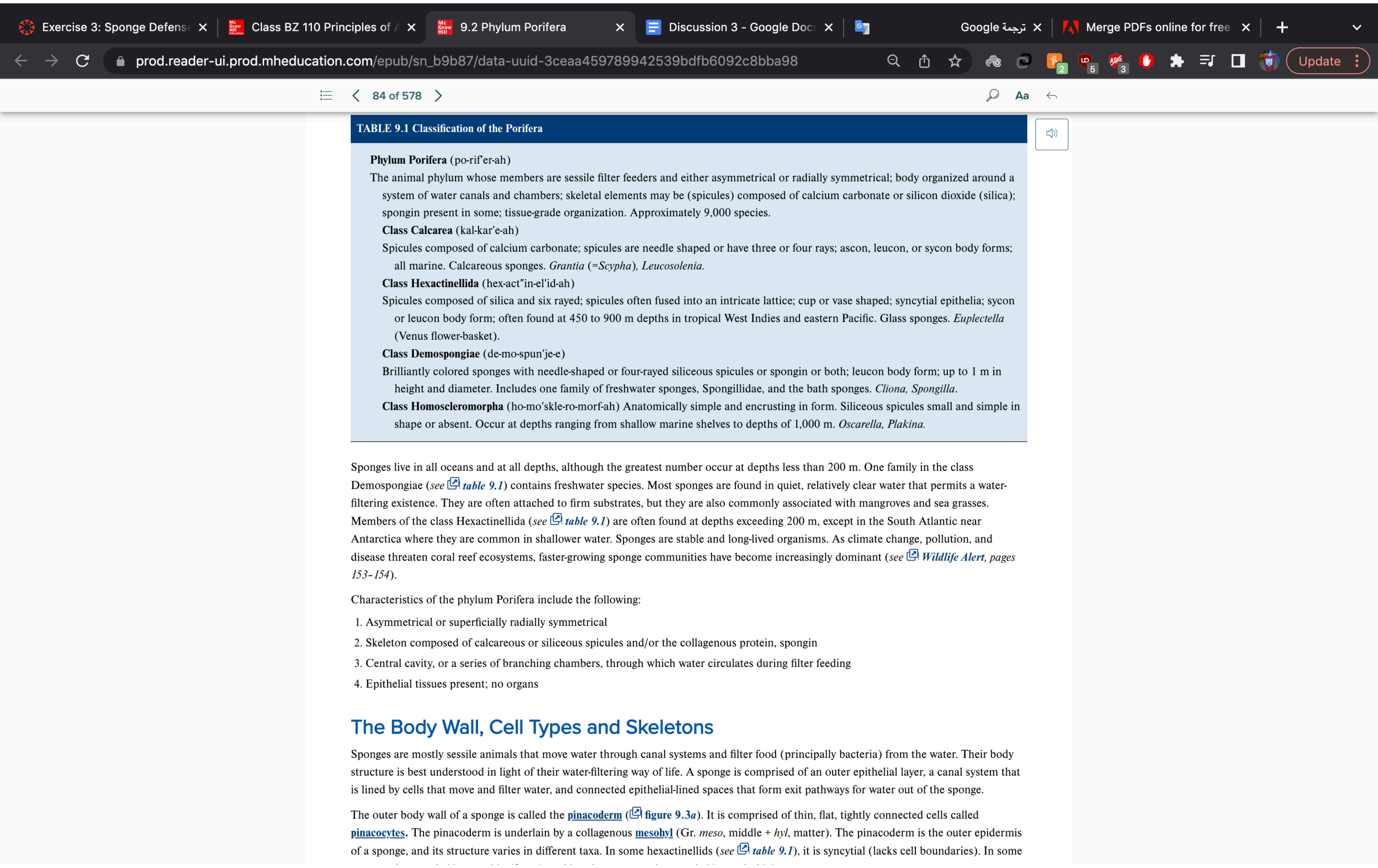
The animal phylum whose members are sessile filter feeders and either asymmetrical or radially symmetrical; body organized around a system of water canals and chambers; skeletal elements may be (spicules) composed of calcium carbonate or silicon dioxide (silica); spongin present in some; tissue-grade organization. Approximately 9,000 species.

Class Calcarea (kal-kar′e-ah)

Spicules composed of calcium carbonate; spicules are needle shaped or have three or four rays; ascon, leucon, or sycon body forms; all marine. Calcareous sponges. *Grantia* (=*Scypha*), *Leucosolenia.*

Class Hexactinellida (hex-act″in-el′id-ah)

Spicules composed of silica and six rayed; spicules often fused into an intricate lattice; cup or vase shaped; syncytial epithelia; sycon or leucon body form; often found at 450 to 900 m depths in tropical West Indies and eastern Pacific. Glass sponges. *Euplectella*



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Class Demospongiae (de-mo-spun′je-e)

Brilliantly colored sponges with needle-shaped or four-rayed siliceous spicules or spongin or both; leucon body form; up to 1 m in height and diameter. Includes one family of freshwater sponges, Spongillidae, and the bath sponges. *Cliona, Spongilla*.

Class Homoscleromorpha (ho-mo′skle-ro-morf-ah) Anatomically simple and encrusting in form. Siliceous spicules small and simple in shape or absent. Occur at depths ranging from shallow marine shelves to depths of 1,000 m. *Oscarella, Plakina.*

Sponges live in all oceans and at all depths, although the greatest number occur at depths less than 200 m. One family in the class Demospongiae (*see* ***table 9.1***) contains freshwater species. Most sponges are found in quiet, relatively clear water that permits a water-filtering existence. They are often attached to firm substrates, but they are also commonly associated with mangroves and sea grasses. Members of the class Hexactinellida (*see* ***table 9.1***) are often found at depths exceeding 200 m, except in the South Atlantic near Antarctica where they are common in shallower water. Sponges are stable and long-lived organisms. As climate change, pollution, and disease threaten coral reef ecosystems, faster-growing sponge communities have become increasingly dominant (*see* ***Wildlife Alert****, pages 153–154*).

Characteristics of the phylum Porifera include the following:

1. Asymmetrical or superficially radially symmetrical
2. Skeleton composed of calcareous or siliceous spicules and/or the collagenous protein, spongin
3. Central cavity, or a series of branching chambers, through which water circulates during filter feeding
4. Epithelial tissues present; no organs

The Body Wall, Cell Types and Skeletons

Sponges are mostly sessile animals that move water through canal systems and filter food (principally bacteria) from the water. Their body structure is best understood in light of their water-filtering way of life. A sponge is comprised of an outer epithelial layer, a canal system that is lined by cells that move and filter water, and connected epithelial-lined spaces that form exit pathways for water out of the sponge.

The outer body wall of a sponge is called the **pinacoderm** (**figure 9.3*a***). It is comprised of thin, flat, tightly connected cells called **pinacocytes**. The pinacoderm is underlain by a collagenous **mesohyl** (Gr. *meso*, middle + *hyl*, matter). The pinacoderm is the outer epidermis of a sponge, and its structure varies in different taxa. In some hexactinellids (*see* ***table 9.1***), it is syncytial (lacks cell boundaries). In some

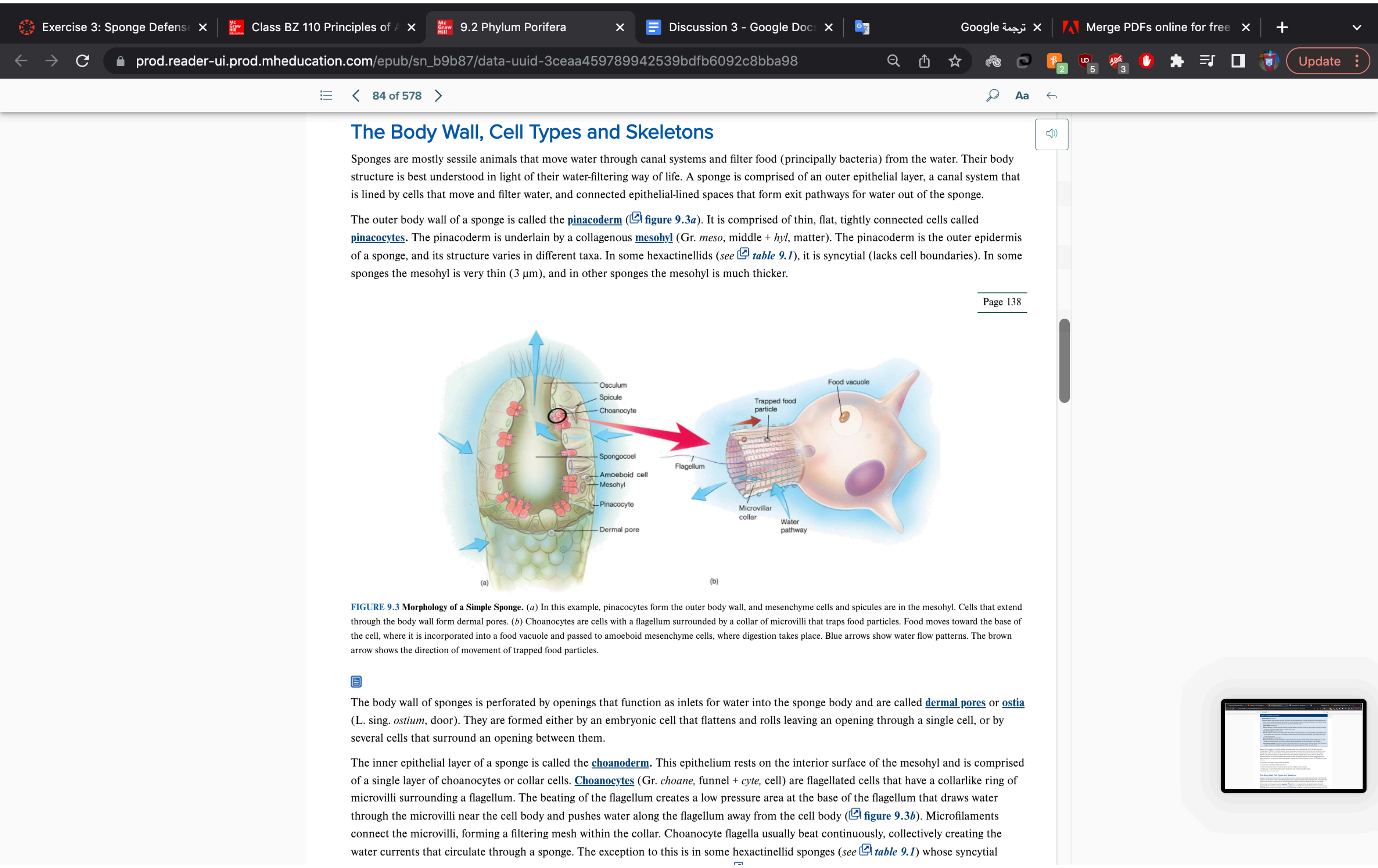

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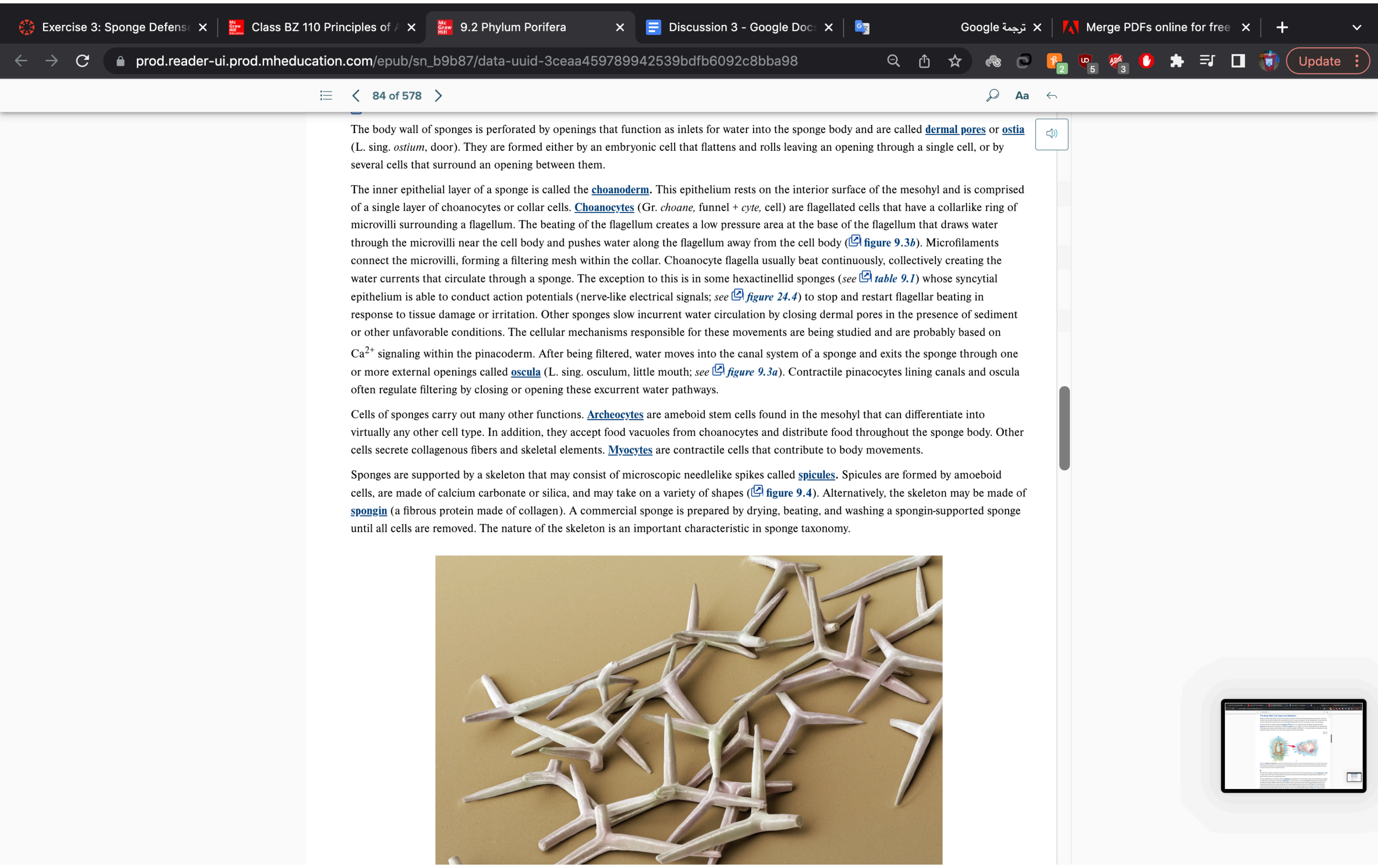
FIGURE 9.3 **Morphology of a Simple Sponge.** (*a*) In this example, pinacocytes form the outer body wall, and mesenchyme cells and spicules are in the mesohyl. Cells that extend through the body wall form dermal pores. (*b*) Choanocytes are cells with a flagellum surrounded by a collar of microvilli that traps food particles. Food moves toward the base of the cell, where it is incorporated into a food vacuole and passed to amoeboid mesenchyme cells, where digestion takes place. Blue arrows show water flow patterns. The brown arrow shows the direction of movement of trapped food particles.

The body wall of sponges is perforated by openings that function as inlets for water into the sponge body and are called **dermal pores** or **ostia** (L. sing. *ostium*, door). They are formed either by an embryonic cell that flattens and rolls leaving an opening through a single cell, or by several cells that surround an opening between them.

The inner epithelial layer of a sponge is called the **choanoderm**. This epithelium rests on the interior surface of the mesohyl and is comprised of a single layer of choanocytes or collar cells. **Choanocytes** (Gr. *choane,* funnel + *cyte,* cell) are flagellated cells that have a collarlike ring of microvilli surrounding a flagellum. The beating of the flagellum creates a low pressure area at the base of the flagellum that draws water through the microvilli near the cell body and pushes water along the flagellum away from the cell body (**figure 9.3*b***). Microfilaments connect the microvilli, forming a filtering mesh within the collar. Choanocyte flagella usually beat continuously, collectively creating the water currents that circulate through a sponge. The exception to this is in some hexactinellid sponges (*see* ***table 9.1***) whose syncytial



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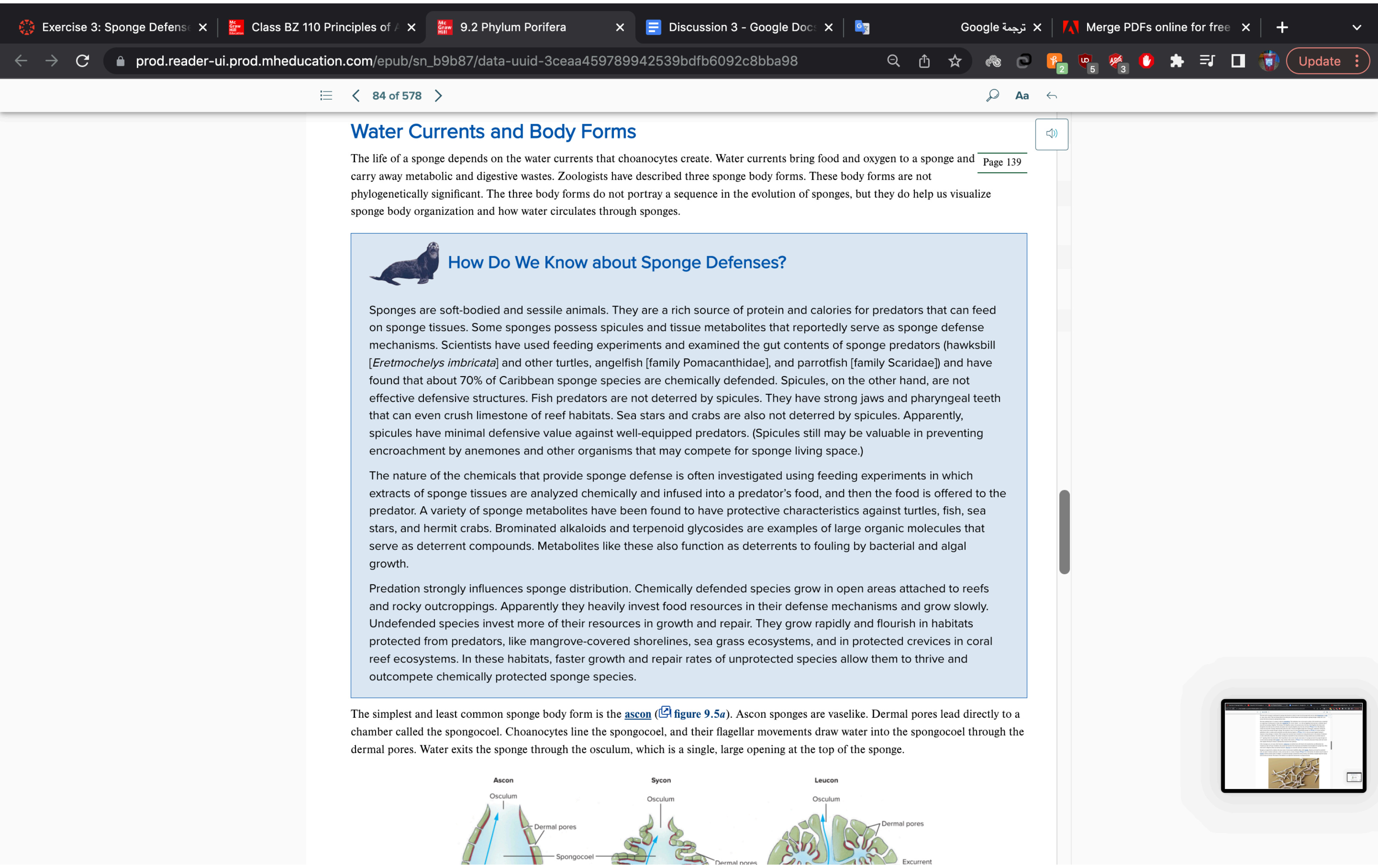
Cells of sponges carry out many other functions. **Archeocytes** are ameboid stem cells found in the mesohyl that can differentiate into virtually any other cell type. In addition, they accept food vacuoles from choanocytes and distribute food throughout the sponge body. Other cells secrete collagenous fibers and skeletal elements. **Myocytes** are contractile cells that contribute to body movements.

Sponges are supported by a skeleton that may consist of microscopic needlelike spikes called **spicules**. Spicules are formed by amoeboid cells, are made of calcium carbonate or silica, and may take on a variety of shapes (figure 9.4). Alternatively, the skeleton may be made of **spongin** (a fibrous protein made of collagen). A commercial sponge is prepared by drying, beating, and washing a spongin-supported sponge until all cells are removed. The nature of the skeleton is an important characteristic in sponge taxonomy.



Water Currents and Body Forms

The life of a sponge depends on the water currents that choanocytes create. Water currents bring food and oxygen to a sponge and carry away metabolic and digestive wastes. Zoologists have described three sponge body forms. These body forms are not phylogenetically significant. The three body forms do not portray a sequence in the evolution of sponges, but they do help us visualize sponge body organization and how water circulates through sponges.

How Do We Know about Sponge Defenses?

Sponges are soft-bodied and sessile animals. They are a rich source of protein and calories for predators that can feed on sponge tissues. Some sponges possess spicules and tissue metabolites that reportedly serve as sponge defense mechanisms. Scientists have used feeding experiments and examined the gut contents of sponge predators (hawksbill [*Eretmochelys imbricata*] and other turtles, angelfish [family Pomacanthidae], and parrotfish [family Scaridae]) and have found that about 70% of Caribbean sponge species are chemically defended. Spicules, on the other hand, are not effective defensive structures. Fish predators are not deterred by spicules. They have strong jaws and pharyngeal teeth that can even crush limestone of reef habitats. Sea stars and crabs are also not deterred by spicules. Apparently, spicules have minimal defensive value against well-equipped predators. (Spicules still may be valuable in preventing encroachment by anemones and other organisms that may compete for sponge living space.)

The nature of the chemicals that provide sponge defense is often investigated using feeding experiments in which extracts of sponge tissues are analyzed chemically and infused into a predator's food, and then the food is offered to the predator. A variety of sponge metabolites have been found to have protective characteristics against turtles, fish, sea stars, and hermit crabs. Brominated alkaloids and terpenoid glycosides are examples of large organic molecules that serve as deterrent compounds. Metabolites like these also function as deterrents to fouling by bacterial and algal growth.

Predation strongly influences sponge distribution. Chemically defended species grow in open areas attached to reefs and rocky outcroppings. Apparently they heavily invest food resources in their defense mechanisms and grow slowly. Undefended species invest more of their resources in growth and repair. They grow rapidly and flourish in habitats protected from predators, like mangrove-covered shorelines, sea grass ecosystems, and in protected crevices in coral reef ecosystems. In these habitats, faster growth and repair rates of unprotected species allow them to thrive and outcompete chemically protected sponge species.

The simplest and least common sponge body form is the **ascon** (**figure 9.5*a***). Ascon sponges are vaselike. Dermal pores lead directly to a chamber called the spongocoel. Choanocytes line the spongocoel, and their flagellar movements draw water into the spongocoel through the dermal pores. Water exits the sponge through the osculum, which is a single, large opening at the top of the sponge.

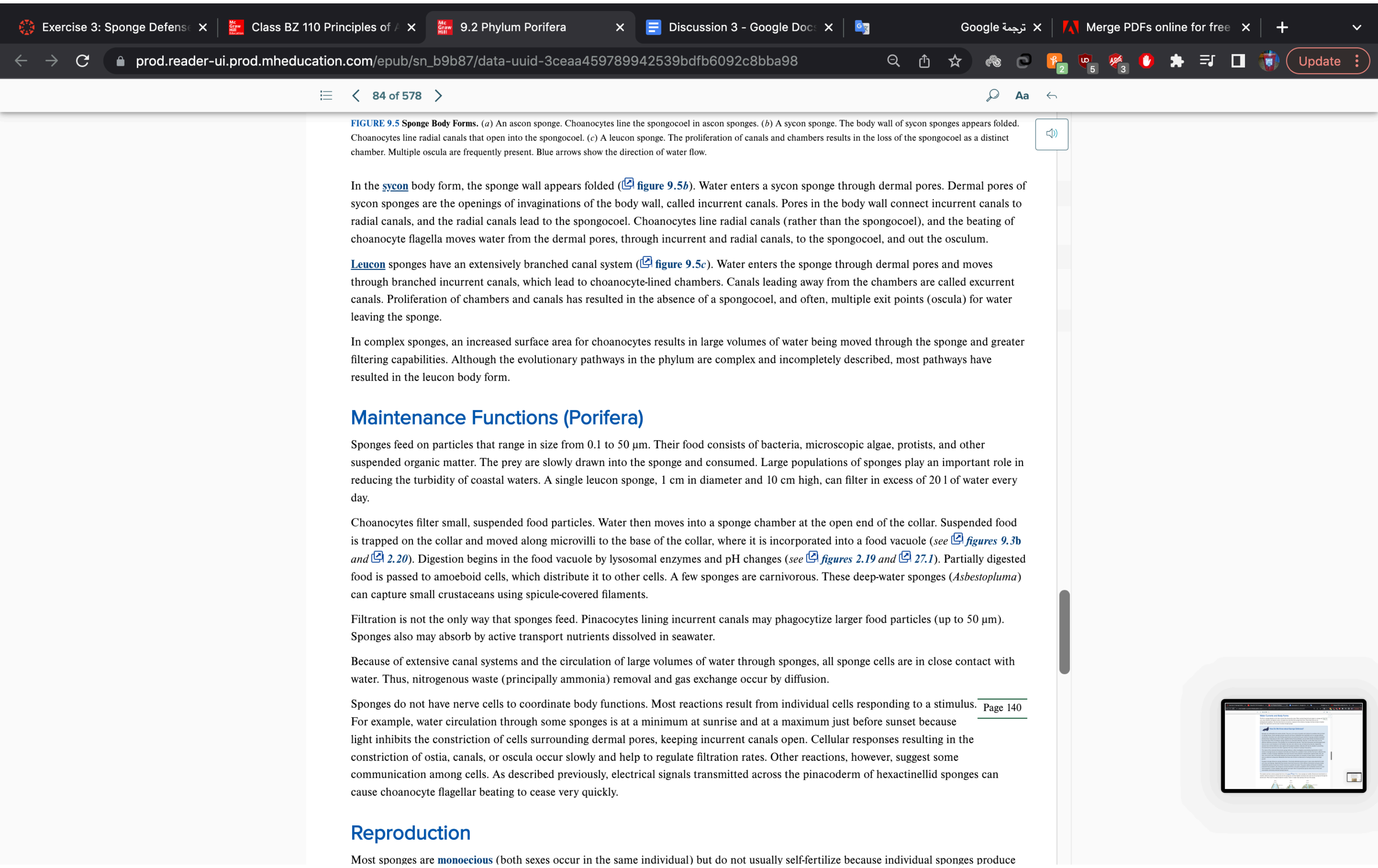


FIGURE 9.5 Sponge Body Forms. (*a*) An ascon sponge. Choanocytes line the spongocoel in ascon sponges. (*b*) A sycon sponge. The body wall of sycon sponges appears folded. Choanocytes line radial canals that open into the spongocoel. (*c*) A leucon sponge. The proliferation of canals and chambers results in the loss of the spongocoel as a distinct chamber. Multiple oscula are frequently present. Blue arrows show the direction of water flow.

In the **sycon** body form, the sponge wall appears folded (**figure 9.5*b***). Water enters a sycon sponge through dermal pores. Dermal pores of sycon sponges are the openings of invaginations of the body wall, called incurrent canals. Pores in the body wall connect incurrent canals to radial canals, and the radial canals lead to the spongocoel. Choanocytes line radial canals (rather than the spongocoel), and the beating of choanocyte flagella moves water from the dermal pores, through incurrent and radial canals, to the spongocoel, and out the osculum.

Leucon sponges have an extensively branched canal system (**figure 9.5*c***). Water enters the sponge through dermal pores and moves through branched incurrent canals, which lead to choanocyte-lined chambers. Canals leading away from the chambers are called excurrent canals. Proliferation of chambers and canals has resulted in the absence of a spongocoel, and often, multiple exit points (oscula) for water leaving the sponge.

In complex sponges, an increased surface area for choanocytes results in large volumes of water being moved through the sponge and greater filtering capabilities. Although the evolutionary pathways in the phylum are complex and incompletely described, most pathways have resulted in the leucon body form.

Maintenance Functions (Porifera)

Sponges feed on particles that range in size from 0.1 to 50 µm. Their food consists of bacteria, microscopic algae, protists, and other suspended organic matter. The prey are slowly drawn into the sponge and consumed. Large populations of sponges play an important role in reducing the turbidity of coastal waters. A single leucon sponge, 1 cm in diameter and 10 cm high, can filter in excess of 20 l of water every day.

Choanocytes filter small, suspended food particles. Water then moves into a sponge chamber at the open end of the collar. Suspended food is trapped on the collar and moved along microvilli to the base of the collar, where it is incorporated into a food vacuole (*see* ***figures 9.3b** and* ***2.20***). Digestion begins in the food vacuole by lysosomal enzymes and pH changes (*see* ***figures 2.19** and* ***27.1***). Partially digested food is passed to amoeboid cells, which distribute it to other cells. A few sponges are carnivorous. These deep-water sponges (*Asbestopluma*) can capture small crustaceans using spicule-covered filaments.

Filtration is not the only way that sponges feed. Pinacocytes lining incurrent canals may phagocytize larger food particles (up to 50 µm). Sponges also may absorb by active transport nutrients dissolved in seawater.

Because of extensive canal systems and the circulation of large volumes of water through sponges, all sponge cells are in close contact with water. Thus, nitrogenous waste (principally ammonia) removal and gas exchange occur by diffusion.

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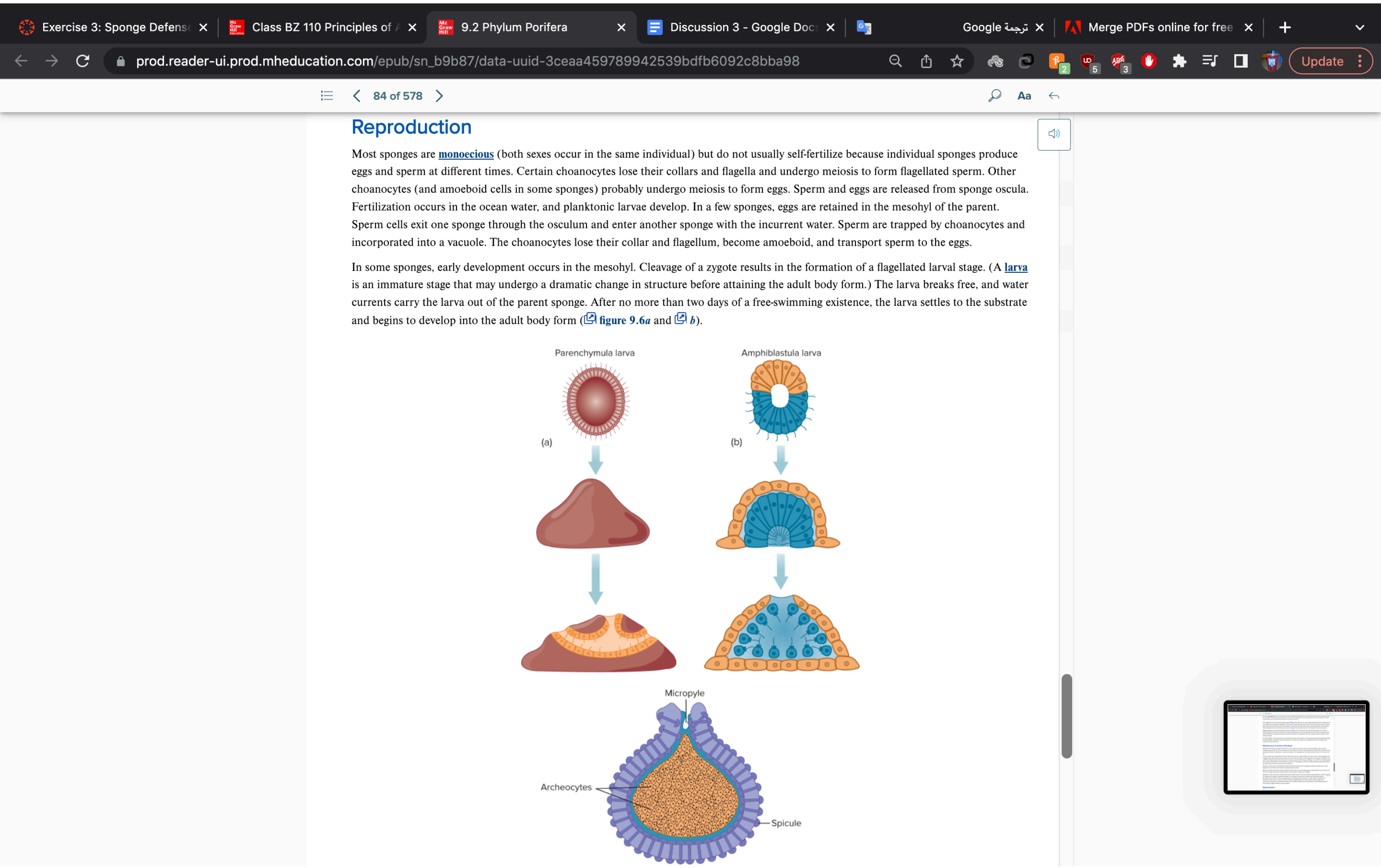
Sponges do not have nerve cells to coordinate body functions. Most reactions result from individual cells responding to a stimulus. For example, water circulation through some sponges is at a minimum at sunrise and at a maximum just before sunset because light inhibits the constriction of cells surrounding dermal pores, keeping incurrent canals open. Cellular responses resulting in the constriction of ostia, canals, or oscula occur slowly and help to regulate filtration rates. Other reactions, however, suggest some communication among cells. As described previously, electrical signals transmitted across the pinacoderm of hexactinellid sponges can cause choanocyte flagellar beating to cease very quickly.

Reproduction

Most sponges are **monoecious** (both sexes occur in the same individual) but do not usually self-fertilize because individual sponges produce



Reproduction

Most sponges are **monoecious** (both sexes occur in the same individual) but do not usually self-fertilize because individual sponges produce eggs and sperm at different times. Certain choanocytes lose their collars and flagella and undergo meiosis to form flagellated sperm. Other choanocytes (and amoeboid cells in some sponges) probably undergo meiosis to form eggs. Sperm and eggs are released from sponge oscula. Fertilization occurs in the ocean water, and planktonic larvae develop. In a few sponges, eggs are retained in the mesohyl of the parent. Sperm cells exit one sponge through the osculum and enter another sponge with the incurrent water. Sperm are trapped by choanocytes and incorporated into a vacuole. The choanocytes lose their collar and flagellum, become amoeboid, and transport sperm to the eggs.

In some sponges, early development occurs in the mesohyl. Cleavage of a zygote results in the formation of a flagellated larval stage. (A **larva** is an immature stage that may undergo a dramatic change in structure before attaining the adult body form.) The larva breaks free, and water currents carry the larva out of the parent sponge. After no more than two days of a free-swimming existence, the larva settles to the substrate and begins to develop into the adult body form (**figure 9.6*a*** and ***b***).

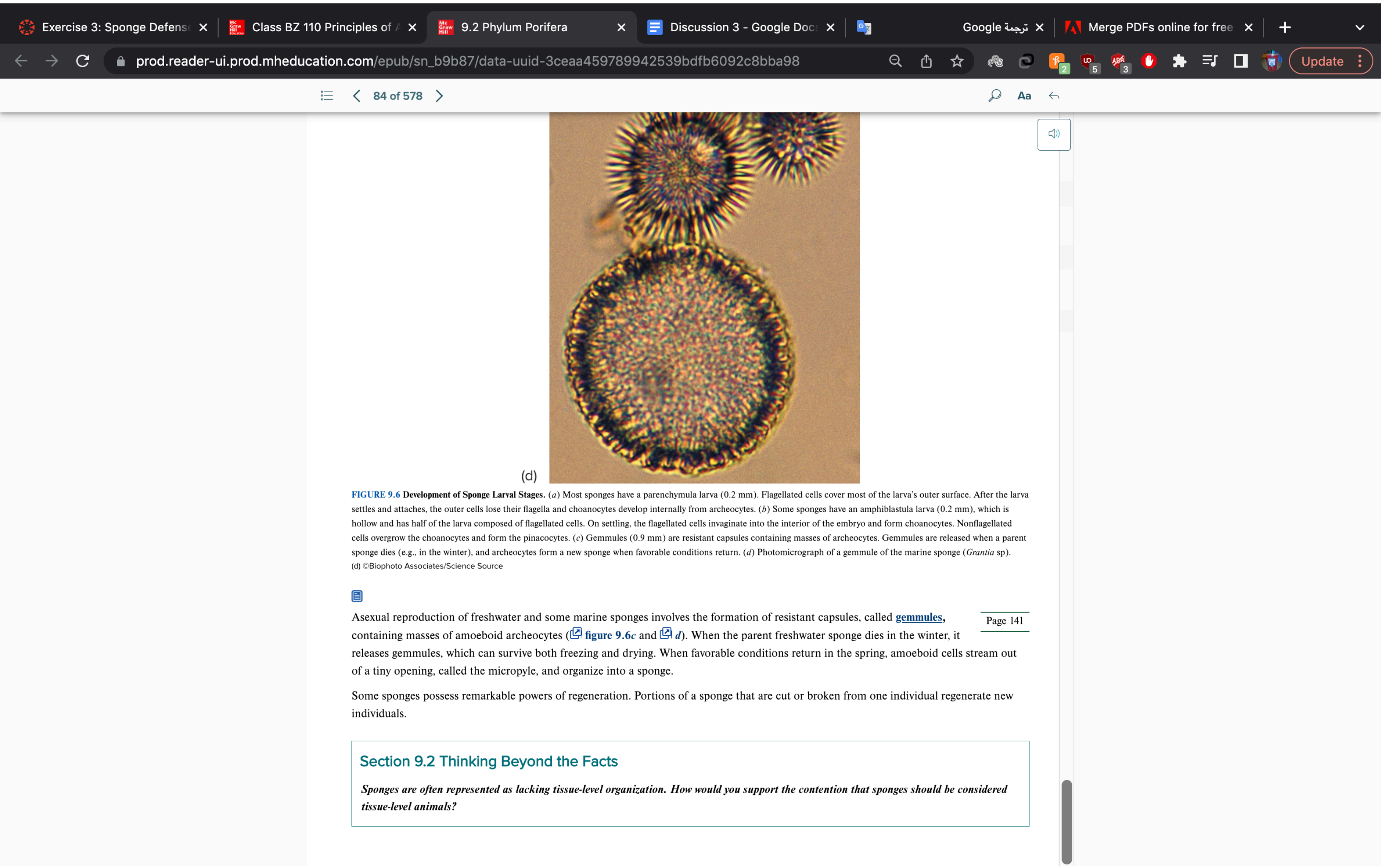


FIGURE 9.6 **Development of Sponge Larval Stages.** (*a*) Most sponges have a parenchymula larva (0.2 mm). Flagellated cells cover most of the larva's outer surface. After the larva settles and attaches, the outer cells lose their flagella and choanocytes develop internally from archeocytes. (*b*) Some sponges have an amphiblastula larva (0.2 mm), which is hollow and has half of the larva composed of flagellated cells. On settling, the flagellated cells invaginate into the interior of the embryo and form choanocytes. Nonflagellated cells overgrow the choanocytes and form the pinacocytes. (*c*) Gemmules (0.9 mm) are resistant capsules containing masses of archeocytes. Gemmules are released when a parent sponge dies (e.g., in the winter), and archeocytes form a new sponge when favorable conditions return. (*d*) Photomicrograph of a gemmule of the marine sponge (*Grantia* sp).

(d) ©Biophoto Associates/Science Source

Asexual reproduction of freshwater and some marine sponges involves the formation of resistant capsules, called **gemmules**, containing masses of amoeboid archeocytes (**figure 9.6*c*** and ***d***). When the parent freshwater sponge dies in the winter, it releases gemmules, which can survive both freezing and drying. When favorable conditions return in the spring, amoeboid cells stream out of a tiny opening, called the micropyle, and organize into a sponge.

Some sponges possess remarkable powers of regeneration. Portions of a sponge that are cut or broken from one individual regenerate new individuals.

Section 9.2 Thinking Beyond the Facts

Sponges are often represented as lacking tissue-level organization. How would you support the contention that sponges should be considered tissue-level animals?