HOW TO DO IT

The Madagascar Hissing Cockroach: A New Model for Learning Insect Anatomy

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Abstract

Teaching and learning animal anatomy has a long history in the biology classroom. As in many fields of biology, decades of experience teaching anatomy have led to the unofficial selection of model species. However, in some cases the model may not be the best choice for our students. Our struggle to find an appropriate model for teaching and learning insect anatomy has resulted in experiments with a variety of species. In our experience, none of the available models seems as useful as the Madagascar hissing cockroach. In this article, we advocate the use of this species in laboratory studies of insect anatomy.

Key Words: *Madagascar hissing cockroach; anatomy; dissection; model organism.*

For instructors electing to incorporate animal dissection in their courses, there are a number of standard model species from which to choose. In our experience, some species are more user-friendly than others. For example, the standard models for teaching and learning insect anatomy are the American cockroach (*Periplaneta americana*) and the lubber grasshopper (*Romalea microptera*). However, our experience using these species has not been ideal. Lubber grasshoppers are large and readily available as preserved specimens, but they frequently have poorly preserved internal anatomy, which makes structure identification difficult. Students often become frustrated because their specimens look so different from published images, which are often photos of fresh specimens.

Thus, our objective here is to advocate the use of the MHC in laboratory studies of insect anatomy.

The American cockroach presents some of the same challenges, with the added difficulty of being considerably smaller. Dissection of an American cockroach requires careful work, best conducted by students with considerable dissection experience.

Fortunately, another species of cockroach, already a widely used model organism (e.g., Osipov et al., 2002; Varadínová et al., 2010), has become available. The Madagascar hissing cockroach (MHC; *Gromphadorhina portentosa*) has been kept in captivity for several decades. We have kept MHCs for many years but have only recently considered using the animal as a model for teaching and learning anatomy. Although a technical treatment of the anatomy of this species exists in the literature (Dailey & Graves, 1976), we are not aware of a resource for educators who wish to pursue anatomical studies in their classrooms. Thus, our objective here is to advocate the use of the MHC in laboratory studies of insect anatomy. **Instructors choosing to adopt this exercise for use in their classrooms may wish to view the color version of this article, including color photographs, available at dx.doi.org/10.1525/abt.2012.74.3.11.**

○ Acquiring & Keeping Hissing Roaches

Madagascar hissing cockroaches have been used as educational animals, including in classrooms (Wagler & Moseley, 2005), for years. As a result, most major biological suppliers raise and sell these animals both as living and preserved specimens. Additionally, the popularity of these animals as pets has resulted in numerous new online suppliers. Another possibility for acquiring these animals may be local colleges or universities, which often keep colonies of MHCs and may be willing to donate specimens for use. Keep in mind that some states, where a risk of MHCs becoming established exists, require a permit. Once the animals are acquired, they may be immediately sacrificed for dissection purposes or kept alive until needed. Alternatively, the animals may be cultured as a ready source of animals for this or other classroom activities. For instructions on keeping MHCs in the classroom, consult Wagler (2010).

○ Preparing Animals for Dissection

When animals are desired for dissection, we recommend two strategies for humane euthanasia. The first strategy is to use an insect kill-jar such as those used by entomologists to collect specimens for research purposes. The second technique is freezing. Freezing

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is humane, quick, effective, and safe for the user. Freezing does have limitations, as it may produce tissue damage. Fortunately, most freezing-induced damage is at the microscopic scale and does not negatively affect gross dissections. As an alternative, commercial biological suppliers sell MHCs fixed in standard preservative formulations. However, in our experience, preserved animals are far inferior to freshly euthanized animals.

○ Dissection

Begin with examination of external anatomy. This species' sexual dimorphism makes determination of sex simple. Male MHCs have large bumps or horns on the pronotum (Figure 1). Students often confuse the horns for eyes, which in reality are much smaller and located under the pronotum on the head (Figure 2). Like all insects, MHCs have three distinct body parts or tagmata (head, thorax, and abdomen), three pairs of legs, compound eyes, and one pair of antennae. Like all roaches, MHCs also have a pair of sensory appendages at the end of the abdomen known as cerci (Figure 1). Other external features worth examining include leg parts: coxa, trochanter, femur, tibia, and tarsi; dorsal and ventral sclerites; and spiracles (Figure 1).

Mouthparts of MHCs are of the simple chewing type. Moving from anterior to posterior, the mouthparts are labrum, mandibles, maxillae, and labium (Figure 2). The labrum serves as the "upper lip" of sorts, moves along the longitudinal axis of the insect's body, and is hinged with the clypeus. The mandibles are paired chewing structures analogous to vertebrate jaws. The mandibles move laterally and have a broad chewing surface in this species. The maxillae are also paired and equipped with palps for food manipulation. Last is the labium, also equipped with palps, which assists with food manipulation and closes the mouth posteriorly.

The internal anatomy is best accessed ventrally. To open the specimen, a sharp pair of fine scissors should be inserted under the posterior-most ventral sclerite; cut a longitudinal medial incision along the ventral surface. Only the exoskeleton and underlying membranes should be cut if at all possible. Proceed anteriorly until just behind the head. Once opened, the ventral exoskeleton can be folded back and pinned to the dissection tray. The specimen should be submerged in water at this point to keep it moist and to help float internal structures away from one another, which aids in identification. If the lining of the visceral cavity is still intact, this can be cut to expose the underlying organs.

Upon opening the visceral cavity, the most notable structure is typically the large and diffuse fat body (Figure 3). Depending on the nutritional and reproductive status of the animal, the fat body may virtually fill the body cavity. Although it is tempting to immediately remove the fat body to expose underlying organs, doing so may result in damage to other organs. The preferred strategy is to leave the fat body mostly intact until after other structures are safely located.

Other notable structures within the body cavity are the tracheae (Figure 3). Tracheae appear as slightly iridescent

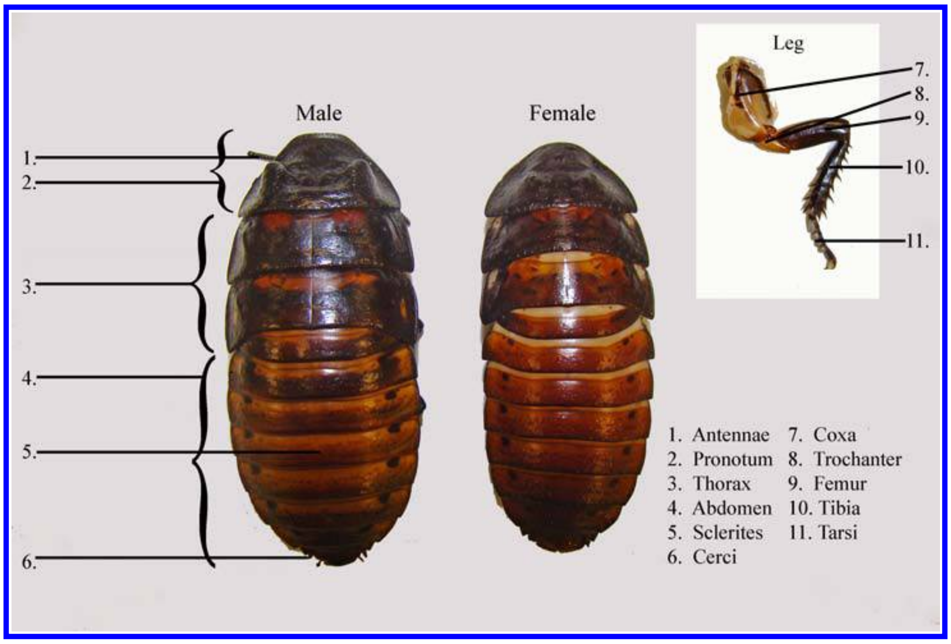

Figure 1. External anatomy of male and female Madagascar hissing cockroaches, including leg close-up.

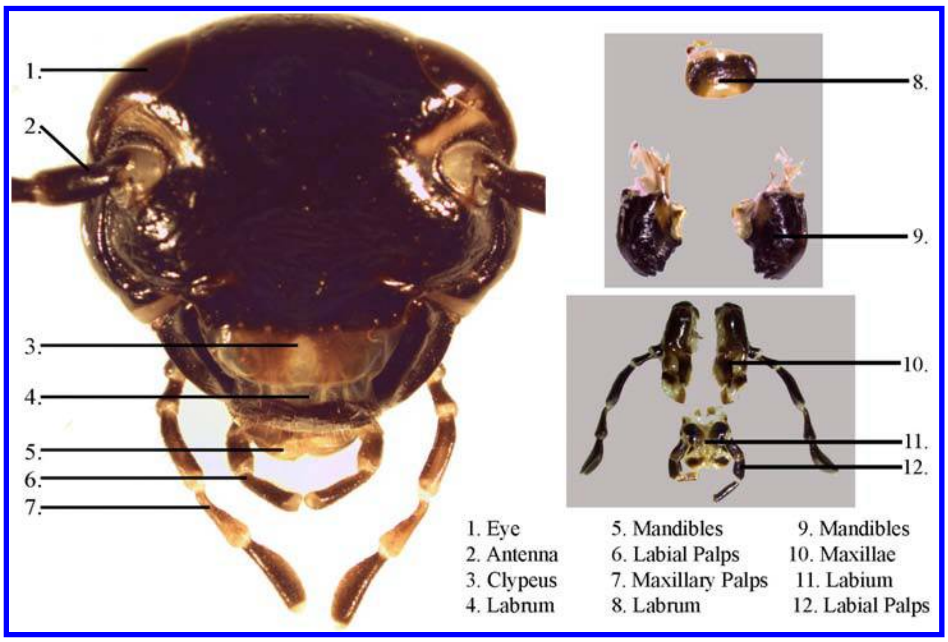

Figure 2. Close-up of head and mouth-part anatomy of Madagascar hissing cockroach.

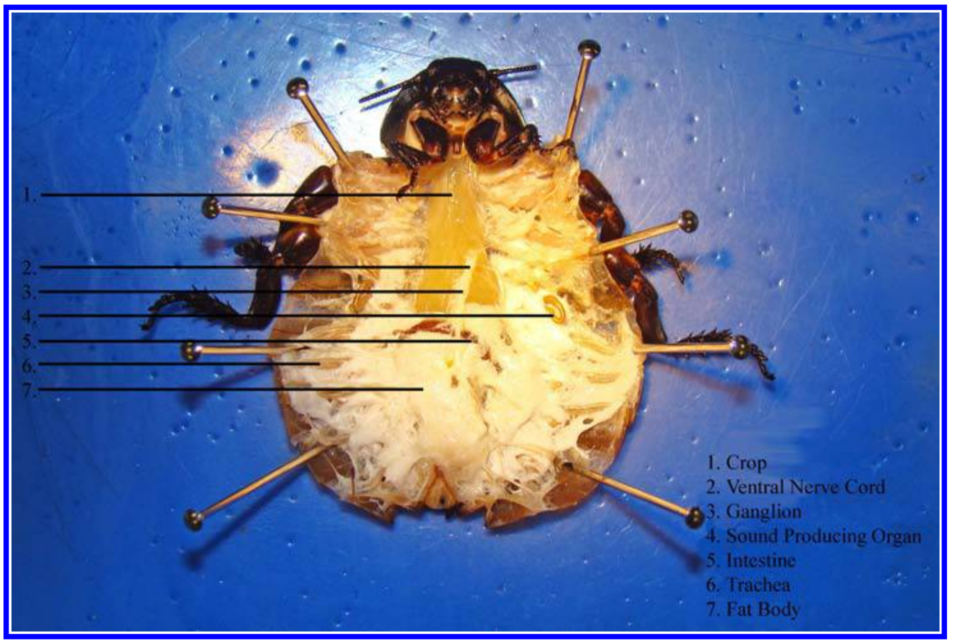

Figure 3. Ventral view of male Madagascar hissing cockroach internal anatomy.

Figure 4. Ventral view of male Madagascar hissing cockroach internal anatomy with fat body removed and digestive tract extended.

light-colored tubes beginning at the body wall and extending interiorly. The tracheae end at the body margin with spiracles, valved openings that control the exchange of gasses with the external environment. Internally, tracheae branch repeatedly until microscopic divisions (tracheoles) of the system make contact with metabolically active tissues. Hissing cockroaches have evolved the ability to rapidly express air from modified spiracles for intraspecific communication and defense (Figure 3). This characteristic "hiss" has led to the common name of this species.

Coiled inside the visceral cavity, the digestive system is nearly twice the animal's body length. The parts of the digestive tract from anterior to posterior are the buccal cavity, pharynx, esophagus, crop, proventriculus, midgut (with associated gastric caeca), ventriculus, ilieum, colon, rectum, and anus. Liberation of the digestive tract from the visceral cavity will allow for maximal identification of individual structures. Use a teasing needle or dissection probe to tease apart the coiled digestive tract, which should then float neatly in the water used to submerge the specimen (Figure 4). Separation between the buccal cavity and pharynx and the ileum and colon can be difficult to ascertain. Interested readers can refer to Dailey and Graves (1976) for specific identifying features of these structures. Associated with the digestive tract, but part of the excretory system, are the Malpighian tubules (Figure 4). Located at the posterior end of the midgut (= ventriculus), the tubules extend into the visceral cavity to absorb nitrogenous waste for excretion into the digestive tract for eventual elimination.

The most apparent structure of the male reproductive system is the accessory gland (Figure 4). Secretions of the accessory gland provide spermatozoa with nutrition and environmental conditions necessary for survival. Utriculi (finger-like projections of the gland surface) occur in two different lengths and may extend to near the middle of the visceral cavity. Posterior to the accessory gland are the ejaculatory pouch and duct, which may or may not be apparent in each specimen. Paired testes are the second most apparent male reproductive structures (Figure 4). Typically imbedded within the fat body, these ovoid structures should be carefully identified before attempting to remove the fat body. The fat body can be removed using forceps, or a disposable plastic pipette can be used to suck it up from the dissection tray. Once liberated from the fat body, the testes can be seen to connect to the ejaculatory pouch via vas deferentia, which bend posteriorly before reversing course and attaching near the anterior margin of the ejaculatory pouch. External male genitalia are housed within an inverted phallic pouch until copulation. Dissection of these structures is possible, but difficult for a novice dissector given their size.

Depending on the reproductive status of female specimens, reproductive structures may or may not be evident. Gravid females are immediately distinguishable by the developing ootheca contained in an expanded brood sac (Figure 5). Also typically evident are the paired colleterial glands. Other female reproductive structures, including external genitalia, are housed in a genital pouch medial to the colleterial glands. The structures contained in the genital pouch are difficult to see clearly without magnification. Again, we refer interested readers to the paper by Dailey and Graves (1976).

The central nervous system of MHCs includes both a brain and a ventral nerve cord. Careful dissection through the ventral surface may often leave the ventral nerve cord intact (Figure 6). Worries about destroying the ventral nerve cord can be remedied by performing

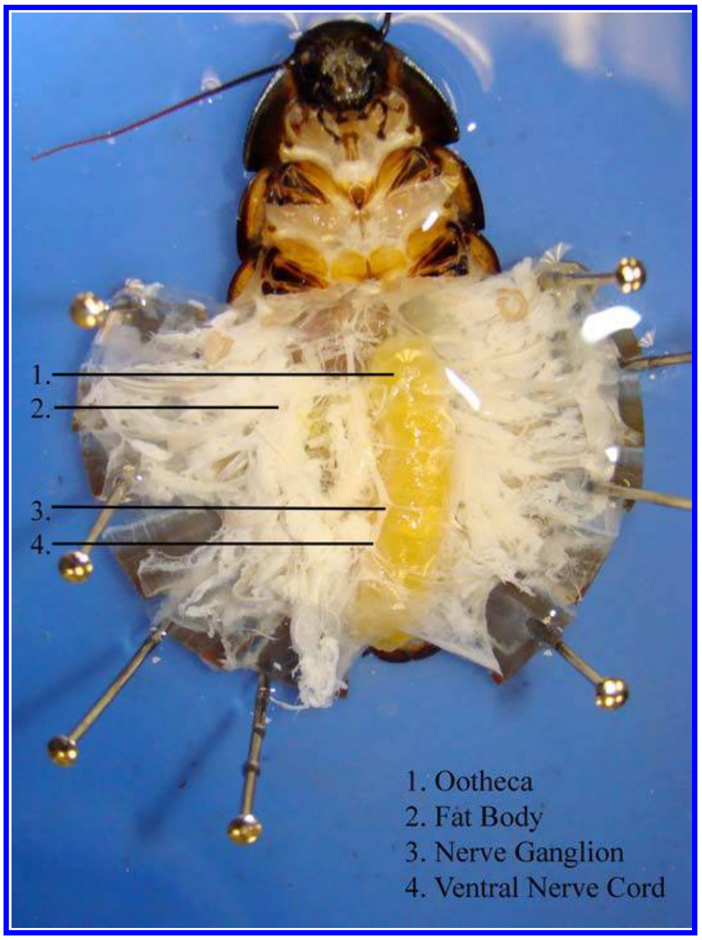

Figure 5. Ventral view of female Madagascar hissing cockroach internal anatomy.

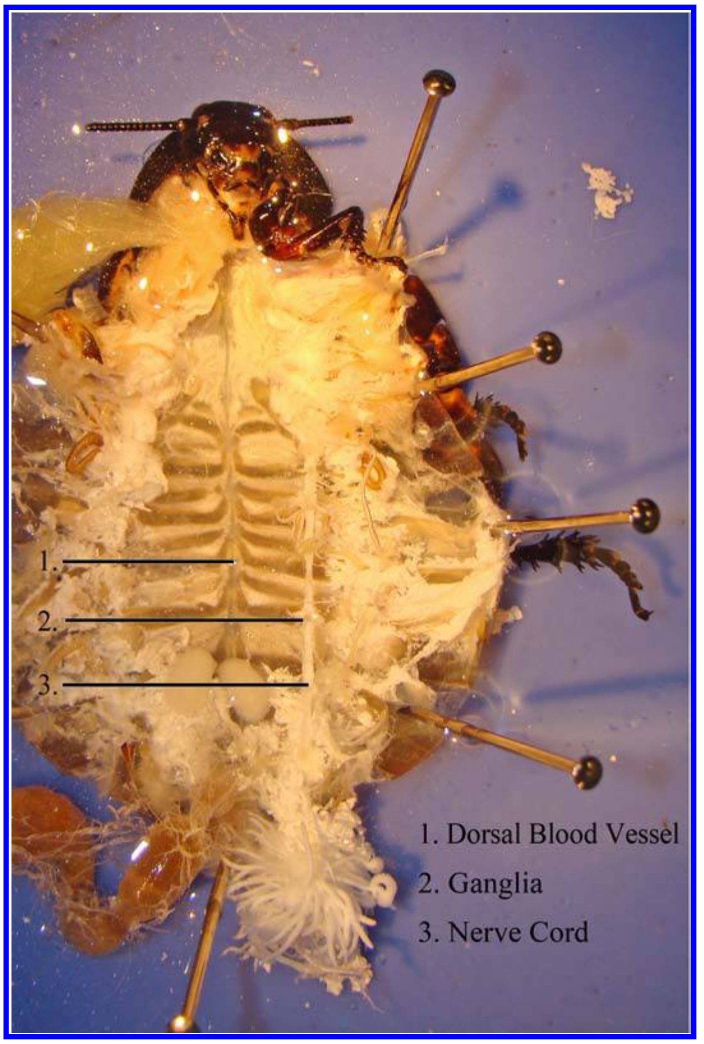

Figure 6. Close-up ventral view of male Madagascar hissing cockroach internal anatomy with fat body removed and digestive tract extended.

a dorsal dissection with carful removal of the viscera. The length of the ventral nerve cord is interrupted by numerous thoracic and abdominal ganglia (Figure 6). Dissection of the brain has not been attempted by the current authors but is carefully described and illustrated by Daily and Graves (1976).

Insects possess an open circulatory system. Only major vessels exist, minor vessels being replaced by open sinuses. The major organ of the roach circulatory system is the dorsal vessel. Careful removal of the digestive tract and fat body will expose the dorsal vessel (Figure 6). In the abdomen, the dorsal vessel is expanded into contractile elements sometimes referred to as "hearts." Small openings known as ostia allow blood to return to the dorsal vessel after circulation through the body sinuses. In the abdomen, lateral vessels can be observed branching off the dorsal vessel to facilitate blood distribution to the body.

○ Instructional Notes

The authors have used MHC dissections in college biology courses with both introductory students and upper-division invertebrate biology students. With introductory students, we used the activity as an introduction to insect anatomy. With upper-division students, dissections were compared with the anatomy of other invertebrate groups. In both instances, we successfully utilized commonly used assessment tools, including practical examinations, diagram labeling, and oral quizzes. Although we have no experience using this activity with middle school or high school students, it seems reasonable that teachers at this level could also utilize MHCs for anatomy instruction. Use of this activity in grades 8–12 would address *National Science Education Standards* (National Research Council, 1996) content standard A (Science as Inquiry) and content standard C (Life Science).

Madagascar hissing cockroaches make great classroom and laboratory animals. Because of their large size, lack of flight, and docile nature, students often find them less objectionable than other invertebrates. Besides their use as anatomical models, we have used MHCs for studies on metabolism and behavior, and we routinely use them as live examples of hemimetaolous insects. For additional ideas on using MHCs in the classroom, consult Wagler and Moseley (2005).

Students' reactions to the experience have been positive, and we have found the MHC to be a superior model species, preferable to commonly utilized alternatives. The availability of this species has increased dramatically in recent years, and laboratory rearing is simple, providing live animals for a range of learning activities.

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