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## Maria Sibylla Merian (1647-1717): Pioneering Naturalist, Artist, and Inspiration for Catesby

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# Maria Sibylla Merian (1647-1717): Pioneering Naturalist, Artist, and Inspiration for Catesby

## **Abstract**

**Book Summary:** While accessible to the interested general reader, it is a technical standard that is usable academically. Containing significant new information, this work is the most comprehensive and accurate book written about Catesby and is the legacy of the Catesby Commemorative Trust's Mark Catesby Tercentennial symposium held in 2012.

**Chapter Summary:** Merian's books on European and Surinamese insects and plants provided new models for representing nature that were echoed in the work of artists and naturalists working in the eighteenth century and beyond. This chapter discusses how Mark Catesby, the subject of the book, was particularly influenced by Merian.

## **Keywords**

Maria Sibylla Merian, botany, naturalist, Mark Catesby

## **Disciplines**

Biology | Botany | Horticulture | Plant Sciences

## **Comments**

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# 4

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## Maria Sibylla Merian (1647–1717): pioneering naturalist, artist, and inspiration for Catesby

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FLORENCE F. J. M. PIETERS

In 1699 a fifty-two-year-old woman and her younger daughter embarked in Amsterdam on a two-month voyage to the Dutch colony of Surinam in South America. Maria Sibylla Merian undertook this journey specifically to study insects in the tropical jungle and to document their metamorphoses and food plants, a study that today would be considered ecology. By this time in her life Merian was a renowned naturalist and had published two books on European caterpillars, moths, and butterflies. The book that would result from this extraordinary undertaking, *Metamorphosis insectorum Surinamensium*,<sup>1</sup> was the first to show New World plants and animals together in colorful images (figure 4-1) and would make a strong impression on Mark Catesby, as it did on other naturalists who followed her. Along with her volumes on European caterpillars, Merian's book on New World organisms, like Catesby's, changed the way in which the natural world was perceived and portrayed.

Maria Sibylla Merian's background and artistic training made her uniquely suited to write and illustrate the first books to portray the interactions of animals and plants. Born in the German city of Frankfurt am Main in 1647, Maria Sibylla grew up among artists and publishers (figure 4-2). During the second part of her life she lived in Amsterdam, where her work is still celebrated today. Her name, "M. S. MERIAN," appears on the façade of the Artis Library (built in 1867) along with those of thirty-five famous men of science, including Aristotle, Pliny, and Linnaeus.<sup>2</sup> The name Artis is derived from the motto "Natura artis magistra" of the Zoological Society of Amsterdam, which founded a zoo, a zoological museum, and a library in Amsterdam in 1838.<sup>3</sup> This motto seems an appropriate starting point for a discussion of Merian and Catesby, as it means: Nature is the teacher of the arts and sciences. Interestingly, in her native Germany, Maria Sibylla Merian seems to be regarded as the earliest female German artist of renown,<sup>4</sup> whereas in the Netherlands she is generally considered to be the first important female scientist.

FIGURE 4-1. Banana (*Musa × paradisiaca*) with moth and larva of the bullseye moth (*Automeris liberia*); plate 12, M. S. Merian, 1719, *Over de voortteeling en wonderbaerlyke veranderingen der Surinaemsche insecten*. (Courtesy of Artis Library, University of Amsterdam.)

Maria Sibylla's father, the prominent engraver, painter, and publisher Matthäus Merian (1593–1650), died when she was only three years old. Her mother, Merian's second wife, Johanna Sibylla Heim (c. 1620–1690), then married the versatile painter Jacob Marrell (1613–1681). Within these households, Maria Sibylla was taught and influenced artistically by her stepfather and her half-brothers. Her favorite half-brother, Caspar Merian, was probably her teacher in the arts of etching and engraving on copper, and printing, but it was her stepfather to whom she owed much of her excellent artistic education. Jacob Marrell has long been celebrated for his splendid flower paintings, which in the tradition of that period included insects and other small animals to enliven the composition and to denote important symbolism. Animals such as a butterfly or a lizard could symbolize resurrection, and a snail could indicate caution or laziness; floral symbolism was complex as well, with withering flowers indicating mortality, columbine signifying the Holy Spirit, or others,

FIGURE 4-2.  
Maria Sibylla  
Merian; anonymous  
1679, oil on canvas.  
(Reproduced by  
permission of  
Kunstmuseum Basel.)

such as lily-of-the-valley, representing humility (figure 4-3).<sup>5</sup> Apart from masterworks in oil, Marrell also produced highly detailed and life-sized portraits of tulips in watercolor on parchment for catalogs used by the tulip trade in Holland.<sup>6</sup> At least four of his “tulip books,” sometimes with prices of the bulbs indicated, are extant.<sup>7</sup> It is striking that he added small animals to these images even though they were generally not of use in such a trade catalog (figure 4-4). His stepdaughter also produced beautiful and detailed images of tulips and decorated her early flower paintings with little animals, but she would later include insects with a new and clearly scientific purpose (figure 4-5).

Maria Sibylla’s artistic training in the relatively liberal Marrell household was fortuitous. At that time in Germany, girls were barred from painters’ guilds, and in some towns it was forbidden for women to sell their own oil paintings.<sup>8</sup> In addition, Maria Sibylla grew up among printing presses and a vast array of books, a promising start in life for someone who would go on to publish several natural history books of her own. The Merian family firm published natural history books such as John Jonston’s *Historia animalium*, an early zoological encyclopedia for which the plates were engraved by her half-brothers. Jonston’s volume on insects, which included large plates with many creatures in rows, may have particularly caught her eye (figure 4-6).<sup>9</sup> Such childhood influences appear to have piqued her curiosity, for at the age of thirteen, Maria Sibylla observed the metamorphosis of silkworms and documented

FIGURE 4-3.  
Flower still-life painting  
by Jacob Marrell, with snail  
and lily-of-the-valley in  
the foreground; undated,  
oil on canvas. (Courtesy  
of Art Gallery P. de Boer,  
Amsterdam; private  
collection.)

FIGURE 4-4.  
Watercolor on  
vellum, 1639, in a  
tulip book by Jacob  
Marrell with butterfly,  
shell, and dragonfly  
added. (Reproduced  
by permission of  
Rijksmuseum,  
Amsterdam.)

FIGURE 4-5.  
Metamorphosis of a  
moth (possibly the  
purple clay moth, *Diarsia  
brunnea*) on a tulip; plate  
2, M. S. Merian, 1679,  
*Der Raupen wunderbare  
Verwandlung und  
sonderbare Blumen-  
nahrung*. (Courtesy  
of Netherlands  
Entomological Society  
[NEV], Amsterdam.)

FIGURE 4-6. Plates 4 and 21 from J. Jonston's book on insects were originally engraved by Matthaeus Merian jr and Caspar Merian for the Latin edition (1653). These images are from a re-engraved and hand-colored Dutch edition (1660). (Courtesy of Artis Library, University of Amsterdam.)

their transformation from egg to adult. The same patience and skill needed to depict living organisms accurately stood her in good stead as she began to raise insects and study their life-cycles. Thus began a lifetime of pioneering empirical research that breathed the spirit of the early Enlightenment.

When she was eighteen, Maria Sibylla married Johann Andreas Graff, who had been a pupil of her stepfather. They had two daughters: Johanna Helena was born in 1668, and Dorothea Maria ten years later. From 1668 the family lived in Nuremberg, where Maria Sibylla gave lessons in painting and embroidery to young women and published her *Neues Blumenbuch* in three installments. This flower book often included insects in its plates.<sup>10</sup> More strikingly, however,

Maria Sibylla had expanded her investigations of the life-cycles of moths and butterflies, and in 1679 she published the first volume of her studies of the metamorphoses of European moths and butterflies, *Der Raupen wunderbare Verwandlung und sonderbare Blumen-nahrung* (The wondrous transformation of caterpillars and their curious diet of flowers) (figure 4-7).<sup>11</sup> After the death of her stepfather in 1681 she moved back to Frankfurt to assist her mother, and there she published the second volume of *Raupen*.<sup>12</sup> About four years later she moved with her two daughters and her mother to Wieuwerd in Friesland (part of the Dutch Republic) and joined her half-brother Caspar in a Protestant community called the Labadists. During her stay at Wieuwerd, she continued her investigations of the life-cycles of insects. Studying natural history was considered an appropriate occupation for a devout person because it was believed that one could come nearer to God by examining his creations.<sup>13</sup>

Around this time Maria Sibylla began to arrange the loose pages of her detailed paintings on vellum and notes into a large journal containing her observations on metamorphosis, insect behavior, and what we now think of as

FIGURE 4-7. Mulberry wreath (*Morus* sp.) with early life stages of the silkworm (*Bombyx mori*) and several unidentified insects; frontispiece, M. S. Merian, 1679, *Der Raupen wunderbare Verwandlung und sonderbare Blumen-nahrung*. Of particular interest is the depiction of larvae hatching from eggs, published at a time when the idea of spontaneous generation of insects was still entrenched. (Courtesy of the University Library Johann Christian Senckenberg, Frankfurt am Main.)

the ecology of insects. She continued to add to this journal for three decades. For Maria Sibylla as naturalist and artist, this notebook was an indispensable record and an invaluable source of carefully depicted models. The small paintings documented the precise colors of the living insects, their eggs, larvae, and pupae, and in doing so recorded information that would be lost in preserved specimens. Scholars consider this an essential tool for their research on Maria Sibylla Merian, both because her original hand-painted works depict so many details and because some of Merian's notes were not included in her published works. For instance, in 1686 she described the development of frog's eggs and the metamorphosis of tadpoles long before the observations of the same phenomenon by the Dutch microscopist Antony van Leeuwenhoek (1632–1723) were published in 1699.<sup>14</sup> As Maria Sibylla was continuing her work in Wieuwerd, her husband tried unsuccessfully to join the Labadist community as well, and one result of this family drama was their separation.<sup>15</sup> Maria Sibylla left the community and moved with her daughters to Amsterdam in 1691; shortly afterward her marriage was formally dissolved, and she published thereafter under the name Maria Sibylla Merian.

In Amsterdam, Merian made a living selling paintings of flowers and insects and trading in specimens. Like Frankfurt and Nuremberg, Amsterdam was an important hub of the European book trade, and, moreover, it was an epicenter of international trade. By this time, Merian was well respected among naturalists, scholars, and collectors interested in natural history due to her *Raupen* books, and this gave her entry into the drawing rooms, libraries, and natural history collections of Amsterdam, including that of the Director of the East India Company, Nicolaas Witsen.<sup>16</sup> She wrote about this in the introduction to *Metamorphosis*:

In Holland I marveled to see what beautiful creatures were brought in from the East and West Indies . . . in which collections I found these and countless other insects, but without their origins and generation; that is, how they change from caterpillars to pupae and so forth. This prompted me to undertake a long and expensive journey and to travel to Surinam in America . . . to continue my observations there. . . .<sup>17</sup>

Thus Merian made the astounding decision to travel to Surinam to study tropical insects first hand. In June 1699, after having drawn up her will, she embarked for Surinam with her daughter Dorothea. Maria Sibylla Merian became the first naturalist to undertake a voyage specifically to study metamorphoses of New World organisms and one of the few to undertake such a journey without the backing of a wealthy patron or in service to a government. Merian was forced by reasons of health to return to Amsterdam after just two years in Surinam, but in that short time she observed, collected, and documented almost two hundred species of tropical plants and animals. Soon after her return to Amsterdam she began the work necessary to publish her observations, and in 1705 *Metamorphosis insectorum Surinamensium* was published.

For the remainder of her life Merian worked on various projects, including a third volume of her caterpillar book; this volume was edited by Dorothea and published soon after Merian died at the age of sixty-nine, on 13 January 1717.<sup>18</sup> Apparently she had been living in rather poor circumstances, and it is interesting that around the time of her death, Merian's research journal was sold to Robert Erskine (1677–1718), a Scot who was court physician to the Tsar of Russia, Peter the Great.<sup>19</sup> Erskine also bought for the Tsar almost three hundred of Merian's watercolors on vellum at the cost of three thousand guilders, roughly the price of an average house in 1717 Amsterdam. The next year, Dorothea moved with her second husband, Georg Gsell, to Saint Petersburg, where they were appointed art advisors to the Tsar and teachers at the newly founded Russian Academy of Arts and Sciences.<sup>20</sup> Meanwhile, *Metamorphosis* firmly established Maria Sibylla Merian's fame, and it went through several editions during the eighteenth century.

## Merian's books

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During her lifetime Merian published the life-cycles and habits of more than 250 species of insects, and by elucidating their relationship to plants, she can be called one of the first ecologists. Merian's published images were the first to combine biologically linked plants and insects on the same page; in her *Raupen* books, Merian arranged the life stages of each insect, usually a moth or butterfly, around a plant that served as food for their respective caterpillars (figure 4-8).<sup>21</sup> She described the reproduction and metamorphoses of butterflies and moths and was one of the earliest naturalists to write about the insects' defensive behavior and locomotion, as well as myriad other biological details of larvae and adults. She also recorded factors that are part and parcel of contemporary ecological science, including descriptions of environmental effects on insect development and abundance and observations on food choice and feeding behavior.<sup>22</sup> Through her observations of insects in nature and by raising them through all life stages, Merian demonstrated that they reproduce by mating and egg production, which was notable at a time when spontaneous generation of insects was still accepted by many scholars. By the time Merian published her first "caterpillar book" in 1679, she was able to state conclusively that caterpillars hatched from eggs laid after male and female butterflies and moths mated.<sup>23</sup>

Before Merian's innovative compositions were published, plants and animals were illustrated separately for the most part, a model unchanged since medieval encyclopedias and herbals. An entomological example can be seen in Jonston's encyclopedia, in which insects were not only separated from plants, but adults and larvae were depicted on separate plates (see figure 4-6).<sup>24</sup> Even Merian's near contemporary, Hans Sloane, had his illustrators follow this traditional approach in his volumes on Jamaica (figure 4-9),<sup>25</sup> so that similar organisms were arranged on a page with no regard to the other plants or animals that

FIGURE 4-8. One of Merian's earliest studies of metamorphosis, of a small tortoiseshell butterfly (*Aglais urticae*) on the small nettle (*Urtica urens*); plate 44, M. S. Merian, 1679, *Der Raupen wunderbare Verwandlung und sonderbare Blumen-nahrung*. (Courtesy of Netherlands Entomological Society [NEV], Amsterdam.)

might appear in the same habitats. But Merian continued her more naturalistic approach in constructing her images for *Metamorphosis*. As she did for almost every entry on moths and butterflies, she also described the caterpillar she had found feeding on the leaves and the dates of its pupation and of its emergence as an adult. *Metamorphosis*, like her earlier *Raupen* books, focused on insects but included much more information on plants, perhaps because the species pictured would have been unfamiliar to her European audience. For example, in the text accompanying a plate depicting the inflorescence of a banana (see figure 4-1, p. [xref>000](#)), she described the growth-form of the plant and the taste and texture of the fruit.<sup>26</sup> Much of the information on the uses of plants was obtained from slaves on the sugar plantations where she had stayed or from indigenous people who had helped her collect specimens. In *Metamorphosis* she

often acknowledged the role of slaves and “her Indian,” writing in one entry that a plant she wished to study had been “dug up by the roots by my Indian and brought back to my house and planted.”<sup>27</sup> Merian often noted potential medical or other uses of the plants, such as the trunk of the fan palm, which when cooked “tastes better than artichoke hearts.”<sup>28</sup>

As well as adding more botanical information in *Metamorphosis*, Merian broadened her coverage beyond moths and butterflies to include some spiders, reptiles, and amphibians in the hopes of stimulating interest in a further volume (figure 4-10).<sup>29</sup> Her fascination with reproduction and development features in the text and plates of frogs; she was one of the first to represent amphibian reproduction accurately (figure 4-11).<sup>30</sup> In addition to life-cycles, Merian also depicted food chains and portrayed both adult insects and their larvae while feeding. In *Metamorphosis* she included the predation of insects upon frogs (figure 4-11), reptiles upon insects (figure 4-10),<sup>31</sup> and the startling image of a giant spider preying upon a hummingbird while other spiders and ants feed and forage (figure 4-12).<sup>32</sup> The text that accompanied the latter image was more than twice the length of most, and in addition to material on the spiders and the hummingbird, it included a description of the migratory foraging raids of army ants, the ability of leaf-cutter ants to defoliate a tree overnight, and even the fact that the leaf-cutters took their harvest back to deep underground nests.<sup>33</sup> Between her own observations and what she gleaned from her local sources, Merian built up a vivid picture of the teeming life of the Surinam jungle.

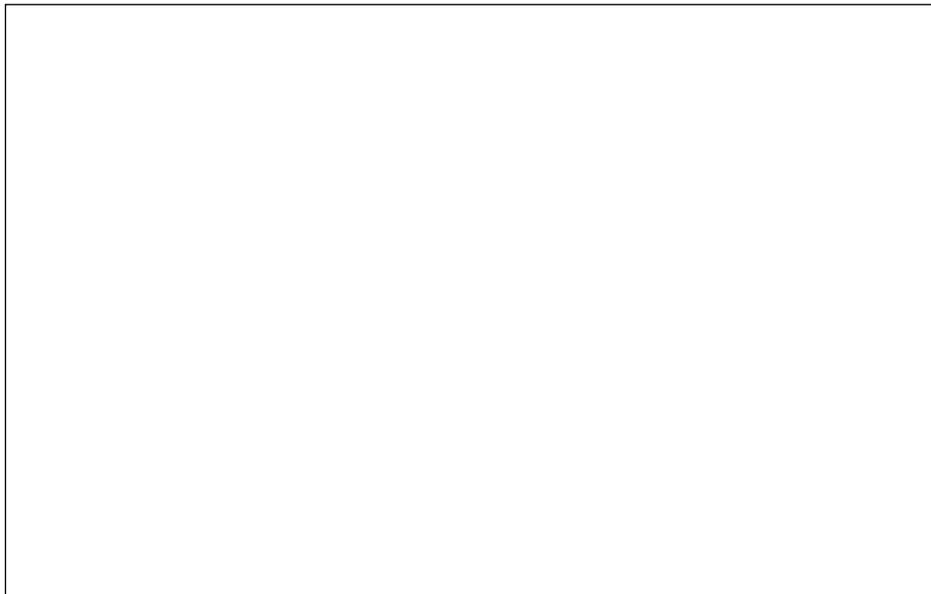


FIGURE 4-9. The poisonous manchineel tree (*Hippomane mancinella*) and the Jamaican boa or yellow snake (*Epicrates subflavus*); plates 159 and 274, respectively, Hans Sloane, 1725, *A voyage to the islands Madera, Barbados, Nieves, S. Christophers and Jamaica. . .* (Courtesy of Missouri Botanical Garden, St. Louis.)

FIGURE 4-10. Metamorphosis of the white peacock butterfly (*Anartia jatrophae*) on cassava (*Manihot esculenta*) with tegu lizard (*Tupinambis merianae*; named after Merian in 1839 by Duméril & Bibron) and unidentified ant; hand-painted version of plate 4, M. S. Merian, 1705, *Metamorphosis insectorum Surinamensium*; pen and ink with watercolor and bodycolor on vellum. (© Trustees of The British Museum, London.)

FIGURE 4-II. Marbled tree frog (*Phrynohyas venulosa*) with tadpoles and eggs, water hyacinth (*Eichhornia crassipes*), and water bug juvenile and adult (*Lethocerus grandis*); hand-painted version of plate 56, M. S. Merian, 1705, *Metamorphosis insectorum Surinamensium*; pen and ink with watercolor and bodycolor on vellum. (© Trustees of The British Museum, London.)

FIGURE 4-12. The pink-toed tarantula (*Avicularia avicularia*), brown huntsman spider (*Heteropoda venatoria*), an unidentified orb weaver of the Araneid family, a roach (*Blattaria* sp.), army ants (*Eciton* sp.), leaf cutter ants (*Atta cephalotes*), and a guava tree (*Psidium guineense*). The hummingbird does not precisely match any known species. Hand-painted version of plate 18, M. S. Merian, 1705, *Metamorphosis insectorum Surinamensium*; pen and ink with watercolor and bodycolor on vellum. (© Trustees of The British Museum, London.)

## Merian's influence

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The *Raupen* books on European insects and *Metamorphosis* provided new models for representing nature that would be echoed in the work of other artists and naturalists in the eighteenth century and beyond.<sup>34</sup> *Metamorphosis* in particular was to become one of the most influential natural history books ever published. It was striking both in its size, roughly 22 inches (54 centimeters) in height, and in its content. The large pages allowed Merian to portray her plant and insect subjects as life-sized, adding further to the biological information contained in the groundbreaking work. Merian offered the option of hand-colored copies, and those books were among the first publications to show New World organisms in colorful splendor. Not only the Tsar but many other influential collectors and naturalists sought out both Merian's paintings on vellum and her books. The London pharmacist James Petiver sent specimens to her and corresponded with her about the possibility of an English edition of *Metamorphosis*. Hans Sloane acquired early editions of Merian's books and a considerable number of her paintings, as did Dr. Richard Mead (1673–1754), whose collection of Merian's paintings and books is now in the Royal Library at Windsor Castle. Sloane and Mead also subscribed to Mark Catesby's book.

Merian's vibrant and dramatic images and her writings would have been viewed with great interest by a circle of naturalists who communicated and worked with these influential patrons, including Mark Catesby and Eleazar Albin (c. 1690–1742). Albin referred frequently to Merian's *Raupen* books in his 1720 work on moths and butterflies, and his compositions of insect life-cycles and the larval host-plants mirror her work to a large extent.<sup>35</sup> Catesby's *The natural history of Carolina . . .* was the most important book about New World organisms to follow *Metamorphosis* and has several similarities to Merian's. The size and layout of Catesby's *The natural history of Carolina . . .* echo *Metamorphosis*, and his images are structured in a similar way (compare, for example, figures 4-11, p. xref>000, and 4-13).<sup>36</sup> As another protégé of Sloane, he would have had opportunity to study Merian's work,<sup>37</sup> and there is direct evidence that he did so, because he made two specific mentions of details from *Metamorphosis*. In the first, he criticized Merian's depiction of the cashew.<sup>38</sup> The second reference is in his description of the geographic range of the opossum, where he noted that Merian "has described them at Surinam."<sup>39</sup> Catesby's mention of Merian's opossum indicates that he must have used one of the posthumous editions of *Metamorphosis*, because the opossum plate was first inserted by the publisher of the 1719 edition.<sup>40</sup> It is possible that Catesby had studied the bilingual 1726 *Metamorphosis*;<sup>41</sup> this edition had text in Latin and in French in a format similar to that used by Catesby in his *Natural history of Carolina . . .*, although his text was in English and French.<sup>42</sup>

FIGURE 4-13. Cananda lily and beetles; plate 11, M. Catesby, 1747, *The natural history of Carolina . . .*, volume II: Appendix. Catesby depicted several insects in *The natural history of Carolina . . .*, including the dung beetle (*Canthon pilularius*) (lower left) and rainbow scarab beetle (*Phanaeus vindex*) (lower right), with the Canada lily (*Lilium canadense*). (Digital realization of original etchings by Lucie Hey and Nigel Frith, DRPG England; courtesy of the Royal Society ©.)

Merian's images of interacting organisms may have led Catesby, consciously or otherwise, to portray his subjects in a more lively way. Catesby also followed Merian by depicting plants and animals close to life-sized, as with his full-page image of a bullfrog. Similarly, he included images such as a sea turtle with her eggs and a tree frog eyeing a spider as prey, akin to the way Merian pictured reptiles with their eggs and animals in various acts of predation. However, major differences exist between these two pivotal natural history books, and one is that Catesby's focus was clearly vertebrates, while Merian included only a few of these. The first edition (1705) of *Metamorphosis* documented two species each of frogs, lizards, and snakes,<sup>43</sup> and the second edition (1719) included a caiman defending its young from an egg-eating snake (figure 4-14), an adult tegu lizard, the opossums, and additional frogs.<sup>44</sup> The unfortunate image of the "frog-fish" added to the later editions came from the Amsterdam pharmacist and collector Albert Seba (1665–1736) and actually served to undermine Merian's reputation in later years, even though it was not her work.<sup>45</sup>

Whereas Merian described the food plants and ecological relationships of dozens of insects, Catesby did this primarily for birds, mammals, fish, reptiles, and amphibians. A notable exception is the Appendix of *The natural history of Carolina . . .*, in which Catesby included information about the habits of some industrious beetles (see figure 4-13, p. [xref>000](#)).<sup>46</sup> Catesby also included a number of moths in the second volume, in some cases showing their pupae and in one instance a lone caterpillar.<sup>47</sup> However, in several cases Catesby depicted insects from the Carolinas on plants from the Bahamas, whereas Merian took care in most instances to pair insects with a host plant of their larvae.<sup>48</sup> In many images Catesby combined his vertebrate subjects with plants found in the same or similar habitat, although not in every case. Similarly, there is no direct association between the few vertebrates Merian depicted and the plants within the same plate other than that they were both found in Surinam.

Merian and Catesby had expertise in different kinds of animals, and Catesby's much more extensive travels are also revealed in the diversity of organisms included in his two volumes. *Metamorphosis* is an intensive look at a relatively small cross-section of terrestrial habitat, whereas Catesby's much more wide-ranging survey delved into both the terrestrial and the marine organisms of the New World. For example, Merian's image teeming with spiders, ants, and their prey depicts a small slice of a tropical jungle in an up-close view, whereas Catesby's broader perspective let him understand something about the migration of birds over long distances. But the two books are similar in several important aspects, such as portrayal and description of organisms existing and interacting in what we now think of as a habitat. Although both Merian and Catesby depicted organisms so accurately that many of their images were

FIGURE 4-14.  
Juvenile spectacle  
caiman (*Caiman  
crocodilus*) with the  
false coral snake  
(*Anilius scytale*); plate  
69, M. S. Merian, 1719,  
*Over de voortteeling  
en wonderbaerlyke  
veranderingen der  
Surinaemsche insecten*.  
(Courtesy of Artis  
Library, University of  
Amsterdam.)

used by Carl Linnaeus and others to describe new species, it could be argued that their major contribution was to lay the foundation for ecological studies of interactions of organisms with their environment. Both authors showed predation and included information about reproduction; both depicted and described the interrelationships of plants and animals. Each of these pioneering naturalists learned from indigenous sources and conveyed to their readers the potential uses of New World plants. But perhaps most importantly, the vision of nature created by Merian and Catesby introduced Europeans to the American flora and fauna in a way never before seen, and the work of both served as models for future work by William Bartram (1739–1823), John James Audubon (1785–1851), and countless others. Maria Sibylla Merian and Mark Catesby viewed the living world in a new way and, by portraying what they saw through text and vivid images, changed the course of natural history.