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Maria Sibylla Merian and metamorphosis

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Despite the fact that art is subjective and concerned with aesthetics, whereas science is an objective enterprise based on observation and experimentation, a combination of these dissimilar activities can yield surprising results. A small group of world-class biologists have also been gifted artists. This group includes the German botanist Julius Sachs, founder of experimental plant physiology[1]; the zoologist Ernst Haeckel; and, perhaps less known, the entomologist Maria Sibylla Merian (Fig. 1), the tricentenary of whose death falls this year.

Merian made significant contributions to the foundation of developmental biology and ecology, but has been neglected. Born in 1647 in Frankfurt (Main), Germany, Merian developed her skill painting insects and plants under the guidance of her stepfather, the artist Jacob Marrel. At the age of 13, she was already an accomplished painter, with an overwhelming drive to study nature. Merian started to collect insects and plants in her early years, focusing on butterflies and their plant hosts. She continued to study the life cycles of animals throughout her life, which she spent working as a professional artist and illustrator. Merian's plants (Fig. 2) were drawn with the same scientific precision as those of the botanist Julius Sachs[1]. In total, Merian analysed and scientifically documented the ontogeny of about two hundred species[3,4].

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Figure 1 | The German-Dutch artist and biologist Maria Sibylla Merian (1647–1717).

Figure 2 | Merian's paintings. Left, watercolour image on the title page of Merian's first scientific book *Der Raupen Wunderbare Verwandelung und Sonderbare Blumen-nahrung* (The Wonderful Metamorphosis of Caterpillars and Strange Flower Nourishment). Merian described the complete life cycles of numerous insect species, including their destructive feeding behaviour on host plants, and rejected the then popular idea of an origin of insects via 'spontaneous generation'. Image courtesy of U. Kutschera. Right, Merian's realistic documentation of the "struggle for existence" in a natural world that was, in her view, God's creation. Plate 18 from her *magnum opus* of 1705, depicts a hairy bird-killing spider, as well as leaf-destroying ants that build bridges between the branches of a guava tree. These "cruel" ecological interactions were questioned by Merian's critics, but later confirmed by independent studies. Image © The British Library Board.

At the age of 18, Merian married an apprentice of Marrel, Johann Andreas Graff, who supported the publication of two volumes of her book[5] on the development of caterpillars and their host plants (*Der Raupen Wunderbare Verwandelung*). The marriage was unhappy, and in 1685 Graff and Merian separated. With her two daughters and her mother, Merian joined the Labadists, a Christian sect in Friesland, Netherlands, where she continued to paint insects and plants, and educated her daughters. In 1691, Merian relocated to Amsterdam, where she worked as a teacher and painter, and became acquainted with the tropical fauna and flora imported from the Dutch colony of Suriname[4].

In 1699, Merian, accompanied by her younger daughter, travelled to Suriname with the aim of collecting and painting living specimens of tropical animals and plants, supported by a grant from the city of Amsterdam. After two years exploration of South American forests, Merian contracted malaria and was forced to return to Amsterdam. Three years later, Merian published her masterpiece, the *Metamorphosis Insectorum Surinamensium*, wherein she described and depicted hundreds of tropical plants and animals[6]. Despite the fact that Merian was a deeply religious woman who praised the "creations of the Biblical God" in her published work[5,6], she also depicted the merciless "struggle for existence" in much of her work (Fig. 2). Like Carl Linnaeus, who later based descriptions

of several insect species on Merian's illustrations, she was a 'theistic naturalist', who did not, however, mix up scientific facts with religious dogma.

Her popular 1705 book brought her recognition and fame. The German writer and botanist Johann Wolfgang von Goethe, among other naturalists, admired and referred to her work. However, these international acknowledgements did not lead to a steady income. A second volume, with images of tropical plants and amphibians, was scheduled, but, due to a lack of subscribers, not published during her lifetime. On 13 January 1717, Maria Sibylla Merian died in Amsterdam, and her body was buried in an anonymous pauper's grave[3,7].

In her three scientific books[5,6], Merian described the life cycles of 186 insect species, from the egg to the dying imago, as well as those of frogs and toads. Based on these empirical findings, Merian thoroughly refuted the classical (Aristotelian) concept of 'spontaneous generation', that is, the belief in the origin of lower animals, such as insects, out of the mud. Nevertheless, this outdated idea was still being seriously discussed in the twentieth century[8]. In her work of 1679 (Fig. 2), Merian had concluded that, following mating of adult individuals, caterpillars originated from eggs that had been attached by the gravid female to their species-specific host plant.

Due to her focus on insect reproduction and the competitive–destructive animal–plant-interactions that Merian studied for the first time on cultivated, living organisms (as well as in the field), she became one of the pioneers of developmental biology and ecology (Fig. 2). In addition, Merian was one of the first Europeans to visit the tropics in order to study native animals and plants, with the explicit aim of elucidating their origin (from eggs) and biotic interactions[6]. However, perhaps since she was not an academic scientist, Merian's biological insights have been largely ignored. This lack of recognition, notably by academic societies of the seventeenth century, may be due to the fact that she was an independent woman in a male-dominated society. Unfortunately, this gender-bias against Merian[7] continues to the present. For instance, in Ernst Mayr's influential *Growth of Biological Thought*, Merian is not mentioned[9].

On the third centenary of her death, it is high time to acknowledge the outstanding scientific achievements of Maria Sibylla Merian — the "forgotten mother" of animal developmental biology and ecology, a term coined 150 years ago by Ernst Haeckel[2]. ❐

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Competing interests

The author declares no competing financial interests.