The influence of artistic talent on scientific appreciation in seventeenth-century entomologist illustrations in Europe

To what extent are seventeenth-century entomologists considered to be artists or scientists by contemporary researchers

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Abstract

The seventeenth century, especially in the second half, was a significant transitional era in the history of the study of insects. Some of the most famous names in this regard are Johannes Goedaert, Maria Sibylla Merian, and Jan Swammerdam. All these naturalists carefully observed insects and turned their findings into illustrations; however, Goedaert and Merian, who possessed excellent painting skills, were described primarily as artists by certain researchers, while Swammerdam was described as a scientist. This phenomenon forms the research problem of this thesis, expressed in a question about the connection of artistic skills of entomologists and recognition of their scientific input. The objective of this research is to determine to what extent is the artistic level of the entomologists' illustrations of influence on the level to which they are considered scientists or artists by contemporary researchers. The methods of the research were data analysis of scientific illustrations history and biographical information of the entomologists as well as comparison of the three entomologists' illustrations of the transformation of insects with the use of the theory of the picture by Gabriele Werner. The key results of the research include the findings that the opinions of the researchers could be influenced by the artistic value of the illustrations and the reputation of the entomologists as artists and scientists. The results bring to the conclusion that although art and science go hand-in-hand and complement and reinforce each other, certain aspects of entomologists' life paths can contribute to the fact that researchers attribute them to only one type of activity.

Keywords: entomological illustrations, study of insects, art vs science, Johannes Goedaert, Maria Sibylla Merian, Jan Swammerdam

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Introduction

Illustrations are an essential medium for the distribution of knowledge, especially in books about natural history, as observations and findings are transformed into illustrations.[1] These illustrations made it possible to show different and distant species in a much more precise way than words. Leonhard Fuchs (1501-1566), one of the founders of the botany, shares this opinion as he writes in his book: ‘‘who in his right mind would condemn pictures which can communicate information much more clearly than the word of even the most eloquent men?’’[2] So, one could imply that the quality of illustrations directly influences the overall quality of a book, which makes the skill of drawing an essential condition for natural, historical research during the seventeenth century. This results in a fluid boundary between artists and naturalists, thus also between making illustrations and knowing.[3] A discipline that clearly shows these fluid boundaries is the field of entomology. Insects were a popular subject of study during the seventeenth century, although the term entomology was not introduced until 1745 by Charles Bonnet (1720-1793), marking it as a distinct discipline.[4] For instance, Johannes Goedaert (1617-1668) extensively studied the transformation of insects, which in his eyes was the evidence of God’s wondrous works.[5] His books, *Metamorphosis Naturalis,* resulted from years of empirical research. These volumes were very influential, as, until his first publication in 1660, the study of insects mainly was focused on a few species, in contrast to the works of Goedaert, who described and illustrated about 150 various sorts.[6] Nonetheless, it is unclear if Goedaert should be labelled as a scientist or an artist. The same applies to Maria Sibylla Merian (1647-1717), a very broadly talented woman who ventured into painting, embroidery, needlework but also trading, depicting and describing insects. Her first book about insects, *Raupenbuch*, published in 1680, was seen as innovative, as she depicted the insects in their different stages of life, including their food plants.[7] A third well-known naturalist interested in the transformation of insects is Jan Swammerdam (1637-1680), who published his first book in 1669. Where Goedaert, and almost every scholar before him, was a fierce supporter of the theory of spontaneous generation, Swammerdam firmly believed that all creatures, even insects, were the result of sexual procreation.[8] Therefore, he was seen as revolutionary.

For an existential time, art and science were considered to be interchangeable terms. During the early modern era, the Latin terms *ars* and *scientia* were rather complementary than distinctive, covering

[1] Bredekamp, Dünkel, and Schneider, *The Technical Image,* 1.
[2] Fuchs, *De historia stirpium, x-xi.*
[3] Jorink and Ramakers, “Undivided territory”, 8.
[4] Ogilvie, “Nature’s Bible”, 5.
[5] Ibid.
[6] Jorink, *Reading the Book of Nature*, 201.
[7] Neri, *The insect and the image,* 140.
[8] Jorink, *Reading the Book of Nature*, 219.

activities as skill, knowledge and experience. According to the writer Willem Goeree (1635-1711), a real artist had to cover many skills and knowledge, for instance, drawing, astronomy, architecture, colour theory, knowledge of the Bible, classical history and natural sciences.[9] However, this interwoven relationship between art and science became unrecognised due to the emergence of modern academic disciplines like art history and the history of the sciences. During these nineteenth and twentieth centuries, the differences and similarities between artistic and scientific illustrations were studied abundantly. Thereby, the impulse to categorise naturalists into scientists and artists arose, although this disregarded the epistemological background. Much has changed in the last twenty years; there is more attention for the historical, intellectual and social context, meaning the epistemological preconditions, in which the objects were created. Art historians like Martin Kemp and Horst Bredekamp have focused on researching the role of images in scientific works. The focus is no longer only on the question: who was first?[10] Instead, researchers of science are now interested in the question: what makes science? Thereby art historian Pamela H. Smith has stressed the importance of the skill of drawing by scientists and the knowledge of the properties of materials by artists for the development of science.[11] Art and science historian Erik Jorink, explains that ‘‘this inclusion of attention to the objects and materials undoes the traditional dichotomies between the scholar and the craftsman, between knowledge and handicraft, between the mind and the hand.’’[12]

Notwithstanding this shift in interests and views on the study of art and science, the opinions on the division between art and science are still divided. On the specific subject of entomology intellectual and cultural historian Brian W. Ogilvie claimed in 2018, that both Johannes Goedaert and Maria Sibylla Merian were merely artists, stating that they ‘‘consciously set out to use their artistic and observational talents to serve ‘investigators of nature,’ denying any fundamental distinction between naturalists and artists.’’[13] Thereby, Ogilvie is negating the fluid boundaries between art and science. He is even denying the epistemological background of these entomologists, by stating that Merian and Goedaert denied the distinction between naturalists and artists, which was not even an existing concept during their lives. However, Ogilvie clearly described Jan Swammerdam (1637-1680) as a prominent scientist and a genius.[14] Ogilvie is not the only one with this specific opinion, professor of entomology Joop C. van Lenteren speaks of Merian and Goedaert as primarily artists. Additionally, Domenico Bertoloni Meli, a professor in the history and philosophy of science, describes Goedaert as merely an artist.[15] Their view is mainly expressed in calling Merian and Goedaert artists in their studies. For example, van Lenteren

[9] Goeree, *Inleyding tot de Practyk der Algemeene Schilderkonst,* 80.
[10] Lindberg and Westman, "Reappraisals of the Scinific Revolution", 1600-1601.
[11] Smith, *The body of the artisan.*
[12] Jorink and Ramakers, “Undivided territory”, 9.
[13] Ogilvie, “Nature’s Bible”, 6.
[14] Ibid., 15.
[15] Meli, “The representation of insects”, 415.

describes their lives and contribution from the position of their artistic work.[16] With this, he distinguishes the concepts of artist and scientist. However, not everybody seems to agree on this division. For instance, Jorink, describes Goedaert as being a scientist.[17] Furthermore, the work of Merian is also described as scientific because of her approach and the subject matter by Janice Neri, a professor in art history.[18] Moreover, she is called both an entomologist and an artist during an exhibition about her in the Neotropical Butterfly Park in Lelydorp, Surinam.[19] Thus, the representatives of this camp of researchers tend to acknowledge all fields of work of Goedaert and Merian, as they write about them as naturalists, entomologists, and artists at once. Hence the question logically follows what affected the opinions of the researchers from both groups. At first glance, it seems like all of the naturalists mentioned above conducted the same kind of empirical research consisting of collecting, observing, describing and depicting. Therefore, it is unclear on which grounds these distinctions were made by Ogilvie, Lenteren and Meli. Without any background information about these entomologists, one could imply that it seems like the more artistic talented naturalists (Merian and Goedaert) are considered artists, and their scientific knowledge is diminished. From this, the question arises: to what extent is the artistic level of illustrations of insect metamorphosis by seventeenth-century European entomologists of influence on which they are considered a scientist or an artist by contemporary researchers? The purpose of this study is to assess on what grounds these divisions are made by some contemporary researchers, by comparing the studies, knowledge, methods and illustrations of the selected entomologists. Are the descriptions by Ogilvie, Lenteren and Meli valid? Is it their artistic talent that overshadows the scientific significance of their work, is it their lack of academic education or are there other major differences in their contribution to the field of entomology? Swammerdam will thereby serve as a comparison, as he is described as a scientist and never as an artist. Of course, various factors could influence why the researchers came to their conclusions. For example, a researcher could compare the contribution of an entomologist to art and science. In addition, their conclusions could be influenced by the peculiarities of the approach that Goedaert and Merian used, their education, as well as the level of recognition they received during their lifetime.

This study will give a brief general overview of the division between art and science; furthermore, the history of scientific images will be discussed. More importantly, this research will attempt to figure out what the knowledge of the naturalists Johannes Goedaert, Maria Sibylla Merian and Jan Swammerdam is, considering the transformation of insects. Hereby, their methods, education, and

[16] Lenteren and Godfray, "European science in the Enlightenment", 17-19.
[17] Jorink, *Reading the Book of Nature,* 201.
[18] Neri, *The insect and the image, 155.*
[19] "Suriname: The Treasury Collection, Works by Maria Sibylla Merian, Exhibited in Suriname," Dutchculture –Centre for International Cooperation, last modified 18 August 2020, accessed on 31 March 2021, https://dutchculture.nl/en/news/suriname-treasury-collection-works-maria-sibylla-merian-exhibited-suriname.

personal interests will be taken into account. By comparing these results and their illustrations, insight will be obtained about whether the naturalist is only judged on their artistic talents or also on other aspects. The comparison of their illustrations of the transformation of insects will be conducted using the *Theory of the Picture* of Gabriele Werner. This theory beholds three assessment criteria: the eidetic competence, conceptual images, and the technique of the illustration. As Werner explains, these questions will lead to answers regarding the knowledge surrounding the illustration, like the quality of the illustration regarding the content, the visual representation and the representation of the research.[20]

The study is focused on insects, to be specific, the transformation of insects. The choice of this specific subject is based on the fact that insects were a new subject of interest for Europeans between the sixteenth and eighteenth century. Their unusual appearance and behaviour are a source of curiosity for many people, naturalists, collectors, artists and scientists. This new popular subject was present in every part of society, which makes the boundaries between the different disciplines regarding insects especially vague. As Janice Neri describes, ‘‘at the same time that insects emerged as new subjects, they also served as vehicles for the construction of artistic and scientific personae.’’[21] Insects became the main subject of many paintings, for instance, by the famous Albrecht Dürer (1741-1528). However, insects' ability to transform, an unravelled mystery during the seventeenth century, was also an intriguing research subject. Many naturalists tried to find out what the origin was for this mysterious change in semblance. The research into insects was often driven by religious beliefs. Insects were either a creation of the devil or God; their transformation was either spontaneous or a product of their sexual intercourse. Accordingly, the personal and religious interests of the naturalists are closely involved with their reasoning about the transformation of insects.

This research is intended to contribute to the field of visual culture, art and science history. While several studies focus on the relation between art and science in the early modern period, this study will provide the reader with specific information to understand on what basis naturalists are categorized into being an artist or scientist. Discussion about the relationship between art and science, as well as their opposition, is especially important today. Although this debate has been raging for centuries, the controversy continues to this day. Nevertheless, especially today, this topic has acquired special meaning for several reasons. First, we live in an era where the media are closely associated with scientific centres, as well as with the idea of rationalizing everything. Thus, the dominance of science in the modern world can negate the feeling of beauty, the ability to wonder. Therefore, it is very important to talk more about the fact that the degree of their significance is equal and both concepts are very closely interrelated: art can be found in science, just like science in art. Secondly, due to the universal penetration of technologies, the world has changed quite a lot; many people from the scientific

[20] Bredekamp, Dünkel, and Schneider, *The Technical Image*, 11-12.
[21] Neri, *The insect and the image,* xi.

community do not imagine how the art world and modern creative movements live; they forget that art has been the forerunner of many scientific discoveries. Therefore, reviving the understanding of the relationship between science and art is an important challenge today.

This research will firstly give a brief overview of the history of technical illustrations and the interdisciplinary boundaries involved with the subject. Subsequently, the knowledge of each of the selected entomologists will be examined separately, considering the transformation of insects. Thereby their education, personal interests, the goal of their work and their empirical methods of research will be investigated. Their knowledge will then be compared before the subject shifts to the illustrations of the entomologists. For each of the entomologists, one or two illustrations of the transformation of insects were selected. These illustrations will be analysed with *the theory of the image* by Gabriele Werner; a more elaborate commentation and the justification for this theory will be discussed. The influence of the artistic talent on the scientific appreciation will be evaluated, according to the obtained results. Eventually, a final conclusion about the findings will close this paper.

1. General history and features of technical illustrations in the seventeenth century

This chapter aims to give a brief overview of the research of insects during the seventeenth century and describe the role that illustrations play in this research. Furthermore, the fluid boundaries between art and science will be discussed, and the involvement of context in these technical illustrations. Research on insects was not something that many naturalists ventured into during the Renaissance, mostly because of their size. In order to study them in detail, optical tools were desired. Nonetheless, the topic gained tremendous popularity in Europe during the seventeenth century.[22] This new subject of study and its additional new knowledge filled up many books, most extensively illustrated. It is not that the insects were not illustrated before this time, but the visual contexts in which they appeared mainly were manuscripts, in which they were depicted alongside many other objects. In the seventeenth century books, this is not the case; the insects are the centre of attention.[23] This way of depicting a subject is called specimen logic, the visual technique of depicting a specimen against a blank background; specimens are decontextualised, and nature is turned into objects.[24] These specimen logic illustrations are an essential medium for distributing knowledge. They enabled people to build up knowledge of objects they did not possess and study them endlessly, even after the insect died. Therefore, images were an essential addition to studying nature, alongside objects and text.[25] In other words, the illustration was perceived as a single whole with the text and was its direct graphic interpretation. For these technical illustrations, it is not only the content they show that is important but also the forms of the imagery, as technical images actively transform observations and insights to inform the reader.[26] Illustrations should not be included for the illustration's sake, instead, the naturalists' purpose is to bring the description and the illustration into harmony; the illustration should complement the written word to make the absent present.[27]

In this study, the illustrations can be referred to as 'technical', meaning that they were not created for an artistic purpose but as instruments for transferring knowledge, insights and observations. These technical images often crossed the disciplinary boundaries; knowledge moved from one context to another.[28] Sachiko Kusukawa, a professor in the history of science, explains that ''naturalistic images, in turn, became a part of a larger visual culture in which nature was regarded as a beautiful and

[22] Ogilvie, "Nature's Bible," 5.
[23] Bredekamp, Dünkel, and Schneider, *The Technical Image*, xi.
[24] Neri, *The insect and the image*, xii.
[25] Kusukawa, "The role of images in the development of Renaissance natural history", 189.
[26] Bredekamp, Dünkel, and Schneider, *The Technical Image,* 1.
[27] Kemp, "Style and non-style in anatomical illustration", 193-196.
[28] Ogilvie, "Nature's Bible", 5.

fascinating object of admiration.''[29] Illustrations could serve scientific purposes but were also artistically used. This emphasises the fluid boundaries between art and science. An artist has to extensively study the outward appearance, form, structure, life cycle, and functioning of the insects, but a scientist should practise drawing and painting the same.[30] Hence, careful observation and accuracy were of great importance in both the field of science and art.[31] So, the skill of drawing was an essential precondition for entomological research. The importance of artistic qualities is emphasised by William Ivins Jr., curator of the Metropolitan Museum of Art, who states that visual artists even advanced science by creating a new visual representation mode. He explains that comparing was crucial for science, and accurate depictions made this possible. Woodcut has introduced a clear, graphic perception of objects, simplified composition, and sketchiness. Therefore, printmaking -and artists- was a crucial part of the development of science.[32] Peter Parshall, the curator of the National Gallery of Art in Washington, goes even further, arguing that images increased the status and authority of visual evidence. An accurate depiction of a subject, for instance, an insect, was employed as visual evidence, making comparison and classification possible.[33] Parshall elaborates on this by stating that ‘‘accurate visual representation was more than just a technical accomplishment. It was a highly specialised form of observation.''[34] With their arguments, both these curators level the inequality of status between artist and scientist. They emphasise the magnitude of illustrations in science, attaching great value to the accuracy. Therefore, excellent observational and artistic skills are an unmistakable addition to science. For this, one could suggest that a great artist, during the seventeenth century, can also be seen as a great scientist, spreading accurate information for other scientists to use. A more detailed, accurate, clear image of an insect has more scientific value than a schematic drawing on which the insect is less recognisable. Does Merian make the illustrations not of great scientific value because of their details and accuracy? Her naturalistic paintings can be seen as a model of perception, a mode of investigation. A faithful representation of an insect could be seen as an imitation of nature, deceiving the eye into thinking the insect was real. The representation of the transformation of insects can therefore be seen as the imitation of nature's process.[35] Many people did not see this process, and a truthful and clear representation is therefore of great value for science and entomology, creating more understanding for the development of insects.

Style is a concept that is inextricably linked with images. Should the naturalist concentrate on a simple, schematic representation of an insect or strive for an appealing, artistic, but truthful

[29] Ogilvie, "Nature's Bible", 5.
[30] Jorink and Ramakers, "Undivided Territory", 7.
[31] Neri, *The insect and the image*, xviii.
[32] Ivins, *Prints and Visual Communication.*
[33] Parshall, "Imageo contrafacta", 554-579.
[34] Ibid., 257-258.
[35] Smith, "Art, Science, and Visual Culture", 91.

representation? According to art historian Martin Kemp, is style ‘‘a rather irrelevant adornment to the business of communicating information and at worst a positive liability.’’[36] Though it is unavoidable that every image has its own style. The creation of a technical illustration is a continuous struggle of style, between creating a simple, schematic depiction of the object, looking precisely as seen, or representing the object how the observer interpreted it.[37] In every image, there is an inclusion of subjectivity, of interpretation. One could say that this is the personal style of the creator. Currently, the style of scientific images is schematic, in order to transfer the information objectively and functionally. However, this has not always been like this; during the seventeenth century, the stylish display of the illustration was either an explicit or implicit goal.[38] The display of the illustration had to be impressive. This makes it harder to categorise these aesthetic seventeenth-century illustrations, is the drawing of a butterfly by Merian a part of the history of art or science? For some contemporaries of Merian, this categorisation is easier to make; for example, Joris Hoefnagel (1542-1601) mainly depicted insects that emerged from his fantasy and are thus totally imaginary constructs.[39] He was striving for the elegance of form instead of the accuracy of the insect's representation, resulting in incongruous creations, which are considered to be art.[40] Trustworthiness is what complicates the judgement of illustrations. There is always the involvement of style and of subjective interpretation of the artist. In the present day, one could compare the historical illustration with a photograph of the same species, assessing it’s accuracy. For instance, by comparing if the legs are in a correct scale with the body. However, with the absence of photo cameras illustrations were more easily believed to be accurate than today. One could suggest that accuracy during the seventeenth century was judged by colleagues in the field, reviewing each other's work and reusing it if it was thought to be credible.

The relation between observation and images is more complex than just the disunity between art and science. The concept of accuracy, which is the goal in natural history, was influenced not only by the style but also by material and social contexts.[41] According to Bredekamp, images are not mere illustrative representations but ‘‘productive agents and distinctive multi-layered elements of the epistemic process.’’[42] He explains that illustrations must be considered in the process; regarding their epistemological background, the context they take to play, the creator of the image and the techniques.[43] Furthermore, the illustrations created by the entomologists played an essential role in shaping insights and findings, and manifesting the perceptions of the naturalist. A lifelike, naturalistic

[36] Kemp, “Style and non-style in anatomical illustration,” 192.
[37] Neri, *The insect and the image*, 194.
[38] Ibid.
[39] Ogilvie, “Nature’s Bible”, 10.
[40] Kemp, “Style and non-style in anatomical illustration”, 193.
[41] Neri, *The insect and the image*, xix.
[42] Bredekamp, Dünkel, and Schneider, *The Technical Image,* 2.
[43] Ibid., 3.

representation of the subjects was in demand during the seventeenth century; both aesthetic and scientific. This is inextricably linked with the context at that moment, as new lands were discovered; the images created a culture of evidence, describing and depicting their world. Discoveries worldwide could easily be shared with many people; printmaking made wide dissemination possible.[44] Additionally, the illustrations served the colonising cultures from Europe in establishing their supremacy; it was a means for spreading evidence of their conquered territories. Furthermore, during the Renaissance, the emergence of naturalistic drawing coincides with a great interest in natural sciences and the world surrounding Europe. For instance, the books of Merian served as the prototype for a new type of entomological work. Her works created the effect when it seemed that the insect was alive and crawling on the paper. In addition, her works were of exceptional precision; subtle transitions were achieved by successive overlaying of coloured layers, using metallic shining paints.

[44] Smith, "Art, Science, and Visual Culture", 90.

2. The knowledge of the entomologists: life and research paths

This chapter will explore the knowledge of the selected naturalists, considering the transformation of insects. Thereby, their education, personal interests, the goal of their work and their empirical research methods will be examined. Hence, they influence the shaping of an opinion on their profession, being either an artist, a scientist or both. Furthermore, their descriptions of the transformation of insects, which accompany the illustrations, will be analysed. Eventually, there will be an exploration of how they were perceived by their contemporaries and current researchers from different field. Of course, there were more entomologists than the few that were selected, but although their methods and interest are diverse, they all had the same goal: to identify and explain the life cycle of insects.

Until the end of the sixteenth century, insects were not a popular object to study, primarily because of their size and texture, making them complicated subjects for research.[45] Optical tools were desired to identify their body parts, but even then, it was a struggle to depict the many kinds of slightly different insects effectively. In fact, entomology was not yet a distinct discipline during these times; the creatures were studied mainly by physicians, artists and apothecaries. Accordingly, both the descriptions and illustrations of the insects crossed the boundaries of these disciplines, knowledge moved from one context to another. Knowledge generated in a certain discipline shifted to others, often critiqued or used for new research. For instance, the work of Goedaert was critiqued but also systematised by the physician Swammerdam.[46]

Until this point, it is unclear whether or not the selected naturalists are to be categorised as scientists or artists; therefore, they will be called entomologists; as they all profoundly researched insects. Although that entomology was not yet a distinct discipline, this does not mean that these researchers of insects cannot be called entomologists; the Cambridge Dictionary describes an entomologist as nothing more than ‘‘a person who studies insects.’’[47] Naturally, the study of insects was on another level during the seventeenth century than after 1745. However, according to the theories of Michel Foucault (1926-1984), Goedaert, Merian and Swammerdam would all be entomologists of their own time when considering the preconditions of their episteme. During the episteme of the Renaissance, in which these entomologists lived, the world was seen as encoded somehow; it was God's encrypted message, which makes natural science the interpretation of this encrypted message. Therefore, myths and scientific investigation both made sense; they both reveal something about God's purpose.[48] All the entomologists were devoted to their research, trying to understand the mythical and symbolic transformation process. They researched insects with all the resources and knowledge available in their episteme. They all used

[45] Meli, “The representation of insects”, 405.
[46] Ogilvie, “Nature’s Bible”, 5.
[47] “Entomologist,” Cambridge Dictionary | English Dictionary, Translations & Thesaurus, accessed March 25, 2021, https://dictionary.cambridge.org/dictionary/english/entomologist.
[48] Foucault, *The Order of Things.*

the same methods for their empirical research, collecting, observing, and drawing conclusions from that, which were processed as descriptions and illustrations. Regardless, their conclusions on the metamorphosis of insects were very different. Until the late seventeenth century, there was the suspicion that insects were the product of spontaneous generation instead of being the product of sexual intercourse.[49] Therefore, they were seen as the lowest form of life. Partly this was caused by Aristotle, who thought that spontaneous generation out of rotting waste, was the only explanation for the existence of insects. His opinion was based on the fact that insects lack the presence of blood and have incisions on their bodies.[50] However, the disinterest in insects completely turned around during the seventeenth century; multiple books focussed on diverse sorts of insects, mostly on their unusual forms and their unique life cycles.[51] This spark of interest in insects was caused by the so-called Dürer Revival, which induced a new interest in depicting nature.[52] Additionally, Georg Hoefnagel (1542-1601) made stunning paintings for the court of Rudolf ll of fantasised insects. However, it is not till the eighteenth century that naturalists ventured into insect research en masse, as the newly invented microscope offered new opportunities for detailed studies of their anatomy.[53]

[49] Jorink, *Reading the Book of Nature,* 182-184.
[50] Aristotle, *Historia Animalium,* 487.
[51] Ibid., 182.
[52] Koreny, *Albrecht Dürer and the Animal and Plant Studies of the Renaissance.*
[53] Ogilvie, "Nature's Bible", 6.

2.1 Exploring the life and interests of Johannes Goedaert (1617-1668)

Johannes Goedaert grew up, worked and lived in Middelburg in the Netherlands. He worked as an alchemist, an engraver and a painter and produced mainly still-lifes. As far as is known, he never studied at a university, which might explain why he did not master the Latin language and published all of his books solely in the Dutch language.[54] Goedaert had a great interest in insects, not just the few popular insects at that moment; he devoted himself to a wide variety of insects. He described approximately 150 sorts, varying from beetles to moths and butterflies.[55] The results of years of research were published in a three volume series of the book *Metamorphosis naturalis, Ofte historische beschryvinghe vanden oirspronk, aerd, eygenschappen ende vreemde veranderinghen der wormen, rupsen, maeden, vliegen, witjens, byen, motten ende dierghelijcke dierkens meer,* of which the first volume was published in 1662 and the last one posthumously in 1669. Although the books were published in Dutch, they were later translated into English, French, and Latin. The title covers the content of the volumes, which is: the historical description of the characteristics, nature, origin and strange transformations of, among others, worms, caterpillars, maggots and flies. The *Metamorphosis* subtitle is as follows: ‘‘discovered, described and artfully illustrated not from several books, but only from personal experience.’’[56] He indeed gained all his knowledge from his empirical research, starting in 1635. For all these years before his publication, he collected insects, mostly larvae, and studied them in their glass jars. Goedaert was mainly interested in their metamorphosis, so he closely observed their different stages. During this process, he experimented with parameters, such as the nutrition, as it was not always known by him what their plant of preference was. His observations were extensively written down: when they changed, how long they remained in every phase, what nutrition had their preference, including sketches of their transformations. However, only rarely he would describe the form of the insect. Goedaert’s religious background can explain his obsession with the transformation of insects. He was an ardent believer in spontaneous generation; although he had seen insects laying eggs, he was still convinced that ‘‘many small creatures, which are said to be created spontaneously, that is by themselves, are bred from rotting and warmth.’’[57] However, mostly Goedaert did not express any strong opinions, which might be caused by his religious beliefs, as being excessively curious might be dangerous, or as he described it himself: ‘‘for God lives in an unapproachable light, and we would be swallowed up by the radiance of his majesty long before we could discover his secrets and inscrutable perfections.’’[58] This might also explain the fact that Goedaert rarely used any magnifying glasses or microscope. In his work, religion is almost as present

[54] Pieter De la Ruë, “Goede onbekenden”, 30-35.
[55] Jorink, *Reading the Book of Nature,* 201.
[56] Goedaert, *Metamorphosis naturalis I,* title page.
[57] Ibid., 18.
[58] Ibid.

as the insects, as his observations were always linked with biblical passages and symbolic meanings.[59] Goedaert was the first in Europe to systematically study the generation of insects, which can be seen as pioneering work. However, the 153 metamorphoses that he described are often incomplete because he had not seen all of the cycle stages.[60]

Goedaert had a particular interest in the process of transformation of insects. He was drawing them in the forms of larvae, pupae and adults.[61] He was among the first who noticed that many insects did not just grow bigger but underwent various transformations. He wrote in his observations that in some cases, a caterpillar gave birth to a butterfly and in others to worms that further transformed into flies.[62] He vividly described his surprise at the results of the observations. For his research, Goedaert gathered larvae in different ways (by himself, with the help of neighbours and his father) and thoroughly studied them, documenting his observations. Firstly, he drew illustrations of larvae and indicated when they changed. Subsequently, he drew their pupae and described how long they stayed in pupal form, when they emerged, and what they looked like (imago or parasite). His observations mentioned the forms of the insects, yet Goedaert mainly focused on their behaviour and metamorphosis, which he described in brief textual notes. The illustrations depicting the insect in various stages, are the centre of his work. When depicting the full picture, this included three stages: the larva, the pupa, and what came out of the pupa. Goedaert sometimes portrayed the leaf, which the caterpillar ate or on which the adult laid its eggs.[63]

It is worth noting that although Goedaert did not always understand the true nature of his observations, he carefully described what he saw, which gave future researchers material to work with. In his publications, he did not try to classify his observables. Nevertheless, it was Goedaert's material that was useful in drawing up some classifications.[64] The main achievement of his descriptions was precisely the confirmation that insects develop diachronically, the very fact of metamorphosis. Although his observations were not fully comprehended and somewhat erratic, they presented a very broad overview of insects, which was recognised by other researchers. Interestingly, Goedaert most likely was not familiar with the work of other researchers who also studied insects at the same time or a little earlier.[65] Thus, his descriptions are entirely independent, pure, and unique, which increases their value. This also contributed to his writings being considered somewhat naive. As Ogilvie described in 2005,

[59] Jorink, *Reading the Book of Nature,* 205.
[60] Ella, *Meria Sibylla Merian & Daughters,* 68.
[61] Ogilvie, "Order of insects", 231
[62] Ogilvie, "Nature's Bible", 11.
[63] Ibid.
[64] Ogilvie, "Order of insects," 232.
[65] Ogilvie, "Description and Persuasion", 7.

‘‘with his naive eye and excellent pencil, Goedaert depicted form without context.’’[66] Certainly, Goedaert’s works were not free from mistakes, but this certainly does not detract from their significance.

The opinions about Johannes Goedaert have always been very diverse; although he was a pioneer in the field and his volumes were very popular, widely spread and translated into multiple languages. Criticism against him included naturalist Martin Lister's (1638-1712) statement that Goedaert did not capture the essence of an insect.[67] The description of Goedaert, corresponding with figure 1 in this research, shows his lack of understanding:

> ‘‘Out of one caterpillar, which had pupated on June 12, there emerged on the 30th the butterfly. But out of another caterpillar of the same species, which had pupated on July 13, there emerged after pupation small flies, as the reader can see in the figure. Thus from one caterpillar a butterfly emerged and from the other 82 small flies.’’[68]

Commenting on this observation, Lister noted that they were flesh flies, meaning that the chrysalis was rotten.[69] In a like manner, naturalist Martin Lister (1638-1712) was pleased with Goedaert’s methods, he was also very critical of Goedaert’s lack of understanding the true nature of his observations. Lister explained that Goedaert spend forty years observing insect, but still failed in distinguishing ‘by-births’ (parasites) from genuine transformations.[70] Additionally, Lister thought that order was absent in the work of Goedaert and beheld mostly just useful illustrations.[71] There are current researchers that agree with these opinions, for instance, Ogilvie called both Goedaert and Merian artists ‘‘that consciously set out to use their artistic and observational talents to serve ‘investigators of nature,’ denying any fundamental distinction between naturalists and artists.’’[72] However, there are also plenty praising opinions about Goedaert’s work. For instance, Jorink describes Goedaerts work as extremely important and influential and calls Goedaert a scientist. Besides, according to entomologist Snellen van Vollenhoven (1816-1880), it is fairly easy to identify the insects that are depicted in his books, thereby emphasising the accuracy of his drawings.[73] Of course, there are many more opinions than the ones that are mentioned here, but this is sufficient to show that Goedaert is labelled as an artist by some and as a scientist by others.

[66] Ogilvie, “Description and Persuasion”, 17.
[67] Ogilvie, “Order of insects”, 232.
[68] Lenteren and Godfray, “European science in the Enlightenment”, 15.
[69] Ogilvie, “Order of insects”, 232.
[70] Ibid.
[71] Jorink, *Reading the Book of Nature,* 207.
[72] Ogilvie, “Nature’s Bible”, 6.
[73] Ibid., 202.

2.2 Exploring the life and interests of Maria Sibylla Merian (1647-1717)

It is needless to say that the upbringing, education, personal interests and religion of the naturalists influence how current researchers perceive them. Therefore, this paragraph will be a summary of the life of Maria Sibylla Merian. Merian was born in Germany, in Frankfurt am Main, in 1647. She had a very art-related upbringing, as the daughter of well-known engraver Matthäus Merian the Elder (1593-1650) and later on as a stepdaughter of the Dutch still-life painter Jacob Marrel (1614-1681). Because of this, Merian developed her artistic talents and became a painter of flower still lifes. Besides painting, she had a great interest in insects, mainly caterpillars. At the age of thirteen, she was collecting the caterpillars in glass jars, studying their behaviour and transformation into butterflies. She published many books with still-lifes and embroidery patterns and Western European butterflies and moths. Merian's first book about the transformation of caterpillars and moths was published in 1679, *Der Raupen wunderbare Verwandelung, un sonderbare Blumennahrung.* The book provides very detailed information on the entire process of the development of larvae and caterpillars; besides these descriptions, the book contains fifty prints that depict seventy-four transformations.[74] Just as for Goedaert, religion also played an important role in the life of Merian. In 1686 she moved to Wieuwerd in Friesland with her husband and daughters to join the Labadists, a religious community. This decision resulted in her divorce, as the Labadists considered all marriages before joining the community as invalid. In 1692, Merian moved to Amsterdam with her daughters, where she opened her own business, selling art supplies, paintings, mounted animals, dried insects and animals conserved in alcohol.[75] However, her desire to study insects was not diminished during her time in Amsterdam; she visited multiple cabinets of curiosities that beheld butterflies from the Dutch Republic.[76] This desire made her move to a Labadist plantation in Surinam, with her youngest daughter, in 1699. During two years in Surinam, she persistently ventured into researching the metamorphosis of insects. As she describes herself, ''I there painted meticulously on vellum these 60 pieces from life with their observations, which, in addition to the dried creatures, are to be seen at my home.''[77] It was this research trip that resulted in her most successful and famous work, *Metamorphosis Insectorum Surinamensium*, about the transformation of Surinamese insects, published in 1705. This publication was studied and used by many international scholars throughout the eighteenth and nineteenth century.

Another aspect that influences the opinion that is formed about the profession of Merian is the way she conducted her empirical research. Similarly to Goedaert, the life and profession of Merian were influenced by her religion. In her religious opinion, every creature was made by God and was therefore

[74] Reitsma, *Maria Sibylla Merian & Daughters*, 7-12.
[75] Ibid., 14.
[76] Merian, *Metamorphosis Insectorum Surinamensium,* preface.
[77] Ibid.

of equal value. She compared the life cycle of a butterfly with that of a man. A caterpillar is covetous and pitiless, then seems dead in its cocoon and eventually rises as a butterfly. The caterpillar hereby represents a man in his phase on earth; he then dies and finally joins the Creator after the Resurrection.[78] Furthermore, in her first book about caterpillars, she describes that her book ‘‘illustrates the miraculous metamorphosis of caterpillars against the background of their host plants. As a means of worshipping God. Man could learn a very great deal from the efficient behaviour and consistent pattern of life of these insignificant yet destructive creatures.’’[79] This emphasises that her religious beliefs led her to research insects specifically. In this book, she also writes that she focused on the insects' origins, development, and behaviour. For this, the caterpillars need to be raised by yourself. For fifty years, she collected insects in glass jars. Observing these creatures was very time-consuming, as she had to feed them and clean their jars every day; if not, they would eat each other. In order to depict the insects accurately, their growth stages, which could take up to a year, were observed constantly over time. Merian made many notes, accompanied by drawings, which were bundled in her study book.[80] This study book was used for the creation of her published volumes. What makes these books extraordinary are the illustrations; almost each of them includes the insect's host plant. According to art historian Ella Reitsma, who devoted a book to the life of Maria Sibylla Merian, Merian was one the first person to depict insects with their host plants, on which they thrived. Reitsma describes that these illustrations revealed her pioneering observations to the reader.[81]

This paragraph will focus on the description of Maria Sibylla Merian about the metamorphosis of caterpillars. The most important misinterpretation about insects in that time, as mentioned before, is their metamorphosis. Although at that time no one was certain that all insects came from an egg, Merian had a very firm opinion about the subject, stating that all caterpillars originate from eggs.[82] This conclusion could only originate from her long and many observations. Merian made a clear distinction between the sexes of the insects - being male or female -, reasoning for natural reproduction. Although, she seemed to understand the common perception that insects rise from the mud because she saw that with her own eyes. Only, she understood through stern observation that these caterpillars pupate in the earth.[83] With this, Merian demonstrated that nature was not chaos but a continuous circle. Another interesting new discovery made by Merian was the difference between moths and butterflies, described in her book in 1679, which was the beginning of a new system. Although her publications were intended to demonstrate biological relationships and not as identification or classification guides, her study

[78] Reitsma, *Maria Sibylla Merian & Daughters*, 25.
[79] Merian, *Der Raupen wunderbare Verwandelung,* preface.
[80] Reitsma, *Maria Sibylla Merian & Daughters*, 26.
[81] Ibid., 8.
[82] Merian, *Der Raupen wunderbare Verwandelung, introduction.*
[83] Reitsma, *Maria Sibylla Merian & Daughters*, 25.

sheets were categorised according to classification systems that did not yet exist at that time. For example, a scorpion and a lizard were bundled together, which are both arachnids.[84]

Every description accompanying an illustration starts with a detailed description of the plant or fruit they thrive on. Often, there are multiple kinds of insects depicted with the plant, which both feed on it. On plate 11, Merian described the palisade tree, its flowers, seeds, and shapes, but also the purposes that the wood is used for, both in Surinam and America. So, not only the insects were described, but additionally also practical uses of plants for food and shelter and medical advice. Then she described the butterfly that is depicted:

> ‘‘This kind of caterpillar occurs on this tree three times a year, being yellow with black stripes, and adorned with six black spines. Once they have reached a third of their full size, they shed their skin and become orange-yellow with black round spots on each segment, and six spines as above. A few days later, they again shed their skin and appear with these spines. On 14 April 1700 I saw one of these change into a pupa. On 12 June the moths depicted opposite emerged. The lower, smaller one is the male, upper one is the female.’’[85]

This proves that Merians observations are described extensively, including the breeding habits, their nutrition, natural predators and their behaviour, and above all, the transformations depicted on the plates. Despite these observations being very extensive, using magnifying glasses, describing every detail, there is not much more information than the description of her observations. However, this might be the thing that makes her work so unique, as she studied behaviour and interactions instead of taxonomy and systematics, which was the primary pursuit of the naturalists at that time. Her research is based on her fieldwork, observing insects in their natural habitat and collecting the living insects instead of dissecting dead ones. By showing the interaction between species and their nutrition, for instance, she shows the damage that the insect left behind on the plant and experimenting with different kinds of nutrition; she was pioneering the field of ecology, which did not exist yet at that time.[86]

Through this global overview of the knowledge, methods, descriptions and background of Merian, an opinion about her profession can be formed. In the same way, others have formed their opinions. Judgements about Merian have changed a lot throughout time, and even now there are very divergent. There are the researchers that considered her work to be merely art. For instance, Ogilvie

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[84] Valiant, “Maria Sibylla Merian”, 470.

[85] Maria S. Merian, *Metamorphosis Insectorum Surinamensium*, 7.
Original citation: ‘Op dezen boom koomen jaarlyks driemaal deze zoort van Rupfen, zynde geel met fwarte ftreepen, en zes fwarte fteekels verciert, als fy een derde van haar groote hebben, zoo vervellen fy, en worde als dan oranjen geel met fwarte ronden vlakken op elk lid, en zes fteekels als boven, eenige dagen daar na trekt fy wederop haar vel uit, en komt zonder deeze fteekels te voorfchyn, den 14 April 1700. is fy my verandert, en tot een Poppetjen geworden, den 12. Juny quamen de nevenftaande Uilkens daar uit te voorfchyn. Het onderfte en kleinfte is het Manneken, het groofte en bovenfte het Wyfken.’

[86] Valiant, “Maria Sibylla Merian”, 469.

stated that her work cannot be called entomology but should instead be categorised as art.[87] Maybe the work of Merian was brought to oblivion by the influential naturalist Landsdowne Guilding (1797-1831), who wrote a scathing critique in which he describes her work as worthless, vile and useless. He felt her illustrations were inaccurate, and she was largely dismissed as a still-life artist.[88] However, there are also researchers who have contrary opinions. For instance, art historian Janice Neri writes that the *Raupenbuch* by Merian is considered to be her first scientific work.[89] Furthermore, she argues that ''Merian's immense artistic talent has to some extent also been a barrier to understanding her visual imagery within its historical, cultural, and artistic context.''[90] While Merian is globally recognised as a remarkable artistic talent, the scientific value somehow seems harder to pin down. Which is exactly the incentive of this research, in which it seems like the artistic talent of Merian is a barrier to the understanding of her scientific contribution to the field of entomology. Another opinion, praising the work of Merian, comes from art historian Ella Reitsma, who describes Merian as a researcher who combined science and art in an original manner. Entomologist Sandrile Ulenberg agrees with this opinion and calls her both a scientist and artist.[91] From these opinions from different perspectives, one can conclude that the opinions about Merian are coming from very different fields. Some entomologists would be in favour of her scientific addition and some not; the same applies to the art historians.

[87] Ogilvie, "Nature's Bible", 6.
[88] "Hidden Women of History: Maria Sibylla Merian, 17th-century Entomologist and Scientific Adventurer," The Conversation, last modified February 20, 2019, https://theconversation.com/hidden-women-of-history-maria-sibylla-merian-17th-century-entomologist-and-scientific-adventurer-112057.
[89] Neri, *The insect and the image,* 155.
[90] Ibid., 141.
[91] Ella, *Maria Sibylla Merian & Daughters*, 8-11.

2.3 Exploring the life and interests of Jan Swammerdam (1637-1680)

Jan Swammerdam was born in Amsterdam in 1637; he had a great interest in insects from childhood. However, at the insistence of his father, he studied anatomy and physiology. Swammerdam made some significant discoveries in these field, thereby gaining a reputation as a scientist. However, he might be even more known in the field of entomology. Swammerdam started dissecting insects in the late 1660s, during which he abundantly used the microscope; as a result of this, he discovered that what was thought to be a king bee turned out to be a queen bee because he found her ovaries. Later on, he ventured into researching the behaviour and structure of insects with a microscope.[92] He described the body parts and the organs of the insects, thereby referring with numbers to the corresponding organised depictions of the insect and its organs. Swammerdam bundled the results of his research in multiple books, of which the most well-known are *Historia Insectorum Generalis* (1669) and *Bybel der Natuure* (1737). The title of this last book gives away the religious undertone of his research. Swammerdam's works were marked by religious convictions, which regularly contradicted the results of his empirical research. Although these religious beliefs were not the same as Goedaert's, in fact, Swammerdam heavily critiqued the works of Goedaert. Swammerdam was, just as Merian, convinced that orderly transformation was the proof of God's handiwork.[93] The goal of the work of Swammerdam was to change the opinion about the belief that insects radically transformed from one kind of creature to another. He attempted to demonstrate that this metamorphosis was a slow and almost imperceptible process.[94] Swammerdam tried to show the large in the small, or as the Dutch philosopher Bernard Nieuwentijt (1654-1718) perfectly describes the thoughts of Swammerdam: ''who could still doubt the existence of God after having examined an insect?''[95] Both Niewentijt and Swammerdam thought that a humble insect deserved just as much admiration as every other of God's creations.[96] Swammerdam's critique on Goedaert was not only based on religion; Swammerdam wrote that Goedaert had studied more caterpillars than any scholar ever had, however, he made gross errors, which made his work worthless.[97] Swammerdam's view on insects seems more corresponding with Merian's, claiming that every creature was the result of sexual procreation. More specifically, Swammerdam stated that the various stages of an insects life are all part of the life cycle of one and the same individual.[98] He thereby might have founded preformationism; the idea that all generations of insects are present in the egg, the form of the insects exists prior to their development. Or as Swammerdam himself explained: ''in nature there is no generation, but only propagation, the growth of parts. Thus original sin is explained, for all men were

[92] Cobb, "Reading and writing The Book of Nature", 122.
[93] Ogilvie, "Nature's Bible", 5.
[94] Ibid., 6.
[95] Nieuwentijt, *Het regt gebruik der werelt beschouwingen,* 560.
[96] Jorink, *Reading the Book of Nature,* 183.
[97] Swammerdam, *Historia insectorum generalis, 45.*
[98] Cobb, "Reading and writing The Book of Nature", 123.

contained in the organs of Adam and Eve.''[99] Suggesting, that succeeding generations all come from the egg of a female from the same species. For this theory he mainly used insects, but he proved similar patterns in frogs, in order to show the parallel in other specimen. Hereby, we again see a great discovery, explained through religion, but very contrary to the vision of Johannes Goedaert.

While working on the anatomy of insects and other animals, Swammerdam continued to expand his insect collection, which was sent from different countries. With his research he made an outstanding contribution to the knowledge on the transformation of insects. A significant part of this contribution is his beautiful drawings. For their creation, Swammerdam used anatomical preparations. Thanks to Swammerdam's careful studies of the microscopic structure of insects, the features of metamorphosis were revealed for the first time in history, and a new system of this group of invertebrates was built on this basis.[100] Swammerdam proposed a classification of insects, dividing them into four groups based on the characteristics of their metamorphosis. However, it has to be mentioned, there was some inconsistency in certain categories, in which he classified many insects in the wrong classes.[101]

The idea that the entire future organism is completely prepared in the egg, where it already has all the parts of its future body, only these parts are small, transparent and folded so that they cannot be seen, is a cross-cutting theme of Swammerdam's publications. With the help of anatomical methods and knowledge, he tried to trace and learn as best as possible the history of the development of insects and those whom he considered insects. The main guiding thread of all his research is the desire to show how the final form of the organism develops from its simplest form. Swammerdam had a deep conviction in the complexity of the structure of all organisms, no matter how small they are, no matter how simple they seem.[102] Indeed, the more complex the organism, the more difficult it is to imagine its origin from unorganized matter, and Swammerdam assumed the existence of a ready-made organism in all its main parts already in the egg.

Swammerdam is always described as a scientist by both contemporaries and current researchers, which might have to do with his educational background, his many discoveries, his classification and the use of microscopes. His first book, published in November 1669, was described as pioneering.[103] Additionally, Jorink states that his study was revolutionary, creating a foundation for a new view on the insects' kingdom.[104] Furthermore, Ogilvie, who was so critical of Goedaert and Merian, is not reticent with his opinion on Swammerdam, calling him a genius. Although that the overall opinion about Swammerdam is positive and praising, Jorink does admit that Swammerdam's lifelike

[99] Mason, *A History of the Sciences,* 363.
[100] Ogilvie, "Order of insects", 239.
[101] Ibid., 238.
[102] Ibid.
[103] Jorink, *Reading the Book of Nature,* 219.
[104] Ibid., 221.

representations of insects were not always objective and neither were his descriptions, which were saturated with religious contemplations. One could say that no research, despite its contribution to science, goes without mistakes. Although Ogilvie seems to be more critical about the mistakes from Goedaert and Merian than on the errors from Swammerdam.

2.4 Comparing the knowledge and interests of the entomologists: revealing similarities and differences

Comparing the entomologists' life paths will help evoke certain patterns and facts necessary for answering the questions raised in this study. Therefore, this section will compare aspects as personal interests, education, scientific methods, religion and their most valuable contributions to entomology. Firstly, it has to be remarked that the bibliographies about Merian are very extensive, in contrast to the bibliographies about Goedaert and Swammerdam. Much has been written about Merian's life path in the last thirty years. This recent increase in the literature about Merian might be caused by the rise in the popularity of Merian's work. This popularity is mainly due to her unique performance as a self-supporting, divorced female researcher, which made her a very unusual figure during the seventeenth century; and an example for feminism today.

The interests of all the three entomologists were associated with either painting or insects, or both. Goedaert was skilled in drawing and engraving, and insects were his passion. Even despite his writings, from his work, it is noticeable that pictures took the central place. This raises the question, was he all the same an artist who was just fond of insects? Speaking about Merian, this question becomes even more complex. She inherited her father's artistic talent and worked hard to develop it. Merian was very fond of painting, especially with watercolours, she showed delicate taste in the selection and arrangement of her models, but the main thing in her work was colour.[105] She succeeded in this artistic area and gained fame in certain circles, way more than Goedaert. Swammerdam agreed with Goedaert that insects were wondrous creations, however, his experience of wonder drove him to seek for an underlying order, where Goedaert just observed and described.[106]

There is not much accurate information concerning the details of the life and education of Goedaert. As mentioned above, he possibly did not have a secondary education and did not attend a university.[107] Goedaert's contemporaries knew him primarily as a painter. There is an obvious parallel with the biography of Merian. Merian also grew up in an artistic environment: almost all her relatives, including her father and brothers, and later husband, were painters.[108] She, as well as Goedaert, studied engraving and even worked as a book illustrator for some time. As far as known, the entomologists never met, but there is a suggestion that it was Goedaert's example that inspired Merian to publish her observations of insects.[109] As well as Goedaert, Merian did not study at university, nor was she a member of the academies; her main virtues were hard work and diligence. However, unlike Goedaert, Merian was well regarded by her contemporaries as a researcher, for instance, she was sponsored for her exhibition

[105] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 31-32.
[106] Ogilvie, "Nature's Bible", 16.
[107] Jorink, *Reading the Book of Nature*, 201.
[108] Ogilvie, "Order of insects", 233.
[109] Ibid., 234.

to Suriname by the city of Amsterdam and was referenced multiple times in *Systema Naturae* by Carl Linnaeus (1707-1778); the first book to present a systematic classification of species.[110] Unlike Goedaert and Merian, Jan Swammerdam received medical education and, besides entomology, made a great contribution to anatomical research. He began studying medicine in 1661 at the University of Leiden; during these studies he began collecting insects. After he graduated with a PhD in medicine, Swammerdam continued to work scientifically, especially in anatomy, but he never practised as a doctor.[111] Thus, based on the biographical facts explored in this chapter, we can conclude that his level of education distinguishes him from Goedaert and Merian.

The scientific methods of the three entomologists were similar, yet, with their peculiarities. Goedaert's interest in insects appeared thanks in no small part to his belief in God. First of all, he did not strive to study the scientific side of the issue but sincerely admired God's creatures.[112] The methods of Goedaert were very simple, he gathered the insects in the fields and observed them, especially during the process of transformation. Here Goedaert's skills as a painter proved useful, as although he rarely used microscopes or magnifiers; the illustrations show great detail. Maria Sibylla Merian was also an observer to a great extent, however, she did use microscopes and magnifiers. Since childhood, she observed the development of silkworm caterpillars, sketched them in albums and even tried to engrave them.[113] Merian discovered that everything in the world – plants, animals, and humans – is subject to unexpected transformations. By showing these interactions between species and their nutrition, she can be seen as a pioneer in the field of ecology. As well as Goedaert, she used her pictorial talent to capture all the vicissitudes of the life of caterpillars as if on a photograph, which was unique for that time. Similarly, the methods of Jan Swammerdam were partly shaped by his education and related studies. As previously mentioned, Swammerdam had done extensive work as an anatomist; thus, his methods and research tools were predominantly anatomical.[114] With the help of these anatomical methods and knowledge, he tried to trace and learn as best as possible the history of the development of insects and those he considered insects. Swammerdam attempted to demonstrate that this metamorphosis was a slow and almost imperceptible process by also depicting the processes between the stages of transformation. The main guiding thread of all his research is the desire to show how the final form of an organism develops from its simplest form. This aspect brings his method closer to the methods of Merian and Goedaert. The scope of their research is similar, focusing on the transformation of insects. Also, their empirical methods are largely alike: collecting, observing, describing and depicting. With two exceptions, Swammerdam was the only one to dissect the insects, thereby studying and depicting there

[110] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 35.
[111] Lenteren and Godfray, "European science in the Enlightenment?", 17.
[112] Jorink and Ramakers, "Undivided territory", 18.
[113] Lenteren and Godfray, "European science in the Enlightenment", 19.
[114] Ogilvie, "Nature's Bible", 16.

individual body parts. Secondly, Merian and Swammerdam extensively used magnifiers and microscopes; which Goedaert rarely did.

Religion plays an integral part in the research of all three entomologists, but in its own way. Goedaert was an ardent believer in spontaneous generation; although he had seen insects laying eggs, he was still convinced that they were bred from rotting and warmth.[115] Biblical passages and symbolic meanings accompanied every illustration in his book.[116] Although Swammerdam's work was also marked by religious convictions, reflecting in the title of his book *Bible of Nature,* his convictions were not the same as Goedaert's.[117] Swammerdam claimed that every creature was the result of sexual procreation, corresponding with the beliefs of Merian. A small but essential digression should be made here regarding the similarity of the religious views of Merian and Swammerdam. In order to better understand the direction of the scientific work of these two entomologists, it is important to take into account its ideological background. Each of them, at one time, was a part of the Labadist Protestant movement, which already speaks of the similarities in their beliefs since they considered the teachings of the Labadists close to them. It is difficult to compare with absolute accuracy the beliefs of Merian and Swammerdam since much more is known about Merian's interaction with the Labadists than Swammerdam's. Nevertheless, it is safe to say that for both of them, the new facts discovered in the field of entomology served as proof of the wisdom of God. Their opposition to spontaneous generation was not conventional at that time. Although some researchers of the period challenged spontaneous generation, this was the prevailing opinion. According to ecologist Kay Etheridge, "spontaneous generation of insects was still a widely held belief when Merian published her first Raupen."[118] Thus, the thoughts of both Swammerdam and Merian can be considered revolutionary. In connection with all of the above, the question inevitably arises as to whether there is a connection between the discoveries of these entomologists and the Labadist community's beliefs. In the case of Merian, the answer is more likely positive, and this applies not only to the teachings. The Labadist movement was for gender equality and had an open mind considering scientific pursuits.[119] Thus, Merian was free to engage in research. Swammerdam joined the sect towards the end of his life; long before that, he had a rather strong faith in the creator.[120] Therefore, unlike Merian, the discoveries of Swammerdam did not intersect with the teachings of the Labadists; nevertheless, both were believers, which is inextricably linked with their research work.

[115] Goedaert, *Metamorphosis naturalis I,* 18.
[116] Jorink, *Reading the Book of Nature,* 205.
[117] Original title: Bybel der Natuure.
[118] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 37.
[119] Pieters and Winthagen, "Maria Sibylla Merian, naturalist and artist", 4.
[120] Meli, "The representation of insects", 428.

When looking at the impact of the works of the entomologists on contemporaries and future researchers, there are some significant distinctions between the three entomologists. Goedaert was the first in Europe to systematically study the generation of insects, which can be seen as pioneering work. The main achievement of his descriptions was the confirmation that insects develop diachronically, the very fact of metamorphosis. Nevertheless, Goedaert did not always understand the true nature of his observations, and his writings were somewhat naïve and erratic.[121] However, because his observations were carefully described, he gave future researchers material to work with. Furthermore, even though Goedaert never attempted to classify the insects, he gave a broad overview of the insects he encountered, which was used to draw up some classifications by other researchers.[122] Merian, just as Goedaert, was driven to observe the transformation of insects. However, where Goedaert only rarely described the form of the insect, Merian constantly observed the insects, enabling her to depicted and describe every growth stage.[123] She thereby discovered the difference between moths and butterflies, which formed the beginning of a new system. Merian's illustrations can be described as extraordinary, as Merian was the first person to depict insects with their host plants, on which they thrived. By revealing her observations on the interaction between species and their nutrition, Merian can be described as pioneering in the field of ecology.[124] Swammerdam, just as Merian, opposed the doctrine of the origin of small animals from decaying substances. However, Swammerdam went even further with his theories on this, by conducting an especially great study on the morphology, development, and metamorphosis of insects. This way, he became the creator of the preformation theory, which other scientists adopted.[125] Additionally, thanks to Swammerdam's careful studies of the microscopic structure of insects, the features of metamorphosis were revealed for the first time in history, and a new classification system was built on this basis, dividing them into four groups based on the characteristics of their metamorphosis.[126] When comparing the contribution of Goedaert, Merian and Swammerdam to the field of entomology, it seems like Goedaerts work mainly was revolutionary because he was the first in Europe to systematically study the generation of insects and impressively depict them. However, his belief in spontaneous generation, which his fellow entomologists Merian and Swammerdam refuted, influenced many of his observations and conclusions. Although he was heavily critiqued on this, Goedaerts broad overview of the insects was frequently used by his contemporaries. On the other hand, this was also the case for Swammerdam, whose work was both revolutionary and extensively studied and used by others. For example, the primary source for the *Raupenbuch* of Merian was the works by both Goedaert and

[121] Ogilvie, "Description and Persuasion", 7.
[122] Ogilvie, "Order of insects", 232.
[123] Reitsma, *Maria Sibylla Merian & Daughters*, 26.
[124] Valiant, "Maria Sibylla Merian", 469.
[125] Jorink, *Reading the Book of Nature*, 231.
[126] Ogilvie, "Order of insects", 237.

Swammerdam. Although both works describe the transformation of insects, Merian came up with the idea of metamorphosis independently of them, with a revolutionary ecological approach.[127]

Overall concluding, features of Goedaert, Merian, and Swammerdam's past experiences and knowledge affected their entomological research and the peculiarities of the descriptions of the insects. They all described their observations in great detail, thereby contributing to the knowledge of insects, although each in their own way. There are parallels in the beliefs of Merian and Swammerdam and the lack of scientific education of Merian and Goedaert. However, despite all three entomologists' different life and research paths, the similarities in their experiences are also undeniable. The three entomologists made various anatomical and biological remarks, sometimes very accurate and important, sometimes inaccurate and less revolutionary. However, it has to be underlined that the statements of both Merian and Swammerdam on the transformation of insects were unique and revolutionary for that time. As well was Merian's contribution to the field of ecology and Swammerdam's addition to preformism and the classification of insects.

[127] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 37.

3. Analysis of the entomologists' illustrations using *the theory of the image* by Gabriele Werner

In order to find out on what grounds the selected entomologists are specified as a scientist or an artist, a comparison of their illustrations and their artistic qualities is of importance. This comparison will be conducted with the use of *the theory of the image* from Gabriele Werner. This theory perceives illustrations as epistemic agents; they are not just illustrations but objects of knowledge. Werner explains that ''they are also treated as active and operative entities that organize and regulate a knowledge process.''[128] Her theory is focused on how knowledge is manifested in an image. The first parameter of this theory will assess the illustration's eidetic competence, meaning the accuracy and vivid recall of the image. The image is defined as structurally contingent concerning the representation and the openness to interpretation. This is directly influenced by cultural pictorial traditions of that time, both within as without the discipline. The second parameter of the theory is focused on the quality of the concept; the evidential value of the illustration is evaluated. Thereby it is assessed whether the visual means used are the right ones to convey the information understandably. Finally, the last parameter will focus on the technique of the illustration. The image can be manipulated in order to make it easier to comprehend; the visualisation techniques make it possible to reduce complexity to depict a concept more clearly. The different perspectives will shed light on the communicative process of the illustrations.[129] Each of these three parameters will be addressed in relation to the three entomologists and their illustrations of the transformation of insects.

The theory of the image by Gabriele Werner most of all meets the objectives of this study. It allows examining knowledge the pictures encompass, the quality of the research they represent, their eidetic content, as well as the visual realisation of the latter.[130] The main benefit of the theory is that it considers different perspectives of the picture at once, making it the theory that offers the broadest view of the concept of the picture. However, there are limitations to this approach, as not all pictures necessarily convey information and knowledge; thus, it can be mainly applied to scientific images. However, this is precisely what is needed in this study. Thus, Werner's theory was chosen as the most appropriate alternative out of the other most popular picture theories. For example, W. J. T. Mitchell interpreted the image as an instrument of the politics of representation.[131] However, this theory does not explain how knowledge is represented in a picture as clear as Werner's theory. The same applies to the theories of Ludwig Wittgenstein (1889-1951) and Gottfried Boehm, who also followed the path of focusing on representation; they explored the image's internal structure and connection with the

[128] Bredekamp, Dünkel, and Schneider, *The Technical Image*, 11.
[129] Ibid., 12.
[130] Ibid., 11.
[131] Purgar, *WJT Mitchell's Image Theory: Living Pictures*, 11.

material carrier.[132] However, the theory of Gabriele Werner is, in fact, the only theory that allows fully investigating scientific images because images of epistemic value should be, first of all, comprehensively analysed as objects of knowledge. Werner's theory's advantage over the other theories is that it considers not only the concept of representation but also the technical quality of the picture, qualifying physical visual perception as a tool for assessment and observation.[133]

[132] Purgar, *WJT Mitchell's Image Theory: Living Pictures*, 33-123.
[133] Bredekamp, Dünkel, and Schneider, *The Technical Image*, 12.

3.1 The analysation of the illustrations by Johannes Goedaert considering the transformation of insects

The theory of the picture by Gabriele Werner suggests first looking at the image's eidetic competence. Goedaert's approach to the study of insects was reflected in his illustrations: he spent hours observing insects under a glass shell, which allowed him to convey the smallest details of their tiny bodies very accurately.[134] For example, the image of a butterfly is so realistic that it seems like one can see the rough surface of its wings (fig. 1). Being both a researcher and an artist, he also managed to convey the piercing delight of the discoverer and the perfection of the insect world in the image. His main goal was to convey all the stages of the metamorphosis of a caterpillar into a butterfly. However, he did it with an aesthetically pleasing approach. As for scientific utility, he accurately conveyed the details of the appearance of insects at different stages of their transformation. The drawings show soft transitions between colours; minor details are drawn with great care. The cocoon around which small flies curl is presented not just as a fact (statically) but in motion: it seems like these flies are alive and will start flying around the room. He also paid attention to the asymmetry of the butterfly's wings, which can be overlooked if not carefully observed. One wing is slightly lighter than the other; also, it is noticeable that the right-wing is slightly shorter. This also applies to the details of the pattern. However, Goedaert hand-coloured his plates and only depicted insects on a white backdrop, creating a specimen logic. Thereby, he missed such features as white hairs.[135] At the same time, his choice of colour was not always precise. Still, in general, he was characterised by accuracy and attentiveness, in addition to decorativeness, which did not prevent his illustrations from being useful for future researchers.

The second criterion concerning the quality of the concept implies analysing the visual means conveying the information from the image. Goedaert's drawings have a diachronic aspect. Each engraving follows a specific vertical order, usually starting with the larva at the top of the page and ending with the imago at the bottom of the page. He drew the figures in the same scale to identify the relative sizes of larva, pupa and imago.[136] The diachronic relationship between the figures is implied rather than overt since they appear alone against a neutral backdrop. The engravings merely indicate that the insects portrayed belong together; however, the notes fill the gaps. As mentioned before, Goedaert was especially interested in the transformation process of insects. His engraving from *Metamorphosis Naturalis* (fig. 1) is one of such illustrations, showing the metamorphosis of a caterpillar into a butterfly. However, Goedaert did not possess the full understanding, and the illustration reveals this. He was sure that caterpillars could produce adult flies as well as butterflies.[137] The given picture

[134] Ogilvie, “Nature’s Bible”, 11.
[135] Meli, “The representation of insects”, 415.
[136] Ogilvie, “Nature’s Bible”, 12.
[137] Ogilvie, “Order of insects”, 232.

depicts two pupae, from one of which small flies or parasitoids come out. Nevertheless, his observations and patience are remarkable; these qualities helped him consistently convey the concept of metamorphosis in images. Ogilvie describes this as following: ‘‘to Goedaert himself, on the other hand, the act of illustration was necessarily diachronic. He drew the caterpillar and waited. He drew the pupa and waited. Then he drew the animal that emerged from it.’’[138] Thanks to his (criticized by some), to a certain extent, decorative approach to the creation of illustrations to his observations, their colourfulness and beauty, it is this aesthetics and pleasantness to the look that allowed entomologists and future researchers at one time to freely, easily, and with pleasure use his illustrations to complement and conduct their own research. At the same time, precision and attention to detail have contributed to the convenience and precision of future research. Although Goedaert did not understand everything about the processes occurring with insects, in his drawings, there are both correct conclusions and some misconceptions.

Finally, the last criterion is the technique of illustration. Goedaert was a pioneer in that he used etchings instead of woodcuts to draw his insects, which resulted in better quality.[139] Copper engraving is quite a laborious technique and required professionalism; the engraver had to have significant knowledge and confident skill. The master had to work painstakingly, carefully and slowly, since there was no way to make significant corrections. The advantage of copper engraving was that it originated in the professional environment and differed from woodcuts (which, for example, Swammerdam used) in a higher artistic quality. In such a type of engraving, the professional artist works with line and stroke. Goedaert’s images are distinguished by the rhythm and accuracy of the movement of lines in the outlining of the form. The variety of strokes and their direction, different depths of lines and strokes gave him the opportunity to approach the light and shadow construction of space, images and details, and to achieve a certain tonal solution in the image. When working with a metal plate, the pattern deepens, and the background remains intact. In the accuracy and precision of Goedaert’s approach to the depiction of insects, one can see his awe and admiration for these creatures.[140] While this sometimes contributed to his leaning toward beauty rather than precision, this attitude also contributed to the fact that he tried to convey every little detail of those creatures he had watched and admired for so long. Although he tried to convey the actual size of his observables, he was not always precise. However, Goedaert's new technique, detailing, and distinctive style made his work highly sought after by the next generation of entomologists.

[138] Ogilvie, “Nature’s Bible”, 12.
[139] Ogilvie, “Description and Persuasion”, 17.
[140] Ogilvie, “Order of insects”, 231.

3.2 The analysation of the illustrations by Maria Sibylla Merian considering the transformation of insects

The first criterion for assessing the illustrations of Maria Sibylla Merian is the eidetic competence, thus the accuracy and vivid recall. The sixty copperplates in her last book show, among other worms and caterpillars, shedding skin and changing colour and form until their metamorphosis into a butterfly, moth, moth, or beetle is complete. Besides this entire process depicted, the plants, fruits, and flowers on which these animals thrive have been represented.[141] The illustrations of Merian are life-size, guaranteeing detailed realism, which made the books massive.[142] It seems like the continual struggle between the scientist and the painter, in which the one is striving for the elegance of form and the other on the accuracy of the depiction, is not present in her books.[143] Her illustrations behold both elegance and accuracy. Merian has observed the insects using magnifying glasses, and when looking at her illustrations, the same effect is created; the details are very realistic. The insects are shown in many different compositions, with folded wings or spread-out wings, from the top and underside. This is unique as mostly the focus is mainly on the topside of the insect. Everything is represented in detail, from the complex patterns on the wings to the antennae's feathery structure.[144] These details are visible because of the size of the illustrations, which impacts the viewer, as insects are relatively small. The clearness and accuracy of the image increase the scientific value of the illustrations. It is undeniable that the *Raupenbuch* signalled a massive shift in her career. The books published before 1679 were focused on art containing embroidery patterns and aesthetically coloured plates of flowers. However, for the *Raupenbuch,* she observed many insects and devised methods for depicting their transformations. Even though she turned to a more scientific approach, she did not abandon the 'design principles' of the decorative arts. She was praised by scientist Johann Wolfgang von Goethe (1749-1832) for having the ability to move 'between art and science, between nature observation and artistic intention.'[145] Merian not only had great artistic talent but also delved into the essence of what was portrayed. An important role in this was played not only by the accuracy of fixing the object but also by selecting colours. She painted each insect, butterfly, beetle, or caterpillar with watercolours in its habitat on amazing exotic flowers. This is especially evident in figure 2: butterflies, caterpillars, and even pupae have wrapped around a beautiful plant. Another aspect worth noting is that, although many did not distinguish between butterflies and moths, Merian noticed them and reproduced their differences in the drawings. In contrast to a moth, a butterfly, perching on a flower to rest or drink nectar, folds and raises its wings,

[141] Merian, *Metamorphosis Insectorum Surinamensium,* preface.
[142] Kemp, "Style and non-style in anatomical illustration", 192.
[143] Ibid., 193.
[144] Neri, *The insect and the image,* 156.
[145] Goethe, *Goethes Sämtliche Werke in 36 Bänden*, 279.

showing the observer their back, faded side. In her compositions, she strove to demonstrate the butterfly in positions, not only sitting but also in flight, when its brightest colours are open to the eye.

The second criterion is focused on the quality of the concept, whether the visual means used are the right ones to convey the information understandably. Merian studied the illustrations of Goedaert extensively before publishing her *Raupenbuch* and published a few illustrations in the same vertical arrangement, with a solid background and a static position.[146] However, she decided that each element had to receive equal attention in her illustrations, emphasising the characteristics of the insect's form in various stages in their natural habitat. In her paintings, they are depicted in their natural habitat, on flowers and plants. They move, eat, fly, and crawl. In one picture (fig. 2), Merian depicted all the stages of metamorphosis on one flower: both larvae and caterpillars are on it, and butterflies are already flying around. In front, the leaves are already bitten by caterpillars: for them, it is both a home and food. In the works of Merian, insects almost always coexist with plants, making up one composition with them. At the same time, the artist was interested in entomological objects more than botanical ones. Plants and flowers, for all their brilliance and grace, appear more flat. Sometimes it even seems that these are specimens of the richest herbarium revived by the artist's skill. Careful drawing makes some of the artwork look like embroidery patterns. It is the presence of insects that gives the compositions a special flavour, dynamics, and variety. This shows that they were the centre of her attention. Merian used very natural shades of yellow and brown to paint butterfly wings (fig. 3). To give the picture a natural look, Merian also depicted a butterfly resting on a green leaf, as well as a dark but bright caterpillar crawling along the stalk. Here, too, all the stages of the butterfly's metamorphosis are shown in one picture, even on one flower, not schematically, but vividly and naturally. In both figures 2 and 3, the close relationship between the world of animals and plants, the continuity of this interaction, and especially clearly reflected the life cycle of various creatures: she showed how something completely new is created from the same parts in the process of growth and development. Of course, her works do not always reflect the correct scientific interpretation of certain processes in the world of insects, but the artist cannot be accused of being too decorative. She painted every detail with special care, so the drawings were distinguished by the accuracy of execution.

The third criterion concerns the technique of the illustration. The text and pictures from Merian's works were the product of decades of careful studies of insect life cycles, and her ability to capture what she observed surpassed any naturalist before her or by her contemporaries. Her skills as an artist were much superior to those of prior entomologists who also possessed drawing skills, and the majority of Merian's illustrations were created from live or freshly gathered specimens.[147] Fresh-material paintings enabled her to depict an insect's behaviour and accurately represent the colour, which is difficult to do

[146] Neri, *The insect and the image,* 157.
[147] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 33.

with preserved specimens (they tend to lose colour).[148] Merian experimented with drawing material to create detailed complex compositions featuring a great variety of species that were also realistically portrayed. She drew each organism on a separate piece of vellum and then replicated it into a larger composition.[149] She made very few changes, preserving the creature's pose, colour, and other features. When engraving copper plates, Merian combined linear and point techniques, using the so-called inverted seal. Reverse images were obtained with barely noticeable outlines, which made it possible to convey the most delicate strokes, nuances and overflows of colours. Thanks to careful technique, a unique charm and nobility characterise Merian's paintings. Decorated with motifs fashionable at that time – flowers, birds, herbs, trees – Merian's products looked great and, thanks to the fantastic properties of her self-made paints, did not fade. Neither insects nor plants are formally depicted; even the curvature of the leaves has the character of a graceful ornament. At the same time, lighting is almost absent in Merian's paintings; shadows are minimal. The thin parchment she used for her art was primed with white to give the surface a soft and smooth finish. The paints look so fresh that it seems as if they were just painted after a few centuries. Extraordinary precision and subtlety in the transfer of details helped her depict the most complex patterns on butterfly wings. Accuracy of execution, subtlety and radiance of colours, reminiscent of the shine of metal or precious stones, gave her works a unique charm.

Undoubtedly, the artistic side of her watercolours attracted people and researchers, but, above all, they were interested in their cognitive and scientific value. The accuracy of the artist and the scrupulousness of the researcher: Merian laid these foundations of entomological illustration. Her illustrations are stunning and challenging in their artistry; she created an entirely new approach to science. However, it has to be noted that both Merian and Goedaert focused on insects with a 'complete' metamorphosis, meaning the stages of development are drastically different. Thereby they excluded many insects that undergo 'incomplete' metamorphosis, for which the changes in appearance appear more gradually. Therefore, their different stages of development are harder to distinguish. Goedaert and Merian preferred the insects with a 'complete' metamorphosis for their more dramatic transformation and more appealing visual appearances. They both mostly depicted just one larval stage, generally the most aesthetic one, although butterflies and moths undergo between four and nine stages of development during the larval phase.[150] There are no scientific arguments for this decision, which results in ruling out many species, except the challenges of depicting these insects with 'incomplete' transformations and their less obvious changes.

[148] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 33.
[149] Ibid.
[150] Neri, *The insect and the image,* 157.

3.3 The analysation of the illustrations by Jan Swammerdam considering the transformation of insects

Unlike the illustrations of Goedaert and Merian, the illustrations of Swammerdam not only portrayed insects with a new level of detail, he also depicted the exact moment of transformation itself.[151] Such a criterion as eidetic competence will help to explore this aspect. For example, at the top of the page, he depicted a caterpillar, in which one can even see such details as small teeth and hairs (fig. 4). Next, he depicted a butterfly, noting the smallest details: the proboscis and the transparency of the wings. Nearby, he depicted a chrysalis. Interestingly, the description of this image reads, ‘‘the proboscis is elegantly tilted.’’[152] This says a lot about the author’s attitude to the way he viewed insects and his approach to drawing them. He saw beauty, elegance in the appearance and habits of insects, so his illustrations do not look dry but sophisticated. He further focuses on *Vermis ficarius*. He examines the insect in great detail through a microscope and records everything in illustrations, describing his observations. Initially depicting him as a whole, he, according to his custom, depicts his body parts separately. Here, too, one can see his attention to detail and accurate scientific approach to the transfer of information. It depicts one of the insect’s horns, its optic nerve, brain, and other organs. In the case of the horn, one can see how even depicting such a tiny organ he approached the matter very carefully; he managed to convey the texture of the surface of the horn and various small details. However, due to the lack of bright colours and design, the decorative element in his illustrations is not so high. Yet, the art of woodcut printing required some artistic ability; even the special sonority of the comparison of black and white already determines in advance the great decorativeness of such an engraving, as well as sweeping strokes and a grid of fine shading. Such an engraving, built on combinations of parallel, sometimes monotonous strokes, conveys the general tone of the picture, light and shadow. Of course, in his illustrations, first of all, he set himself the goal of reflecting not so much beauty as accuracy in reproducing details. Despite the fact that he, being a religious person, certainly admired the beauty of the creatures he studied, he was more inclined not to decorativeness but to precision. In addition, it is impossible not to notice the outstanding accuracy and cleanliness of his illustrations.

The next criterion is the quality of the image’s concept. While the two other entomologists, Goedaert and Merian, painted mainly whole insects, Swammerdam paid attention to the depiction of individual insides and organs of insects. Obviously, his illustrations differ from the work of the two previous entomologists in that they are not coloured; which can be an important aspect for determining the specie. Swammerdam’s illustrations show the approach of a physician: for doctors of that time, especially anatomists, it was customary to have drawing skills. However, Swammerdam’s illustrations

[151] Ogilvie, “Nature’s Bible”, 15.

[152] Swammerdam, *Bybel der Natuure,* 68.
Original citation: ‘Proboſcis five Lingua, eleganter verſus pectus reclinata.’

are not only meticulously accurate, but they also have a clear aesthetic aspect. His illustrations show a tendency towards accurate drawing of details and greater educational value of the material. Although the artistic component fades into the background, it is still noticeable. He used a lens and/or microscope to examine insects, and he cut the pupal case to show beneath the adult insect's slowly developing limbs.[153] All the plates are the product of hours of observation and meticulous delineation. There are two concepts the pictures were to transfer: metamorphosis can be not a complete transformation, and there are four major transformations that insects go through.[154] The pictures were to demonstrate these claims and thus showed what Swammerdam was able to achieve with his persistence and abilities. Furthermore, figure 5 is of special interest. He carefully observed the butterfly on the chrysalis level and noticed that its parts, as well as of other insects, are already visible at that stage. In this image, Swammerdam's main concept is the detailed stepwise metamorphosis of the butterfly. He describes and depicts thoroughly how the caterpillar begins to change, how its skin and other parts of the body change, as well as how the butterfly itself then completely changes size. In addition, when studying caterpillars just before they entered the pupa state, he saw the organs of the future stage in outline and came to the conclusion that development represents the expansion of already shaped parts. His approach to creating illustrations corresponded to his idea: on one plate, he depicted a large number of elements, including not only the insects themselves at their different stages but also their individual organs, often extremely small, requiring tremendous precision.

The final criterion is the technique of illustration. As mentioned earlier, Swammerdam's methods were predominantly anatomical. He dissected insects, even the smallest, with finely honed scalpels, small sharp scissors with thin ends, and sharp needles. Often he cut in water. Thinly elongated glass pipettes, with the help of which he inflated various organs, also played an important role in his research.[155] Sometimes he put insect organs in alcohol so that they became less transparent and the contours were more delineated.[156] With the help of these techniques, he achieved excellent results, which are reflected in his illustrations. His images are represented as woodcuts. It is clear that when working on metal, an artist can get much more differentiated and subtle strokes, which means much more detailed images. At the same time, woodcut has its own advantages and its own aesthetics: the stroke here is more powerful, more expressive. Even with limited possibilities for creating images, he was able to display everything he needed in them. In fact, only two colours were enough for him to convey all the magnificence of processes in the world of insects. Using this technique, he achieved not just contrasts of black and white but gradual transitions from dark to light. He showed excellent contrast between light and shadow. His drawings turned out to be clear and subtle; every smallest stroke is

[153] Ogilvie, "Nature's Bible", 16.
[154] Ibid.
[155] Meli, "The representation of insects", 422.
[156] Ibid.

visible. Small strokes create volume, and the engravings themselves do not come out flat, but they have depth, chiaroscuro, and nuances. In his illustrations, it can be seen that he brought into these illustrations a special picturesqueness, the freshness of black tones, and chased clarity of line. Thus, his drawings, carrying primarily a scientific task, received a new artistic quality. Additionally, as mentioned before, the structural numbering of the depicted body parts, which correspond with the descriptions, underlines his scientific approach. His works are a manifestation of high artistic skill. In addition to talent in composition and drawing, he has that look that is inherent in a person who knows the secrets of nature.

4. Evaluating the influence of artistic talent on the scientific appreciation of the entomologists' work

Now that an analysis has been carried out for the illustrations of the selected entomologists, this section is focused on reflecting these analysis results, with the aim to formulate the answer to the question of whether the artistic level of the entomologist is of influence on what extent they are considered to be a scientist or an artist, during the seventeenth century in Europe? Although mentioned before, it has to be emphasised that there would be no division between art and science when these entomologists are considered in their epistemological context. These terms were rather complementary than distinctive. However, the impulse to categorise naturalists into scientists and artists was present during most of the nineteenth and twentieth century. Although the categorisation of seventeenth-century naturalists is not conventional anymore today and has not been for the last twenty years, some researchers are still explicitly labelling these naturalists as either being an artist or a scientist. This section will answer whether the artistic talent of Goedaert and Merian overshadows the scientific significance of their work or if other underlying reasons are causing them to be labelled as artists by contemporary researchers, such as cultural historian Ogilvie (in 2008) and entomologist Lenteren (in 2005).

First of all, it is worth mentioning the peculiarity of Europe's general cultural and social background. The so-called scientific revolution especially marked the seventeenth century. Under the influence of various large-scale transformations, radical changes are taking place in people's consciousness, including the awareness of the importance of the purposeful experimental study of the world.[157] Scientific research is encouraged, and more and more inventions appear. However, art, in particular painting, also remains a popular and actively developing occupation. Is it possible for someone to show and receive recognition in both areas equally? This begs the example of Leonardo da Vinci (1452-1519); although he lived several centuries before, his example remains relevant. He was a famous artist and at the same time received some recognition as a man of science and inventor (the concept of *homo universalis*). This suggests that a person with the reputation of a great artist can receive recognition for their scientific research, even if Leonardo was an exception. Nevertheless, what if a person is not the owner of unprecedented achievements in many fields but is only an artist who did not engage in engineering but in such a still non-existent science like entomology?

Now, the discussion can move on to answering the questions mentioned in the beginning of the section. Firstly, the artistic level of the drawings does have a certain influence. The illustrations of Merian and Goedaert demand the attention of the viewer because of their high aesthetic value. They cannot be overseen and stick to the mind. It is impossible not to call the works of Merian and Goedaert artistic, which causes the scientific value to be overseen more easily. With their artistic talent, they created highly

[157] Jorink, *Reading the Book of Nature*, 418.

accurate illustrations, thereby spreading high-quality content, which other scientists could use. In contrast to Swammerdam, they used colours, which made their work more helpful in determining different species. Furthermore, the past of the entomologists influences the perception of their work. Comparison of the illustrations of the three entomologists showed that it was the illustrations of Merian were the most perfect in the artistic sense, and her fame as an artist was the greatest and most apparent. Even when her interest shifted to the research of insects, the artistic aspect remained an essential part of her published research, which makes it more obvious to call her an artist in the first instance. Interestingly, the same thing happened with Swammerdam, but the other way round: he already had a reputation as a scientist when he began to study insects and created the corresponding illustrations. Therefore, no one would say that he became an artist only because he recorded his findings in paintings, although they have a particular artistic aspect. However, in the case of Goedaert, whose artistic activity was not too apparent, people started talking about him as an artist when this side of him manifested itself in his naturalistic works.[158] Given this, the scientific appreciation of the work of these entomologists by contemporaries like Ogilvie might be just as much influenced by the education the entomologists received as by the artistic level of their work.

Hence, it is still unsure on what grounds the opinions of contemporary researchers like Ogilvie and Lenteren are based when labelling Goedaert and Merian as merely artists. While art uses scientific problems and developments for expressive purposes, science seeks to use art as a tool for visualising discoveries as an additional channel for the popularisation of knowledge. Copper print, watercolour, woodcut: different methods, different artistic approaches to the creative process, the purpose of which was to comprehend the essence of the processes of insects, and the result of which was an invaluable contribution to science. Concisely, one could say that scientific work characterises itself, opposed to art, with the intention to find underlying order, answers for emerging questions, and discoveries that are of significance for science, or in this case, entomology.

Johannes Goedaert ventured into the research of insects without any academic education but with experiences as a still-life painter and engraver. The combination of these interests was manifested in his most famous work *Metamorphosis Naturalis*, which contained no less than 140 pages of drawings of insect metamorphosis.[159] Therefore, it is evident that judgments about whether he was considered an artist or a scientist are based precisely on this work. Goedaert was recognised as a stubborn researcher developing a new direction. However, his illustrations show an artistic approach. This includes the copper engraving technique to create illustrations of better quality, whereas, at that time, they used mainly woodcut. Goedaert did not just depict what he observed but used real artistic techniques, with a certain decorativeness and a beautiful selection of colours. Therefore, one might consider his work only

[158] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 31.

an application of his artistic skills in a new context. However, he did have a reputation as a researcher, for contemporaries regularly approached him for identifying a butterfly.[160] Although religion plays a role in each of the entomologist's works, it is most present in the work of Goedaert. Although he observed insects for forty years, his religious beliefs still led him to believe that insects were the product of spontaneous generation. His book is filled with biblical passages and symbolic meaning. Additionally, his beliefs led him to be reticent with being excessively curious, which might have prevented him from making significant discoveries in entomology. Although that Goedaert was the first to systematically study insects in Europe and thereby provided a valuable overview of insect species, his work was heavily critiqued by his contemporaries. Goedaert did not possess the full understanding, which, to a certain extent, also reflect in his drawings. For instance, he was sure that caterpillars could produce both flies as butterflies, so his illustration depicts two pupae, from one of which flies come out. Goedaert's work was called naïve, erratic, lacking order and understanding of the true nature of his observations. Overall he mainly was praised for his highly accurate illustrations and the confirmation that insects develop diachronically. Contemporaries used Goedaert's work for proper oversight of insect species; however, it did not seek any underlying order or answered any insect-related questions. For this, and his lack of education, one can relate to the opinion of Ogilvie and Lenteren. One could opt that the work of Goedaert should be considered a significant part of the histories of the study of insects, revealing the historical interpretation of insect transformation, but with a less apparent scientific contribution.

Maria Sibylla Merian first pursued an artistic career, which brought her certain popularity. However, this did not prevent her from gaining recognition from many scientists both of her time and in subsequent centuries, when she turned her interest to researching insects.[161] Merian's determination in researching insects even lead her to travel to South America, bringing her on a par with the distinguished and courageous pioneers of her era. This journey turned out to be very fruitful from a scientific point of view. During her stay in Surinam, Merian collected an invaluable and extensive amount of insects. Her collection has long been the most detailed and scientifically systematised etymological survey of South America. In the centuries that followed, the writings of Merian remained an unsurpassed model for many researchers, including entomologists.[162] Although Merian was not the first to portray the life cycle of insects, she was the first to depict them together with their host plants. From analysing Merian her drawings, we can conclude that her illustrations were very detailed and accurate and conveyed the information aesthetically and clearly, which increases the scientific value. She meticulously observed and described the behaviour of the insects and their context in detail, much more than Goedaert. For instance, she described the threatening postures that caterpillars take in moments of danger.

[160] Ogilvie, "Order of insects", 231.
[161] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 46-47.
[162] Ibid., 32.

Additionally, she had a scientific diary, *Studienbuch*, full of detailed notes and careful sketches.[163] In this, Merian described where the caterpillar was found, the plant on which it was caught, what it ate in captivity and after how many days the transformation began. By describing the interaction between the insect species and their surroundings, Marian can be seen as a pioneer in ecology, or maybe even a precursor of the field of biosemiotics, which was not officially established untill the *Umwelt theory* by Jakob Johann von Uexküll (1864-1944). Uexküll argued that understanding the habitat is as important as understanding the features of the individual bodies of the insects.[164] Furthermore, unlike Goedaert, Merian was one of the few who refuted the theory of spontaneous generation, which she reasoned through her attentive observations. Merian's books served as an important source of information on entomology; other scientists based their research on them; samples and compilations were created from them. Thus, she was already famous both as an artist and a scientist; she was known as an insect researcher and the author of several books. At the same time, the carefully crafted, accurate, graceful drawings of Merian contrasted science with the ideas of contemporaries who considered insects to be evil and had many misconceptions about these creatures. There is little to suggest that the work of Merian was not systematic or methodological, meaning that art and science were not separate concerns in her work.[165] Many of the ecological orders that she established in her work, like the distinction between moths and butterflies, would coalesce into classification systems in the eighteenth century when entomology was established as a distinct discipline.[166] Her scientific activity became so ambitious that it was impossible to call her just an artist. Maria Sibylla Merian was both an artist and a scientist, capturing in her watercolours the amazing world of insects, as well as animals and plants. They combine many wonderful features: observation and attention to detail, artistic taste, perseverance and amazing diligence, and most importantly, curiosity. It is the passion for the topic that does not allow the scientist to live in peace, gives rise to new questions and forces them to conduct research deeper, broader, makes them seek answers, regardless of the different circumstances of life. It is, therefore, that this study concludes that the opinions of Ogilvie and Lenteren, labelling her as merely an artist, cannot be considered valid. Although Merian did not have any scientific education, she was not someone who '"consciously set out to use their artistic and observational talents to serve 'investigators of nature,' denying any fundamental distinction between naturalists and artists.'', as Ogilvie stated.[167]

Lastly, the works of Jan Swammerdam were analysed to serve as a comparison, as he is considered a scientist. This section will prove that although Swammerdam's work was focused on dissection and Merian's on ecology, there are many similarities in their beliefs, goals, and contribution

[163] Etheridge, "Maria Sibylla Merian: The First Ecologist?", 33.
[164] Tønnessen, ''Umwelt Transitions'', 47.
[165] Neri, *The Insect and the Image,* 141.
[166] Ogilvie, "Order of insects", 18.
[167] Ogilvie, "Nature's Bible", 6.

to the field. Swammerdam was the discoverer of many new and important facts about insect development and a thinker deeply interested in many issues discussed in science to this day. His large-scale work, *Historia insectorum generalis,* became quite famous during his lifetime. Where Merian was a pioneer in ecology, Swammerdam is the founder of insect anatomy. One of his main methods was the dissection of even the smallest insect organs, and it was the illustrations that could show or serve as proof of his painstaking work.[168] Swammerdam, just as Merian, opposed the theory of spontaneous generation; however, he went even further and created the preformation theory. Additionally, with his careful studies, the features of insect metamorphosis were revealed for the first time, and a new classification system was built on this basis. Swammerdam's anatomical research and classification would become a part of the new discipline entomology in the eighteenth century, just as Merian's classification would. As for illustrations, Swammerdam's drawings are far from being as artistic as those of Goedaert or Merian, which also prevented the question of whether he was an artist; he was unambiguously considered a scientist. He did not have a reputation as an artist, and neither was it his goal to create art; he was more inclined to precision than decorativeness. At the same time, illustrations played the same crucial role in his works as in Goedaert's and Merian's. He was united with the two above-considered entomologists by the same goal: to trace and show the metamorphosis of insects.[169] While the illustrations of Goedaert and Merian were characterised by great decorativeness and colourfulness of images, Swammerdam's illustrations are also not devoid of style and 'elegance'; even with limited possibilities for creating art, he was able to display everything he needed in them. Only two colours were enough for him to convey the insects' magnificence and his revolutionary discoveries. Therefore, his contribution to science, and entomology, is inevitable.

From this analysation, a conclusion can be made. Several aspects could have influenced on what basis these entomologists could be attributed more to science or art:

1) the artistic value of the illustrations themselves; their value, separate from the text, as works of art;
2) the past of the entomologist: his past education and activities, such as his reputation as an artist;
3) the reputation of the entomologist as a scientist: the value of the discoveries themselves, or rather the recognition and awareness by others, contemporaries, of the contribution he or she made to science.

At any rate, the huge role of scientific-artistic pictures is undoubted, conveying with highly increased reality, with the necessary completeness and convincingness, everything essential and basic, and the means of transmission and perception are expanding. This way, scientific and artistic work is already not only the author's creative scientific documentation, which is comprehensively understandable for a specialist but also becomes quite accessible to a broad layer of non-specialists in natural science, who are included in the field of scientific knowledge and generalisation through

[168] Ogilvie, "Nature's Bible", 6.
[169] Ibid., 16.

scientific and artistic works. Moreover, the research object not only becomes an artistic object but also frees itself from magical and religious dependence, and at the same time, retains intellectual as well as sensual beauty.

Conclusion

This study raised the question if the artistic level of illustrations on insect metamorphosis by seventeenth-century European entomologists is of influence on whether they are considered a scientist or artist by contemporary researchers. Although most art historians have recognised the interwoven relationship between art and science for the last twenty years, there are still contemporary researchers who deny these fluid boundaries. One of those contemporary researchers is cultural historian Brian W. Ogilvie, who made some distinct statements, thereby categorising seventeenth-century naturalists as either artists or scientists. There are three entomologists about whom he explicitly expresses his opinion. In 2018 he stated that Johannes Goedaert and Maria Sibylla Merian were merely artists who ''consciously set out to use their artistic and observational talents to serve 'investigators of nature,' denying any fundamental distinction between naturalists and artists.'[170] However, one could say that it is the other way around, as there were no fundamental distinctions between science and art in the seventeenth century; and it is Ogilvie that is denying the epistemological context of these entomologists. Additionally, he negates the current recognition of the absence of any fundamental distinction. Nonetheless, Ogilvie does not stand alone with his opinion; for instance, entomologist Joop C. van Lenteren shares his opinion, speaking of Goedaert and Merian as primarily artists. However, Swammerdam is always labelled and praised as a scientist. Therefore, these three entomologists, Johannes Goedaert, Maria Sibylla Merian, and Jan Swammerdam, were selected to analyse what grounds this distinction between scientists and artists was made. With this, Swammerdam served as a comparison. Furthermore, this study has given a general history of technical illustrations and considered the historical features of the era. The knowledge of the entomologists was also analysed, including their biographical information regarding education and personal interests. Also, their descriptions, knowledge and their methods of research were analysed. Finally, the illustrations of the three entomologists were described and analysed using *the theory of the picture* by Gabriele Werner.

The entomological illustration is a specific art genre. It has seemingly incompatible qualities; on the one hand, scientific accuracy, on the other, masterful painting performance. Purposeful thematic art is a way of manifesting and shaping the discoveries of the insect world, and depiction is the study of natural phenomena in illustrations. At the same time, they are characterised by the objectivity of perception and transmission of reality, simplicity and clarity of the image. In addition, the selected entomologists are characterised by excellent efficiency, stubbornness and tense constancy because all their work was based on direct observations and sketches from nature. The artist strove to understand and reproduce the world around him, which required a scientific and artistic approach. One could say, artists have the same state of mind as scientists, in the sense that they learn the art as a discipline,

[170] Ogilvie, "Nature's Bible'', 6.

seeking to convey realism. This process is indeed scientific, exploring perspectives and proportion, but there is plenty of room for creativity too. Thus, we can say that artists and scientists similarly look at the world, moving in the same direction.

Maria Sibylla Merian was credited for her detailed and colourful images, but also for her pioneering role in the field of ecology. She managed to combine art and science in her work and make them serve each other, combining high art with the goals of biological science. Johannes Goedaert was a pioneer in researching a wide variety of insects and provided a valuable overview of many species. However, Jan Swammerdam's anatomical approach sets him apart from the other two entomologists. Although being a scientist, in order to fulfil his desire to show that the final form of the organism develops from its simplest form, his artistic skills were beneficial. According to Ogilvie, there is one common feature that unites the illustrations of Goedaert, Merian and Swammerdam: the implicit persuasive function of the illustration.[171] Although Swammerdam's and Merian's contribution to science and entomology is more evident than Goedaert's contribution, labelling the entomologists as artists or scientists remains unconventional in the twenty-first century. Both art and science were born from the eternal human need for knowledge. Art is the 'mother of sciences,' it arose much earlier and constantly absorbed all forms of cognition. Thus, these entomologists' entire lives and work paths were vivid proof of the enormous importance of the relationship between science and art. Their approach to illustrations demonstrates the relationship between artistic, pictorial language and scientific, materialistic penetration into organic nature. It is the great social significance of their work and the foundations of the broadest prospects of the direction that synthesises science and art. These considered researchers, entomological illustration authors, and hundreds of others have shaped a distinct aesthetic based on scientific precision and close attention to the smallest detail.

These entomologists were among those who created a unique precedent: science began to help artists develop techniques, create new tools, study the structure of the living and non-living, and the art of helping science with illustrations and accompaniment. Thanks to the efforts of these entomologists, it became evident that it is not worth separating these two areas, always trying to surpass one another, but that they should help each other achieve their own goals. All of them were very interested in living nature – and not only as an object of aesthetic worship but also as an object of a close study. They observed, recorded in their notes the process of transformation of insects, divided them into parts, sketched, systematised, and made research trips. All of them never ceased to be amazed at the variety of Lepidoptera, their transformations and their bright beauty. These exploratory artists have left a rich legacy behind them. At the same time, they contributed to the development of art, for example, by inventing unique art forms and actively using various types of engravings. Each of them showed that it

[171] Ogilvie, ‘‘Description and Persuasion’’, 7.

is not worth separating science and art; conversely, they can serve each other if the two areas are combined. Thus, these entomologists had artistic talent and delved into the essence of the depicted; their notable examples of human determination and dedication are known to history and can teach a lot today.

Illustrations

Figure 1: Johannes Goedaert, *Plate LXXVII,* 1662, engraving, (Metamorphosis Naturalis)

Figure 2: Maria Sibylla Merian, *Plate 11,* 1704, watercolour and bodycolour with gum arabic and silver paint over lightly etched outlines on vellum, 37.3 x 30.2 cm, (Metamorphosis Insectorum Surinamensium)

Figure 3: Maria Sibylla Merian, *Plate 20,* 1704, watercolour and bodycolour with gum arabic and silver paint over lightly etched outlines on vellum, 37.3 x 30.2 cm, (Metamorphosis Insectorum Surinamensium)

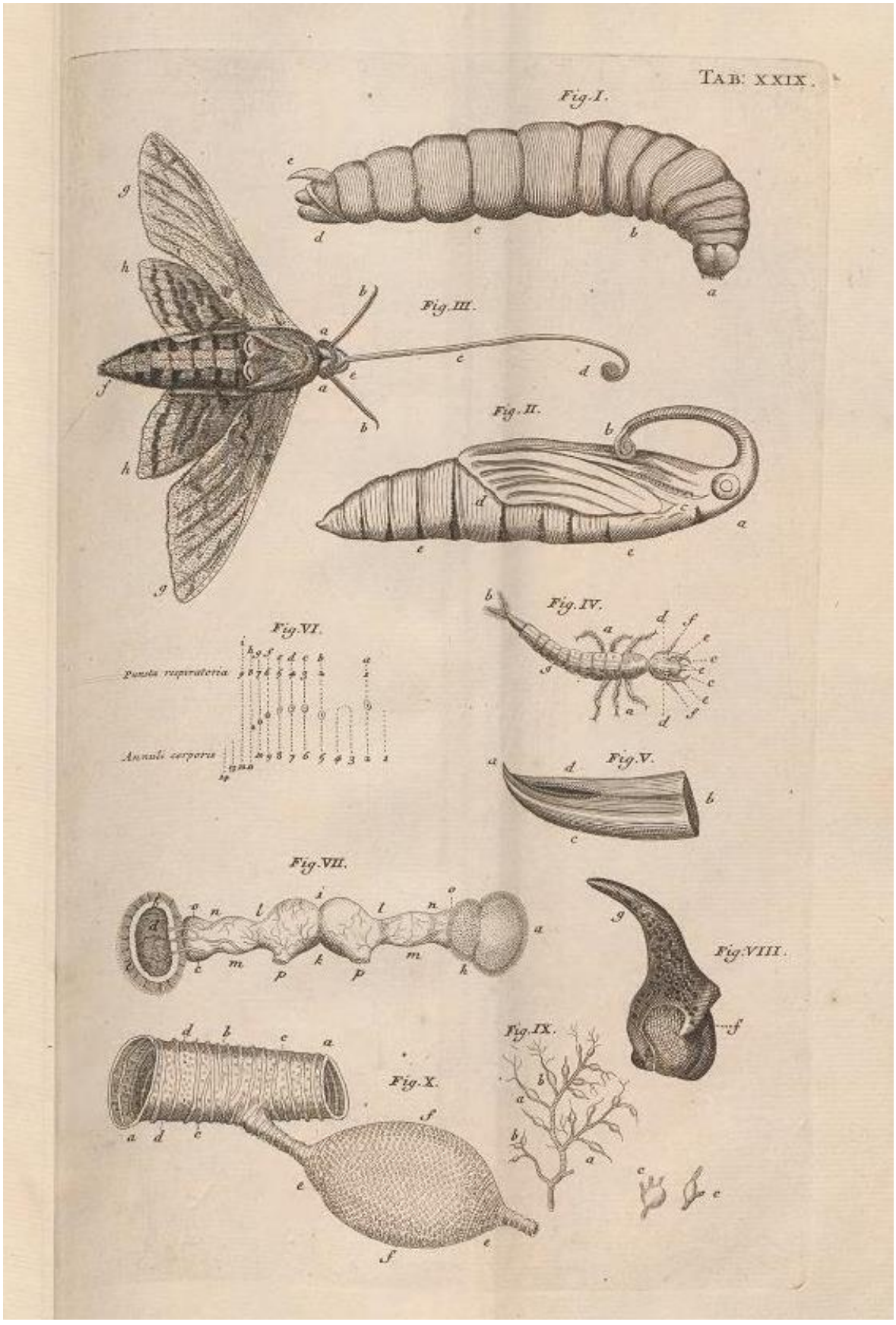

Figure 4: Jan Swammerdam, *TAB XXIX*, 1738, woodcut, (Bybel der Natuure)

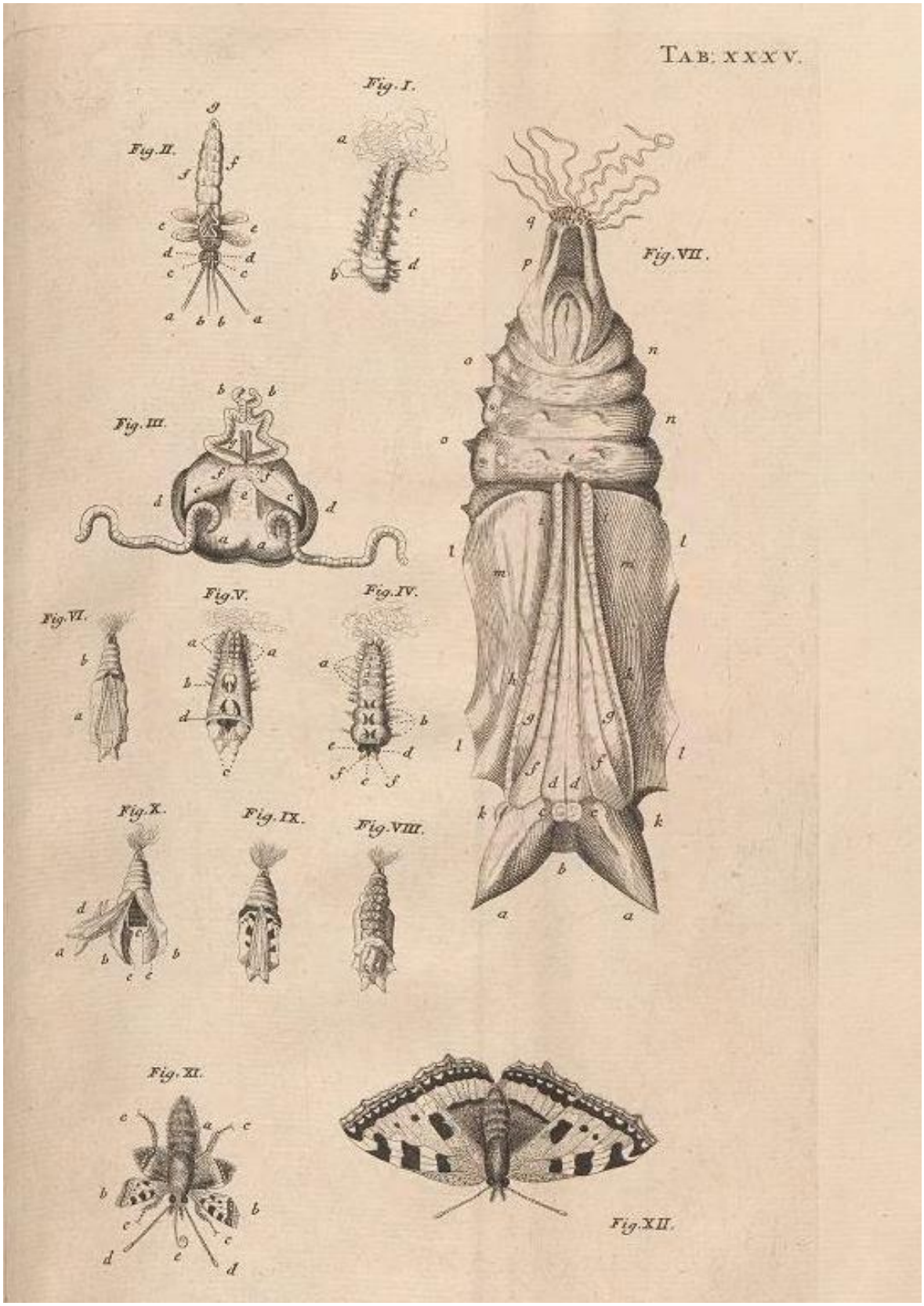

Figure 5: Jan Swammerdam, *TAB XXXV*, 1738, woodcut, (Bybel der Natuure)

Credits illustrations

Figure 1: Goedaert 1662, Plate LXXVll.

Figure 2: Merian 1704, plate 11.

Figure 3: Merian 1704, plate 20.

Figure 4: Swammerdam 1738, TAB XXIX.

Figure 5: Swammerdam 1738, TAB XXXV.

Bibliography

Primary sources

- Aristotle. *Historia Animalium*. 1984.
- Fuchs, Leonhard. *De historia stirpium*. Basel, 1542.
- Goedaert, Johannes. *Metamorphosis naturalis, ofte Historische beschryvinghe vanden oirspronck, aerd, eygenschappen ende vreemde veranderingen der wormen, rupsen, maeden, vliegen, witjens, byen, motten ende dierghelijcke dierkens meer ; niet uyt eenighe boecken, maer alleenelijck door eygen ervarentheyd uytgevonden, beschreven, ende na de konst afgeteyckent*. 1662.
- Merian, Maria S. *Der Raupen wunderbare Verwandelung und sonderbare Blumen-Nahrung: worinnen durch eine gantz-neue Erfindung der Raupen, Würmer, Sommer-vögelein, Motten, Fliegen, und anderer dergleichen Thierlein Ursprung, Speisen und Veränderungen samt ihrer Zeit, Ort und Eigenschaften, den Naturkündigern, Kunstmahlern und Gartenliebhabern zu Dienst, fleissig untersucht, kürtzlich beschrieben, nach dem Leben abgemahlt ins Kupfer gestochen un selbst verlegt. Vol I*. Nürnberg, 1683.
- Merian, Maria S. *Metamorphosis Insectorum Surinamensium*. Amsterdam, 1704.
- Nieuwentijt, Bernard. *Het regt gebruik der werelt beschouwingen, ter overtuiginge van ongodisten en ongelovigen aangetoont*. 1759.
- Swammerdam, Jan. *Historia insectorum generalis, ofte algemeene verhandeling van de bloedeloose dierkens: waar in, de waaragtige gronden van haare langsaame aangroeingen in leedemaaten, klaarelijk werden voorgestelt ... ende beknoptelijk, in vier onderscheide orderen van veranderingen, ofte natuurelijke uytbottingen in leeden begreepen*. 1669.
- Swammerdam, Jan. *Bybel der natuure, door Jan Swammerdam, Amsteldammer. Of Historie der insecten, tot zeekere zoorten gebracht: door voorbeelden, ontleedkundige onderzoekingen van veelerhande kleine gediertens, als ook door kunstige kopere plaaten opgeheldert: Verrykt met ontelbaare waarnemingen van nooit ontdekte zeldzaamhedenin de natuur*. 1738.

Secondary sources

- Bredekamp, Horst, Vera Dünkel, and Birgit Schneider. *The Technical Image: A History of Styles in Scientific Imagery*. Chicago: University of Chicago Press, 2019.
- Bredekamp, Horst. *Lure of antiquity and the cult of the machine: The Kunskammer and the evolution of nature, art and technology.* Princeton: Markus Wiener Publishing Inc, 1995.
- Cobb, Matthew. "Reading and writing The Book of Nature: Jan Swammerdam (1637–1680)." *Endeavour* 24, 3 (2000), 122-128.
- De la Ruë, Pieter. "Goede onbekenden." *Geletterd Zeeland* (1734): 30-35.
- Etheridge, Kay. *Maria Sibylla Merian: The First Ecologist?.* Cambridge: Gettysburg College, 2011.
- Fransen, Sietske. "Antoni van Leeuwenhoek, His Images and Draughtsmen." *Perspectives on Science* 27, 3 (2019): 485–544.
- Fransen, Sietske. "Science made Visible: Drawings, Prints, Objects." *Exhibition Catalogue Royal Society London* (2018): 1-48.
- Freedberg, David. *The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History*. Chicago: University of Chicago Press, 2003.
- Freedberg, David, and Jan D. Vries. *Art in History, history in Art: Studies in Seventeenth-Century Dutch Culture*. Chicago: Getty Publications, 1991.
- Goeree, Willem. *Inleyding tot de Practyk der Algemeene Schilderkonst*. Middelburg, 1670.
- Goethe, Johann W. *Goethes Sämtliche Werke in 36 Bänden. Mit Einleitungen von Karl Goedeke*. 1895.
- Ivins, William M. *Prints and Visual Communication*. Cambridge: MIT Press, 1969.
- Jorink, Eric. *Reading the Book of Nature in the Dutch Golden Age, 1575-1715*. Translated by Peter Mason, Leiden: Brill, 2010.
- Jorink, Eric, and Bart Ramakers. "Undivided territory: 'Art' and 'science' in the early modern Netherlands." *Netherlands Yearbook for History of Art* 61 (2011): 6-32.
- Jorink, Erik. *Art and Science in the Early Modern Low Countries (Netherlands Yearbook for History of Art)*. Edited by Bart Ramakers, Zwolle: WBooks, 2012.
- Jorink, Erik. "Insects, philosophy and the microscope." In *Worlds of natural history*, edited by H. Curry, N. Jardine, J.A. Secord, and E. Spary, 131-150. Camebridge: Camebridge University Press, 2018.
- Jorink, Erik. *Lessons in Art. Art, Education and Modes of Instruction since 1500 (Netherlands Yearbook for History of Art 68)*. Edited by A.S. Lehmann and Bart Ramakers, Leiden: Brill, 2019.

- Kemp, Martin. *The Human Animal in Western Art and Science*. Chicago: University of Chicago Press, 2007.
- Kemp, Martin. “Style and non-style in anatomical illustration: From Renaissance Humanism to Henry Gray.” *Journal of Anatomy* 216, 2 (2010): 192-208.
- Kusukawa, Sachiko. “Patron’s review. The role of images in the development of Renaissance natural history.” *Archives of Natural History* 38, 2 (2011): 189-213.
- Kusukawa, Sachiko. *Picturing the Book of Nature: Image, Text, and Argument in Sixteenth-Century Human Anatomy and Medical Botany*. Chicago: University of Chicago Press, 2012.
- Lefèvre, Wolfgang, Jürgen Renn, and Urs Schoepflin. *The Power of Images in Early Modern Science*. Basel: Birkhäuser, 2012.
- Lindberg, David C., and Robers S. Westman. "Reappraisals of the Scinific Revolution." *Science* 250, 4987 (1990): 1600-1601.
- Tønnessen, Morten. "Umwelt Transitions: Uexküll and Environmental Change." *Biosemiotics* 2 (2009): 47–64.
- Van Lenteren, J. C., and H. C. J. Godfray. “European science in the Enlightenment and the discovery of the insect parasitoid life cycle in The Netherlands and Great Britain.” *Biological Control* 32.1 (2005): 12-24.
- Mason, Stephen. *A History of the Sciences*. New York: Collier Books, 1962.
- Meli, Domenico. “The representation of insects in the seventeenth century: a comparative approach.” *Annals of Science* 67, 3 (2010): 405-429.
- Merian, Maria S. *Metamorphosis Insectorum Surinamensium*, edited by Marieke Van Delft and Hans Mulder. Tielt: Lannoo, 2016.
- Neri, Janice. *The Insect and the Image: Visualizing Nature in Early Modern Europe, 1500-1700*. Minneapolis: University of Minnesota Press, 2011.
- Ogilvie, Brian W. “Description and Persuasion in Seventeenth-century Entomological Illustrations.” *Seeing Science Conference* (2005).
- Ogilvie, Brian W. “Nature’s Bible: Insects in Seventeenth-Century European Art and Science.” *Tidsskrift for kulturforskning* 7, 3 (2008): 5-21.
- Ogilvie, Brian W. “Order of Insects. Insect Species and Metamorphosis between Renaissance and Enlightenment.” *The Life Science in Early Modern Philosophy* (2014): 222-245.
- Parshall, Peter. “Imageo contrafacta: Images and Facts in the Northern Renaissance.” *Art History* 16 (1993): 554-579.
- Parshall, Peter, and David Landau. “The Renaissance Print.” *Print Quarterly* 12, 4 (December 1995): 405-407.

- Pieters, Florence FJM, and Diny Winthagen. “Maria Sibylla Merian, naturalist and artist (1647–1717): a commemoration on the occasion of the 350th anniversary of her birth.” *Archives of natural history* 26, 1 (1999): 1-18.
- Purgar, Krešimir, ed. *WJT Mitchell's Image Theory: Living Pictures*. Taylor & Francis, 2016.
- Reitsma, Ella. *Maria Sibylla Merian & Daughters*. Zwolle: Waanders Publishers, 2008.
- Smith, Pamela H. *The body of the artisan. Art and experience in the Scientific Revolution.* Chicago: The University of Chicago Press, 2004.
- Smith, Pamela H. “Art, Science, and Visual Culture in Early Modern Europe.” *Isis* 97, 1 (2006), 83-100.
- Valiant, Sharon. “Maria Sibylla Merian: Recovering an Eighteenth-Century Legend.” *Eighteenth-Century Studies* 26, 3 (1993), 467-479.

Websites

- Cambridge Dictionary. ‘‘Entomologist.’’ Accessed on 24 March 2021. https://dictionary.cambridge.org/dictionary/english/entomologist
- Dutchculture – Centre for International Cooperation. ‘‘Suriname: The Treasury Collection, Works by Maria Sibylla Merian, Exhibited in Suriname.’’ 2020. Accessed on 31 March 2021. https://dutchculture.nl/en/news/suriname-treasury-collection-works-maria-sibylla-merian-exhibited-suriname
- The Conversation. ‘‘Hidden Woman of History: Maria Sibylla Merian, 17th-century Entomologist and Scientific Adventurer.’’ 2019. Accessed on 2 May 2021. https://theconversation.com/hidden-women-of-history-maria-sibylla-merian-17th-century-entomologist-and-scientific-adventurer-112057.