

1. Title

From Hooke's *Micrographia* towards the construction of a simple microscope for the teaching and learning of primary science

2. Authors and Institutions

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3. Abstract

This is an inquiry conducted with 40 children of the 6th grade of a Greek primary school, divided in two classes. Initially, each child constructed a simple reflective microscope using modern materials like a plastic tube and two plastic lenses (objective and eye piece), which were extracted out of single-use disposable cameras. It is actually a modified (re)construction of a microscope (approximate magnification 20x), which has been proposed by researchers of the Istituto e Museo di Storia Della Scienza of Florence. At a later phase, an extra middle lens was added to the microscope to minimize distortion, create sharper images and enhance magnification by 3-5 times.

*The children have been briefly introduced to the historical development of the microscope, with a focus on the life and discoveries of Robert Hooke (1635-1703), from the early years at the Isle of White till the achievements of *Micrographia* (1665), having him portrayed as a natural philosopher and polymath who played an important role in the scientific revolution, through both experimental and theoretical work. After that, microscope studies were conducted with each child recording their observations with the constructed microscope on a notebook with text and sketches, in an approach inspired by Hooke's *Micrographia*. Before putting down their notes on paper, they studied a relevant extract from the classic text of Hooke, adequately transformed and adjusted for the instance. Thus, following similar steps to those of Hooke, the children initially studied the point of a needle and a small printed dot, which have also worked as focus exercises for the use of the microscope. Then they studied plant seeds (thyme and petunias) as well as parts of plants during their development in the greenhouse and the school garden. Later, they studied garden insects, conducting "insectigations" as they called them, examining ants and isopods. They concluded with a free study, on either plants or insects, since they had developed interests in various and diverse*

specimens they wanted to examine further. The children discussed and exchanged in class their notes and observations, within a framework of investigations about the development and functions of plants and insects. The analysis of children's notebooks is expected to reveal aspects of "doing science" in an authentic environment (inquiry-based teaching and learning approach), within a framework of learners' scientific community dealing with an intentional task and/or investigative activity.

Keywords:

simple microscope, study of plants, observation notebooks, primary science.

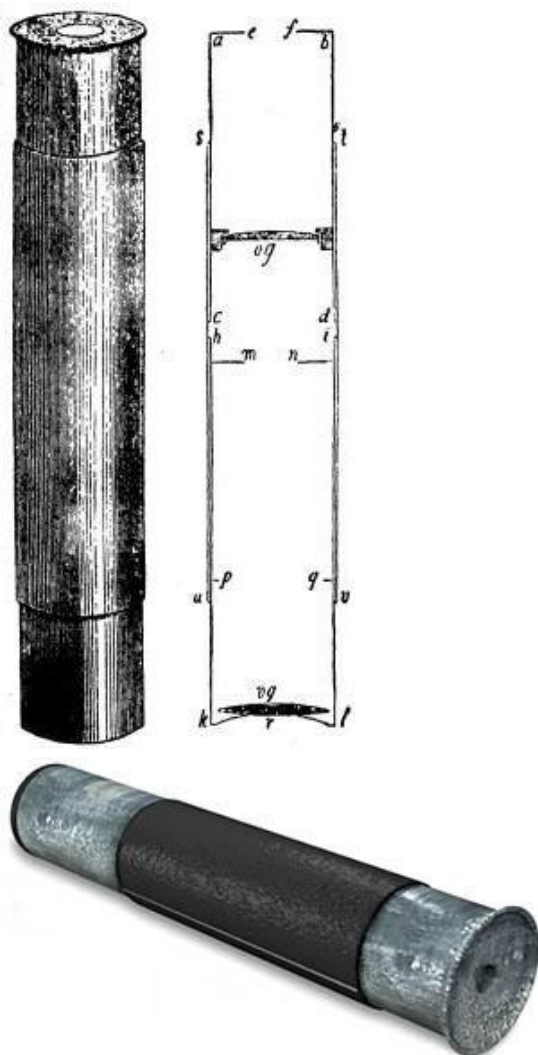


Fig. 1: The Middelburg microscope, believed to be the invention of Zacharias Janssen (1590) [From "Origin and Development of the Microscope" courtesy of the Royal



Fig. 2: The (re)construction of a simple reflective microscope (above) with modern readily available materials (below).

Microscopic Society, London].

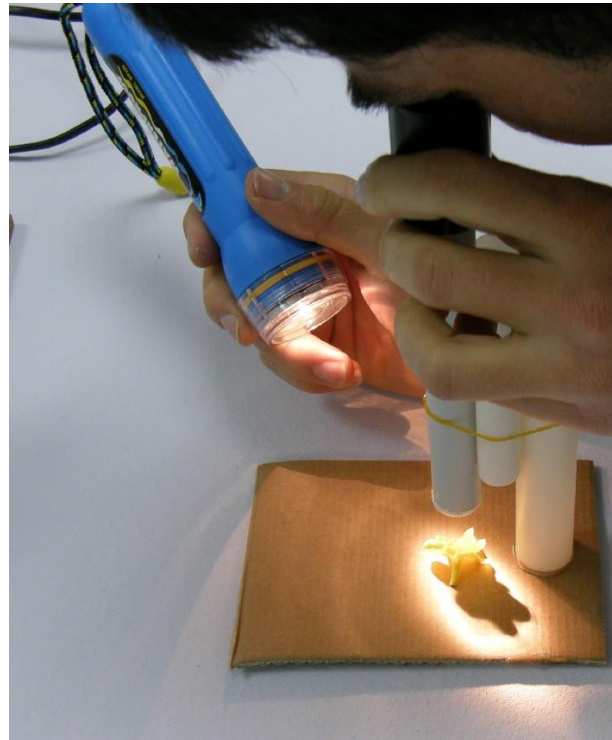
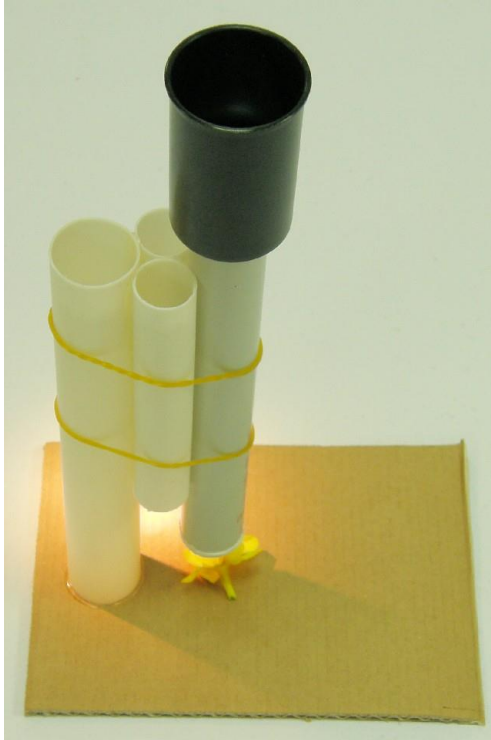


Fig. 3: The microscope, a closer look. Fig. 4: The microscope in action ...

4. Description of Case Study

The educational setting of this case has been a 6th grade of a primary school with 40 12-year-old children divided in two class groups. It is actually a developed educational scenario within a framework of an inquiry-based teaching and learning approach in primary science. It was conducted at the Science Laboratory for Primary education, located at the 9th Primary School of Rethymno, Crete, Greece. All children have been actively involved in the construction of simple reflective microscopes made with modern materials, which were later used for the development of microscope studies. The children were provided with assistance and guidance from their teacher, who also acted as a researcher and four students from the Primary Education Department of the University of Crete, who were involved during their placement in teaching practice. These people constituted a small supervisory team throughout the development of this educational scenario, although not all were present at each phase of its course, due to other academic commitments.

This educational scenario consists of two parts. In the first part the children worked initially in pairs and later individually to construct a simple microscope. Each pair initially constructed a modified version of a microscope (approximate magnification 20x), which has been proposed by researchers of the *Istituto e Museo di Storia Della Scienza* of Florence, chronologically placed at the end of the 16th beginning of the 17th century, mainly influenced by the first Middelburg microscope, attributed as an invention to Hans & Zacharias Janssen, circa 1590-

1595 (see fig. 1 above). They used a PVC tube and two plastic lenses (objective and eyepiece), which had been extracted out of single-use disposable cameras (see fig. 2). They fixed their microscope inside the niche of a 2-tube base glued on a third supported tube and they made some initial observations on small objects (see fig. 3 & 4). A small and cheap reading spotlight was used to shed light to the objects under investigation. Rather soon, we realised that we could make an improvement to the microscope in order to have more precise and crisp images, with less distortion. The idea was to use an extra field lens to achieve this. So, by extending the microscope pipe with a conjunction piece we added a third lens. Thus, an extra field lens was fixed in between the end of the initial microscope pipe and the new location of the eye piece, placed at the end of the attached conjunction piece (see photos in the construction of the microscope [page](#)). The microscope pipe was stabilised to the support base with a plastic cable tie fastener, which enabled the learners to focus on images and remain stable for longer observation time. At this phase, each individual child was involved in the construction of a microscope, which they kept as their own, in order to conduct the relevant studies. These improvements have completed the construction of a simple compound microscope with readily available materials, which was now ready to be used for microscope studies.

In the second part of the development of this educational scenario, the microscope studies were linked to a classic scientific book on microscope studies, that is Robert Hooke's *Micrographia* (1665). Pieces of text and drawings have been selected from the book to be added to worksheets, in order to provide inspiration and guidance to children's investigations. Thus, seven worksheets were developed with the text pieces adequately translated into Greek and adapted to the framework of study. The children were asked to record their observations and drawings on the worksheets, in a way that Hooke had done in *Micrographia* and then they discussed them with their classmates. Gradually, they formulated notebooks of text and drawings which were exchanged and commented in class. The analysis of these texts and drawings has revealed explicit aspects of children's approaches to microscope studies in primary science.

5. Historical and philosophical background

In the museum of *Middelburg* a very old microscope is preserved, which is reputed to be an instrument constructed by *Zacharias Janssen* himself, probably with the aid of his father *Hans*, circa 1590-1595 (Bradbury, 1967). Despite the fact that there is no direct evidence to link this particular microscope to the *Janssens* and their craftsmanship on lenses at the time, it is still a remarkable instrument, which includes two draw tubes that could slide out of another outer casing tube, acting as a supporting sleeve. The lenses were in the ends of the draw tubes; the eyepiece lens was bi-convex and the objective lens was plano-convex. There was no stand provided for this instrument, which was apparently held in hand whilst in use. It is estimated that it was capable of

magnifying images approximately three times when fully closed and up to ten times when extended to the maximum.

Galileo Galilei (1564-1642) mentioned in *Il Saggiatore* [The Assayer] (Rome, 1623) that he had probably achieved to have a "telescope modified to see objects very close". It appears that in 1625 a member of the *Accademia dei Lincei* and friend of Galileo, *Johannes Faber* (1574-1629) conferred on the instrument, until then called "occhialino", "cannoncino", "perspicillo", and "occhiale", the name of "microscope". In the second half of the 17th century, remarkable results were achieved by the Italian instrument makers *Eustachio Divini* (1610-1685) and *Giuseppe Campani* (1635-1715), while in England levels of excellence were reached by *Robert Hooke* (1635-1703) or opticians and instrument makers like *Christopher ***** (circa 1665).



Divini's vase-shaped microscope



Campani's ivory turned monocular microscope



****'s compound microscope, manufactured in London for R. Hooke

Microscope studies began during the course of the 17th century with *Federico Cesi* (1585-1630) and *Francesco Stelluti* (1577-1651) in the *Apiarium* (Rome, 1625). *Melissographia* (also appearing in Greek as "ΜΕΛΙΣΣΟΓΡΑΦΙΑ") is a work of *Stelluti*, covering a single folio of extraordinary size, containing detailed descriptions on bees, seen as a free inquiry into nature from the bondage of scholastics "who have presumed to dogmatize on Nature", as *Bacon* criticized. Later, *Giovanni Battista Hodierna* (1597-1660) published, in *L'occhio della mosca* (Palermo, 1644), a text dedicated to the anatomy of insects, a masterly example of naturalist research conducted with the aid of the microscope. *Robert Hooke* has been undoubtedly one of the greatest personalities of English science of the 17th century. He was one of the first to realize the potentialities

of the new invention of the microscope, which had been recently brought to England from the Continent. He was born in 1635 in Freshwater, Isle of White, and upon the death of his father he was apprenticed to a portrait painter in London. He soon abandoned this, however, and went to Westminster School and subsequently to Oxford. It appears that the originator of the superb microscopical illustrations later to be drawn in *Micrographia* (1665) had not only artistic talent, but also some formal training in a branch of art, which required accurate delineation and observation of detail (Bradbury, 1967).

Hooke was a scientist with a curious mind. From a very early age he worked in many scientific fields such as physics, chemistry, geology, biology, meteorology and astronomy, thus he has often been called the *Leonardo* of England (Inwood, 2003). He also knew and worked with some of the greatest scientists of the 17th century, like *John Wilkins*, *Robert Boyle*, *Christopher Wren*. He also discussed his ideas with *Isaac Newton*, *Christiaan Huygens* and *Johann Hevelius*, although he had strong disagreements and finally became rival with all three of them on different scientific issues (Burgan, 2008).

Hooke became associated with the newly formed “*Royal Society of London for Improving Natural Knowledge*”, which was initially a small group of scientists, called *fellows*, who met once a week to discuss their latest experiments and scientific ideas (Jardine, 2004). In 1662 the group decided to hire someone to do experiments and then report the results. Hooke was the first choice for the job, so he became the “*Curator of Experiments*”. It was this time that he carried out microscopical studies, and the Royal Society recognizing the importance of this new branch of study, encouraged this endeavor. In 1663 he was solicited by the Society to prosecute his microscopical observations in order to publish them eventually and he was also instructed to “*bring in at every meeting one microscopical observation, at least*” (Bradbury, 1967). Hooke faithfully complied with this directive and showed the Society fellows the appearance under the microscope of common moss, the view of the edge of a sharp razor and of a point of a needle etc. He demonstrated various insects such as the flea, the louse, the gnat, the spider, the ant and various types of hairs. All these observations and many others besides were published in 1665 under the long title “*Micrographia: or some physiological description of minute bodies made by magnifying glasses with observations and inquiries thereon*”.



A detailed drawing of an ant by R. Hooke with the description on page 203 of *Micrographia*

Micrographia was a huge book and was filled with descriptions of what Hooke saw under the microscope. He claimed that his goal was to use “a sincere hand, and a faithful eye, to examine, and record the things themselves as they appear”. Along with texts of lucid descriptions, Hooke included stunning, detailed drawings of what he saw under the microscope’s lens, which often folded out of the book. For the first time ever, natural scientists as well as common people could see a new world around them which they barely knew it existed (Burgan, 2008). His lively drawings of insects made them seem “as if they were lions or elephants seen with the naked eye”, he commented. The book was a great success and still ranks high today as one of the great masterpieces of microscopical literature (Inwood, 2003).

No original painted portrait of Hooke is known to exist. It is said that any existing portrait disappeared when Newton was elected president of the Royal Society. Despite the claim that a recently discovered portrait is considered to be the one of Hooke’s (Jardine, 2004), it is still not fully accredited and/or

mutually accepted as such. Nevertheless, for the educational purposes of this inquiry, for the children

to have a more immediate link to the scientist and his work, a visual image of Hooke has been drawn out of the paintings of the history artist *Rita Greer*. Her paintings, based on two detailed written descriptions, aim “to put him back into history”, in an attempt to recreate his face and appearance.



'The Fossil Hunter'. Robert Hooke as a ten year old child on the Isle of Wight at Freshwater Bay. Oil on board by *Rita Greer*, 2005



'Robert Hooke, Engineer'. A memorial portrait by the history painter *Rita Greer*, 2009

6. Target group, curricular relevance and didactical benefit

The construction of a microscope with common and readily available materials has been the first part of the twofold objective of this inquiry. The second part has been its implementation into practice, within the framework of children's laboratory work linking it with Hooke's *Micrographia* (see section 7).

The initial idea for the microscope construction was one that resembled to the first *Middelburg* compound microscope, in a simplified version with one tube, two lenses and a diaphragm (Vannoni *et al.*, 2006; 2007). Thus, initially the children used a PVC tube (16,5 cm length and 16 mm inner diameter) and two plastic lenses (objective and eyepiece), which had been extracted out of single-use disposable cameras. A piece of black carton was rolled and inserted inside the plastic tube, to avoid light reflections. The lenses were put inside adequate metal washers and affixed with sticky tack. To reduce colour and spherical aberration, the aperture of the objective lens needed to be reduced, thus a black rubber washer was used as a diaphragm and stuck on top of the washer of the objective lens. At the other end of the microscope tube, a black film can was cut and fixed accordingly at the eye piece, providing a smooth dark base for the observer's eye. The microscope was finally fixed inside the niche of a 2-tube base glued on a third bigger supporting tube. This base was glued with a glue-gun on a piece of cardboard and the microscope was ready for observations.

The microscope tube was held onto the base with two or three elastic bands and it moved up and down to focus. The children made some initial observations on small objects, like sand, salt, but also feathers, pieces of cloth etc. A small and cheap reading spotlight was used to shed light to the objects under inspection.

Rather soon, we realized that we could make an improvement to the microscope, in order to have more precise and crisp images, with less distortion. The idea was to use an extra *field lens* to achieve this. So, by extending the microscope tube with a conjunction piece we added a third lens. Thus, an extra field lens was fixed in between the end of the initial microscope tube and the new location of the eye piece, placed at the end of the attached conjunction piece. The microscope tube was stabilized to the supporting base with a plastic cable tie fastener, which enabled the children to focus on images and remain stable for longer observation time. The friction created by the cable tie fastener, forcing the microscope tube and its base in contact, kept it firm and steady. In order to focus on the specimen, the children now had to turn the microscope gently and simultaneously move it up and down. To reach upon this cost effective, simple solution, we had spent quite some time trying out alternative ideas, always in search for the better one, dealing with a particular problem with an intentional added value in the result. These improvements have completed the construction of a simple compound microscope. In fact, we made more than 45 of them, ready to be used for microscope studies (click [here](#) to see the construction phases in more detail).

The children were very curious to put their microscopes into action and investigate various specimens. In classroom discussions, after some arbitrary microscope observations, we agreed that we needed some sort of guidance to lead us along the way of microscope investigations. It was exactly at this point that the idea of linking our observations with those of a distinguished scientist came into context. Thus, Robert Hooke, in fact the first scientist to conduct systematic microscope studies in his *Micrographia*, was introduced to the children, in order to act as a scientist from the past to assist us with our studies. For this to be a successful endeavor, children had to know more about who Hooke was, starting from his early age on the Isle of White, till the writing of *Micrographia* and further on. Thus, Hooke had to be placed into a historical context, didactically transposed in an adequate manner, familiar and suitable for the children of this age. A presentation has been developed for this purpose, using many paintings of Rita Greer, the history artist, which helped a lot to visualize aspects of Hooke's life (these paintings are available in the following URL: http://commons.wikimedia.org/wiki/Category:Paintings_by_Rita_Greer).

Robert Hooke was often sick as a child and his parents thought that he would not survive his childhood, but eventually his health improved as a teenager. His parents decided to teach him at home rather than send him to school. He developed a natural intelligence and curiosity about the world around him. Surrounded by the sea, he seems to have taken an early interest in ships and he had constructed a very detailed model toy ship (Burgan, 2008). He would have seen tall chalk cliffs on the Isle of White and worn seaside rocks. He had probably discovered fossils, remains of ancient plants and small animals preserved in the soil and rock of the island. The young Robert also showed his artistic skills by copying paintings he saw in his family's house with impressive detail. Soon after the death of his father in 1648, Robert, at the age of 13, moved to London to begin his education as a scientist in the Westminster School, one of the oldest and best schools in England. As a teenager, he studied Euclidian geometry and learned Greek and Latin. He also developed practical skills by learning how to use the lathe, a machine used to shape wood or metal. In 1653, Hooke left Westminster and moved to Oxford University to study "natural philosophy", which included many branches of science such as physics, biology and chemistry. By the time he published *Micrographia*, in 1665, he was in his thirties, a distinguished member of the Royal Society, a polymath, a very skilful scientist and probably the first systematic microscopist.

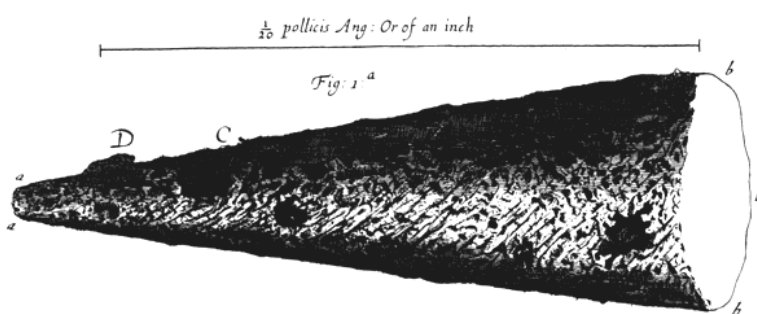
The children were impressed by the presentation of the life story of a scientist such as Hooke and were very curious to see more closely what he had actually written and drawn in *Micrographia*. They mentioned that it would be interesting to have him alongside as a "teacher", to guide us through our own microscope studies. Hence, for the purposes of this inquiry, seven worksheets have been designed, starting from adequately translated pieces of Hooke's text and drawings, which turned into hands-on classroom investigations and

observations with similar specimens (i.e. point of needle, a printed dot, seeds of thyme, the ant). These investigations were extended to the study of other resembling specimens, which have been discussed in class and the children were curious to observe (i.e. the seeds and parts of the petunia plant, other insects like the isopods etc.). In the end, they had developed the skills and the interests to study lots of various different specimens, which were waiting for them, just outside the Science Laboratory, at the school garden. Thus, they concluded their observations with a “free study” to investigate “*something particularly of our own*”, as they insisted. A brief discussion of all these studies follows in the subsequent sections (all seven worksheets are presented [here](#) in Greek).

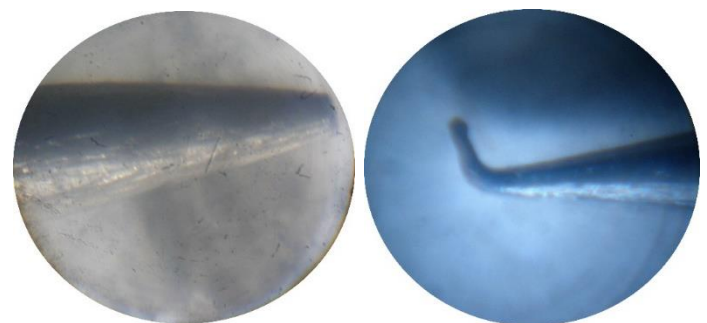
7. Activities, pedagogical skills and research evidence

7.1. Microscope studies on the point of a needle and a printed dot

The first two study worksheets were linked to the beginning of Hooke’s studies in *Micrographia*. The worksheet on the study of *the point of the needle* is directly linked with page 1 of *Micrographia*, where Hooke comments that “we will begin these our Inquiries therefore with the Observations of Bodies of the most simple nature first, and so gradually proceed to those of a more compounded one” [emphasis in the original]. This appears to be an interesting scientific, but also didactical proposition, which we adopted with the study of the point of the needle and later with the printed dot. Both symbolise something extremely small and rather dimensionless, similar to the Euclidian “point” in geometry or the “physical point” according to Hooke, which might in fact look rather different and huge under the microscope.



Hooke’s drawing of the point of the needle



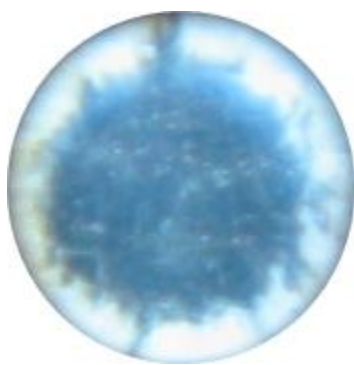
Two digital photos of needles the children observed under their microscopes

The children read in class Hooke’s description of **the point of the needle**, which referred to the relevant detailed drawing (see drawing above). Then, they were invited to observe the point of a needle with their microscopes, record their own description and make their own drawings. In the beginning, they had some difficulties in finding the point of the needle and then focus on it, but rather

quickly they developed skills and their own techniques, which they shared with each other. Each worksheet was kept in a plastic pocket inside a binder folder. So, at the end of children's microscope studies, all of the worksheets together constituted an *observation notebook* (Klentschy, 2008; Martin, 2009).

Hooke noted that the point of the needle looked rather sharp and smooth to the naked eye, but under the microscope it *“could not hide a multitude of holes and scratches”*. A child wrote in his description that the point of a needle *“although in reality it is very straight and very sharp, under the microscope it is a bit curved and not sharp at all. It has a slight bump, probably from its bad use. At the rest part of the needle there are cracks and small bumps”*. Another child noted that *“the needle has an edge, which looks as if it is cut. It is as if it has a lot of damages on it, like long narrow bumps. It has a dark colour and a small cut. Anyhow, it is not as flat and sharp as we could imagine. At the centre the needle is more flat than at its point. Under the microscope it reminds me more of the point of a pencil”*. Although the photos of fig. 9 are not very clear, because of the inappropriate contact of the digital camera lens on the eye piece part of the microscope, it appears that the children could observe the point of the needle in a similar magnification to that of Hooke's. But, they reported a greater variety of cases, since they even found a couple of “imperfect”, rather curved, needle points in each class.

Observing **the printed dot**, or *“a mark of full stop or period”*, Hooke mentioned that it had various irregularities and in fact it reminded him *“a great splash (splash) of London dirt”*. One of the children wrote that *“the dots appear totally different under the microscope than with the naked eye. This one has a gray-black colour and it looks like a hairy fur ball or like a splash. It has a strange and uneven shape, which looks like the surface of the sun. At some points it appears that small sticky points are edging out of the dot”*. Another child compares a printed dot with a handwritten one and claims that the first *“has a lot of “peaks” and it appears like a big black hole”*, whereas the latter *“looks like a big cloud of smoke”* and also *“some curly pieces of hair are formed, all around the dot”*.



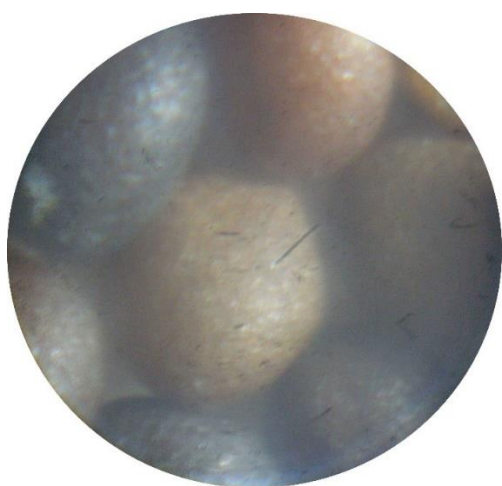
A digital photo of a printed dot under the microscope



A child's drawing of a printed dot

7.2. Microscope studies on the seeds of thyme and petunias

Moving on with the microscope studies, we examined **the seeds of thyme** as Hooke had also described in *Micrographia*. He noted that the seeds had a variety of shapes, whereas “each of them exactly resembled a Lemmon or Orange dried; and this both in shape and colour” and they were different from common seeds like beans and peas. The children used the needle, they had examined earlier, as a tool to put the small thyme seeds in place under the objective lens of the microscope and again they had to deal with some problems regarding the focus and the lighting of the specimens under inspection. Soon these were resolved with persistence and patience; virtues which children started to develop, improving their technical and methodological skills. One child wrote that some of the seeds of thyme “have bumps and others have peaks and they look like lemons, oranges, olives and some look like “choco pop” cereals. Most of them have some small “bumps” than others which have “scratches”. Most with the scratches look like nuts, whereas those with bumps look like the skin of a rotten orange and their colours are black brown or brown with black”. Another child noted down in her worksheet that the seeds of thyme reminded her of lemons or oranges and “they are all in a different position. There is a great variety in the volume and shape of the seeds. The seeds under the microscope have a black or a brown colour. The seeds are nose-y or common like lemons. Every time we observe things they are not as we see them. The seeds look bigger and different than we see them with the naked eye. Thus, we should never say we see something unless we observe it with other methods like the microscope etc.” The latter statement appears to be an interesting epistemological note.



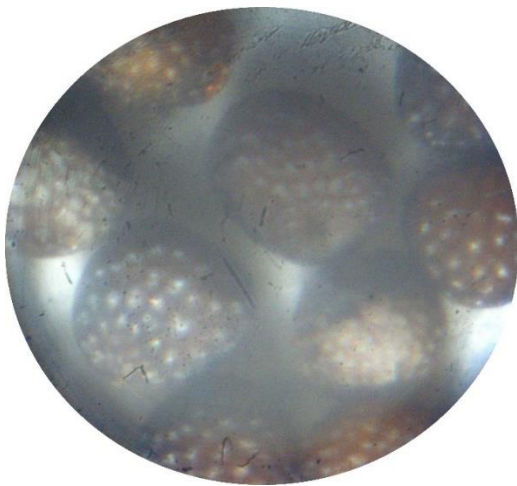
A digital photo of seeds of thyme under the microscope



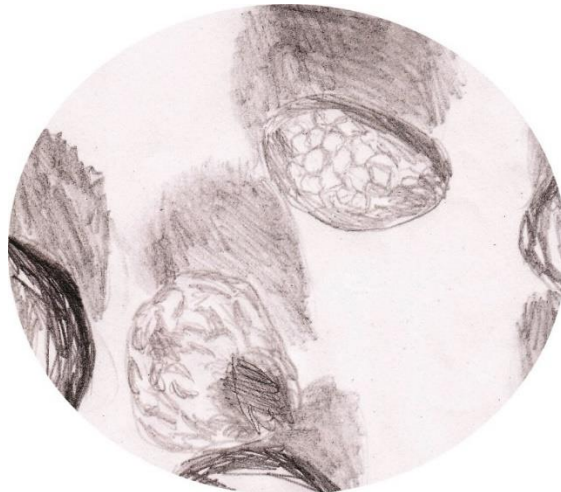
A child's drawing of seeds of thyme. Notice the shadows she has observed and drawn, created by the small reading spotlight lamp, which illuminated the seeds from an angle.

When the children were preparing their seed plants to be raised in the greenhouse of the organic school garden, they were impressed about the small

size of some seeds. The smallest seeds they had planted were **the petunia seeds**. Hence, they were very interested to observe them under the microscope and this is exactly what happened as an extended investigation, following the one on the seeds of thyme. A child commented that *“the colour of the petunia seeds is dark brown. Their shape is round and they have holes and bumps. They look like small insects. In front they have something like a piece of string hanging out, whereas the back side is a bit round”*. Another child wrote that the petunia seeds *“are very small and different to those of thyme, but under the microscope they look rather big. They remind me of raisins, rotten fruits, cereals, small olives etc. They look like small bumpy marbles with brown colour”*.

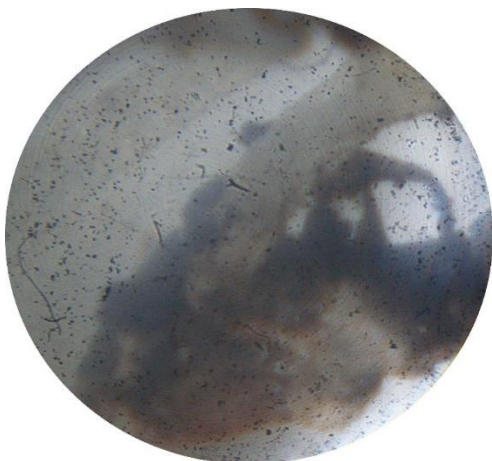


A digital photo of seeds of petunia



A child's drawing of the petunia seeds

The children went on to observe **parts of the petunia plants** they brought out of the greenhouse at the time of the microscope studies. One child inspecting a petunia leaf recorded that it was very strange, since *“petunias are beautiful plants, but you never know what they are hiding. Their leaves have very small white hair on their surface and they glitter as they stick out of the leaf, but they also look a bit transparent”*. Another child noted that *“the roots of petunias look like hands with fingers sticking out, with some soil on them and short hair. The roots are very small and thin, but I can see them clearly.”*



A digital photo of petunia roots with soil

A digital photo of the tip of a “hairy”
petunia leaf

7.3. Microscope studies on insects like ants and isopods

The next study was **an investigation on insects, an “insectigation”** in a creative term (Blobaum, 2005). Hooke had conducted several studies of insects in *Micrographia*, but one of his most descriptive and at the same time more familiar to primary school children is the one on the ant. He mentions that he had a hard time trying to keep the ant steady under the microscope for observation. Having selected some ants he “*made choice of the tallest grown among them, and separating it from the rest, gave it a Gill of Brandy, or Spirit of Wine, which after a while knocked him down dead drunk, so that he became moveless, though at first putting in he struggled for a pretty while very much, till at last, certain bubbles issuing out of its mouth, it ceased to move*”. Then he was able to take the ant under the microscope and study it, although after an hour or so “*upon a sudden, as if it had been awoken out of a drunken sleep, it suddenly revived and ran away*”. He records that this could happen a few more times, so he could inspect the insect without killing it.

The children found this whole process rather strange at first, but fascinating later on, since they had to deal with the exactly same problem in their study of the ant. So, they went out in the school garden “*hunting for ants*” to be kept in small plastic pots filled with alcohol lotion. They observed that the ants were “*unconscious*” after 10 minutes in the alcohol lotion, ready to be put under the microscope for inspection. All of a sudden, most of them revived and started moving after 20 to 30 minutes or so. In this way most of the children managed to observe the ants in a steady position, but also in motion and they were very thrilled to be able to do so.



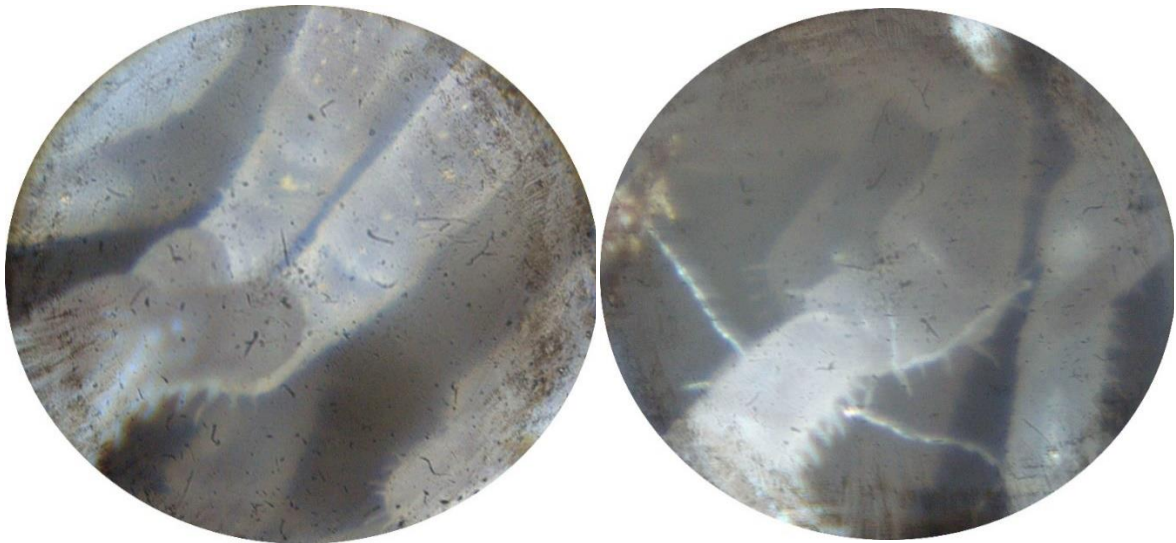
A digital photo of an ant held down with a tooth stick (left)



A drawing of an ant by a child, with letters in various parts of its body for text descriptions

One child mentions that “the ant was very difficult for me to draw, since it did not easily stay in its position. When I took the ant out of the alcohol lotion it was asleep and I could observe it for a while and I started drawing it, but after 15 minutes it woke up and started moving again. The shape of its head is triangular and its eyes are sticking out. It has a big mouth with bumpy sawing teeth and it also has two long horns in front. The biggest part of its body was its belly, which is connected to its legs with some sort of small waist. Over all, it was a very strange insect under the microscope and it surprised me when I saw it so big for first time”.

The children decided to look at another very common insect of the school garden, which was **the isopod (*Armadillidium nasatum*)**. They knew that they could find them in dark and wet places, under rocks or grass. So, now they went for “isopods hunting” in the garden and they also collected them in small plastic pots filled with alcohol lotion. Similarly to the ants, the isopods were fell “unconscious” for a while, but then again they revived after 15 minutes or so. The children observed the isopods in whole, but also some of their parts like their legs, heads etc.



The legs of the isopods under study

A child, describing the isopod, comments that “it is like an insect with a suit of armour all over. Its body also reminds me of a stair, challenging me to climb up the steps. Its front part has two horns, which have something like joints. There is also something like a mouth in front and a sort of tail at the rear part of its body; a strange insect indeed.”



Drawings of an isopod & its legs

7.4. A free microscope study

By this time, the children had performed several investigations and they had developed interests in various organisms, plants and insects, they wanted to examine more carefully. Hence, they went back to the school garden to collect their specimens and examine them under the microscope. They brought back different kinds of leaves and flowers, but also all kinds of insects from bees to spiders etc. They observed them thoroughly and they created their own final worksheet.

One child, for example, collected and observed **a raspberry** and was impressed by its “bright red colour, which looks like a small red ball with some sort of tinny yellow horns hanging out of it. Observing them more carefully I found out that they look like yellow hair magnified by the microscope”.

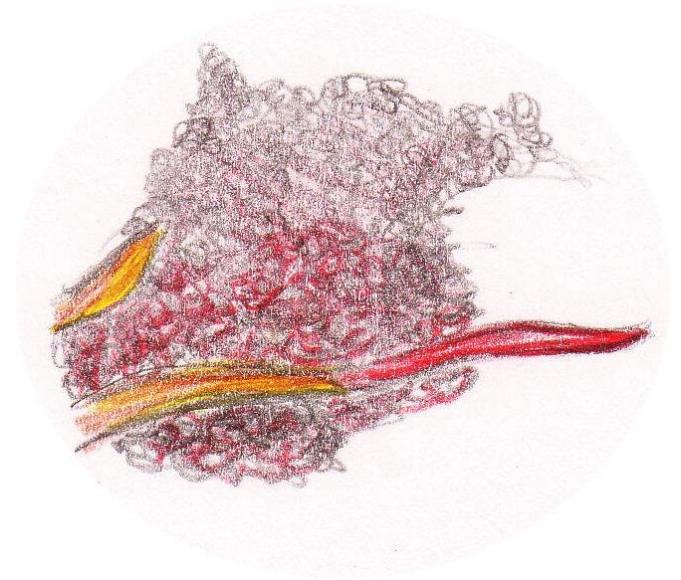
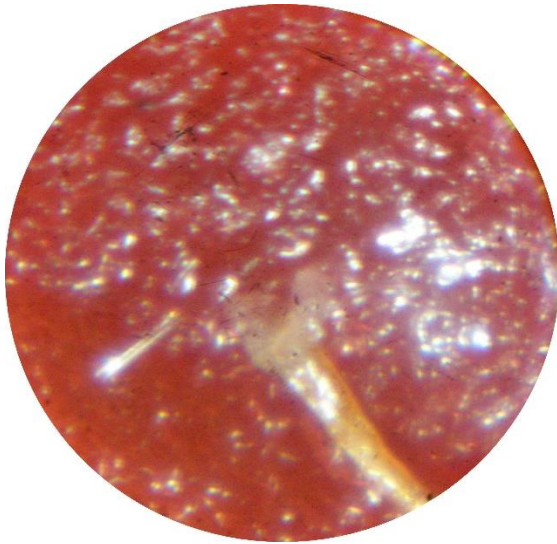


Photo and drawing of a raspberry with “*some sort of tinny horns hanging out of it*”.

8. Obstacles and reflections to teaching and learning with microscope studies

It appears that the children have been mentally and emotionally involved in their microscope studies and they have been led with interest into their investigations and observations. The microscope studies, as approached through the texts and drawings of Hooke, appear to enroll elements of intentionality with an increased interest for the outcome and the recorded observations. During the process of recording the observations and/or descriptions, it was noticed that they came about smoothly, whereas the framework of the activity seemed to have facilitated and enhanced the text production and drawings.

The descriptions produced seem to have an initial influence from those of Hooke, whereas they are simultaneously developed and enriched within a concurrent field of language and communication. The drawings, either simple or more complex and more descriptive, appear to be created by children with interest and commitment, because they claim that they want to work in a “scientific” way as Hooke has done. Even if some children complain that they cannot make “nice drawings”, they get into the endeavour of “drawing something” and attempt to comment on it verbally.

It appears that the whole framework of these microscope studies has elements of authenticity and the children get into the process of “*doing science themselves*”. The character and nature of science is being demystified as it becomes an everyday activity dealing with an instrument, the microscope, constructed by children themselves with simple and common materials. Yet, it appears to introduce them “naturally” to a framework of scientific study and investigation.

9. Further user professional development

- *Micrographia* full text and high quality drawings in [Project Gutenberg](#)
- A [site](#) on Robert Hooke
- Robert Hooke in [wikipedia](#)
- [The Inspirational Father of Modern Science in England? ... Robert Hooke](#)

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[cf. URL:
< <http://brunelleschi.imss.fi.it/esplora/microscopio/dswmedia/risorse/erisorse.html> >].
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The following video shows aspects of children's microscope studies investigating the "ant" and the "isopod". As mentioned above, the children used alcohol lotion to "make them unconscious". But, after a while they "woke up and moved", the way you can watch them in the video ...

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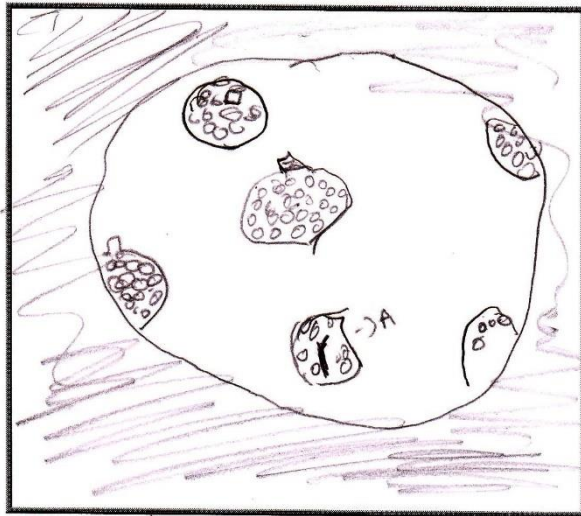
children's texts & drawings

In the pages that follow there is an indicative list of children's texts and drawings extracted from their notebooks. The documents have been scanned and are presented in their original form. The text is also translated into english, for better communication, providing an insight to data analysis and findings.



on petunia seeds & plants

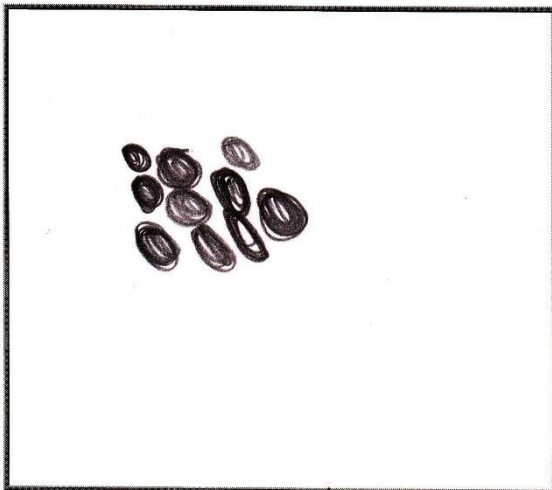
Indicative pieces of text and drawings from children's notebooks "on petunia seeds and plants" are presented below. The text is also translated in english.



Ο σπόρος της πετούνιας στην
πραγματικότητα είναι πολύ
πλευράει αλλά στο μικροσκόπιο
είναι ένα τετράγωνο γεμάτο τρύπες
φτιαγμένες με ένα μικρό ατσάλι
στη βάση. Το σχήμα του είναι
παχύ στη βάση και λεπτό στη
βασίση αλλά και γεμάτο μικρο-
τρύπες (δακτυλίδες) Στο σπόρο

Α στη βάση υπάρχει μια τρύπη γράβη

The colour of the petunia seeds is dark brown. Their shape is round and they have holes and bumps. They look like small insects. In front they have something like a piece of string hanging out, whereas the back side is a bit round.

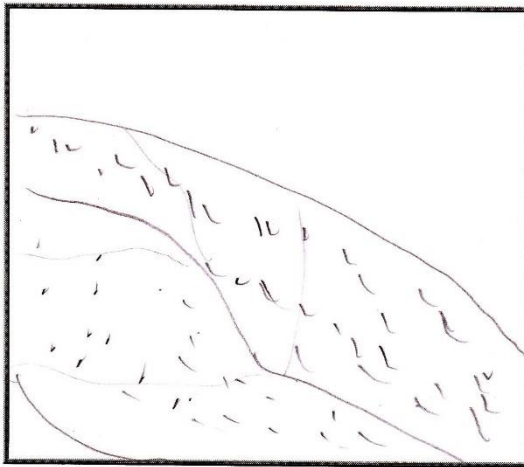


Οι σπόροι πετούνιας
είναι πολύ μικροί.
Όμως στο μικροσκό-
πιο φαίνονται αρκετά
μεγαλύτεροι. Μοιάζουν
πολύ με σταφύδες, σάντια
φρούτα, δημητριακά, γέλις
κ.α. Φαίνονται σαν
μικρά μπαλάκια με

κάτι χρώμα. Μοιάζουν αρκετά με τους
σπόρους θυμάριου στην επιφάνεια αλλά όχι
στο μέγεθος

The petunia seeds are very small. In the microscope though, they appear a lot bigger. They appear like raisins, rotten fruit, cereals, olives etc. They

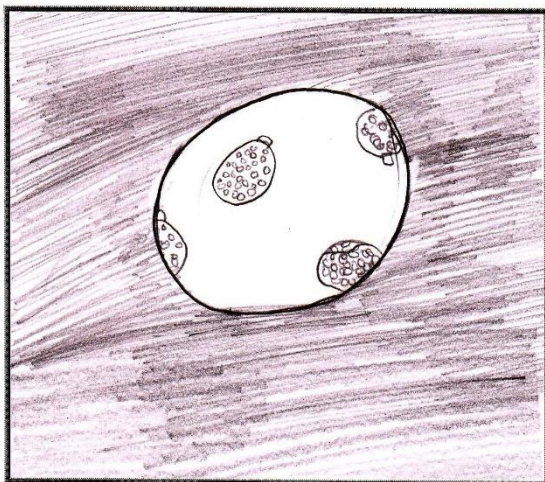
appear like very small marbles with brown colour. They look alike the thyme seeds in their surface, but not in their size.



Το φύλλο^{τους} είναι πολύ περίεργο. Οι πετούνιες είναι όμορφα φυτά αλλά ποτέ δεν ξέρεις τι κρύβουν. Έχουν πολύ μικρές, άσπρες τρίχες στην επιφάνειά τους. Φαίνονται διαφορετικά και στο μικροσκόπιο.

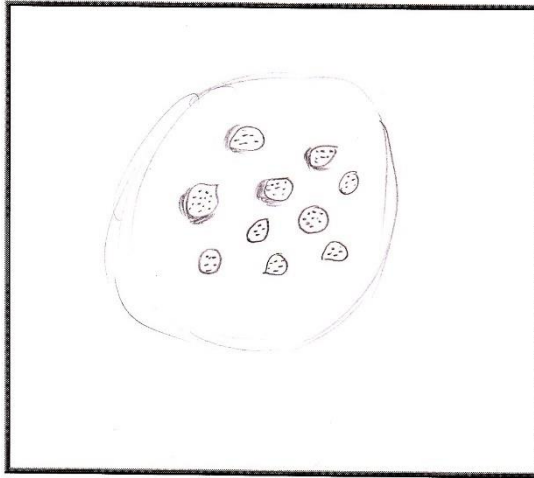
Και το κοτσάνι του είναι περίεργο με πολλές τρίχες. Αυτές οι τρίχες φαίνονται σαν να χυμίζουν και έτσι ξεχωρίζουν αυτό το φυτό γιατί είναι και λίγο «διαφανές».

Their leaves are very strange. The petunias are beautiful plants, but you never know what they are hiding. They have very small white hair on their surface [the leaves]. They look very different at the microscope. Their branch is also very strange, with a lot of hair. These hair look as if they are shiny and so they are picked out of the plant, because they are a bit "transparent".



Το χρώμα της πετούνιας είναι καφέ σκούρο. Το μέγεθος της είναι στρογγυλό και έχει κάποια βαθουλώματα. Μοιάζει με πασχαλινές Μήροσται έχει ένα κοτσανάκι και πίσω είναι κόπως στρογγυλό.

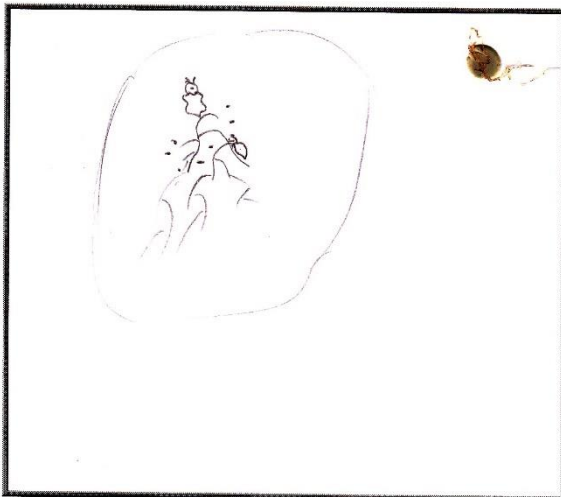
The colour of petunia is dark brown. Its shape is round and it has some bumps. They look like lady bugs. In front they have a stem and the back is somehow round.



Οι σπόροι πετούνιας στο μικροσκόπιο
 μου θυμίζουν σαν φανταστικά
 μεγάλα με κάποιες ριζές που έχουν
 παύση. Τα φανταστικά δηλαδή οι
 σπόροι πετούνιας έχουν χρώμα
 μαύρο ή και σκούρο καφέ. Όλοι
 οι σπόροι μου μοιάζουν οι ίδιοι
 μόνο μερικοί μου φαίνονται
 να είναι πιο μεγάλοι. Μερικά

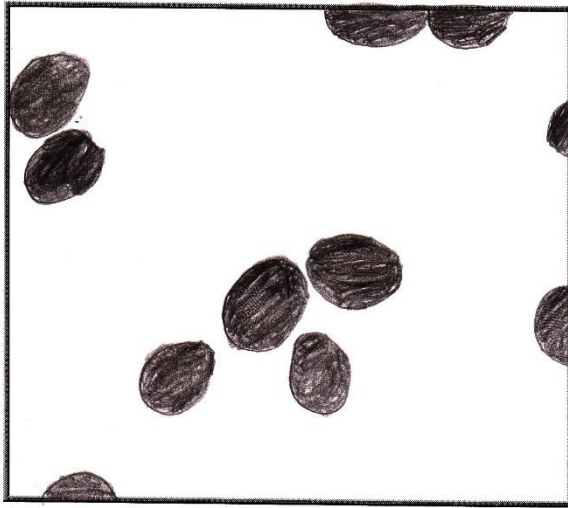
είναι αφύκοιλο το μέρος ενώ πίσω είναι λίγο μωσαϊκό. Πάντα
 όλα τα πράγματα μου είναι εντύπωση με τον τρόπο που φαίνονται.

The petunia seeds under the microscope remind me of big nuts that have something like dots all over. The nuts, that is the petunia seeds, have black and/or dark brown colour. All seeds appear to me to be the same, only a few are a bit bigger. The front part is a bit curved, whereas the back is a bit peaky. Always, all things impress me the way they look.



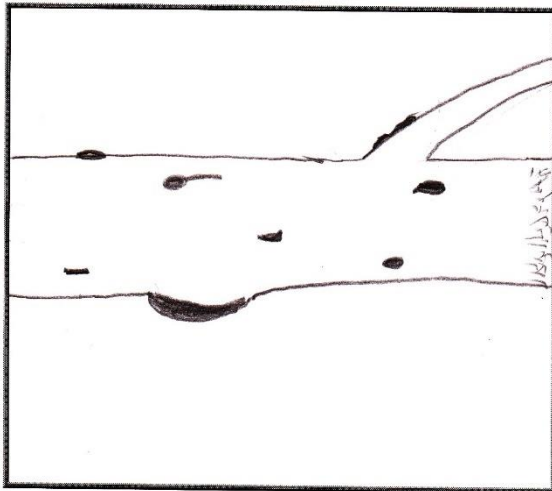
Οι ρίζες της πετούνιας μου
 μοιάζουν κάπως σαν χέρια με
 κάποιες χιμώσες που έχουν τρυχαλίες.
 Πάνω οι ρίζες έχουν μια πετα-
 λίδα που έχει πεθάνει από
 εμπύση μου φαίνεται. Είναι
 λίγο καφέ προς λίγο κίτρινο.
 Είναι πολύ λεπτές οι ρίζες.
 Γι' αυτό φαίνονται πολύ καθαρά.

The petunia roots appear to me like hands with some soil and they have hair. The roots have a butterfly on top, which is dead. This is what appears to me. It is a bit brown towards yellow. The roots are very thin, that's why they appear very clear.



Οι σπόροι πεταλιδιάς είναι δια-
φορετικοί από του θυμάριου
έχουν πολλά βαθουλώματα και
είναι πιο μικροί.

The petunia seeds are different from those of thyme. They have a lot of bumps and they are smaller.



Η ρίζα ενός φυτού μοιάζει αδύναμη
και αδύναμη, ενώ όταν τη βλέπουμε
στο μικροσκόπιο φαίνεται με-
γάλη και δυνατή σαν ρίζα δέντρου!

The root of a plant looks thin and weak, whereas when we put it under the microscope it looks big and strong like the root of a tree!

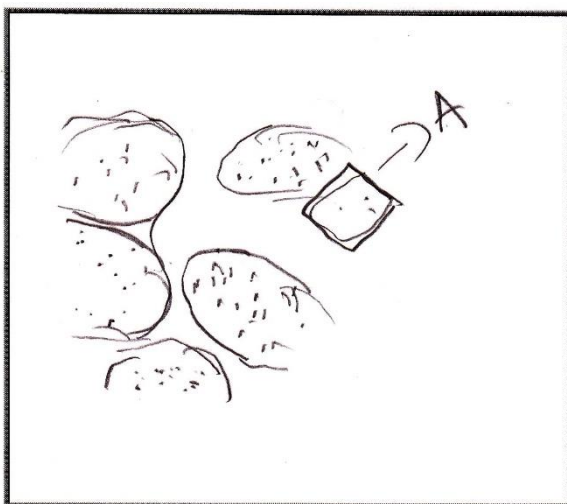
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on sand, salt & sugar

Indicative pieces of text and drawings from children's notebooks "on the study of sand, salt & sugar" are presented below. The text is also translated in english.

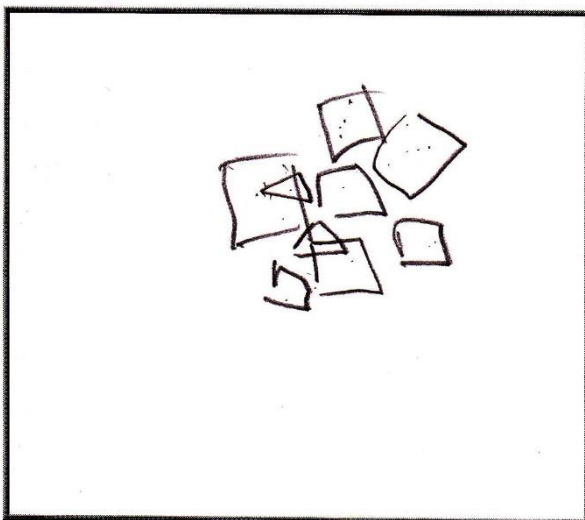


Στην διατήρησή είδα να παρατηρή-
φαίμε κάτι μικρούς κόκκους
αίθρα που στο μικροσκό-
πιο μοιάζαν πιο πολύ
με μαρμελάδες παρά με
ζάχαρη από πάνω. Στο
σημείο Α βλέπουμε κάτι
που μοιάζει με τετραγώνω
πο και έχει και πιο

ανοιχτό χρώμα (ήτοι το ασπρό) από τα υπόλοι-
πα.

At the drawing aside we observe some crystals of blue sand, which under the microscope look like blue caramels with some sugar on top. At point A we see something that looks like a square and it has a more bright colour (nearly white) from the rest.

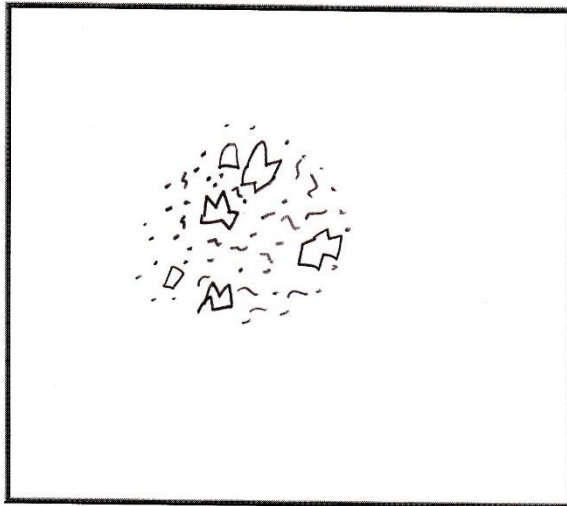
Ας παρατηρήσουμε **κόκκους καφέ ζάχαρης** στο μικροσκόπιο. Μπορούμε να φτιάξουμε ένα σκίτσο και να γράψουμε μια περιγραφή;



Δίνοντας στο σκεύασμα παρα-
τηρούμε κάτι πολύ μικρούς
κόκκους ζάχαρης. Το σχήμα
τους είναι τετραγωνικό αλλά
σε κάποιους κόκκους ζάχαρης είναι
επιγώνιο. Στο πρώτο μέρος της
ζάχαρης υπάρχουν κάποια πολύ
μικρά βασικά κρυστάλλια. Το πιο
σημείο τους μοιάζει σαν ένα

διαφορετικό χρώμα ανοιχτό καφέ.

At the drawing aside we observe some very small and brown grains of sugar. Their shape appears square, but in some grains of sugar it is triangular. At the inner part of the sugar there are some very small bumps. Their whole shape looks like a diamond of a light brown colour.

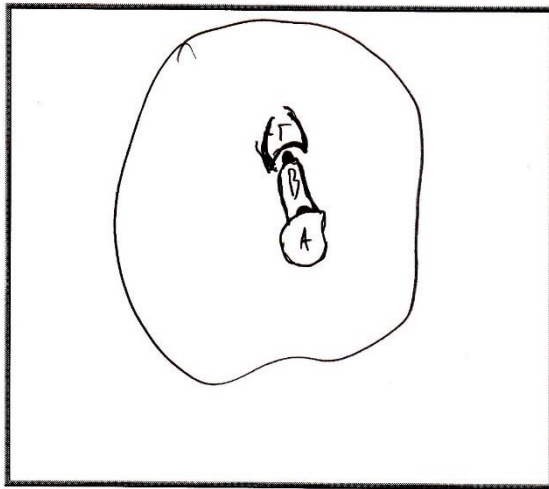


Ο κόκκος αλάτιου στο μικροσκό-
πιο μας μοιάζει σαν βράχος
ή σαν βουνάκια οι μύτε-
ρες. Το μικροσκόπιο μας δείχνει
και με άλλο τρόπο τα
αγάλματα που ενυψώσαμε.

The grains of salt at the microscope look like rocks or like mountains with peaks. The microscope also shows things in another way, more impressive.

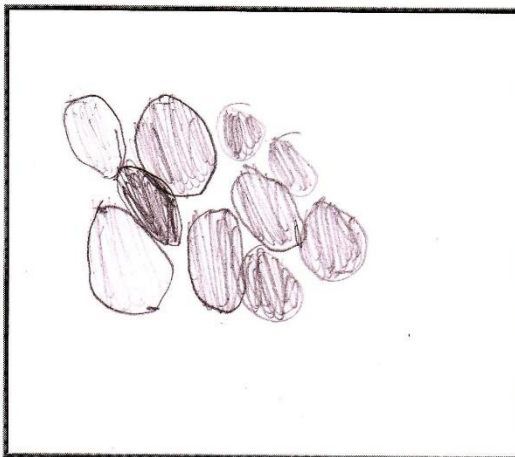
on seeds of thyme

Indicative pieces of text and drawings from children's notebooks "on seeds of thyme" are presented below. The text is also translated in english.



Παρατηρούσατε ότι ο Α σπόρος
είναι κυκλικός ενώ ο Β σπόρος
είναι κάπως ψηλός αλλά ο
Γ είναι ήλιος και παρασηορηγός.

We observe that the A seed is a round one, whereas the B seed is somehow long, but the Γ seed is half and miserable.



Οι σπόροι του θυμάριου
φαίνονται σχεδόν το
ύδιο στο μικροσκόπιο
απότι με χυμό μάτι.
Άλλοι έχουν βαθυλό-
ματτα άλλοι έχουν κόμματα
και κρίζουν με χερμόνια
πορτοκαλιά, ελιές, λίζο με
φασόλια και με δη-

μηπεριλάκι «choco cop». Οι περισσότεροι
έχουν μικρές «λουκουβίζες» απότι άλλους
που έχουν «σιβόκια». Τα περισσότερα
που έχουν αβλάκια μοιάζουν με καρύδια ενώ
αυτά με τις τρύπες με φλούδα σάπιου
πορτοκαλιού. Και απότους σπόρους άλλοι είναι
καφέ, άλλοι μαύροι και άλλοι καφέ με μαύρο.

The thyme seeds look nearly the same under the microscope and the naked eye. Some have bumps and others have peaks and they look like lemons, oranges, olives and some look like “choco cop” cereals. Most of them have some small “bumps” than others who have “scratches”. Most with the

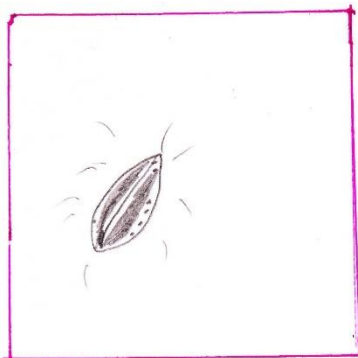
scratches look like nuts, whereas those with bumps look like the skin of a rotten orange and their colour is black brown or brown with black.



Οι σπόροι του θυμάριού μου
 θυμίζουν λεμόνια ή πορτοκάλια.
 Είναι όλα σε διαφορετική στάση.
 Υπάρχει μεγάλη ποικιλία τόσο στον
 όγκο όσο και στη μορφή των σπόρων.
 Οι σπόροι του μικροσκοπίου έχουν
 χρώμα μαύρο ή και αλλιώς καφέ.
 Οι σπόροι είναι πεταχτοί ή και
 πολύ συνηθισμένοι σαν λεμόνια.

Κάθε φορά όπως παρατηρούμε σε όλα τα πράγματα ή και φαγητά
 (ζαχαρή) δεν είναι όπως και στο ανθρώπινο μάτι. Είναι ή μεγάλα
 ή διαφορετικοί όπως στο ανθρώπινο μάτι. Γι' αυτό την γη μας ποτέ δεν
 πρέπει να λέμε ότι κάτι βλέπουμε αν δεν το παρατηρούμε με άλλες
 μεθόδους (μικροσκόπιο, φακοί κ.α.)

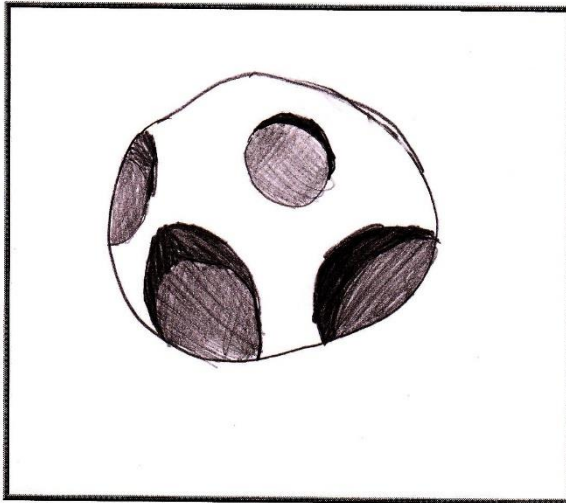
The seeds of thyme remind me of lemons or oranges. They are all in different position. There is a great variety in the volume and shape of the seeds. The seeds under the microscope have a black or a brown colour. The seeds are nosey or common like lemons. Every time we observe things they are not as we see them. The seeds look bigger and different than we see them with the naked eye. Thus, on our earth we should never say we see something unless we observe it with other methods (like the microscope, lenses etc.).



Το φύλλο του θυμάριου είναι απ'την μια
 μεριά μαύρο πολύ μαύρο σαν να θρωμάει
 και απ'την άλλη μεριά μωβ. Το φύλλο μου
 έχει μια θρωμάτι πάνω που έχει παραμεινει
 ή κανένα σκαμνί. Είναι λίγο σπείρειο αλλά στο
 δικό μου μάτι το δείχνει κανονικό. Το μικροσκόπιο
 μου δείχνει κάθε φορά την αληθινή πλευρά
 είτε ανεκείμενα είτε ζυγανά είτε δε.

The leaf of thyme is black from the one side, very black as if it stinks and

from the other side it is purple. My leaf has some dirt on it that has been retained or some sort of a rubbish. It is a bit awful, but to my eye it looks normal. The microscope shows every time the true aspect of an object, either alive or not.

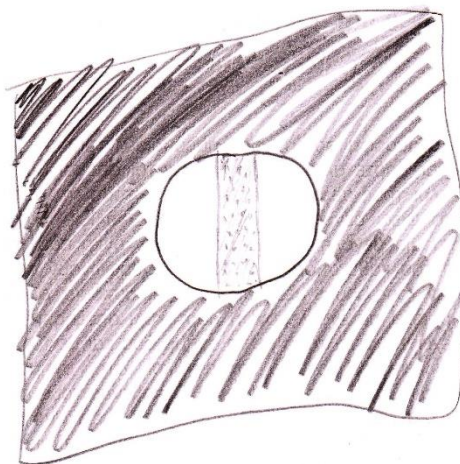


Οι σπόροι του θυμάριου είναι λίγο
 σκούρα καφέ, ορισμένοι είναι μεγαλύτεροι
 και άλλοι λίγο μικρότεροι, είναι
 στρογγυλοί και οξυών όλοι ίδιοι.
 Μοιάζουν με πράσινες γρόλες, Αβελόνια
 και σοκολατένια δημητριακά, επειδή
 έχουν και μικρές ρωγμές.

The seeds of thyme are a bit dark brown, some are big and some are a little smaller. They are round and they are almost all the same. They look like golf balls, lemons, chocolate cereals, because they have something like small holes.

Κοτσάνι Θυμάριου

ΠΑΡΑΤΗΡΗΣΗ



Το κοτσάνι του θυμάριου είναι καφέ
 προς το πράσινο. Είναι λεπτό και έχει
 και άσπρες κηλίδες μικρές και φοιτίζει
 με λάστιχο.

Branch of thyme

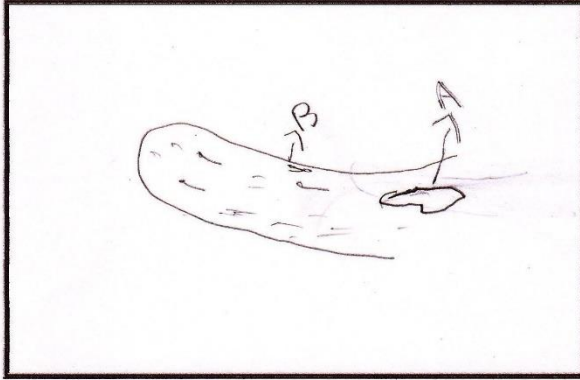
Observation

The branch of thyme is brown towards yellow. It is thin and it has white, small hair and it looks like a rubber band.

on the point of a needle

Indicative pieces of text and drawings from children's notebooks "on the point of a needle" are presented below. The text is also translated in english.

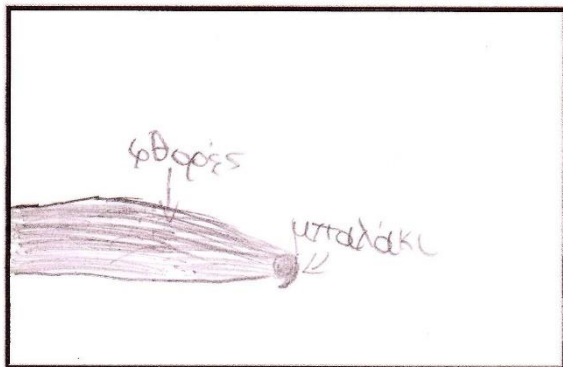
Ας παρατηρήσουμε κι εμείς τη μύτη μιας βελόνας στο μικροσκόπιο. Μπορούμε να φτιάξουμε ένα σκίτσο και να γράψουμε μια περιγραφή, όπως έκανε και ο Hooke;



Έδω βλέπουμε την άκρη μιας βελόνας όπου αν και στην πραγματικότητα είναι οξεία και πολύ λυγρή στο μικροσκόπιο είναι λίγο στροβή και καθόλου λυγρή. Στο σημείο

A έχει ένα ελαφρύς βαθύ-από καρδού από κακή χρήση της άκρας και στο σημείο B στο υπόλοιπο κομμάτι της βελόνας υπάρχουν χαρακί-τιες αλλά και μικρές πικουβίτσες.

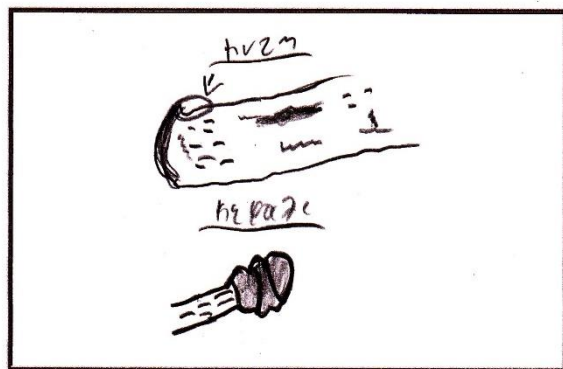
Here we see the point a needle, which although in reality it is very straight and very sharp, under the microscope it is a bit curved and not sharp at all. At point A it has a slight bump, probably from its bad use as well as in point B . At the rest part of the needle there are cracks and small bumps.



Η καρπίτσα έχει μια άκρη που μοιάζει να είναι κομμένη. Είναι σαν να έχει φθόγες πάνω της σαν μακροσκοπικές χαρπίδες. Έχει ένα μαύρο

χρώμα και ένα μικρό κόψιμο. Πάντως δεν είναι τόσο αιχμηρή και λεία όσο θα την φανταζόμαστε. Στο κέντρο είναι πιο λεία η καρπίτσα απ' όση η άκρη της. Η καρπίτσα στο μικροσκόπιο φαίνεται πιο μαύρη απ' όση τη βλέπουμε με το μάτι. Μου θυμίζει μύτη συσμένου μουριού.

The needle has an edge, which looks as if it is cut. It is as if it has a lot of damages on it like long narrow bumps. It has a black colour and a small cut. Anyhow it is not as flat and sharp as we could imagine. At the centre the needle is more flat than at its point. Under the microscope it appears more black than what we see with the eye. It reminds me more of the point of a pencil.



Η ηυζη δηλ είναι ποτ ηεφεση ενω οζην πανη ηεφια εηφαισσηι ενα βαθουηηα ενα σεο ηυρε - ηυρε ηπαρην χαρπίδες. ηεφαση παρασηραηι σε η ηεφαση της βεθουης εχει παρασηο οχηηα ενω εινε σεηαση χαρπίδες.

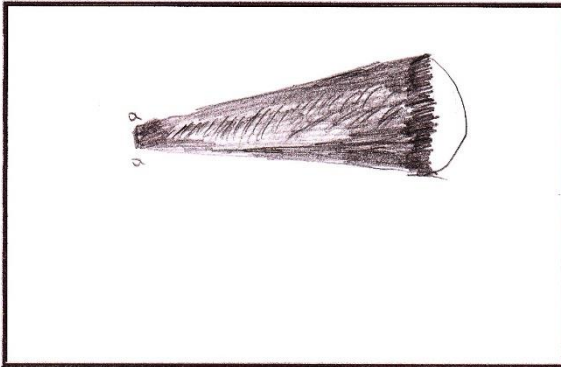
The point

The point of the needle is not sharp, whereas at its top part there appears a bump and there are a lot of scratches all around.

The head

We observe that the head of the needle has a very strange shape and it is full of scratches.

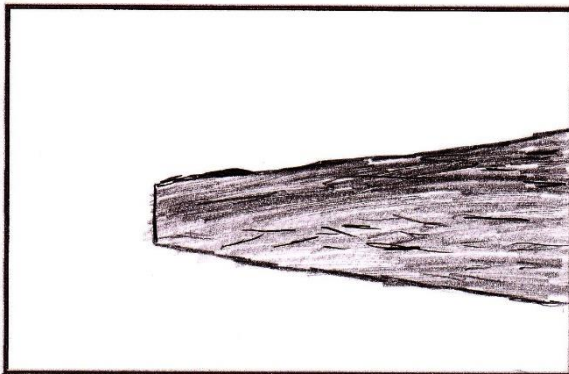
Ας παρατηρήσουμε κι εμείς τη μύτη μιας βελόνας στο μικροσκόπιο. Μπορούμε να φτιάξουμε ένα σκίτσο και να γράψουμε μια περιγραφή, όπως έκανε και ο Hooke;



Η μύτη της βελόνας δεν μοιάζει καθόλου όπως την βλέπει το ανθρώπινο μάτι. Στην άκρη είναι πολύ πλατιά και πολύ κακή όχι λεπτή όπως φαίνεται σε εμάς. Στο μικροσκόπιο όλα τα πράγματα φαίνονται διαφορετικά όπως το σημείο της

μύτης. Ενώ δεν τσιτώνει καθόλου ελασκή στο μικροσκόπιο ενώ όταν την πιάνουμε μας τσιτώνει.

The point of the needle does not look at all as we see it with the human eye. At its edge it is very broad and very fat, not thin as it looks to us. With the microscope all things appear different, as the point of the needle does. Here, that is, through the microscope, it is not at all spiked, whereas when we touch it can spike us through.

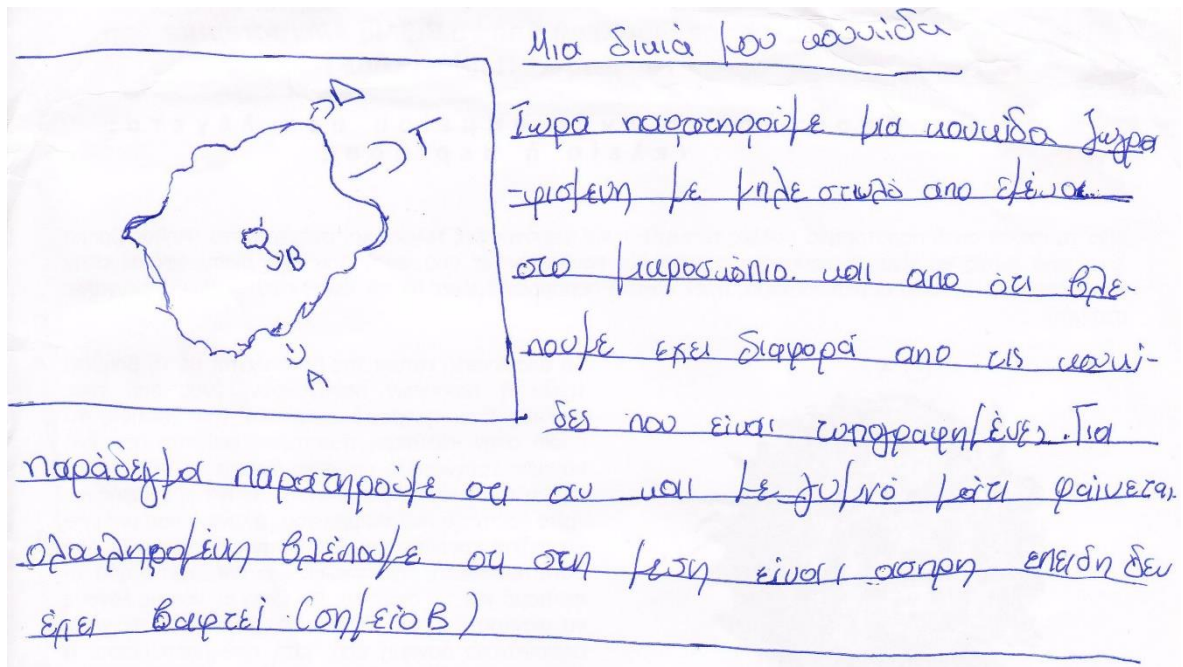


Η μύτη μιας βελόνας έχουμε όλοι μας τσιτώνει. Στο μικροσκόπιο φαίνεται πως είναι ένας απότομος γροβελός και μοιάζει με ένα πλάγιο βουνό ή ηφαιστεια. Έχει πολλές γρατζουνιές και κάποιες φορές έχει κάτι μαύρο που είναι η φθομής. Επίσης βλέπουμε να βγαίνει

από τα δεξιά ενώ την έχουμε βάλει από τα αριστερά.

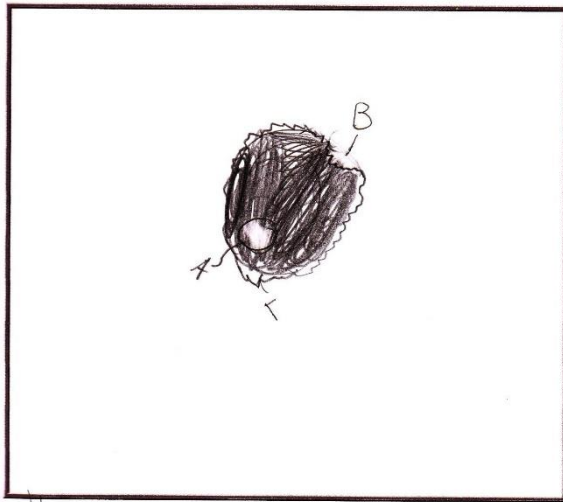
The point of the needle we all know that it can spike us through. At the microscope it appears to be like a steep cliff and it looks like a slant mountain or a volcano. It has a lot of scratches and it some attritions. I has something black which is something like dirt. We also see it coming out from the right, whereas we have put it from the left

The shape of the dot, as Hooke had said, is not as we see it on paper. We see that it is like a hairy sphere (ball) with some bumps and some scratches. For example, at the point AB we see a bump, whereas in point AA we see a scratch with a concaved shape. Moreover at point ΣM we see, as in all of the dot, that some curly pieces of hair are formed, all around the dot. In the end we observe that although a very small dot how many imperfections it has or that its shape is totally different under the microscope.



A dot of mine

Now we observe a dot drawn with a blue pen by myself under the microscope and from what we see it has a difference from the printed ones. For example, we observe that although with the naked eye it appears a total one we see that in the middle it is white because it has not been painted (point B).



Βγερουμε μια ^{μικρή} κουκίδα
 όπως τον Hooke. Μια η
 κουκίδα μας φαίνεται με μια
 σφαίρα χρησιμοποιήσιμη και σκαρι-
 σμένη. Ακόμα στο σημείο Α
 είναι λίγο πιο ανηλεές.
 Στο σημείο Β έχει ένα μικρό
 βουλωματάκι. Επίσης στο σημείο
 Γ είναι λίγο πιο μπειρο.

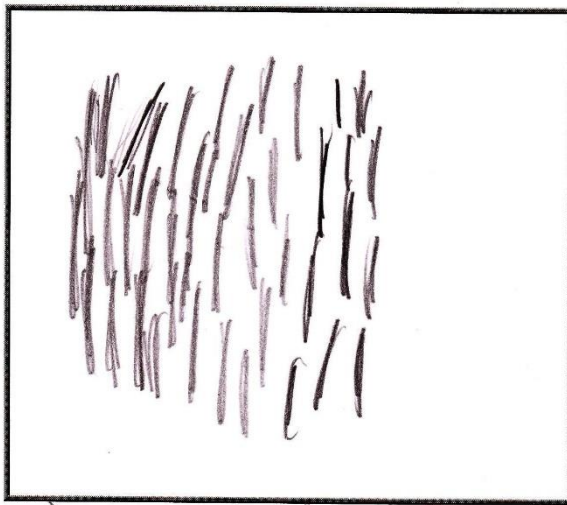
Η μεγαλύτερη είναι πολύ στρογγυλή και μεγάλη γιατί
 είναι από το μικροσκόπιο. Μια μικρή κουκίδα
 είναι καλύτερη σε μέγεθος και λίγο στρογγυλή
 έχει νόση σκαριανισμένη. Στη μικρότερη.

We see a small dot like Hooke. But, the dot looks like a sphere used and rusty. Moreover, at point A it is a bit more lightcloured. At point B it has a small bump. Also at point Γ it is a bit picky.

The bigger dot is very round and big, because it covers all the microscope. A medium-sized dot is normal in magnitude and a little round and it has ups and downs. But it looks all right.

on the study of cloth

Indicative pieces of text and drawings from children's notebooks "on the study of cloth" are presented below. The text is also translated in english.

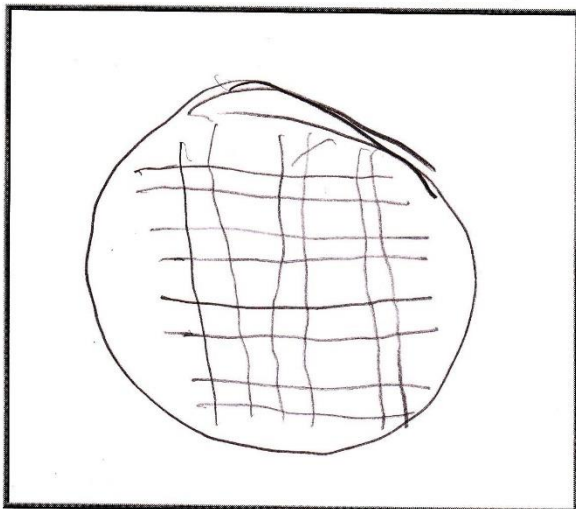


Το ύφασμα μοιάζει
με μικρούς κάκτους
ή με μικρά καλάμια.
Έχουν ένα πολύ περί-
εργο, μπελεγμένο και
πολύπλοκο σχήμα. Δεν
έχει κενά ανάμεσα τους.
Αυτές οι μικρές κρο-
στές φαίνονται να

είναι κομμένες. Το χρώμα δεν αλλάζει στο
μικροσκόπιο. Φαίνεται ^{σαν} να έχει πολλά αγκάθια
και σαν να είναι δεμένο πολλές φορές.
Τα κομμάτια του υφάσματος μοιάζουν να έχουν
σηματώσει από ^{πολύ} μικρά τετραγώνια.

The cloth looks like small cactus or small bamboos. They have a very peculiar, messed up and complex shape. It does not have many empty spaces in between. These small threads appear to be cut off. The shape does not change under the microscope. It looks as if it has a lot of spikes and as if it has been tied many times. The pieces of the cloth appear to have been formed by many small squares.

Ας παρατηρήσουμε κι εμείς κομμάτια υφάσματος στο μικροσκόπιο. Μπορούμε να φτιάξουμε ένα σκίτσο και να γράψουμε μια περιγραφή, όπως έκανε και ο Hooke;



Στην διπλανή εικόνα παρατη-
ρούμε ότι αν και στη
παρατήρηση είναι ένα υφά-
σι ορατότατο είναι εύκολο
στο με το μικροσκόπιο ότι
υπάρχουν τετράγωνα μέσα στα
μεσα στην υφασμα. Μπορούμε
να πούμε ότι μοιάζει με
πλάτα μιας ράβας, ζυγίων

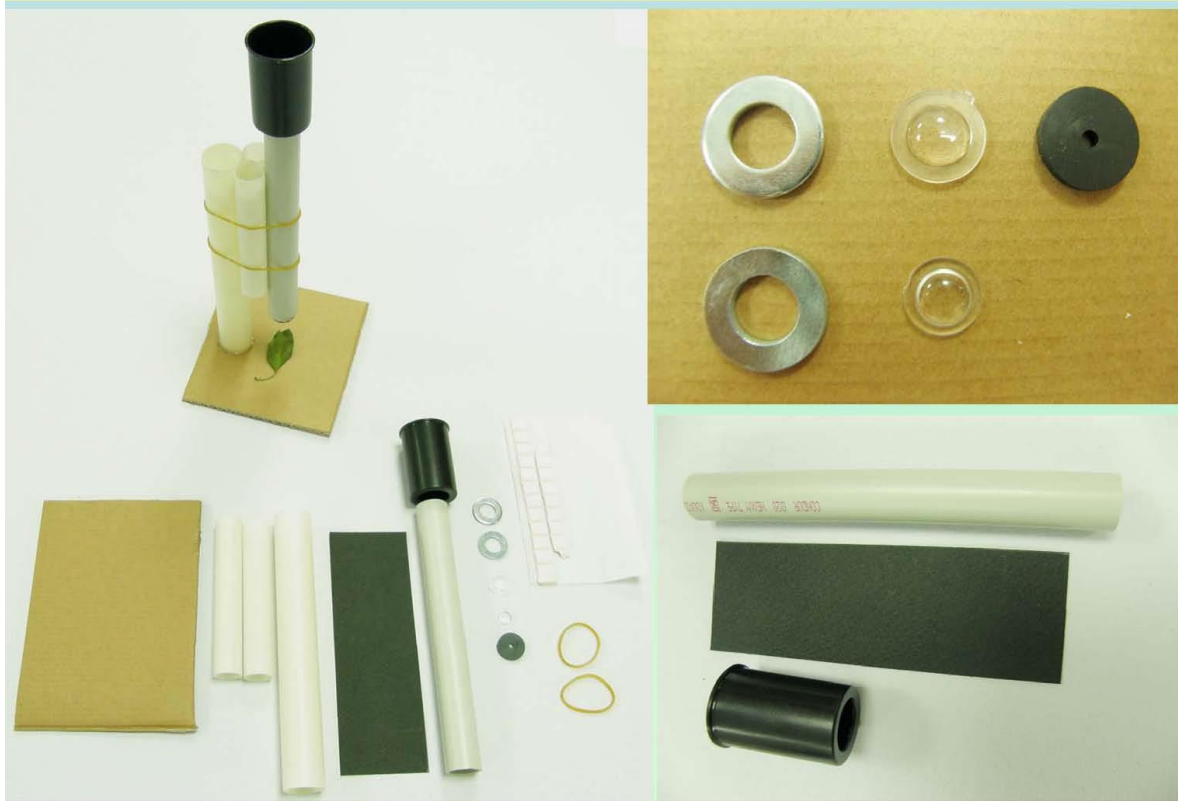
υφάσματος ή με ένα υφάσι επίσης φάρμα.

In the aside drawing we observe that although in reality it is a whole piece of cloth, we see that through the microscope there are big gaps in between the threads. We can say that it looks like the straw-mat of an old wooden chair or a straw-woven basket.

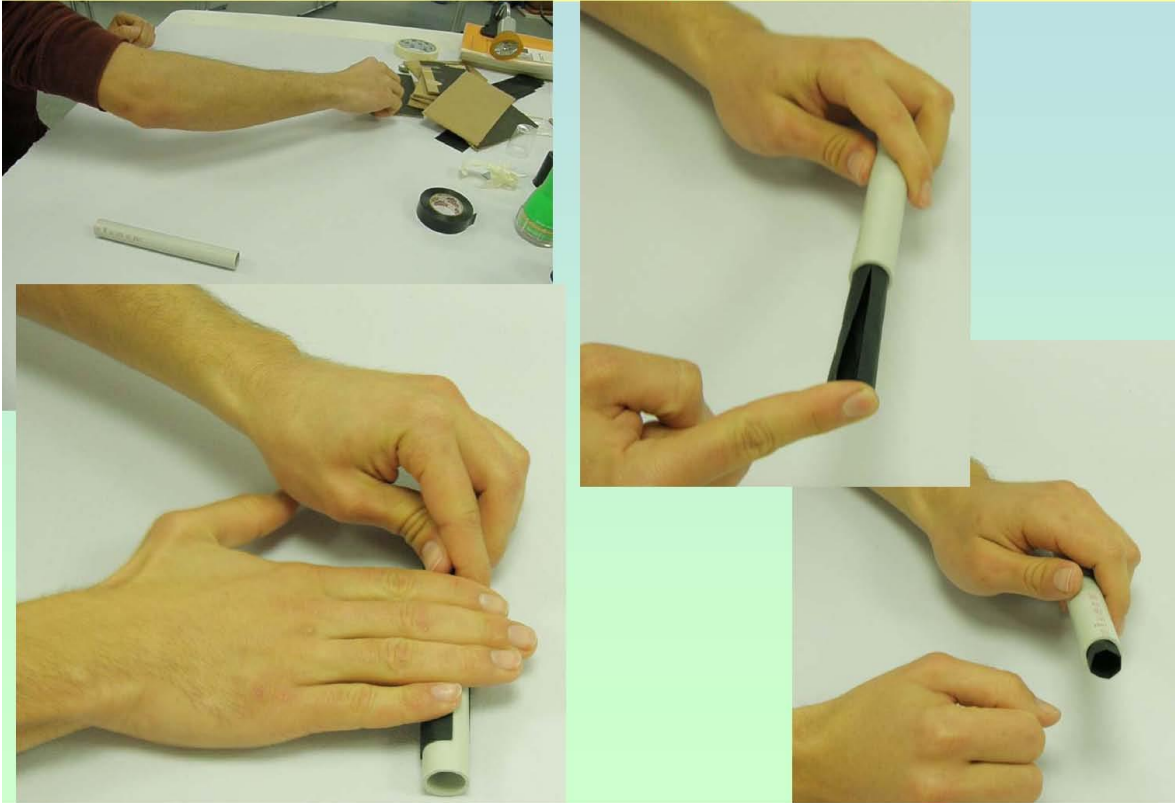
constructing the microscope

A sequence of transparencies is presented below, depicting the phases of construction of the microscope under study. Initially, the microscope was constructed with two lenses, an objective and an eye piece.

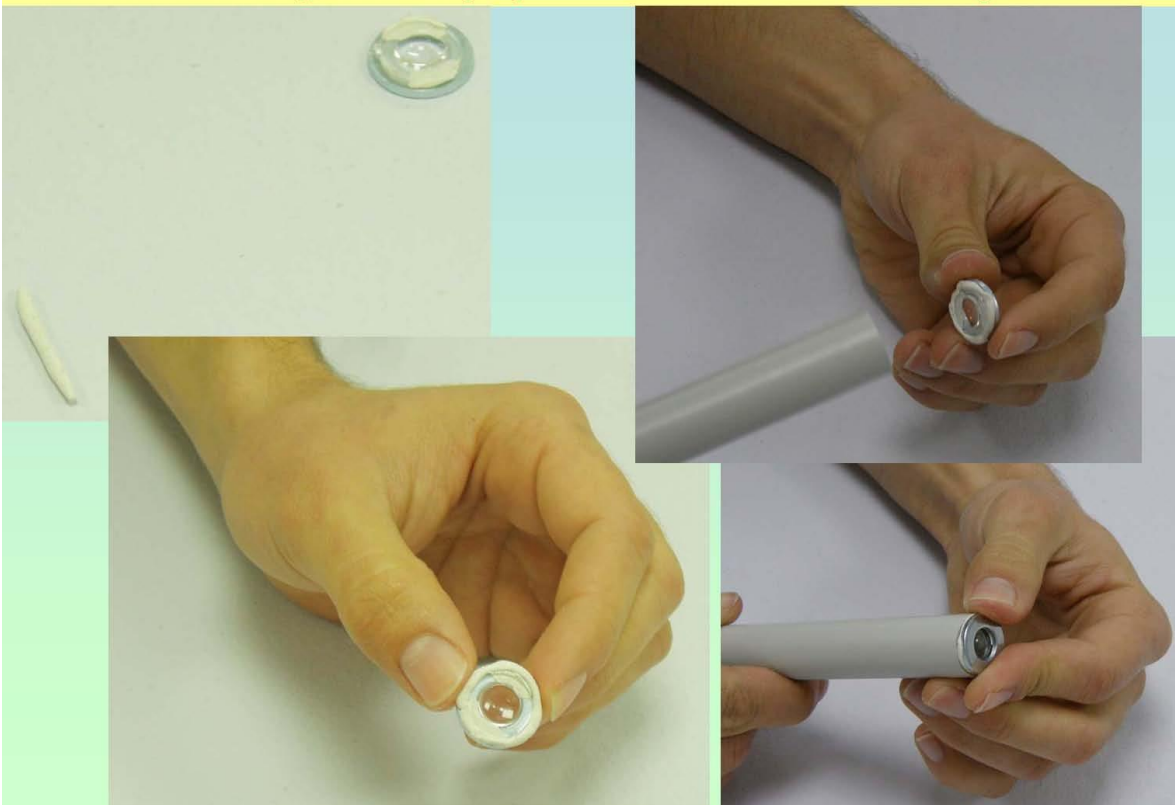
Construction of a simple microscope (materials)



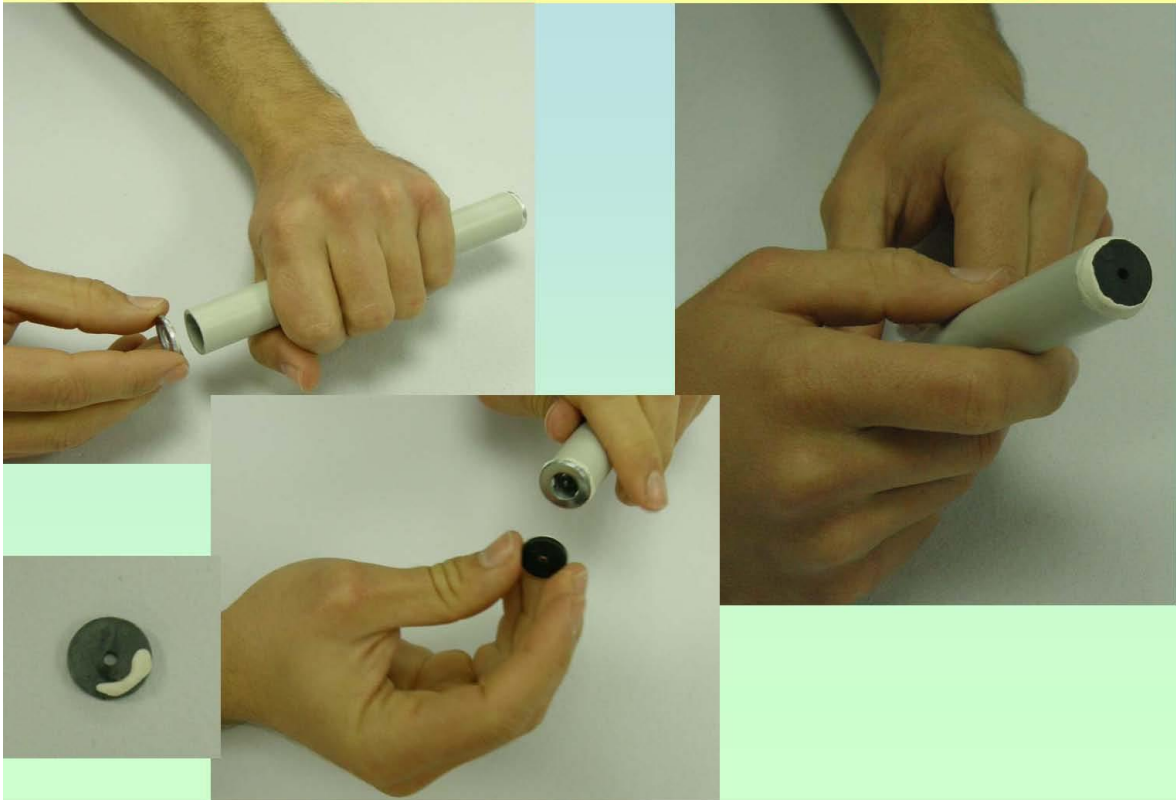
Black carton inside the plastic body-tube



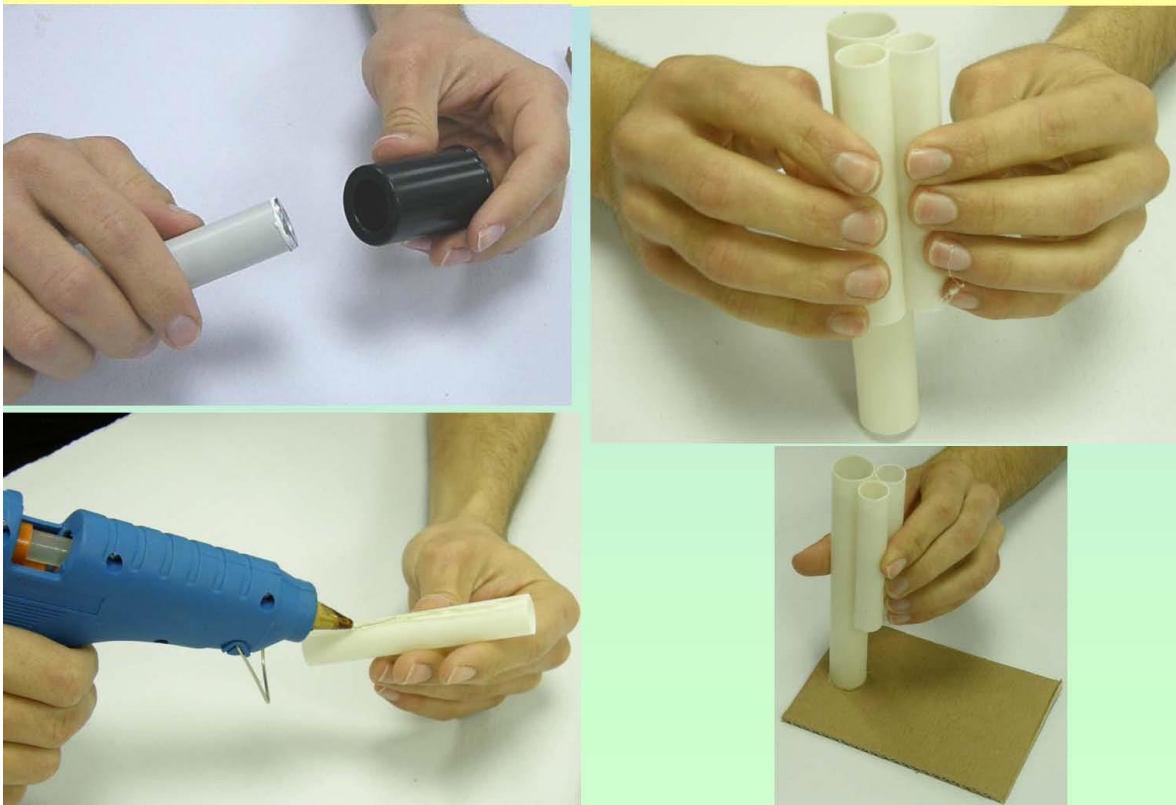
Constructing the eyepiece end of the body-tube



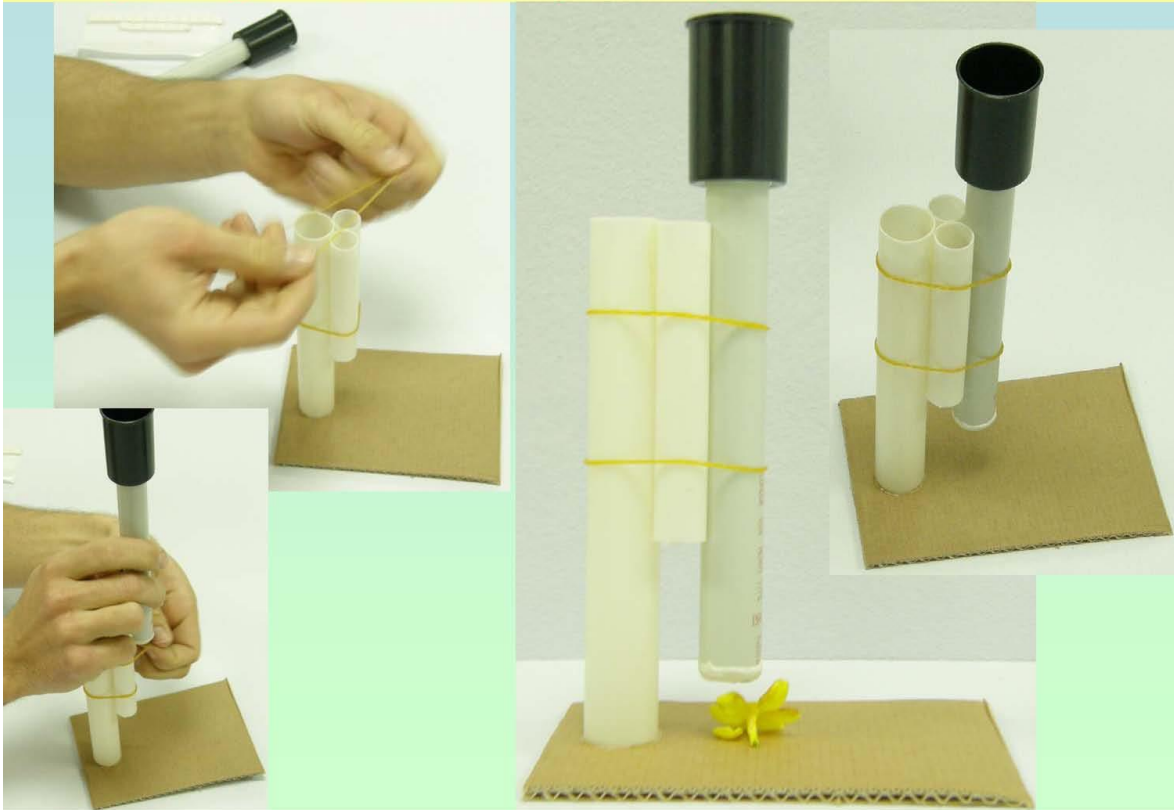
Constructing the objective (lens & diaphragm)



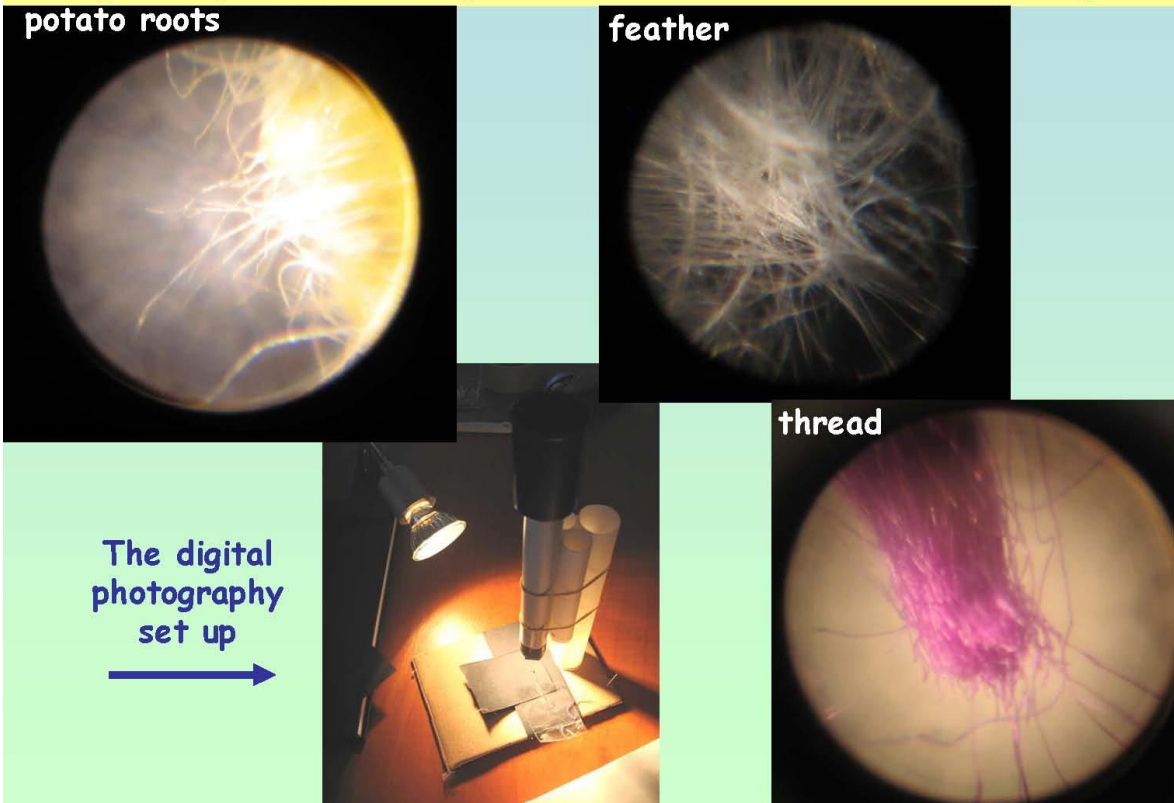
Completing the eye piece and support base construction



Adjusting the microscope body-tube on the base



Digital photos of specimens with this microscope



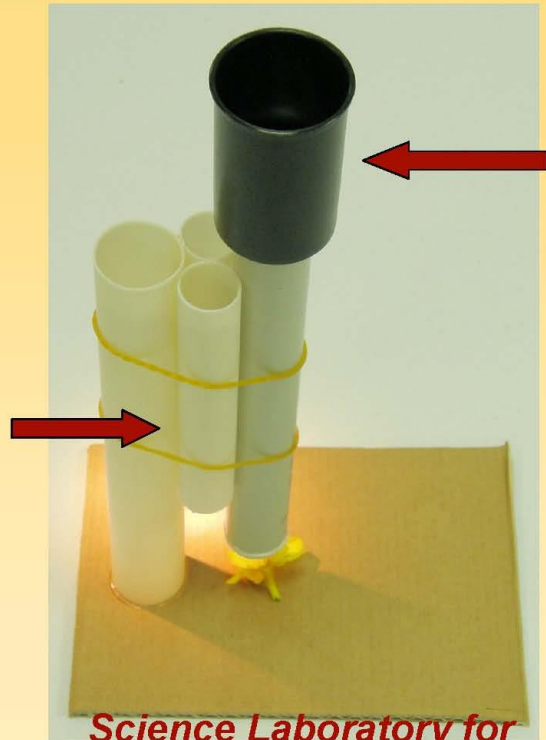
The initial construction of the microscope was with two lenses (objective and

eye piece), as described above. The idea from the *Istituto e Museo di Storia Della Scienza* is presented on the left, whereas the alternations and additions to the microscope from the Science Laboratory for Primary Education are presented on the right (see transparency that follows).

The microscope with 2 lenses ...



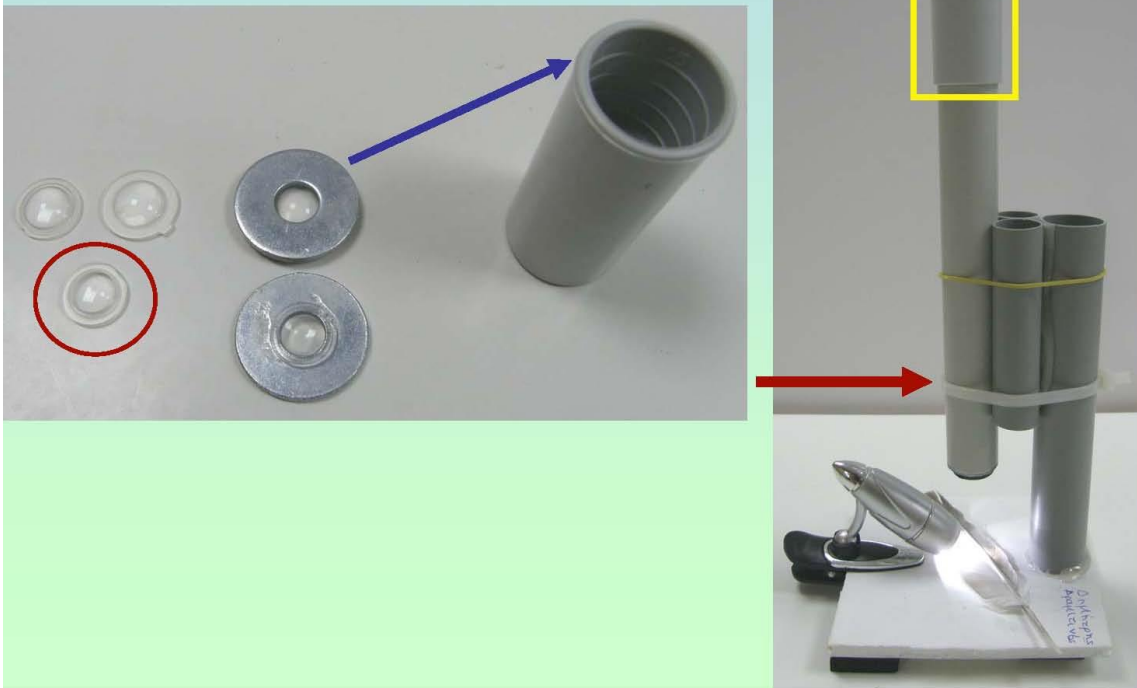
*Istituto e Museo di Storia
Della Scienza*



*Science Laboratory for
Primary Education*

After a while, an additional middle lens (field lens) was suggested to be put in between the two. An extra piece for joining pipes (a conjunction or extension part) was used as a junction piece, on top of the microscope pipe, to separate the field lens from the eye piece. Another problem to be resolved was the stabilization of the microscope at a particular place for image refinement and observation. After a few alternative attempts (see transparencies below), we ended up with a plastic cable tie fastener to hold the microscope pipe in place, inside the niche formulated by two other pieces of pipe glued appropriately on its support base (see below).

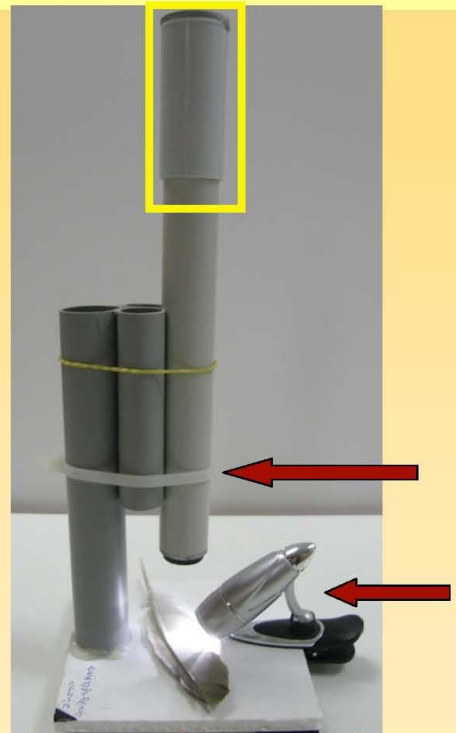
Addition of the third lens to the microscope



The microscope with 3 lenses ...

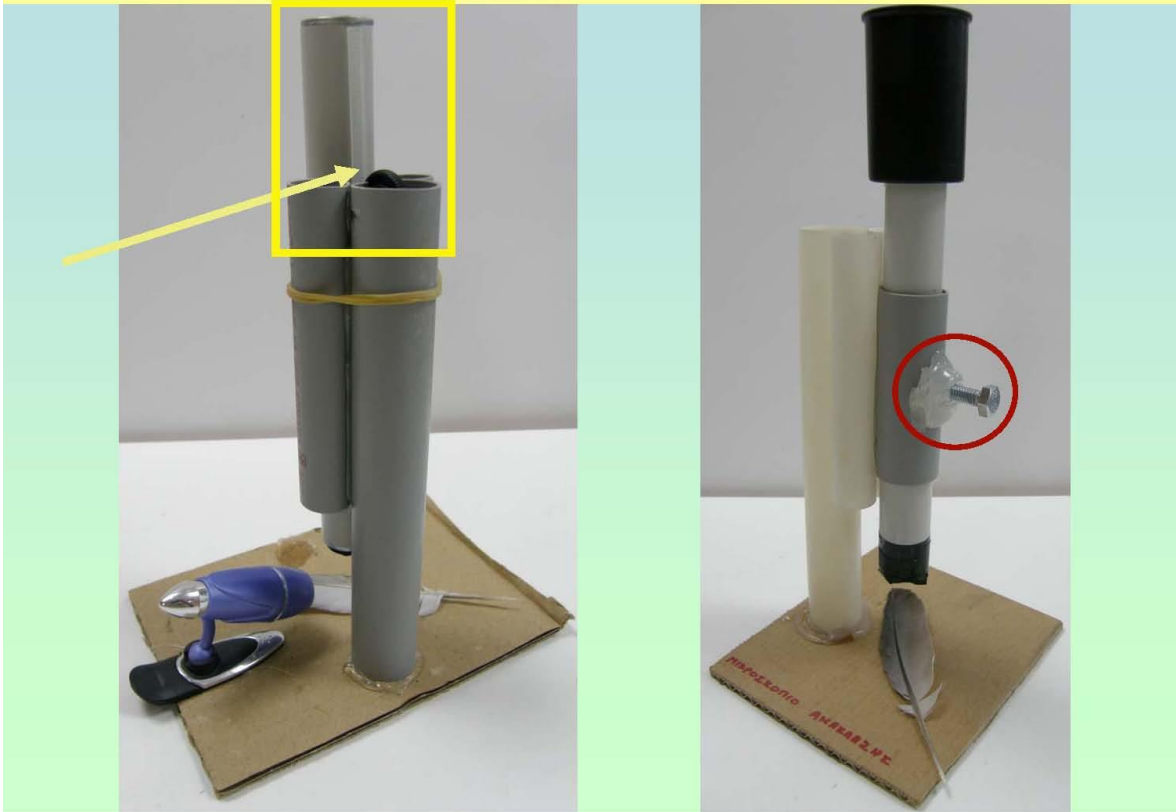


*Istituto e Museo di Storia
Della Scienza*

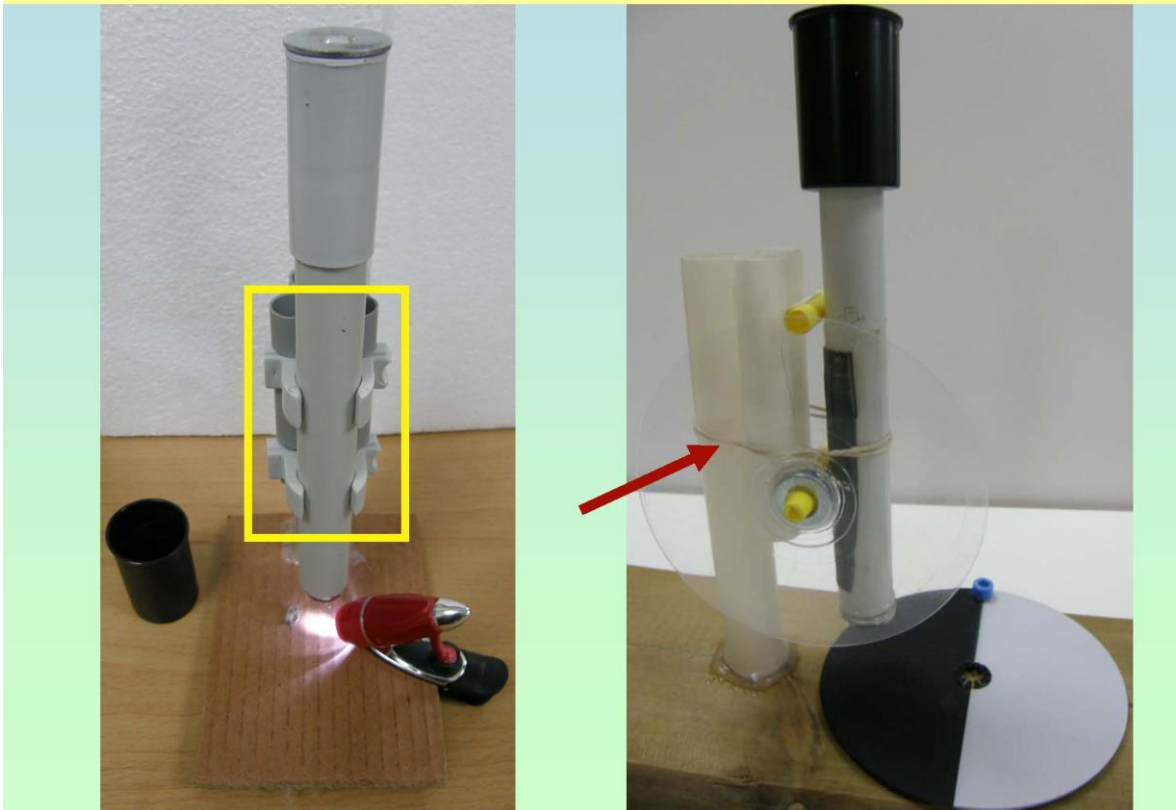


*Science Laboratory for
Primary Education*

Alternative attempts of stabilizing the microscope



Alternative attempts of stabilizing the microscope



microscope construction worksheet

The worksheet used with pupils to construct the first version of the microscope with two lenses (objective and eye piece) is presented below. The language of the worksheet is Greek.

Εργαστήριο Φυσικών Επιστημών Ρεθύμνου
© Νεκτάριος Τσαγλιώτης & Αριστοτέλης Θεοδωράκης
e-mail: ntsag@edc.uoc.gr & ekfepe@gmail.com

Κατασκευή ενός μικροσκοπίου με απλά υλικά*



Galileo
Microscope
(circa late 1600s)

Φαίνεται ότι το πρώτο μικροσκόπιο ήταν βασικά ένας σωλήνας με μια μικρή πλάκα στη μία μεριά για την τοποθέτηση του αντικειμένου και με ένα φακό στην άλλη μεριά, ο οποίος μεγέθυνε το αντικείμενο κατά 10 φορές ή και λιγότερο. Το 1597 ο Ολλανδός επιστήμονας Zaccharias Jansseen και ο γιος του Han Jansseen καθώς πειραματιζόταν με διάφορους φακούς που έβαζαν μέσα σε ένα σωλήνα βρήκαν ότι ο συνδυασμός δύο φακών με ένα συγκεκριμένο τρόπο έδινε καλύτερα αποτελέσματα στη μεγέθυνση των αντικειμένων. Κατασκεύασαν έτσι μια πρώτη εκδοχή του σύνθετου μικροσκοπίου με ένα προσοφθάλμιο φακό από τη μία μεριά και ένα αντικειμενικό φακό από την άλλη, ο οποίος πλησίαζε στο υπό μελέτη αντικείμενο. Πιστεύεται ότι η ιδέα τους αυτή με τους δύο φακούς στηριζόταν πάνω στην αντίστροφη ιδέα της διάταξης των φακών του τηλεσκοπίου, γι' αυτό άλλωστε και οι πρώτες τους κατασκευές είχαν μήκος περίπου 60 εκ. και ήταν αρκετά βαριές. Αναμφίβολα όμως ήταν οι πρωτεργάτες του σύνθετου μικροσκοπίου, το οποίο αργότερα τελειοποίησε ο Robert Hooke γύρω στα 1665 (πρβλ. *Micrographia*). Εικάζεται ότι και ο Γαλιλαίος είχε κατασκευάσει παρόμοιο μικροσκόπιο στις αρχές του 17^{ου} αιώνα (βλ. διπλανή φωτογραφία).

Η βασική ιδέα, λοιπόν, αυτού του σχεδίου εργασίας είναι η κατασκευή ενός απλού μικροσκοπίου με υλικά σύγχρονα, άμεσα διαθέσιμα και ανακυκλώσιμα ή έστω με υλικά που μπορούν να έχουν και δεύτερη χρήση. Επιχειρείται έτσι μία εισαγωγική προσέγγιση των εκπαιδευτικών και των μαθητών στο ενδιαφέρον αυτό διδακτικό αντικείμενο, με ελάχιστο κόστος αλλά με προσωπική συμβολή στη δημιουργία και στη διερεύνηση.



Υλικά που χρειαζόμαστε

- ✓ 2 φακούς από φωτογραφικές μηχανές μιας χρήσης
- ✓ 1 σωλήνα πλαστικό, εσωτερικής διαμέτρου 16 χιλιοστών και μήκους 16,5 εκ.
- ✓ 2 ροδέλες μεταλλικές, με εξωτερική διάμετρο 2 εκ. και εσωτερική 1 εκ.
- ✓ 1 ροδέλα λαστιχένια που χρησιμοποιείται για να συγκρατεί τα καρφιά στις σκεπές με εξωτερική διάμετρο 12 χιλ. και εσωτερική 2 χιλ.
- ✓ 1 μαύρο κουτάκι από φιλμ τρυπημένο κυκλικά στη βάση του (το κόβουμε προσεκτικά με κοπίδι και τη βοήθεια ενός ενήλικα)
- ✓ 1 μαύρο παραλληλόγραμμο κομμάτι χαρτόνι 15 x 5 εκ.
- ✓ μερικά μικρά λαστιχάκια
- ✓ κολλώδη πλαστελίνη, τύπου "blue tack"
- ✓ 1 κομμάτι πλαστικό ηλεκτρολογικό σωλήνα, εξωτερικής διαμέτρου 20 χιλιοστών και μήκους 17 εκ.
- ✓ 2 κομμάτια από πλαστικό ηλεκτρολογικό σωλήνα διαμέτρου 15 χιλιοστών και μήκους 10 εκ.
- ✓ Ένα κομμάτι σκληρό χαρτόνι από χαρτόκουτα περίπου 15 x 10 εκ.
- ✓ Πιστόλι θερμοσιλικόνης
- ✓ Ψαλίδι, σεγάκι, κοπίδι, χάρακα, μολύβι ή στυλό



* Αυτό το σχέδιο εργασίας (project) εκπονήθηκε στο πλαίσιο της πτυχιακής εργασίας του Αριστοτέλη Θεοδωράκη στο ΠΤΔΕ του Πανεπιστημίου Κρήτης (Ιούνιος 2008), με επίπτηρα της εργασίας την επίκουρη καθηγήτρια *Μαριάννα Καλαϊτζιδάκη* και συνεπόπτη τον καθηγητή *Κώστα Τζανάκη* και σε συνεργασία με το Εργαστήριο Φυσικών Επιστημών για την πρωτοβάθμια εκ/ση του Νομού Ρεθύμνης, Μάχης Κρήτης 33, Μισίρια, 74100 Ρέθυμνο (ekfepe@gmail.com).



Ας το φτιάξουμε

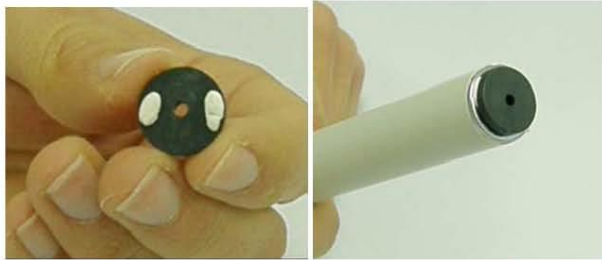
- 1** Τυλίγουμε το μαύρο κομμάτι χαρτόνι γύρω από ένα κυλινδρικό σωλήνα και το σπρώχνουμε μέσα στο σωλήνα του μικροσκοπίου.



- 2** Κολλάμε με "blue tack" τους φακούς στις μεταλλικές ροδέλες, προσέχοντας να μην καλύπτονται οι φακοί από αυτό το υλικό. Στη συνέχεια τους τοποθετούμε όπως είναι στις άκρες του σωλήνα μήκους 16,5 εκ. προσθέτοντας πάλι "blue tack" όπου χρειάζεται.



- 3** Στον αντικειμενικό φακό του μικροσκοπίου (εκείνον που θα βρίσκεται στην κάτω μεριά), προσαρμόζουμε τη λαστιχένια ροδέλα στερεώνοντας και πάλι με "blue tack" έτσι, ώστε η οπή της να βρίσκεται στο κέντρο του φακού.



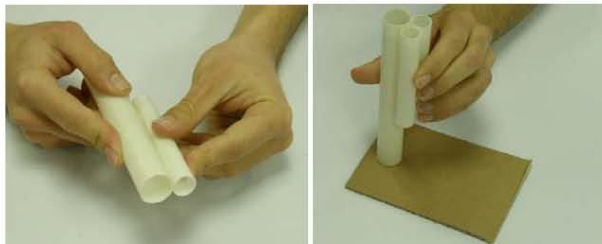
- 4** Προσαρμόζουμε το κουτάκι του φιλμ στο πάνω μέρος του σωλήνα.

Θυμίζουμε ότι από το κουτάκι του φιλμ έχουμε αφαιρέσει με κοπίδι ένα κυκλικό δίσκο από τον πάτο του, στις διαστάσεις του σωλήνα μας.

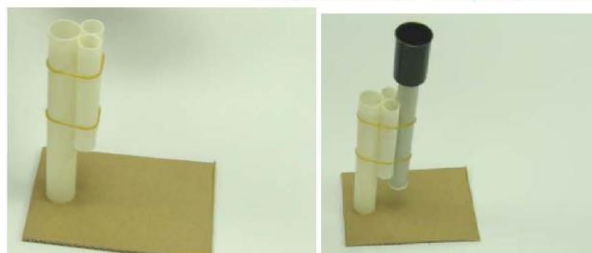


- 5** Με του υπόλοιπους τρεις σωλήνες κατασκευάζουμε τη βάση στήριξης του μικροσκοπίου μας.

Κολλάμε, δηλαδή, δίπλα-δίπλα τους δύο μικρούς επάνω στο μεγαλύτερο σωλήνα και έπειτα ολόκληρη τη βάση επάνω στο χαρτόνι, με θερμοσιλικόνη.



- 6** Περνάμε δύο ή τρία λαστιχάκια στη βάση στήριξης και ύστερα τοποθετούμε και το μικροσκόπιο, προσέχοντας αρχικά η απόσταση αντικειμενικού φακού και χαρτονιού να είναι περίπου 4 εκατοστά.



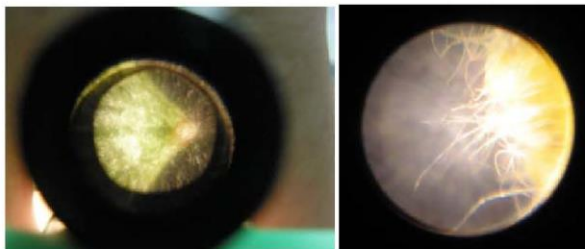
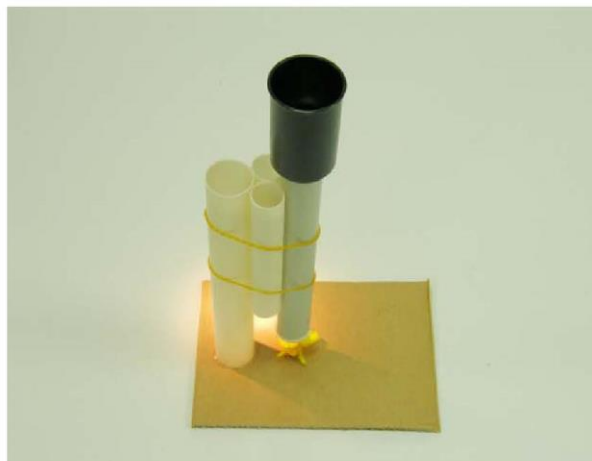
- 7 Το μικροσκόπιό μας είναι τώρα έτοιμο!!!**

Για να μπορέσουμε να δούμε διάφορα αντικείμενα όπως φύλλα άνθη κλπ. θα πρέπει να φωτίσουμε καλά το αντικείμενο με ένα φακό ή ακόμα καλύτερα με ένα μικρό ηλεκτρικό προβολέα, δηλαδή ένα σποτάκι.

Για να εστιάσει το μικροσκόπιό μας θα πρέπει να το κινήσουμε προσεκτικά πάνω κάτω και μέσα στην εσοχή που σχηματίζουν οι δύο μικροί σωλήνες της βάσης. Τα λαστιχάκια μας βοηθούν με την τριβή τους στη σταθεροποίηση του σωλήνα του μικροσκοπίου.

Με λίγη υπομονή και λεπτές κινήσεις για την εστίαση θα μπορέσουμε να δούμε αντικείμενα 20 φορές μεγαλύτερα ή αλλιώς με μεγέθυνση 20 X.

- 8** Κοιτάξτε, για παράδειγμα, πόσο μεγάλη φαίνεται η μύτη ενός πολύ μικρού φύλλου και λεπτομέρεια από ριζίδια πατάτας σε φωτογράφιση με ψηφιακή μηχανή (βλ. κάτω)

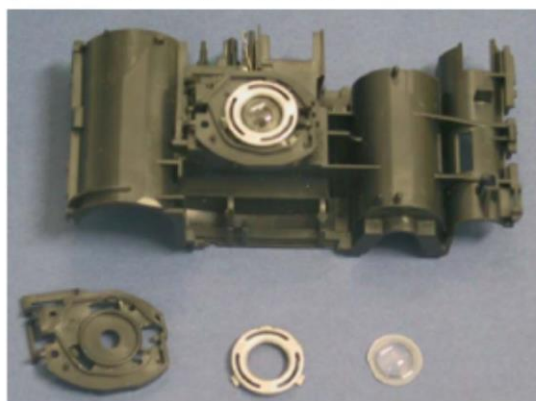


Λεπτομέρειες από πούπουλο & κλωστή



Χρήσιμες συμβουλές ...

Οι φακοί που θα πρέπει να βρούμε για την κατασκευή του μικροσκοπίου βρίσκονται σε χρησιμοποιημένες φωτογραφικές μιας χρήσης. Αν και δεν αποτελούν μια τόσο οικολογική προσέγγιση για τη λήψη φωτογραφιών, εντούτοις με τη δεύτερη χρήση φακών και εξαρτημάτων τους ενδέχεται να αποβούν περισσότερο χρήσιμες για εκπαιδευτικούς σκοπούς από ότι είχαν αρχικά σχεδιάσει οι κατασκευαστές τους. Οι δύο φακοί που μπορούμε να πάρουμε από το μπροστά μέρος τους είναι κυρτοί με εστιακή απόσταση περίπου 35 χιλιοστών. Μπορούν να χρησιμοποιηθούν ως προσοφθάλμιοι φακοί στο πάνω μέρος του σωλήνα του μικροσκοπίου αλλά και ως αντικειμενικοί φακοί στο κάτω μέρος του (πρβλ. παρακάτω φωτογραφία).



Πολλές φορές οι φακοί αυτοί, όπως θα τους πάρετε από τις μηχανές ενός φιλικού σας φωτογραφείου, θα πρέπει να καθαριστούν από σκόνη και σκουπιδάκια, για να έχουν καλύτερη ευκρίνεια. Επίσης, θα πρέπει να προσέξουμε κατά τη διαδικασία στερέωσης των φακών πάνω στο σωλήνα να χρησιμοποιήσουμε προσεκτικά κατάλληλη ποσότητα "blue tack" ώστε να μην κρύψουμε μέρος του φακού και ακόμα να μην τον λερώσουμε ξανά. Ειδικά στον αντικειμενικό φακό στο κάτω μέρος

του σωλήνα του μικροσκοπίου θα πρέπει να προσέξουμε να εφαρμόσουμε όσο γίνεται καλύτερα το σωλήνα, τη μεταλλική ροδέλα και τη λαστιχένια ροδέλα.



Οι λαστιχένιες αυτές ροδέλες χρησιμοποιούνται για να συγκρατούν τα καρφιά ή τις βίδες κατά την κατασκευή σκεπών με πάνελ. Δοκιμάσαμε τρεις διαφορετικές διαστάσεις που είχαμε διαθέσιμες με εσωτερικές διατομές 2, 6 και 8 χιλιοστά και βρήκαμε ότι το μικροσκόπιο «δουλεύει» με όλες αν και μια ενδιάμεση διάσταση οπής γύρω στα 4 χιλιοστά φαίνεται να είναι η καλύτερη σε σχέση με τη φωτεινότητα του αντικειμένου και το εύρος του πεδίου παρατήρησης.

Επιπλέον, ένας σημαντικός παράγοντας που επηρεάζει την τελική εικόνα είναι η φωτεινότητα του αντικειμένου προς παρατήρηση. Φωτίζοντάς το με ένα σποτάκι ή ένα λαμπατέρ γραφείου, αυξάνουμε κατά πολύ την ευκρίνεια του ειδώλου από ότι αν το φωτίσουμε με ένα κοινό φακό χειρός. Ακόμα, είναι βασικό κατά την παρατήρηση να πέφτει όσο το δυνατόν λιγότερο φως στο μάτι από τον περιβάλλοντα χώρο, γι' αυτό χρησιμοποιούμε και το μαύρο κουτί από φιλμ.

Βιβλιογραφία

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microscopes construction in class

The construction of the first version of microscopes with two lenses was conducted in class in a two-hour period with the materials readily available to children. The children were supervised by the teacher and the 4 student-teachers involved in the project. The addition of the third, extra lens (field lens) took about one more teaching hour. Some indicative snapshots of the process are presented in the transparencies below.

Construction of the microscopes



Breaking the cameras in pieces for secondary use of materials, especially lenses



Construction of a microscope with simple materials



Projection of guidelines and comments for the construction of the microscope from the Wiki HIPST

Construction of a microscope with simple materials



Distribution of materials
in each group ...
6 sets of materials for a
respective number of
groups of four children,
for the construction of 2
microscopes per group

Construction of a microscope with simple materials



Construction of a microscope with simple materials



Construction of a microscope with simple materials



Construction of a microscope with simple materials

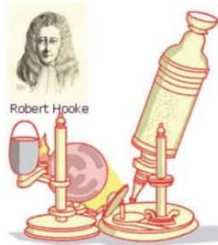


Initial "random" observations .. Just after the completion of the first version of the microscopes



A set of six+one worksheets have been used in this case for microscope studies. They are presented in English below.

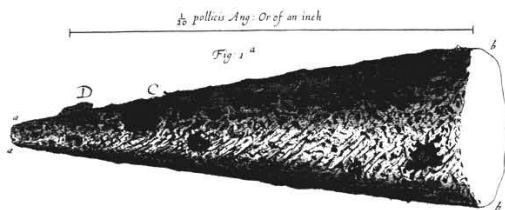
Worksheet 1: The point of a needle



Pieces of text and drawings from Robert Hooke's *Micrographia* (1665)

Of the Point of a sharp small Needle

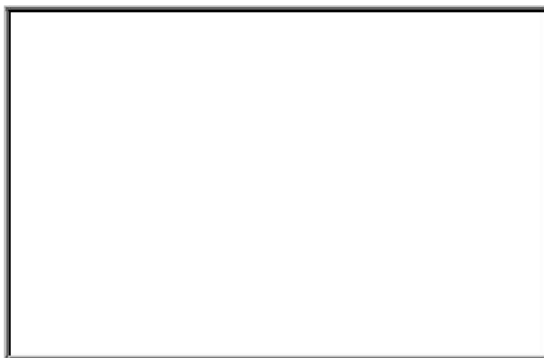
"We will begin these our Inquiries therefore with the Observations of Bodies of the most *simple nature* first, and so gradually proceed to those of a more *compounded* one. In prosecution of which method, we shall begin with a *Physical point*; of which kind the *Point of a Needle* is commonly reckoned for one; and is indeed, for the most part, made so sharp, that the naked eye cannot distinguish any parts of it: It very easily pierces, and makes its way through all kind of bodies softer than itself ...



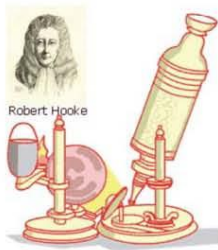
But if viewed with a very good *Microscope*, we may find that the *top* of a Needle (though as to the sense very *sharp*) appears a *broad, blunt*, and very *irregular* end; not resembling a Cone, as is imagined, but only a piece of a tapering body, with a great part of the top removed, or deficient ...

The image we have here exhibited in the first Figure, was the top of a small and very sharp Needle, whose point *aa* nevertheless appeared through the *Microscope* above a quarter of an inch broad, not round nor flat, but *irregular* and *uneven* ... The surface of which, though appearing to the naked eye very smooth, could not nevertheless hide a multitude of holes and scratches and ruggednesses from being discovered by the *Microscope* to invest it, several of which inequalities (as A, B, C, seemed *holes* made by some small specks of *Rust*, and D some *adventitious body*, that stuck very close to it) were *casual*. All the rest that roughen the surface, were only so many marks of the rudeness and bungling of *Art*."

Let us observe the point of a needle under the microscope. Can we make a drawing and write a description, as Hooke has done?



Worksheet 2: The study of a dot



Pieces of text and drawings from Robert Hooke's *Micrographia* (1665)

Observation of a *point*, commonly called, the mark of a *full stop*, or *period*.

"And for this purpose I observed many both *printed* ones and *written*; and among multitudes I found *few* of them more *round* or *regular* then this which I have delineated in the third figure of the second Scheme [see below], but *very many* abundantly *more disfigured*, and for the most part if they seemed equally round to the eye ...

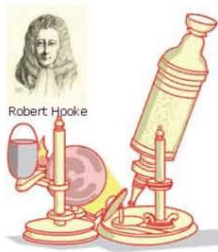


But to come again to the point. The *Irregularities* of it are caused by three or four *coadjutors*, one of which is, the *uneven surface* of the *paper*, which at best appears no smother then a very course piece of *shagged cloth*, next the *irregularity of the Type or Engraving*, and a third is the *rough Daubing* of the *Printing-Ink* that lies upon the instrument that makes the impression, to all which, add the *variation* made by the Different *lights* and *shadows*, and you may have sufficient reason to guess that a *point* may appear much more *ugly* then *this*, which I have here presented, which though it appeared through the *Microscope gray*, like a great splatch of *London dirt*, about three inches over; yet to the *naked eye* it was *black* and no bigger then that in the midst of the Circle A."

Let us observe some printed and handwritten dots under the microscope. Can we make a drawing and write a description, as Hooke has done?



Worksheet 3: Seeds of thyme



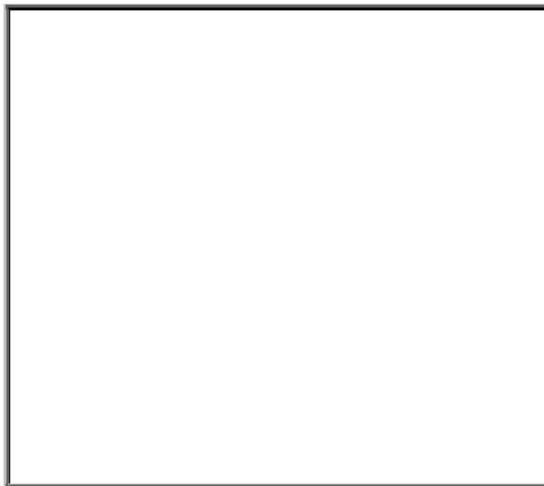
Pieces of text and drawings from Robert Hooke's *Micrographia* (1665)

Of the seeds of Thyme

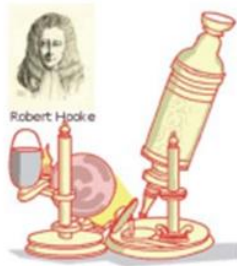


"These pretty fruits here represented, in the 18. *Scheme*, [see drawing aside] are nothing else, but nine several seeds of Thyme; they are all of them in differing posture, both as to the eye and the light; nor are they all of them exactly of the same shape, there being a great variety both in the bulk and figure of each seed; but they all agreed in this, that being looked on with a *Microscope*, they each of them exactly resembled a Lemmon or Orange dried; and this both in shape and colour. Some of them are a little rounder, of the shape of an Orange, as A and B, they have each of them a very conspicuous part by which they were joined to their little stalk, and one of them had a little piece of stalk remaining on; the opposite side of the seed, you may perceive very plainly by the Figure, is very copped and prominent, as is very usual in Lemons; which prominences are expressed in D, E and F. They seemed each of them a little creased or wrinkled, but E was very conspicuously furrowed, as if the inward make of this seed had been somewhat like that of a Lemon" ...

Let us observe some seeds of thyme under the microscope. Can we make a drawing and write a description, as Hooke has done?



Worksheet 4: Petunia seeds and plant



Pieces of text and drawings from
Robert Hooke's *Micrographia* (1665)

Observation of petunia
seeds and plants



Let us observe some seeds of petunia under the microscope. Can we make a drawing and write a description, as Hooke has done?

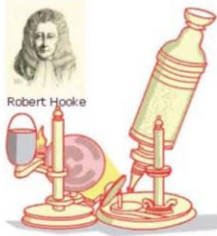


Let us observe some parts of the petunia plant (roots, sprout, leaves, flowers etc.) under the microscope. Can we make a drawing and write a description, as Hooke has done?



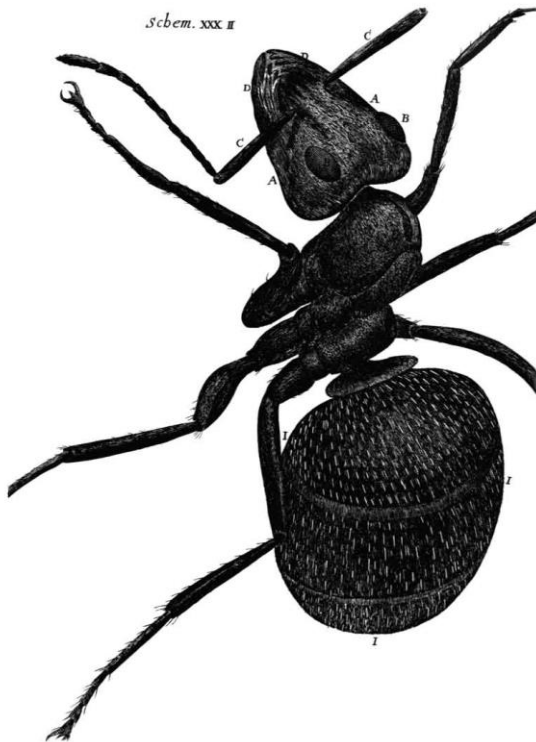
Worksheet 5: The study of an ant

page 1



Pieces of text and drawings from Robert Hooke's *Micrographia* (1665)

O f a n A n t



"This was a creature, more troublesome to be drawn, then any of the rest, for I could not, for a good while, think of a way to make it suffer its body to lay quiet in a natural posture; but whilst it was alive, if its feet were fettered in Wax or Glue, it would so twist and wind its body, that I could not any ways get a good view of it; and if I killed it, its body was so little, that I did often spoil the shape of it, before I could thoroughly view it ...

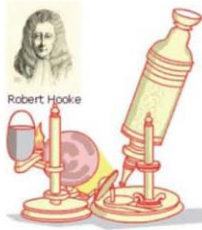
Having ensnared several of these into a small Box, I made choice of the tallest grown among them, and separating it from the rest, I gave it a Gill of Brandy, or Spirit of Wine, which after a while even knocked him down dead drunk, so that he became moveless, though at first putting in he struggled for a pretty while very much, till at last, certain bubbles issuing out of its mouth, it ceased to move; this (because I had before found them quickly to recover again, if they were taken out presently) I suffered to lay above an hour in the Spirit; and after I had taken it out, and put its body and legs into a natural posture, remained moveless about an hour; but then, upon a sudden, as if it had been awoken out of a drunken sleep, it suddenly revived and ran away ...

This Creature appeared through the *Microscope*, in the 32 *Scheme* [see above] ... had a large head AA, at the upper end of which were two protuberant eyes, pearled like those of a Fly, but smaller BB; out of the Nose, or foremost part, issued two horns CC, of a shape sufficiently differing from those of a blew Fly, though indeed they seem to be both the same kind of Organ, and to serve for a kind of smelling; beyond these were two indented jaws DD, which he opened side-ways, and was able to gape them asunder very wide; and the ends of them being armed with teeth, which meeting went between each other, it was able to grasp and hold a heavy body, three or four times the bulk and weight of its own body. It had only six legs, shaped like those of a Fly ...

The third and last part of its body III was bigger and larger then the other two, unto which it was joined by a very small middle, and had a kind of loose shell, or another distinct part of its body H, which seemed to be interposed, and to keep the *thorax* and belly from touching.

The whole body was cased over with a very strong armour, and the belly III was covered likewise with multitudes of small white shining bristles; the legs, horns, head, and middle parts of its body were bestuck with hairs also, but smaller and darker."

Worksheet 6: The study of an isopod



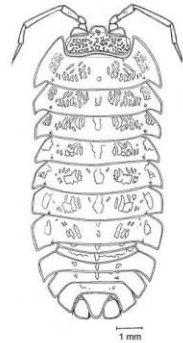
Pieces of text and drawings from Robert Hooke's *Micrographia* (1665)

Observation of a terrestrial isopod



Let us observe an arthropod, which we commonly find in the garden and it is called **terrestrial isopod**, although its common names are "pill-bug" or "pill woodlouse". Its scientific name is **Armadillidium nasatum** and it likes to hide under dark and wet places in the garden. When threatened, it takes the shape of a small marble and rolls down the ground.

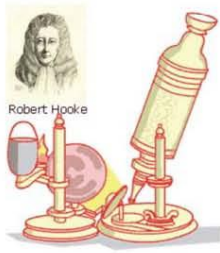
Let us observe it under the microscope. Can we make a drawing and write a description?



Let us observe **the body parts of a terrestrial isopod** (head, tail, legs ...) under the microscope. Can we make a drawing and write a description?



Worksheet 7: A free study



Pieces of text and drawings from Robert Hooke's *Micrographia* (1665) A free observation study

Let us observe _____



Let us observe **the parts** _____



The above set of six+one worksheets, which have been used in this case for

microscope studies, can also be downloaded in English as a .pdf file [here](#).

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