Building Models to Build Up Unterstanding

Peter Lampert, Martin Rose, Michael Kiehn.
Botanischer Garten Wien (Botanical Garden, University of Vienna)

The workshop shows a practical approach to teach pollination biology both at botanical gardens and at schools, using self-made flower models. The models take up the results of recent empiric studies on learners' concepts about pollination (Lampert, 2012).

THE RELEVANCE OF POLLINATION BIOLOGY IN TEACHING

Pollination is essential to the production of fruit and seed and it therefore plays a major role in the lifecycle of higher plants. Furthermore, animal pollination (=zoophily) links the two fields zoology and botany, and the resulting coevolution between pollinators and flowers has led to the broad variety of shapes, colors and scents of flowers. Additionally, recent discussions about the worldwide declines of bee hives brought pollination and their protagonists in the focus of public attention. Therefore, the interaction between flowers and pollinators are a rewarding topic for teaching botany in botanical gardens or at school.

WHAT DO CHILDREN THINK ABOUT POLLINATION?

Children have got various different pre-concepts about pollination biology. Learning sessions should help students to make a change from nonscientific perceptions, which impede the understanding of biological topics, towards more scientific and "correct" concepts. To reach this so called "Conceptual change" (Duit and Treagust 2003), it is necessary to know about the concepts learners have. For this reason, the concepts of 10 year old children were examined in a qualitative study in which seven children talked about their concepts of pollination (Lampert 2012). A short summary about the results of this study will be given here, since the findings of the study had a strong influence on the design of the presented learning session.

A first insight into the students' perceptions concerns the role of pollination in the life cycle of plants. In the interviews the children showed that they have got great difficulties in differing pollination from seed dispersal. Several children reported that the pollen which is carried by the pollinators falls to the ground and a new plant will germinate out of this pollen. Although some children new, that there is a difference between pollen and seeds, they were not able to explain how the pollen "changes" to the seed which germinates. For these children, the pollen "ripens" to a seed. In addition, a notably difference regarding the two main agents of pollen dispersal, animals and wind, was observed. Most of the students mentioned, that pollen grains transferred by animals land on another plant, where the fruit or the seed develops. But when it comes to the agent wind, all of the interviewed children described a process which resembled seed dispersal. They gave examples (e. g. dandelion, *Taraxacum* sp., or various trees), where the "pollen" is taken away by the wind, falls on the soil and germinates.

Furthermore, the interviews showed that children at that age know the names of several flowers, but they are not able to tell differences in shapes of the flowers. Therefore, the children struggle with understanding plant diversity. In addition, most of the interview partners were not aware that there is a broad variety of visitors. The only visitor which has been mentioned by all of the students was the honeybee. As a consequence, the students also lack knowledge about differences between the visitor-groups, e.g. different mouth parts. Another important result is that children often have complex concepts about the interactions between flowers and visitors. The children have been asked, what they think why insects visit the plants and carry pollen. Some students replied that the visitors try to collect food and that pollen is not transferred on purpose. According to this concept, which resembles the biological point of view, pollination is a side effect of the search for pollen or nectar. Surprisingly, all of the interviewed students revealed a second concept about the reasons for visiting flowers: This second concept sees carrying of pollen to another flower as a deliberate act of the pollinator. Some of these children see pollination as an act of help, where the pollinator deliberately helps the flower to reproduce. Other students claim that the interactions between animals and flowers are the result of a "smart nature" which knows about the needs of plants and pollinators. The children vary in the way they apply those two concepts on pollination. Some students tend to use the first concept more often; others showed throughout the interview, that they think that animals transport the pollen to the flowers intentionally. One of the students compared the transport of pollen even with a job: "For the animal pollination is like a job, as if a person is working as a gardener. […] The work of a wasp is pollinating flowers."

WHICH CONCLUSIONS CAN BE DRAWN FROM THESE INSIGHTS?
These results show that students lack experiences in the field of pollination biology. As a result, the life cycle of plants cannot be understood, because the processes of pollination and seed dispersal are not separated. Furthermore, the missing concept of diversity of plants and visitors makes it difficult for students to understand the diversity of a flowering field. The findings concerning the interactions between pollinators and flowers reveal that children have got more complex concepts about the backgrounds of pollination than expected. Those concepts interfere with the biological explanation that pollination is a side effect of collecting food.

A PRACTICAL APPROACH TO POLLINATION BIOLOGY USING FLOWER MODELS
The aim of the presented learning session (description on the following pages) is that children literally get in touch with flowers and pollination. The learning session starts with an introduction (or a repetition) of basic terms being used in the context of pollination. Another element is a guided tour through the botanical garden which emphasizes on pollination. Key element of this setting is a "nectar search game" including flower models. While interacting with the models, the children are in the role of different species of insects which try to collect nectar.

Nectar Search Game:
The children are divided into four different groups of insects, namely butterflies, bumblebees, honeybees and beetles. These groups differ in the structure of their mouth parts. (Most butterflies – long sucking proboscis; beetles – biting and chewing mouth parts; honeybees – relatively short sucking proboscis; bumblebees – intermediate length of the proboscis). These different mouthparts are symbolized by straws. Children who play "butterflies" receive the longest straws, the "bumblebees" intermediate straws and the "honeybees" get the shortest straws. The "beetles" do not receive any straws. After the children received their mouth parts, they get the task to search for nectar in the presented flower models. The three different types of flowers differ in the length of the corolla tubes (Figure 1.).

Figure 1. *Flower models with different length of the corolla tubes*

After the foraging of the “insects”, the children receive the task to stand next to the models they would prefer as an insect. Experience shows, that the “insects” prefer the flowers which match with their proboscis’ length. “Bees” prefer the models with the shortest corolla tube, because it is the only place where they can reach the nectar. “Bumblebees” and especially “butterflies” could also choose the flowers with the shorter tubes, but they usually avoid those models, because of the strong competition. The “Beetles” were not able to reach the nectar, so they experience that food is only accessible in certain types of flowers. These results of the game can be discussed in the group (Which insects were successful in gathering nectar? Which insects prefer which flowers? ...).

The attention of the students was intentionally driven to the nectar. While searching for food, “pollen” sticks on their faces (Figure 2.). This pollen is symbolized by curcuma powder, which has been intentionally put on the stamens before the session started. Most of the “insects” usually do not realize that they have been carrying “pollen”. With a mirror, they can convince themselves that the eager foraging led to an unintentional transport of pollen. The experiences can be discussed in the group and parallels to real flowers can be drawn.

Figure 2. *Student with “pollen” after interacting with a model*

Afterwards, the children can try out the remaining flower models of the sage flower (Figure 3) and the composite blossom (Figure 4). The composite blossom offers food (symbolized by sweets) to all insects. In the sage flower, the nectar (also symbolized by sweets) is hidden at the end of the corolla tube. To examine the sage flower, the students stop acting in their former roles. To reach the “nectar”, the whole insect (symbolized by the students hand – this aspect can be emphasized with a “bee glove”) needs to enter the flower. When the children try to reach the sweets, they trigger a mechanism (“turnpike”-mechanism) which places the pollen on the back of the “bee”. Advantages and disadvantages of generalists, where the nectar is available for a broad variety of insects (flower with short corolla tube; composite blossom) can be compared to specialists, where only specialized insects can reach the nectar (flower with long corolla tube; sage flower).

Figure 3. *Salvia model*

Figure 4. *Model of a composite flower*

MAIN POINTS DISCUSSED AT THE WORKSHOP

It has been pointed out that the flower models are an easy and cheap way to bring students closer to the topic of pollination. A learning session about pollination ecology involving flower models, as it is established in the Botanical Garden of the University of Vienna, could be applied in other botanical gardens as well.
An idea to take further advantages of the flower models is to build models about seeds and diaspores. A master thesis about this topic is currently in progress at the University of Vienna. The aim is to develop a learning session which shows the way from a flower to a seed. As it has been mentioned before, the processes of pollination and seed dispersal get often confused by the students. A learning session, which takes up the insights of students' concepts about those two processes, could be an important step towards a conceptual change.

Furthermore, the flower models can be modified in order to represent a broader variety of flowers. Color, shape, size of the organs of the flower can be adapted easily and the panelists are encouraged to develop the models further and gain experience in working with them. Another idea is to replicate more complex pollination mechanisms with flower models. The materials used to build the models can also be varied, depending on the demands (e.g. easy and cheap to build, but short life span vs. more expensive, more difficult to build, but higher durability).

A last option discussed during the session is the development of a role play about natural selection and evolution using flower models. As research showed, students struggle with explaining how the floral structures (e.g. long corolla tubes; nectar) and the proboscis of the visiting insects evolved. Therefore, one of the main aspects of Peter Lamperts' dissertation is the creation of a learning environment, which picks up the students' concepts pollination and their concepts about evolutionary processes. The aim is to create a session, where students experience the process of evolution in the role of "different generations of insects" which interact with "flowers".

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RESOURCE FROM WORKSHOP FEATURED BELOW

Building instructions for "simple" flower models

Materials

- Plastic cup or bowl (calyx)
- Coloured paper, lamination (petals)
- Small clamps (to join calyx and petals/stamina)
- Straws, batting (stamina)
- Straws (and/or pipe cleaners), table tennis ball, drawing-pin (pistil)

Tools: Scissors, laminator, ticket-punch, burner, short wire, hot glue gun.

Realization

Keep correct flower anatomy in mind.

Step 1: Copy the petal pattern onto coloured paper, cut the petals out and laminate them. Each petal needs a hole at the base to join it with the calyx.

Step 2: Melt 5 holes in the top of the calyx-cup for the petals. You can use a heated wire to melt the holes; this reduces sharp edges in the models. The holes should be big respectively small enough that the clams will fit but have no space to move. A bit lower you need to melt 5 holes for the stamina.

Step 3: Put the small clamps to the lower row of the holes and bend them on the inside of the calyx to the top. These are for the stamina to put on.

Step 4: Join the petals and calyx on the top row of holes with the small clamps. The petals are joined on the inside of the cup and folded at the calyx edge.

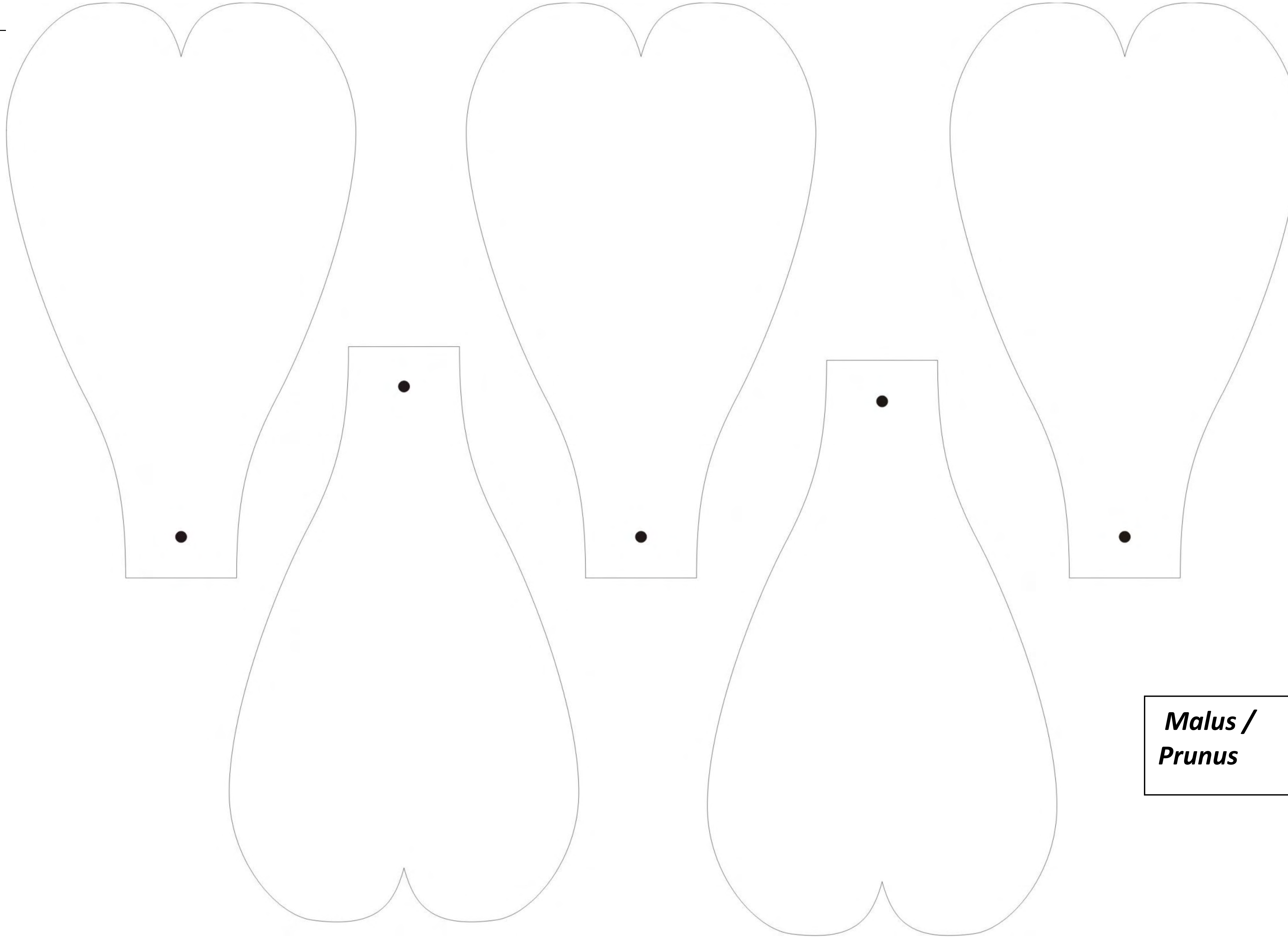
Step 5: 5 Straws are cut to the same length. Each straw (filament) gets a batting head (anther), joined with the hot glue gun.

To create the pistil, melt a hole, as big as a straw (style), in the table tennis ball (ovary) (see step 2). The straw can be fixated with the hot-melt gun. There are two possibilities for the stigma, depending on the flower. You can cut the straw to create stigma branches or you can glue a drawing pin to the top of the straw.

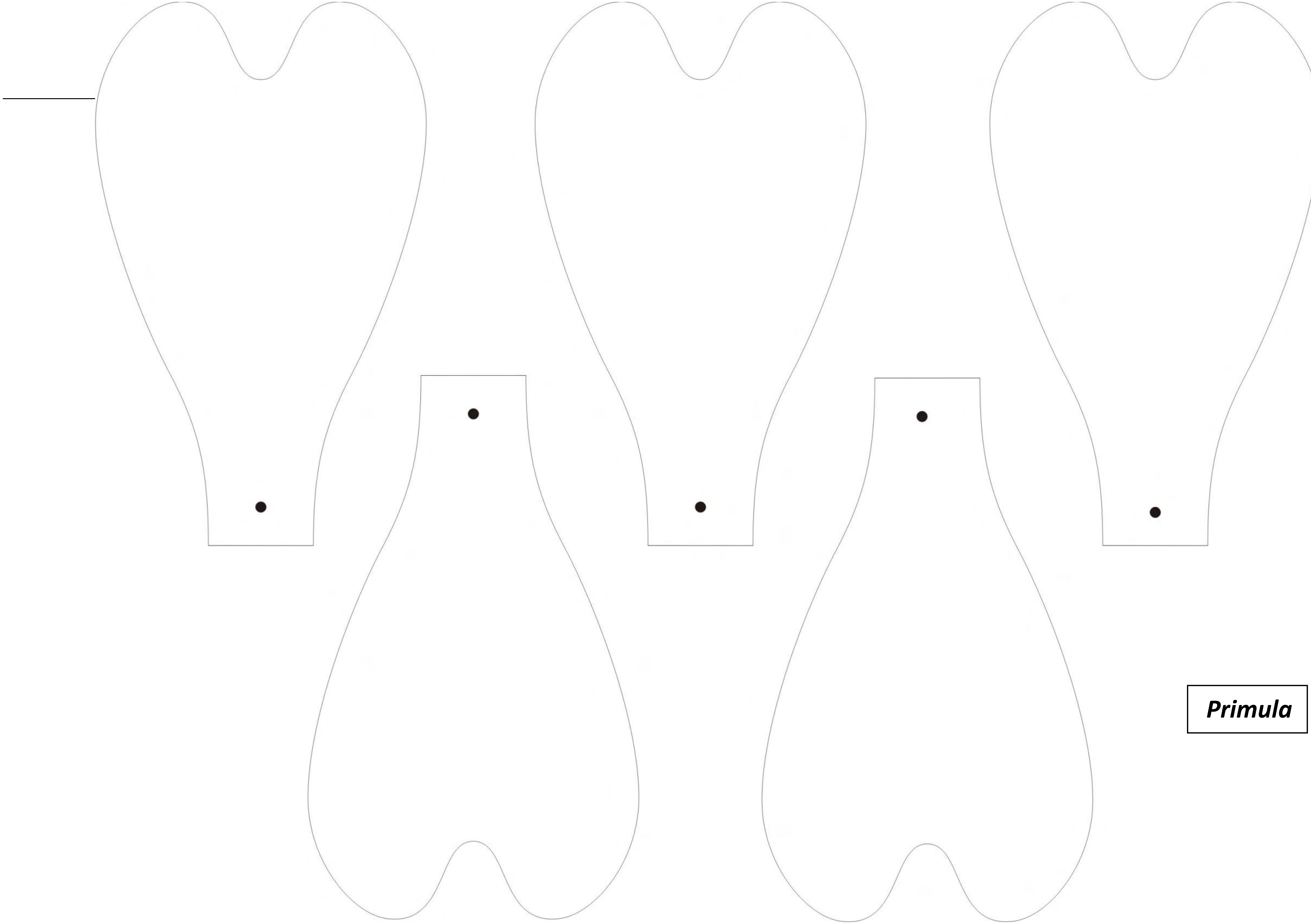
Another possibility to build the pistil is to make a small hole in the table tennis ball with a pin. Stick a pipe cleaner in this hole and cover it with a straw. With the pipe cleaner it is easy to form different shapes of the stigma.

Step 6: Glue the pistil to the bottom of the calyx and put the stamina on the clamps (see step 3)

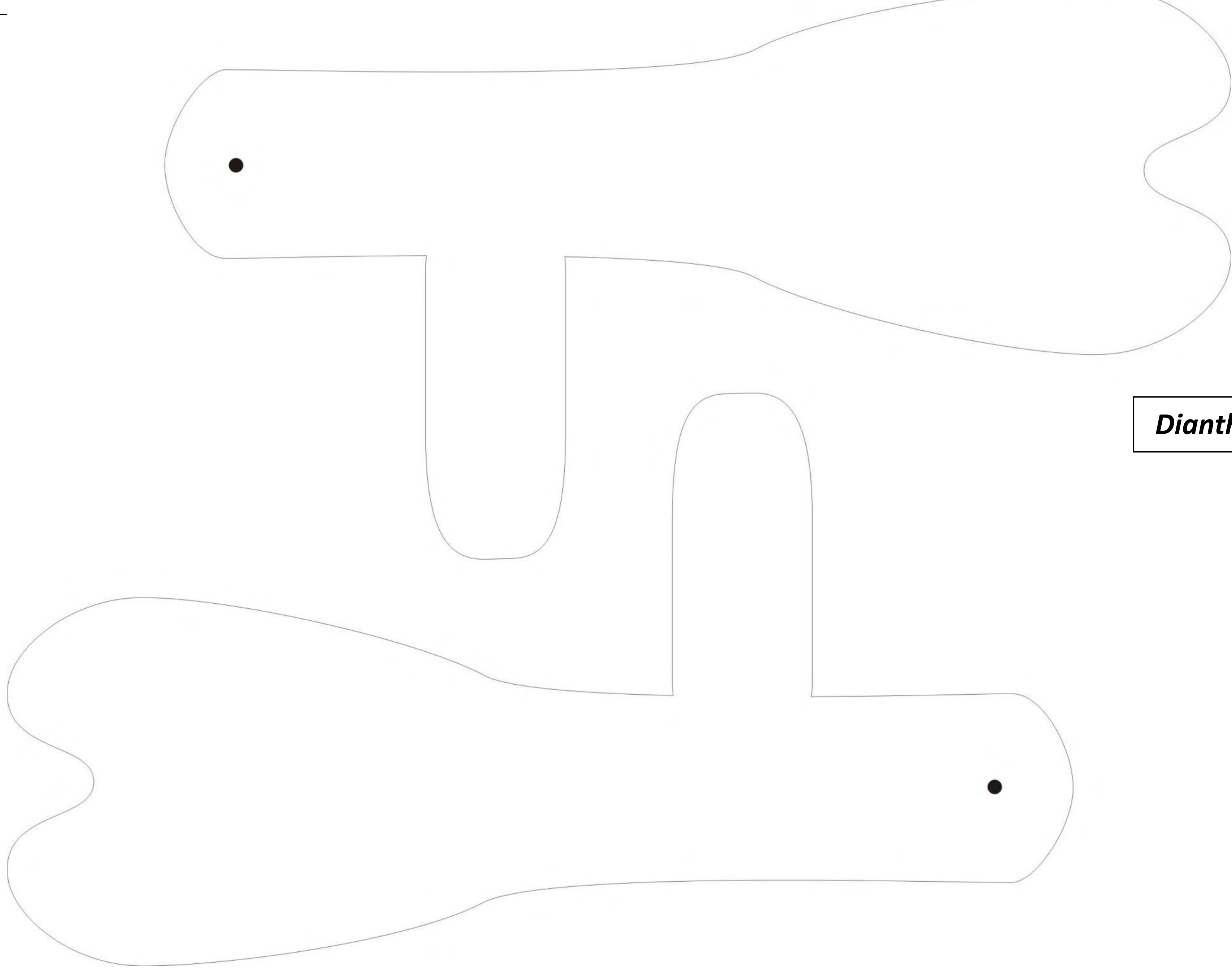
The models were designed for a frequent outdoor use and great variability (change flower type/replace damaged parts)



Malus / Prunus



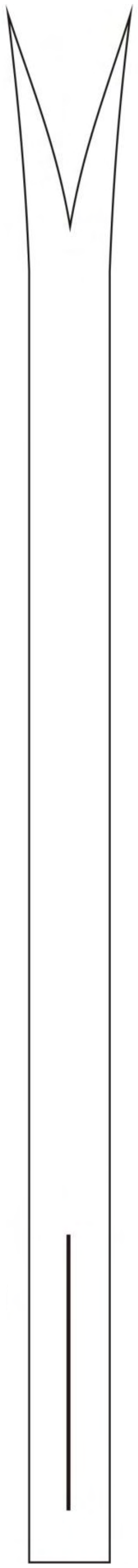
Primula



Dianthus

Building instructions for the *Salvia* model

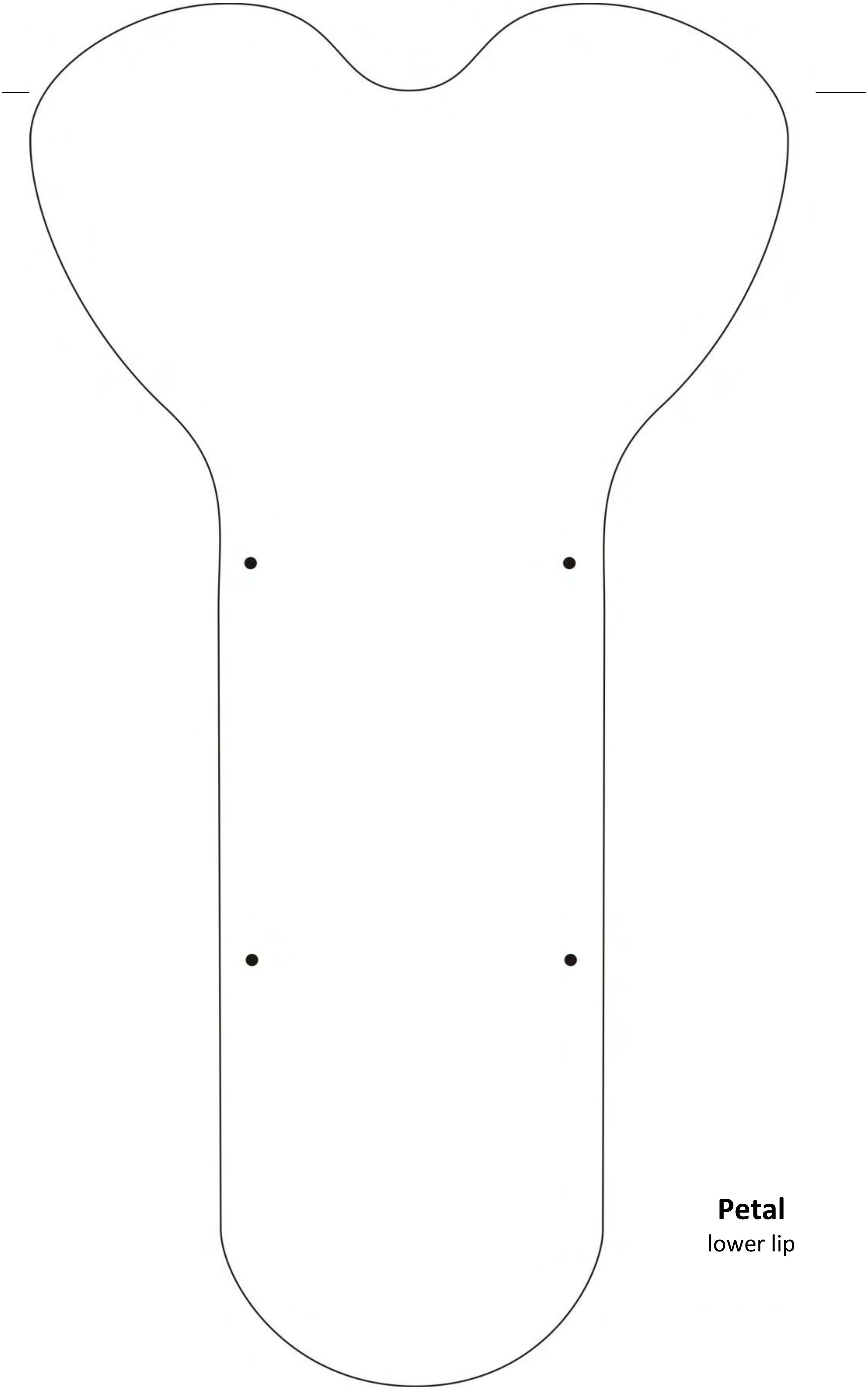
Step 1: Thread five washers (each 14 mm Ø) each on two wires and twist over the whole length. The washers act as counterbalance in the mechanism. Glue batting on the end of each wire for the model's fertile theca. Use small clamps to attach the sterile theca (laminated Paper) to the holes of the washers.
Step 2: Twist the wire with the washers around a round object (for example a pencil) to form a hinged bracket. Keep in mind that the arm's length on the side with the washer should be one third of the arm's length on the other side. The two sides should have a 90° angle.
Step 3: Both parts of the style are connected with small clamps. To achieve this you need to make a cut at the rear end.
Step 4: Both parts of the upper lip are connected with a small clamp. The three parts of the petal base must be bent together and fixed as well. Both parts (upper lip, petals) are connected with small clamps.
Step 5: The ovary is represented by a table tennis ball clued into the rear end of the model. The stylus is glued at the base of the flower as well and stabilized by two transparent supports glued into the model.
Step 6: The upper lip is folded inwards at the dotted line and connected to the lower lip by small clamps. You can stabilize the model by adding a base plate if needed.
Step 7: Finally the stamina are attached. A wooden stick is the axis to allow the movement of the stamina. It is put through the holes in the upper lip and the following parts are added in order:
Piece of straw-Stamen- Piece of Straw-Stamen- Piece of Straw
The pieces of straw keep the stamina in place. The wooden stick is fixated with the hot-melt gun.
In the sheets a black dot symbolizes a hole and a dotted line that you have to fold the sheet.



Anther
sterile theca

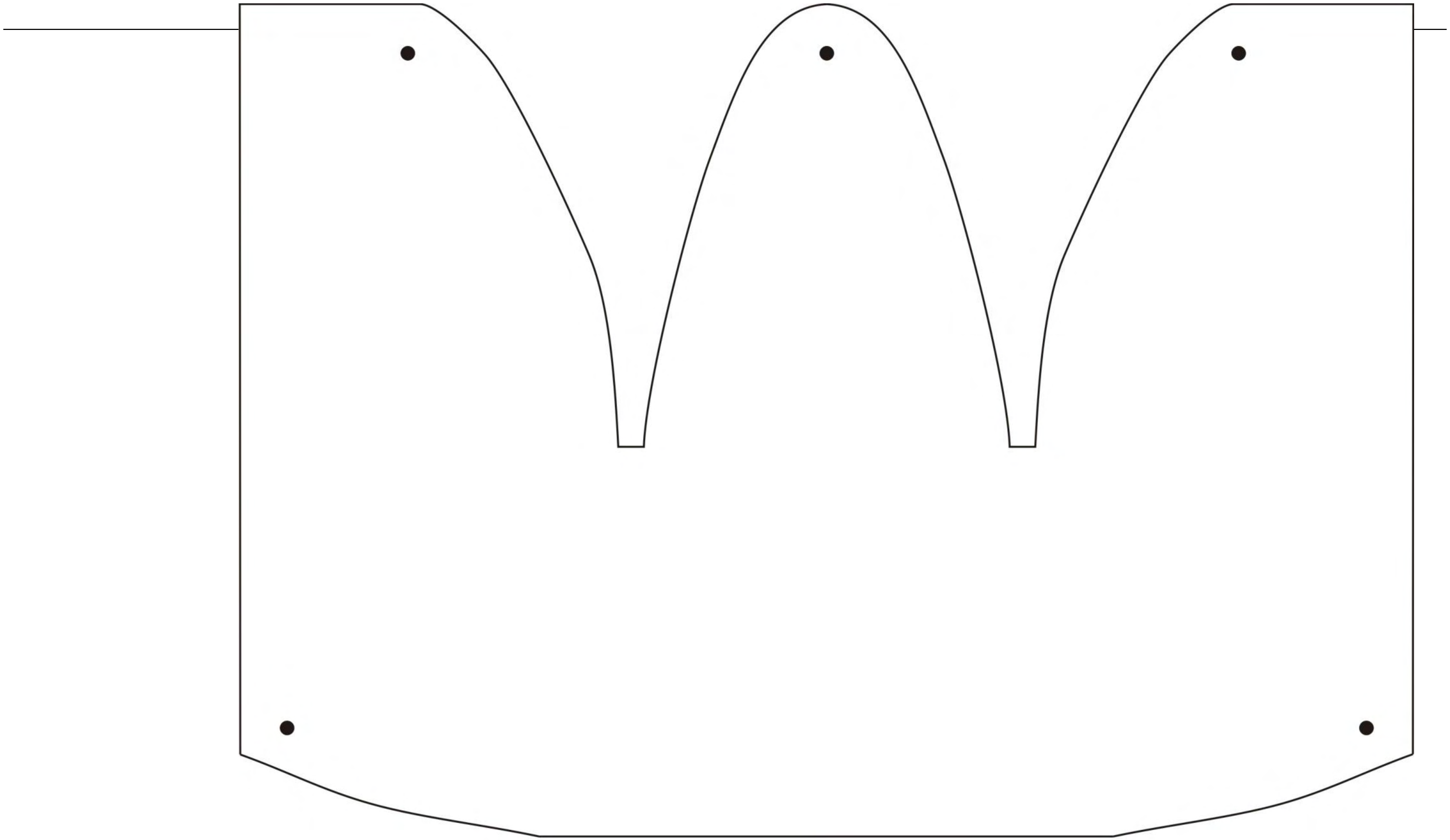
Style
front part

Style
rear part



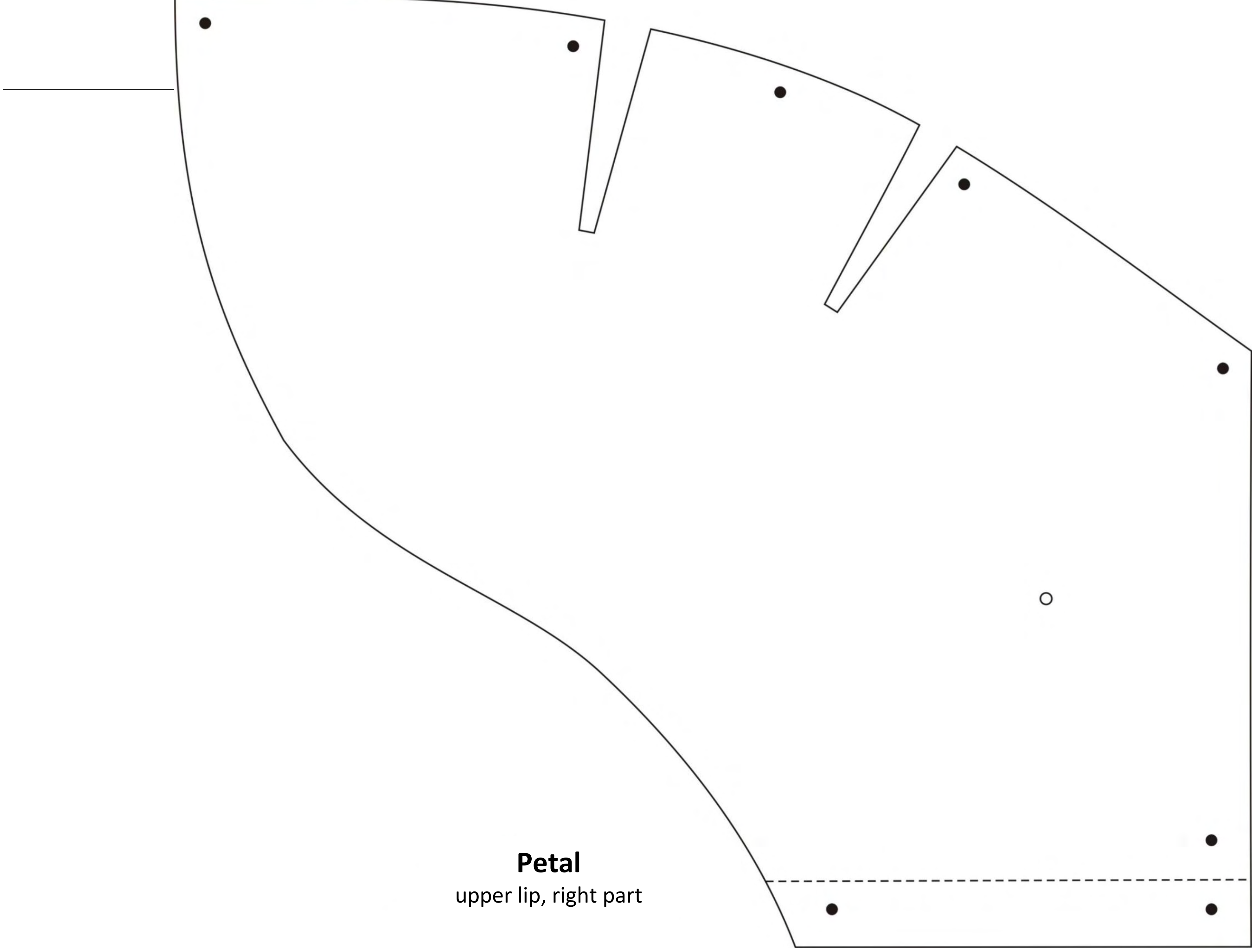
Petal

lower lip



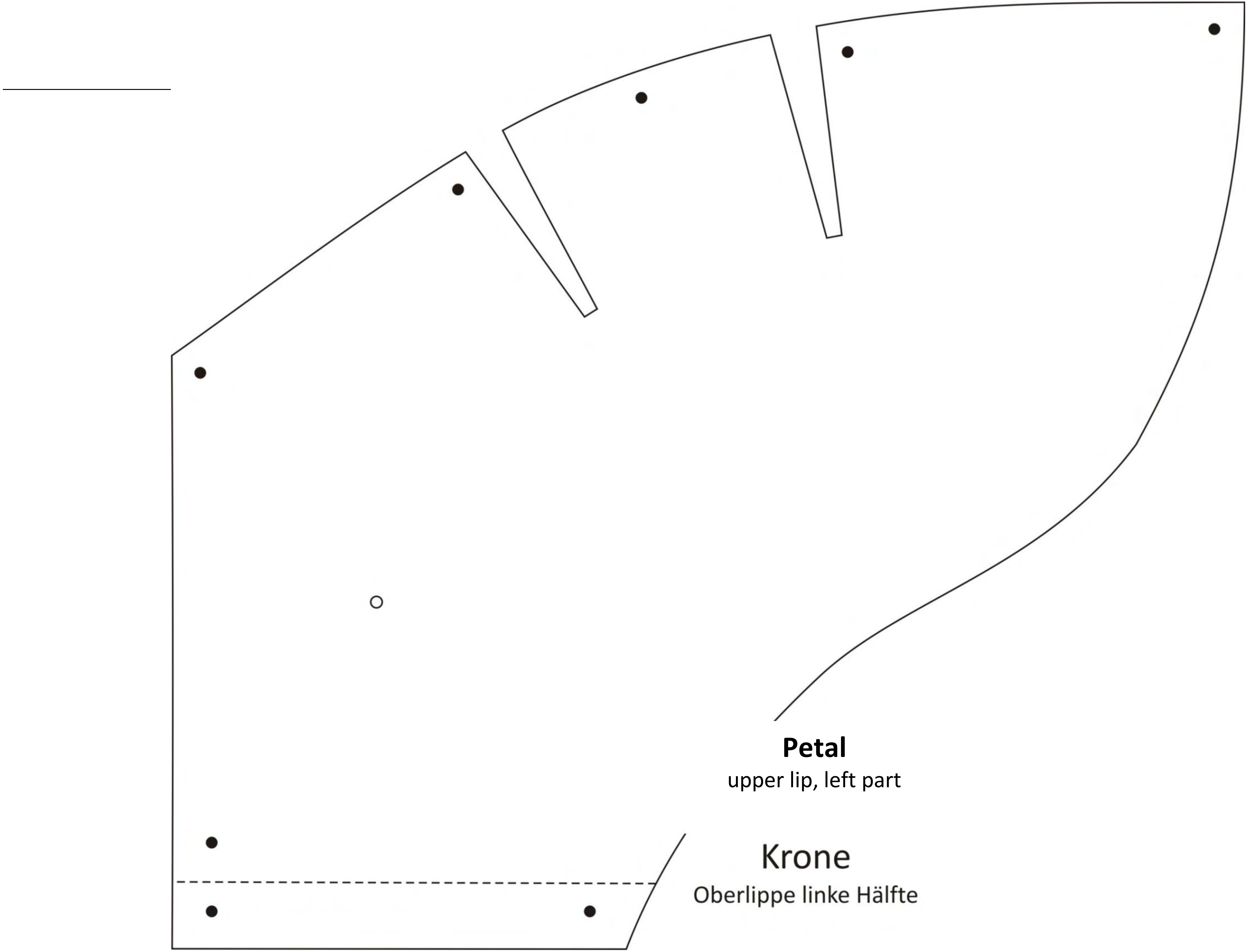
Petal

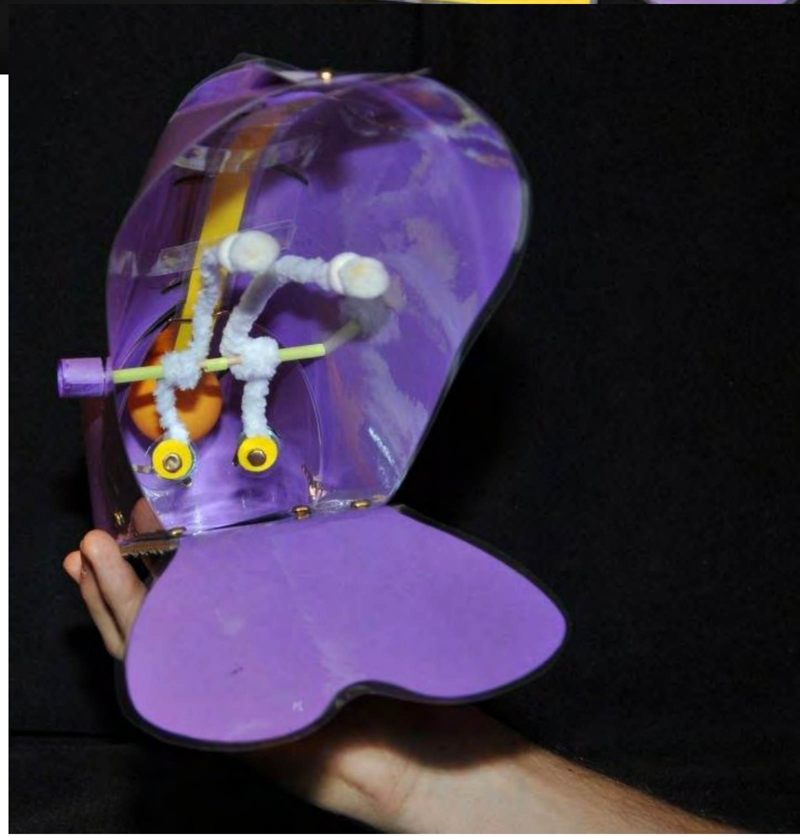
corolla tube



Petal

upper lip, right part


Petal
upper lip, left part
Krone
Oberlippe linke Hälfte



Act like an Insect

I am the following insect: ………………………………….

How did the flower attract me?

Colour: ………………………………….

Odour: ………………………………….

Sketch the structure of the flower:

What do I hope for at the flower?

How could pollination work here?

(*Keep the models in mind and observe the insects visiting the flower at the moment*)

Is the flower fitting to you as a pollinator? Why/Why not?

To which pollinator is the flower adapted?

Present your flower to the other insects and convince them of your choice.

Peter Lampert

Martin Rose
Michael Kiehn

Floral Ecology

Chosen insect: ………………………………….

Flower characteristics?

Colour: ………………………………….

Odour: ………………………………….

Sketch the structure of the flower:

Why would the chosen insect visit this flower?

How could pollination work here?

(*Keep the models in mind and observe the insects visiting the flower at the moment*)

Is the flower fitting the chosen pollinator? Why / Why not?

To which pollinator is the flower adapted?

Present your flower to the others

Observation record: Flower visiting insects

1) What is the proboscis length of the observed "insect":

2) Check which flower is visited by the chosen "insect"; sequence is important

Visited Flower			
1.	O short corolla tube	O medium corolla tube	O long corolla tube
2.	O short corolla tube	O medium corolla tube	O long corolla tube
3.	O short corolla tube	O medium corolla tube	O long corolla tube
4.	O short corolla tube	O medium corolla tube	O long corolla tube
5.	O short corolla tube	O medium corolla tube	O long corolla tube
6.	O short corolla tube	O medium corolla tube	O long corolla tube
7.	O short corolla tube	O medium corolla tube	O long corolla tube
8.	O short corolla tube	O medium corolla tube	O long corolla tube

Flower constancy

If a bee is able to find a sufficient amount of nectar in a flower it will visit flowers of the same plant species. This is called flower constancy.

1) Compare your observation record with the others. Can you find flower constancy in the observed "insects"?

2) Advantages of flower constancy
   - What is the advantage for the insect?
   - What is the advantage for the plant?
   - What is the basic requirement insects need to be flower constant?

Peter Lampert
Martin Rose
Michael Kiehn

Assignment: Find a plant per discussed flower (basket, lever mechanism, funnel shaped flower, disc shaped flower). Find out the following information for each plant:

	Plant 1	**Plant 2**	**Plant 3**	**Plant 4**
Name *(see label)*				
Flower type				
Colour				
Sketch				
Possible visiting insects?				
What does the flower offer these insects?				
How could pollination work?				

Assignment: You, as an insect, are getting to know new flowers. Choose three different flowers and explore them. Think about which one of them fits the best to you. Present this flower to the others and explain why it is your favourite.

Chosen insect: ………………………………….

	Flower 1	**Flower 2**	**Flower 3**
Colour			
Odour			
Sketch			
What offers the flower?			
Which pollinator fits the flower?			
How could pollination work?			