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← *Manually pulling down the wings-keel complex allows a closer look at the stamens and the style (Figure 1). ©Linda Hämmerle*

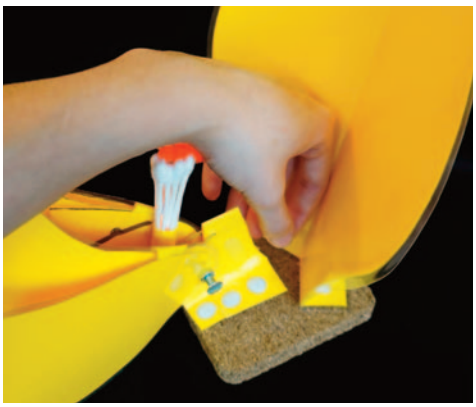
The process of pollination is important to understand plant reproduction. However, pollination often remains invisible for students due to the flowers' small size, which makes it difficult to understand the interactions between flowers and their visitors. Therefore, we have developed a variety of self-made functional flower models of Fabaceae, which visualize the interactions of plants and animals and give students the possibility to experience pollination first-hand. The family of Fabaceae contains various interesting pollination types and illustrates how small evolutionary changes in the structure of the flowers lead to major differences in functionality.

# USING FLOWER MODELS OF FABACEAE TO TEACH POLLINATION AND COEVOLUTION

## INTRODUCTION

"Plant blindness" describes the phenomenon that people overlook plants and their importance for life on earth (Wandersee & Schussler, 1999, 2001). Moreover, the "lack of movement" in plants leads to a lower interest in plants than in animals (Wandersee, 1986) and to the problem that students even see plants as "less alive" than animals (Yorek *et al*., 2009). This perception is likely to be supported by school textbooks, which focus mainly on plant morphology, but lack descriptions about needs, phenomena or interesting adaptations of plants (Schussler *et al*., 2010).

To increase students' interest in plants it is important to focus on properties which could be interesting for students (Strgar, 2007) and to provide direct experiences with plants (Sanders, 2007; Schussler & Winslow, 2007). Using plants for teaching which affect students' daily lives can support students' interest (Pany & Heidinger, 2015). Also, plant reproduction processes and structures have been shown to be suited to increase students' interests and make plants "liveliness" evident (Stagg & Verde, 2018; Lampert *et al*., 2019).



↑ *"Insect" pushing down the wings-keel complex (Figure 2). ©Linda Hämmerle*

Taking these considerations into account, the plant family Fabaceae offers several advantages for teaching. It contains many species connected to students' daily lives (e.g. Soy bean *Glycine max* or Pea *Pisum sativum*). Consequently, students are familiar with the fruits and seeds typical for the family. The seeds are easily obtainable and plants can be grown in a classroom in a few weeks. The unique shape of the flowers not only allows an easy identification of members of this family, but also builds the basic structure for a broad spectrum of functional adaptations and pollination mechanisms. These pollination mechanisms can surprise students and create curiosity, since they counteract the perception of plants that do not move. In the following section, we present a teaching approach focusing on these mechanisms.

## USING FLOWER MODELS OF FABACEAE FLOWERS FOR LEARNING

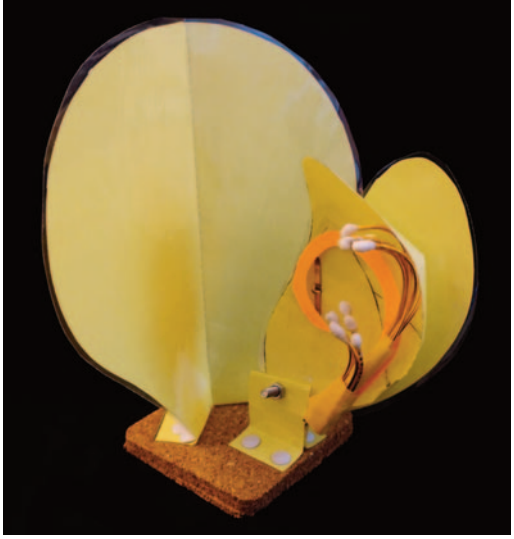
For the following learning session, knowledge about basic flower structures as well as basal knowledge about pollination ecology is recommended. Thus, the session needs to start with a repetition of the basic terms and processes regarding pollination.

**General idea of the lesson & design of the flower models**
The lessons' centrepieces are self-made flower models of various Fabaceae, which were developed in a scientific project at the Botanical Garden of the University of Vienna. The models are based on other self-made functional flower models used to illustrate pollination in tube shaped flowers and *Salvia* (Lampert, Rose, Kiehn, 2015). In the present setting, students interact with flower models of Fabaceae and experience the four main pollination mechanisms within this family: valvular, brush, piston, and explosive mechanisms.

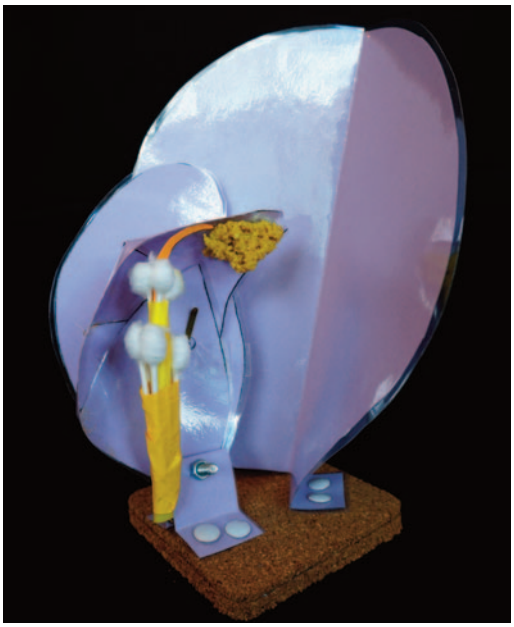
Valvular and brush mechanism are represented by functional models and students can interact with these models and "experience" pollination directly. Piston and explosive mechanism are illustrated by structural models and students can interact with corresponding simplified functional models. All materials used for the models are easily obtainable and building the models is simple. We suggest working with these models in stations, in which students interact with the flower-models.

**Working with the flower-models – working in stations**
The models for the valvular mechanism and the brush mechanism are prepared in two simple steps: 1) Place "nectar" (= a piece of candy) at the base of the corolla; 2) Put "pollen" (= curcuma powder) on the "stamens" (= cotton buds) or the "pollen brush" (= a chenille wire). To examine the flower, a student's hand acts as the "insect". When the "insect" (= student's hand) tries to reach the "nectar" (the candy), it triggers the mechanism and presses down the wings-keel complex, revealing the formerly hidden stamens and the style (Figure 1 & 2). In the valvular mechanism model, the "insect" touches the "stamens" whereas in the brush type models, the "insect" touches the "pollen brush". In both mechanisms, the "pollen" (curcuma powder) is placed onto the underside of the "pollinator" (the hand).

The structural flower models of the piston and the explosive mechanism showcase the stamens' position inside the closed keel, as one side of the keel and one wing have been removed (Figure 3 & 4). In addition, the piston or "pump" mechanism can be illustrated with a large syringe serving as a simplified functional model: The keel is symbolized by the barrel, the filaments by the plunger. The pollen is depicted by a mixture of curcuma powder, flour and water, which needs to be prepared in advance. By pressing the plunger, the "stamens" press out the "pollen" through a hole in the "keel"-tip (the syringe's hub) (Figure 5).



↑ *Structural model of the explosive mechanism (Figure 3). ©Linda Hämmerle*



↑ *Structural model of the piston mechanism (Figure 4). ©Linda Hämmerle*

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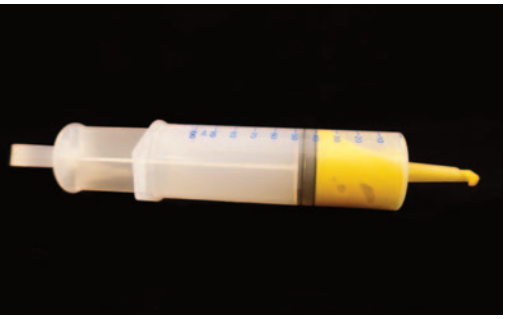

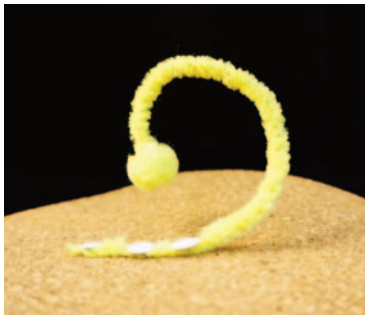

← *Simplified functional model of the piston mechanism (left - Figure 5) and simplified functional model of the explosive mechanism (right - Figure 6). ©Linda Hämmerle*

The functional model for the explosive mechanism consists of a single stamen made from chenille wire that showcases the tensioned position inside the closed keel. The chenille wire must be formed into a curled shape so that holding it flat manually produces tension. When released, the "stamen" snaps forward, hitting the "insect" (the student's hand), releasing all its pollen instantly (Figure 6).

**Connected tasks**

The students take notes regarding the pollination mechanisms in their working groups. Afterwards, the four mechanisms are compared and discussed in class, especially regarding the flowers' organs. This comparison makes clear that the structural differences between the different pollination-mechanisms are minimal. However, these differences have strong effects on the visitors and make the flowers either attractive or unattractive for potential visitors. The advantages and disadvantages of a narrower range of possible pollinators can be discussed, which leads inevitably to the topic of coevolution.

## DISCUSSION

The flower models are an easy and playful way to create student awareness regarding several topics of pollination and evolution. The models can be used both in a classroom setting or to support education at botanical gardens. The models help the understanding of key ideas of structures and functions, which are difficult to observe in the original flowers without prior knowledge. We suggest combining the flower models with observations on original flowers, e.g. *Laburnum anagyroides* (valvular mechanism), *Wisteria sinensis* (brush mechanism), *Lupinus polyphyllus* (piston mechanism) and *Cytisus scoparius* (explosive mechanism). In this way, the models can lead to a profound understanding of the original flowers and their functionality and limits of the models can be discussed.

Furthermore, the presented lesson can be combined with long term observations of growing e. g. peas or soy. These plants can then be pollinated by hand, which leads to additional experiences with the process of pollination. Finally, the development of seeds can be examined. This approach provides experiences with the whole life cycle of a plant and can help students to differentiate between the processes of pollination and seed dispersal, which are often mixed in students' conceptions (Lampert *et al.*, 2019).

To sum up, the presented flower models are suited to create a deep understanding for functional aspects of evolution and illustrate how small changes in the flowers' structure lead to major differences in functionality. Students' experiences with the models can be used to discuss the coevolution of flowers and pollinators. The models also focus on processes and mechanisms, which could improve students' perceptions of plants. The explosive mechanism is especially impressive and contradicts the idea of plants' "lack of movement". Teaching pollination of Fabaceae with the help of functional flower models provides fascinating insights in plant reproduction and evolution.

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