
THE STEINHARDT museum of natural history
מוזיאון הטבע ע"ש שטיינהרדט
متحف الطبيعة
شتاينهارت

אוניברסיטת תל אביב
TEL AVIV UNIVERSITY

Exhibition Curator: **Michal Krasny** Scientific Curator: **Dr. Zohar Yanai**

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# Pollination Unveiled: **A CURATOR'S PERSPECTIVE**

**Michal Krasny**
Exhibition Curator

The exhibition "Pollination Unveiled" was born out of a desire to present the story of pollination as a core biological process in ecosystems, and also, and perhaps mainly, due to the fact that it is not always visible to the eye. Pollination takes place on the sidelines of our consciousness, although its results are present daily on our table and in the landscapes around us. This gap, between the crucial importance of pollination and its transparent nature, gave the exhibition extra validity and relevance, and generated a fascinating work process.

As a temporary exhibition in the Steinhardt Museum, the exhibition presents findings, data and observations that demonstrate the complex interactions between plants and pollinators. However, during the initial planning stages it already became clear that an informative presentation alone could not completely represent the essence of the relationships, and that explanations about the mechanism of pollen transfer would not be enough; we must do all we can to use a visual, esthetic, and interesting approach to convey the fact that this is a dynamic network of relationships, mutual dependence, evolutionary adaptations and great biodiversity, and mainly that this is one of the most beautiful, fascinating, romantic and colorful processes in nature.

In my joint work with the scientific curator of the exhibition, **Dr. Zohar Yanai**, we chose to expand this perspective as much as possible. Thus, instead of

focusing on one familiar pollinator as a symbol, for example, the honey bee, we sought to present the multitude of actors in the system: a diversity of insects alongside mammals, Israeli flowers alongside an exotic orchid from Madagascar, pollination driven by wind and water, and the crucial importance of pollination in agriculture. The decisions for selecting the exhibition topics were not only technical; we also sought to express and emphasize the fact that the power of the system is hidden in its diversity; biodiversity is not a magical, colorful backdrop, but provides the basic conditions for ecological stability.

The artworks in the exhibition are an integral part of it. This is not just an esthetic addition or desire to enrich the perspective on the process, but rather a desire to provide an interpretation that allows further inspection of nature and processes described by science. To this end, we chose wildflower images from the inventory of Flora Palestina by **Nurit Gur Lavy Karni**, installed at the entrance to the exhibition, which offer a broad snapshot of the local vegetation. Unlike the classic botanical illustration tradition, which emphasizes a lone, identified flower, Gur Lavy Karni's work creates the sensation of a field, a system in which many species exist side by side. The choice to install this work as the starting point of the exhibition highlights the fact that pollination is a systemic phenomenon, not a single event. We chose to spread the images along the wall and to its full height to create an entire field at the entrance to the exhibition.

**Merav Cohen's** dried flower wall asks visitors to tackle the question of temporariness and preservation. The flowers, which underwent a traditional process of precise drying, maintain their shape after the end of their natural life cycle. Their installation in the exhibition is undoubtably a tribute to their botanical beauty,

but that is not all; it seeks to generate a discussion on our attitudes towards life cycles, preservation and memory. And in the context of pollination – a process that at its essence ensures continuity – the act of preservation becomes a kind of human echo of the natural mechanism of the continuation of life.

The exhibition will display a range of pollinators from the museum collections, alongside a colorful butterfly wall, installed on the other side of the flower wall. On the same wall, which displays the main actors in the system, there is also a circle of wasps by **Dafna Kaffeman** on display. These are realistic-looking wasps made of glass by glassblowing; an interesting, deceptive work of art, which required protection due to visitor curiosity. The circular motif in this artwork emphasizes cyclicality and continuity, while the glass, as a precise, fragile substance, highlights the vulnerability of pollinator populations in an era of climate change and habitat destruction. The choice to install this artwork alongside items from the scientific collection emphasizes the affinity between scientific documentation and artistic interpretation, and the possibility for these two fields to shed light on each other.

The botanic illustrations of **Bracha Avigad** (z"l), on display in the exhibition, provide historical evidence of the power of art to make a conscious change. In the early 1950s, as part of a public campaign to protect wildflowers in Israel, Avigad's images became an educational tool with real influence. Their integration into the exhibition is significant, mainly because of their spectacular, esthetic beauty, but it also emphasizes the understanding that the meeting between knowledge, image and the wider public can lead to a behavioral change and protection of nature.

Wandering through the exhibition invites a glimpse into the multilayer, rich world of nature, most of which is planted in the local landscape. It was important to

us to begin here: from the vegetation, the insects and the stories of the place in which we live. However, as we investigated the pollination process more deeply, we realized that in order to understand the depth of the phenomenon and its evolutionary sophistication, we must also look far away from here, to stories that were born in another climate, but put the spotlight on the same principle of precise mutuality.

One of these stories is the story of the orchid studied by **Charles Darwin**. After he received an orchid from Madagascar with a particularly long nectar spur, Darwin proposed a daring hypothesis: there is a pollinator in nature with a long enough proboscis that allows it to reach the nectar. Many years passed until a moth was discovered with dimensions that perfectly matched the prediction. This story, which is one of the most impressive examples of evolutionary prediction, demonstrates the extent to which the relationship between flower and pollinator is the result of mutual adaptation. The desire to display the said orchid led us on a long journey, with a detective dimension, among orchid growers in Israel. The journey ended successfully, and a real orchid plant is now on display in the exhibition in a suitable display cabinet.

From our journey to faraway places, we returned to local agriculture. Here we sought to integrate one of the many projects and studies that researchers from the museum are involved in. We chose the bumblebee, a pollinator with a central role in pollinating agricultural crops. This is another layer of the pollination system: advanced agricultural knowledge, planning and conscious activation of pollinators as part of a food production system that operates here in Israel. And from here came the decision to display an active, bustling bumblebee hive in the museum.

Alongside the beauty and sophistication, we cannot ignore the threatening crisis: climate change, habitat destruction and shrinking biodiversity directly impact species of insects and flowers that depend on each other. The pollination process, which for generations appeared to be stable and taken for granted, turned out to be more sensitive than we had imagined. The question of how to protect this system is directed at all of us individually and to the space in which we live and act. In an era in which natural areas are shrinking and ecosystems face accelerated change, the responsibility to protect does not fall only on the shoulders of researchers and decision makers. It has expanded into the private and community space.

**“The wild garden bestows not only interest, knowledge, pleasure, and satisfaction – but also moments of bliss upon its owner... like the song of the bees that resonates from within the oak and the buckthorn, surprising and delighting me anew”**, thus wrote Meir Shalev in the chapter “Moments of Joy” in his book *Wild Garden*. Shalev cleverly captured those same small moments of grace provided by the wild garden: a delicate, almost silent song, a beat of renewed life. Behind the simple happiness described by Shalev hides a complete system of interactions: between flower and pollinator, between tree and wind, between the observing man and the garden he cares for. This melody, which fills the air without us always noticing it, is what we sought to create in the exhibition.

A small wild garden in a private yard, community garden, school yard, or even a window box on the window sill, can become another link in the pollination chain. Sowing local wild plants, creating refuges for insects, avoiding use of harmful pesticides – all of these contribute to the stability of the delicate network that exists between flowers and pollinators. There is also place for human activities, not as a disturbing force, but rather as a responsible partner; these actions are seemingly modest, but have broad repercussions.

In this exhibition we sought to display, alongside the scientific story, local and faraway stories, artworks, Israeli pride and poetry. All of these point to one principle, both simple and complex:

> **Life takes place through connection. And this connection is planted in the nature around us – in the landscapes, fields, gardens and fragile ecosystems that sustain us. It needs our responsibility, just as we need the connection.**

# Pollination
# AS A WINDOW TO RESEARCH

**Dr. Zohar Yanai**
Scientific Curator
of the Exhibition

Curator of the
Entomological Collection,
Steinhardt Museum
of Natural History,
Tel Aviv University

The world of nature is extensive and diverse and can be characterized in different ways; countless phenomena, some common and others unusual, invite in-depth research and a continuous search for universal laws. Many nature researchers have already come to terms with the difficulty in formulating general principles; they usually make do with an in-depth description of one phenomenon or study case, and then apply them in detail to additional species, regions and conditions.

Among all the broad systems in nature, pollination is particularly prominent. As a phenomenon, it garners attention in many diverse fields, and has become a cornerstone of research, teaching and art.

First and foremost, pollination is an ecological interaction that involves different creatures and the environmental conditions in which they live. On one hand is the flowering plant, or more precisely, a very broad selection of flowering plants. The flower is the reproductive organ of the plant, and the pollination process is required to produce progeny in all flowering plants. The flower is also the advertising organ of the plant, through which it attracts the pollinator. On the other hand is the pollinating agent: sometimes it is abiotic, such as wind or water currents; while often it is biotic, in other words, an animal that mediates the transfer of pollen grains from flower to flower. This basic relationship structure develops and becomes complicated: in every ecosystem there is usually a large number of pollinators and plants, and different factors dictate the connections

formed between them. In some cases, there is one specific partner; in others – a large number of partners. The complex interaction networks that form in each ecosystem reflect many preferences and adaptations and provide fertile ground for questions such as what makes a specific connection in the pollination network more stable or fragile than another? Do all the networks act in the same way throughout the world? And more.

The compatible flower and pollinator find each other by means of communication. The flowers broadcast signs in different ways – shape, size, color, fragrance – and the pollinator receives the signs and the evident invitation to take part in the pollination process and get a reward. Sometimes the messages are complex, sometimes they are directed to a unique audience, and sometimes they are completely unreliable. In the world of pollination there is also baiting and deception. For example, the **Israel orchid** displayed in the exhibition mimics the colors of the squill and attracts pollinators who will not get any reward, but the success of this exercise in deception depends on the frequency of the orchids within the squill population. Economic and demographic factors are mentioned in an attempt to explain the success of this phenomenon.

Both flowers and pollinators have adaptations for their roles in the pollination process. These adaptations are expressed in body structure, sensory organs, behavior, activity period and more. Flowers that are pollinated by large, heavy insects, such as flower beetles, will look very different from flowers that are pollinated by hovering birds such as hummingbirds or by delicate butterflies with a long proboscis. Pollinators also have adaptations to the types of flowers to which they are attracted, expressed in their sensory organs, the structure of

the pollen collecting organs scattered over their bodies and the structure of their feeding organs, which enable the pollinator to reach the suitable part of the flower. A few prominent examples of compatibilities between flowers and pollinators are on display in the exhibition, such as beetles, flies, birds and other pollinators, alongside the flowers that are usually linked to them. Adaptations may even be found in the pollen grains themselves: the pollen grains of wind-pollinated flowers have incredible aerodynamic abilities that allow them to be carried easily through the air; while the pollen grains of insect-pollinated flowers have a rough wall that helps them stick to the pollinating insect. Visitors to the exhibition are invited to also inspect enlarged models of different types of pollen grains.

Every such trait serves the relevant pollination mechanism in an undirected, but seemingly perfect way for the task. This is not by chance: it is a masterpiece of evolutionary development, where each species changed slowly and gradually until it reached its current appearance. The change took place in parallel to a change taking place in its pollinating partner; thus, the relationship between plants and pollinators was updated again and again and became more and more precise. This chain of events, in which each side in turn responds to the actions of its partner and gradually improves its abilities, is called **coevolution** (in other words, joint evolution). This process continues even today! In each new generation of plants or pollinators there is the potential for additional honing of abilities and traits, so that pollination can take on a new face.

Pollination enables an in-depth examination of another fascinating evolutionary process – **convergent evolution**. Broad geographic scales reveal appearances that appear similar on distant continents or in separate ecosystems. Scientists identify

organs, traits and behavioral patterns in distantly related groups of plants and animals, such that evolution from a shared ancestor cannot explain the similarity between them. These appearances converged under similar conditions and selection pressures; they teach us an important lesson about mechanisms for coping with challenges in the natural world.

Many times, the reward received by the pollinator is pollen or nectar, but there are less common types of rewards, such as a meeting place, a night refuge, a suitable temperature and more. Of particular interest are the cases in which the pollinators do not receive a reward at all, since the plants are “mimic” plants that deceive the pollinator and attract it with false promises. There are also pollinators who “loot” pollen or nectar without providing pollination services in return. This complex system of promise, advertisement, reward, learning, reactiveness, punishment, mimicry and deception is an excellent model for research in the fields of psychology or economics, particularly when testing the stability of social norms under different conditions. Additional pollination stories from our local nature, accompanied by spectacular photographs and detailed explanations, can be found in the book ***Pollination in an Israeli Mirror*** (Dafni and Eisikowitch).

> **Pollination is one of the most essential ecosystem services in nature, and man benefits from it without investing any effort. But it should not be taken for granted. Each component in the delicate relationship that exists between plants and pollinators may be affected by unexpected disturbances, mainly those created by man.**

Damage to habitats makes them unsuitable for germination or growth of certain plants, or nesting or refuge for pollinators. Moreover, human activity may disturb the free movement of pollinators and pollen among habitats, movement that ensures gene transfer among distant populations. Species alien to the system, such as invasive plant species, or particularly aggressive pollinators, such as the **honey bee**, may compete with the local species and affect their performance. Pesticides and other toxins also disrupt the functioning of plants and insects. Furthermore, the developing climate crisis affects seasonal cycles and may affect the fragile timing between flowering periods and the activity periods of insects. All of these threats are being studied in pollination systems; from these studies, scientists reach understandings about the implications for other ecosystem functions.

For an in-depth understanding of the complex relationships between plants and animals we must familiarize ourselves with the particular species involved in them. This is done via taxonomic research, a scientific field that deals with the classification, identification and characterization of the different species in nature. Experts in identification and classification of plants and animals play a significant role in understanding the pollination process due to their familiarity with biodiversity. Extensive taxonomic research takes place in Israel, a country particularly rich in plants and animals (look for the wall displaying the ***Andrena* bee** in the exhibition...).

An entire scientific field – **palynology** – deals with the pollen grains themselves. Research in this field is facilitated by the high resilience and unique structure of pollen grains. This scientific field has many applications, and is used throughout the world to identify allergens, map pollination networks by collecting pollinators,

reconstruct ancient vegetation landscapes, deepen historical and archaeological knowledge, interpret crimes and much more.

Beyond the scientific, objective aspect, pollination provides inspiration for a range of artistic and cultural products: sculptures and paintings, poetry, music, literature, and other fields of popular culture. The spectacular actors – active pollinators, plants with colorful flowers – in their happy, relaxing environment, invite us to look more deeply, expand our engagement with them and integrate the unique atmosphere in plots, metaphors and imagery.

In summary, there is no doubt that pollination supports many fields of knowledge: reproductive biology, botany, zoology, ecology, evolution, genetics, taxonomy, biogeography, agriculture, nature conservation, physics, biomechanics, economics, archaeology and more. Pollination provides a wonderful opportunity for the wider public to be exposed to the world of nature and fall in love with nature from a new angle. You can be inspired by new aspects of the relationship between different branches of science and the pollination process while visiting the exhibition “Pollination Unveiled”. Among the pages of this catalogue you will find more articles that expand on the topics mentioned here.

**Merav Cohen**
**Israeli Wild Garden**
Pressed dried flowers. Pressed flower technique
Moments by Merav Cohen
2025

# POLLINATION UNVEILED

Pollination is more than a biological process. It's been nature's magic show for millions of years. Countless species of flowers alongside a great abundance of pollinators create a complex web of interactions, in which pollen grains go from flower to flower, carried by wind, water, or animals that are attracted to the flowers.

Plants are not passive partners. Studies have discovered that they listen, respond and lure with colors and scents, thus conducting a quiet dialog with their pollinators. Pollination plays a crucial role in ecosystems and in our daily lives. More than one-third of the food we eat depends on this delicate web of mutual interactions, which is currently in danger.

This exhibition invites you to take a look behind the scenes at one of the most spectacular relationships in nature and discover the full story.

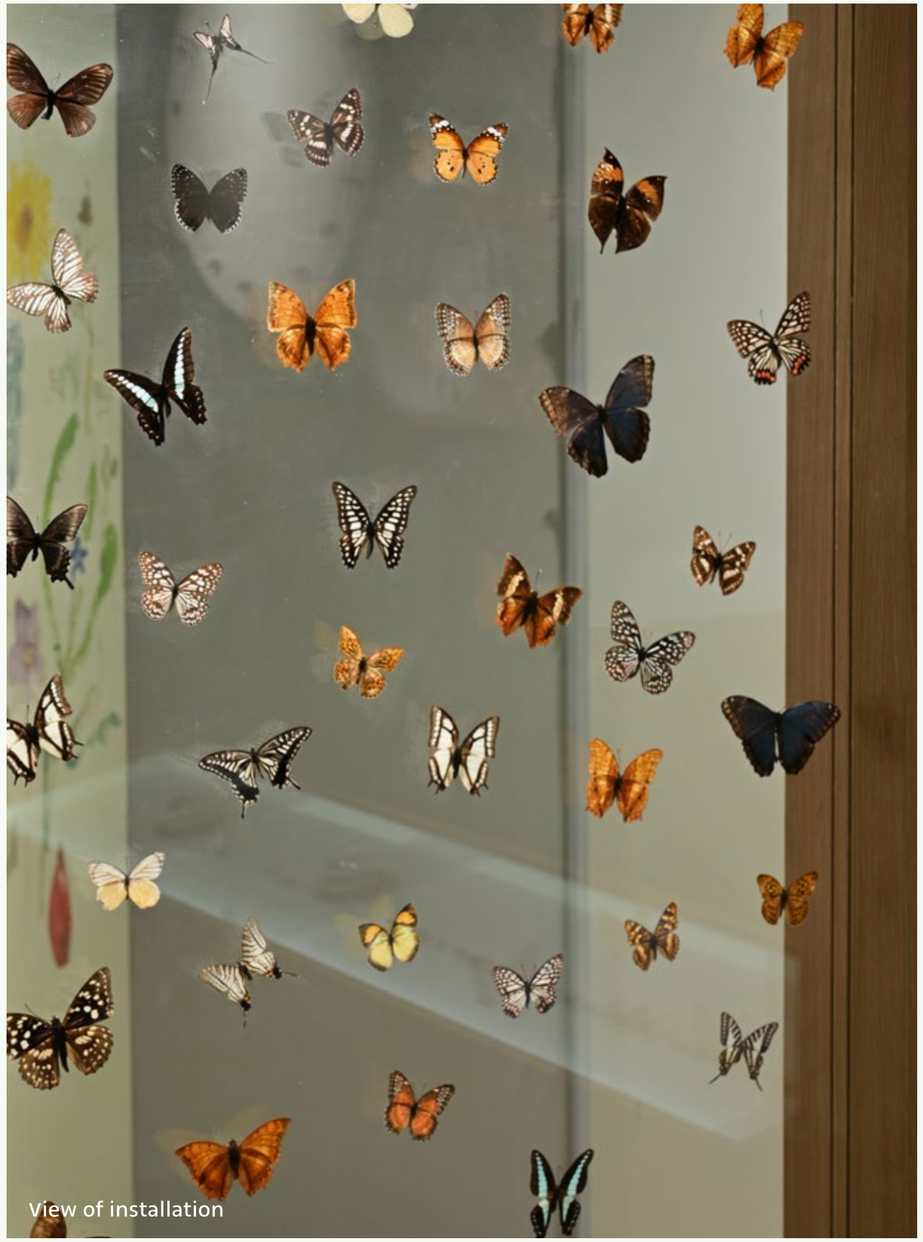

**Nurit Gur Lavy Karni**
**Flora Palestina**
View of installation

View of installation

Over millions of years, evolution has woven a harmonious relationship between flowering plants and pollinating animals in nature. Each flower is an open invitation to an encounter. Pollinators visit flowers in search of food, shelter or a meeting place; during their visit to the flower, their bodies get covered in pollen grains, some of which fall into the next flower they visit. This sophisticated mechanism, which connects flowers across large distances and facilitates the plants' life cycles, is called pollination.

The flower is the reproductive organ of the plant, and also a spectacular, fragrant and sophisticated way to attract pollinators. Countless types of flowers, in a variety of shapes, colors, textures and smells, allow plants to attract a compatible pollinator.

The honey bee is perhaps the most well-known pollinator, but nature abounds in pollinators: thousands of species of native bees, beetles, butterflies, moths, and flies, as well as bats, birds, lizards, crustaceans and worms. Each one of them has sensory, structural and behavioral adaptations that allow it to reach the right flower for it to pollinate.



View of installation

**Dafna Kaffeman**
**Wasp Circle**

This exhibition presents 25 illustrations by Bracha Avigad, from the collection of illustrations she bequeathed to the Botanical Garden of the Hebrew University on Mt. Scopus. Avigad, a Jerusalem artist, sought to reveal her love of nature through paintbrush and paper. She developed a special relationship with the staff of the Botanical Garden of the Hebrew University in Jerusalem, whom she decided to entrust with her illustrations, which she called “my children”.

The illustrations in this exhibition are digital scans of the original works, as part of our wish to make Avigad’s precious treasures accessible to the public.

**Bracha Avigad**, 1919–2016
**The Flowers of our Land, Land of Israel wildflower collection**
Courtesy of The Botanical Garden of the Hebrew University on Mount Scopus, Jerusalem


# HARMONY IN NATURE

Over millions of years, plants and pollinators evolved under continuing mutual influence. Plants that attracted more pollinators – through color, smell, shape or precise timing of flowering – were able to transfer more pollen grains to other flowers; pollinators that were able to effectively exploit the reward hiding in the flowers gained an evolutionary advantage over those that were less successful.

Cooperation between plants and pollinators contributed to the success of both sides in procreating and passing on their traits to the next generation. Coevolution – shared evolution of species with a reciprocal relationship – led to complex, and often wonderful adaptations.

View of installation

**Pied sage and violet carpenter bee**
View of installation

**Sea daffodil and striped hawk-moth**
View of installation


View of installation

# SPEAK TO ME IN FLOWERS

Flowers may not speak, but they send an unequivocal, clear message: “Come to me”!

During evolution, flowers evolved a range of means to attract pollinators: colors, fragrances, shapes, and even structures that mimic other organisms.

The encounter between flower and pollinator is not accidental; they communicate with each other through sensory stimulation, precise responses and wonderful coordination.

The pollinator provides the flower with pollination services and enjoys a reward: sweet nectar or nutritious pollen grains, and often shelter, favorable conditions or a meeting place.

# ABIOTIC POLLINATION

Not all plants need the help of animals for reproduction. Often, pollination is done with the help of the wind or water, which carry the pollen grains from one flower to another. Usually, the flowers of such plants are small and pale, and lack nectar.

## WIND POLLINATION

Plants such as wheat, corn, oak, pine, date and olive release myriad light, aerodynamic pollen grains, some of which find their way to a suitable flower. This may sound futile, but thanks to the great abundance of pollen grains, it works.

## WATER POLLINATION

For some water plants, the current is what “does the work”. The pollen grains float on the water or are swept along by the current, until they encounter the right flower.


View of installation

View of installation

# POLLEN GRAINS

Pollen grains are the tiny male reproductive cells of flowering plants. Each grain is encapsulated in a very resistant, hard outer wall, made from some of the strongest organic substances in nature. This trait enables pollen grains to survive like fossils in soil and rocks for thousands and even millions of years, almost without change.

Pollen grains have a unique structure, which serves as a botanical “thumbprint”. Therefore, they have become an interdisciplinary research tool: in geology they facilitate reconstruction of ancient vegetation and climates; in archaeology they provide information on plants that were used for food, medicines, ritual ceremonies, ornamental gardens and more; in ecology they reveal relationships between plants and pollinators and contribute to our understanding of natural processes and nature conservation; and in medicine they help identify sources of seasonal allergies. In come cases, pollen grains are used as a forensic tool for studying crimes, where the researchers use them to connect between the crime scene and those involved in the crime.

# RECONSTRUCTION OF ANCIENT ORNAMENTAL GARDENS

The garden of the satrap (governor) of the Persian Empire, which controlled the region during the 4th and 5th centuries BCE, was reconstructed by identifying pollen grains trapped in the plaster of one of the garden's ponds. Alongside local trees and shrubs, including grape, myrtle, fig and willow, imported plants such as cedar and walnut were also identified. The most surprising finding was pollen grains of citron (etrog), a tree originating in south-east Asia; this is the earliest evidence of citrus cultivation in the Mediterranean Basin. Later, it entered Judaism as one of the four species waved on the Sukkot holiday.

**Nirit Kedem**
**Restoration of the Persian Royal Garden at Ramat Rachel**
4th-5th centuries BCE (courtesy of the artist)
Pens, colored pencils
2012

View of installation

# THE MYSTERY OF THE ORCHID AND ITS MYSTERIOUS POLLINATOR

Charles Darwin (1809–1882) was one of the most prominent British scientists in history, who was active in England and conducted research expeditions around the world. Darwin formulated the idea of natural selection and explained how species change and evolve through the generations. His research, which focused on animals and plants, laid the foundations for understanding evolution in nature, including the complex relationships between flowers and pollinators.

When Darwin studied a Madagascan orchid flower with a particularly long spur (flower tube), he determined that there must be a pollinator with a particularly long, flexible proboscis, probably a moth, that is perfectly compatible with the flower structure.

Only forty years later was the hawkmoth that specializes in pollinating “Darwin’s orchid” discovered. Although Darwin himself did not merit to find this special pollinator, his prediction turned out to be correct when it was shown that in this case too, the flower and its unique pollinator evolved simultaneously in a process of coevolution.

View of installation

View of installation

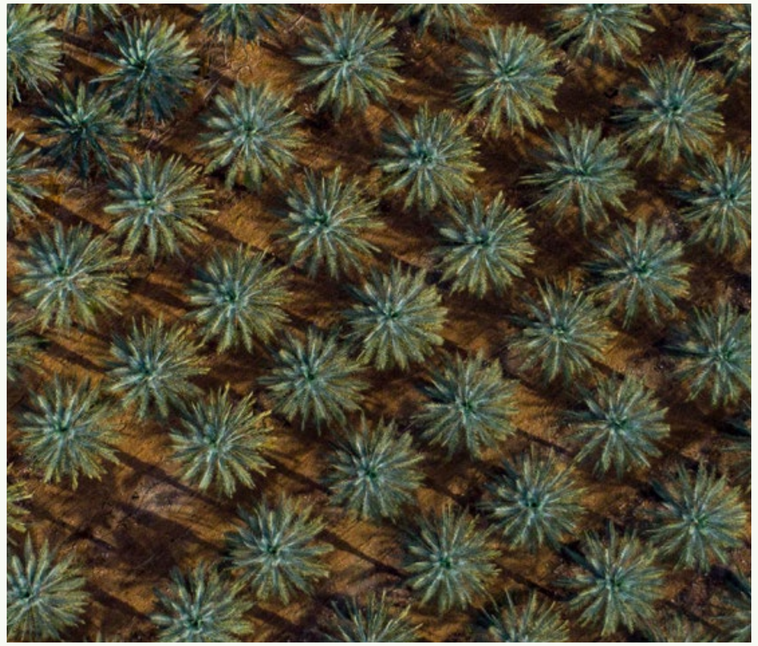
# AGRICULTURE AND POLLINATION

Agriculture depends on pollination. Fruits and seeds develop only after their flowers have been successfully fertilized. Also, for leaf and root crops, such as lettuce and carrot, the pollination process is essential to ensure future yields. It is estimated that about one-third of the food on our plate depends on insect pollination. Modern agriculture does not replace nature, but rather strengthens it through innovative technologies to ensure the stable, long-term production of healthy, high-quality food.

View of installation

## WIND POLLINATION

Some of the most important crops for human nutrition are pollinated by wind. These are mainly cereals, such as wheat, barley, corn and rice, which are the main source of energy in the global diet.



## HUMAN-ASSISTED POLLINATION

Dates are wind-pollinated, but in dense agricultural orchards the wind alone is insufficient. Farmers have found a solution for this through manual pollination methods, tailored to the traits of the date variety and the growing conditions in each region of the country.

## POLLINATION BY HONEY BEES

The main pollinator in agriculture is the honey bee (*Apis mellifera*), the most common domesticated insect, which populates many hives around the world and contributes to the pollination of many agricultural crops, such as apple, sunflower, cucumber, cotton and more.

Beyond their critical role in pollination, honey bees also contribute to another important branch of the economy – production of honey – a sweet output of their widespread activity.

View of installation

# POLLINATION BY BUMBLEBEES

The bumblebee is an important pollinator in agriculture. It is larger than the honey bee and performs “buzz pollination”: it vibrates it wings at high frequency, thus shaking the flower and shaking the pollen grains off it. Thanks to this trait, the bumblebee excels mainly in pollinating flowers whose pollen grains are hidden in the flower’s depths or don’t disconnect easily, such as tomato, eggplant and melon.

## THE IMPORTANCE OF NATIVE POLLINATORS

Alongside the honey bee and the bumblebee, which are used by farmers in modern agriculture, native pollinators also contribute to the success of agricultural crops. These pollinators come to farmlands naturally, and their presence is clearly reflected in the yield and quality of the crop. When they disappear from the landscape, agriculture is also affected. In cases of decreased function of the managed pollinators, that is, honey bees and bumblebees, the native pollinators serve as a natural “safety net” for the agricultural system.

# ISRAEL AS A BIODIVERSITY SUPERPOWER

Israel is located at a unique geographical and climatic junction: the intersection of three continents, different climatic regions and diverse vegetation formations. Thanks to these environmental conditions, which occur within a relatively small geographic area, Israel is home to a wide diversity of plants and animals and thriving ecosystems. Within certain biological groups, diversity is even higher in Israel than in some much larger areas. One prominent example of this is native bees from the genus *Andrena*, a solitary bee that nests on the ground and does not form social colonies.

**Native bees from the genus *Andrena***
View of installation

View of installation

# POLLINATION: SHOULD NEVER END

In the present age, the diversity of plants and pollinators is under greater threat than ever before. Human activity affects the ability of these species to survive, pushes many of them to the brink of extinction and upsets ecosystem stability.

Natural habitats are destroyed for construction and agriculture, and populations of plants and pollinators are separated from each other by structures such as roads and buildings. Unwise use of pesticides affects plants and insects, light pollution disrupts their diurnal activity patterns, and invasive species disrupt the delicate reciprocal relationships present in nature. Even the honey bee, one of man's important partners in agriculture, may affect native pollinators when it moves beyond farmlands. In addition, the climate crisis alters seasonal cycles and temperature and precipitation patterns, thus disrupting the synchrony between the flowering season and the pollinators' period of activity.

# THE SOLUTION IS ALSO FOUND AT HOME

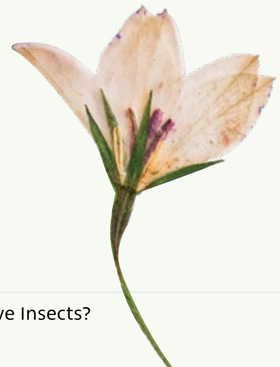
Some of the threats can be solved only by system-wide means, which are in the hands of planners, decision makers and elected officials. However, there are significant steps that each and every one of us can take to help native plants and pollinators.

To compensate for the loss of diverse, high-quality native areas, we can encourage the sowing of seeds of local native plants in private gardens, community gardens, school gardens, and even in window boxes and plant pots on balconies and windowsills. You can find out about initiatives that provide locally-sourced seed, according to the habitat and region of the country you are living in. You can also set up a “hotel” for insects (bug hotel) to provide housing solutions for various wild pollinators. Likewise, we recommend reducing or completely avoiding the use of chemical pesticides against insects or weeds. If you use them, you should only use substances permitted for use, following the manufacturer’s instructions and the law, guided by a professional when necessary.


**Bug hotel for pollinators**
View of installation

Prof. **AMOTS DAFNI**

# THE REWARD ILLUSION: How Do Flowers Deceive Insects?



## THE MASQUERADE IS AN ILLUSION

“Rabbi Purim, Rabbi Purim
tell me, speak
Why can’t Purim come
twice a week”.

A costume comprises items of clothing and makeup that give the wearer an identity other than his true identity. It is often used for deception and impersonation. In the world of flowers, masquerading is not limited to one day in the year, but rather continues throughout the entire flowering season. The “masquerading” flower mimics the appearance, color, fragrance or another characteristic, another flower or an animal, and thus deceives the pollinator, since it does not offer its visitors any reward.

To prove that mimicry indeed exists, between flowers of different species, or between a flower and some other living creature, four conditions must be met:

1. One creature (the mimic) masquerades as another creature (the model) and resembles its appearance, fragrance or other characteristic.
2. The mimic and the model live in the same habitat and are active during the same season.
3. There is a pollinator that has difficulty distinguishing between the signal broadcast by the model and that broadcast by the mimic; as a result it visits both of them.
4. The model rewards the pollinators that reach it. Mimicry is based on deceiving the pollinator, who does not receive the expected reward when visiting the mimic flower.

In this article I will present fascinating examples of mimic flowers, most of which are on display in the exhibition “Pollination Unveiled”.

## BEE ORCHID: A FLOWER THAT MIMICS A BEE

The flowers of the bee orchid (from the orchid family) closely resemble wild bees, hence their name. The similarity is not only visual. The flower also produces a mix of fragrances that resemble the smell of the sex pheromones secreted by the female of the wild bee who is ready for mating. This similarity, in appearance and smell, raises the question: how does the flower benefit from resembling a bee? First, let’s explain that these are wild bees (not honey bees), which are not social. Each female has her own nest, and the role of the male is limited to fertilizing the females. Males identify young females by their unique smell. The male bees emerge from the chrysalis about two to three weeks before the females, and this is exactly when the bee orchid flowers. The male is attracted to the flower as if it were a female bee, and tries to mate with it. He quickly discovers his mistake and goes to another flower, but not before the pollen mass sticks to his head and is transferred to the next flower he visits. And thus, pollination takes place.

Usually, each species of bee orchid is visited by male bees of a certain species. Occasionally, the males may get confused and transfer pollen between different species of bee orchid, thus hybrids may form.

The smell of the female wild bee changes after mating, and then she no longer attracts males. Surprisingly, the bee orchid also changes its smell after pollination, so that the male bees are attracted only to flowers that are still unpollinated. Thus, competition between flowers over the pollination services of male bees is reduced.

***Ophrys arachnites***
**A bee-orchid species not found in Israel**
The Watercolors of Vincent Fossat: Art in the Service of Science - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/publication/357628537_The_Watercolors_of_Vincent_Fossat_Art_in_the_Service_of_Science/figures?lo=1

**Dinsmor's bee orchid**
Photo: Noam Avitzel

As is characteristic of deceptive flower species, the visitor frequency of pollinators is low. Each flower blooms for two to three weeks (in contrast to three to four days for most plants); this long period compensates for the low chance of pollination.

There is a disagreement among researchers: is this complete deception, in which the flower masquerades as the female and the male receives no reward, or does he perhaps receive some other benefit? Some claim that males that train on bee orchid flowers, which flower for two to three weeks before the real female bees appear, will be more experienced and efficient, and will thus mate first with the female bees that appear in their surroundings. Another hypothesis claims that the multitude of bee orchid flowers, which produce the tempting smell, creates an atmosphere that encourages the activity of the males in their search for females.

**Pollination of an orchid that is not found in Israel (*Ophryus bombyliflora*) by a male from the genus *Eucera*.**
Note the similar hairiness of the flower and the bee.
https://www.youtube.com/watch?app=desktop&v=q0LcGbLcdA

## ISRAEL ORCHID: A FLOWER THAT MIMICS ANOTHER FLOWER

The flowers of the Israel orchid closely resemble those of the common Roman squill that flowers in the same habitat and season. The similarity between the two is expressed particularly by dark spots on a pale background; we believe that the purple dots on the labellum (the part of the flower that points forward and is used as a landing pad by insects) of the Israel orchid mimic the purple stamens of the squill.

**Israel orchid**
Photo: Eitan Shapira

Our observations in the field revealed that the Israel orchid and common Roman squill share the same pollinators, and the that the rate of production of the capsules (fruits) of the former depend on the density of the latter in the habitat. We also found that Israel orchid flowers were visited by hairy hoverflies *(Bombylius)* as well as wild bees of the genera *Eucera* and *Anthophora*, which were observed visiting the squill as well. When we collected several dozen visitors of the squill, we found that about one fifth of them were decorated with pollen masses from the Israel orchid, clear proof that they previously visited the orchid. This finding is proof of pollinator sharing, and the fact that the same pollinators get confused between the orchid and the squill and pollinate it. Therefore, it has been proposed that the flowers of the Israel orchid mimic those of the common Roman squill.

A study that examined the visual similarity between the mimic and the model showed that indeed, this is the cause of pollinator errors. The bees view the flowers of both species similarly and confuse them.

**Israel orchid and squill**
Photo: Noam Avitzel

## EASTERN MARSH HELLEBORINE: A FLOWER THAT MIMICS APHIDS

The labellum of the eastern marsh helleborine (orchid family) comprises two parts: the inner part resembles an elongated boat, whose basic color is yellow, with dark bumps that are dark red to black in color at its center; its outer part, which points forward, resembles a heart with two erect, triangular, lateral lobes. It has a shiny white spot on the end. There is a strand between the two parts of the labellum that enables the outer part to move due to pressure resulting from the weight of the pollinator.

The plant's pollen is packaged in masses and is not collected by insects for food. A small amount of nectar is secreted at the base of the labellum, adjacent to the dark bumps. The flowers are yellow with red stripes, and striking to the human eye. The flower's fragrance is weak to the human nose.

**Eastern marsh helleborine**
Photo: Yael Orgad

The mode of pollination is characteristic of all the observed hoverflies: the fly (male or female) lands on the outer part of the labellum, and due to its weight, causes it to bend downwards, like when sitting on a swing (the movement axis is the strand that connects the two parts of the labellum). When the arriving fly advances to the base of the flower, where the nectar is found, the balance between the two parts of the labellum is disrupted. As a result, the outer part of the labellum, which was previously pushed downwards, returns to its previous position and pushes the fly towards the sticky stigma located above the nectary. During the fly's attempts to free itself, pollen masses stick to it. When the pollen-loaded fly arrives at another flower, the pollen masses it brought with it are caught in the sticky liquid that covers the stigma, and thus pollination takes place. The female flies lay some of their eggs on different parts of the helleborine flowers, sometimes right next to the dark bumps in the middle of the inner part of the labellum. Female hoverflies have been observed touching the bumps with the end of their abdomen, and then laying eggs right next to them. In light of these findings, we proposed that the dark bumps of the labellum mimic by color, and perhaps also by smell, the aphids found on the flowers.

**Eastern marsh helleborine, view of the inner labellum.**
The dark bumps thought to mimic aphids are noticeable.
Phot: Uri Stein

**Eastern marsh helleborine front view**
Photo: Amots Dafni

A test of the fragrance compounds revealed the presence of three compounds that also exist in vetch aphid secretions. Tests of the hoverfly response revealed that both males and females “recognize” these fragrance compounds. Additional tests showed that the presence of these compounds causes the female hoverflies to lay eggs in exactly the same way as the presence of actual aphids. Female hoverflies lay their eggs near concentrations of aphids, and the emerging larvae feed on the aphids. Female hoverflies carefully choose the site to lay their eggs based on visual and olfactory stimuli. The fragrance compounds identified from the eastern marsh helleborine are the alarm pheromone of several aphid species. This pheromone is secreted regularly by the aphids, but in times of danger it is secreted in a much larger quantity. It thus appears that the eastern marsh helleborine flowers mimic the aphids’ alarm pheromone, which attracts hoverflies. This explanation is supported by behavioral experiments, which showed that the flowers’ smell (whether natural or synthesized) induces egg-laying by the female fly. This is proof that carnivorous


**A hoverfly visiting a flower of eastern marsh helleborine (left), on the right - two eggs laid on the flower by the migrant hoverfly**
Photo: Johannes Steckel

hoverflies use the aphids' pheromone as a reliable signal for locating their colonies. The data indicate that the flower does not mimic a particular species of aphid, but rather the compounds secreted by many aphid species, thus this mimicry attracts different species of hoverfly.

There is a small amount of nectar in the helleborine flowers, thus, probably by definition, this species is not a "deceiver". On the other hand, the signal advertised by the plant that attracts pollinators to it is deceptive and offers them a different reward (edible aphids, which in many cases are not present on the plant at all), thus, this advertisement is considered "false advertising". The question remaining is: what is the price of pollination from the perspective of the pollinator, since the larvae developing in eggs laid on a flower without aphids are liable to die of starvation.

## EPILOG

In all cases of deception presented above, some of which are displayed in the exhibition, the flowers use color, shape and smell to produce a "misrepresentation" that generates an "illusion" for the visiting insect, which thinks that it is the rewarding flower, based on its previous experience visiting "fair" flowers, i.e., those that pay a real reward for the visit. The question around this entire issue is why is it worthwhile for flowers to "deceive" insects? There is no consensus among researchers; rather, there are two main opinions: some hypothesize that "deceptive" plants save the energy required to produce nectar and can channel it towards other needs, such as growth or production of additional flowers. Others believe that the fact that the pollinators visit few flowers of "deceptive" plants and move on to plants that offer a reward increases the chance of cross pollination, which has an advantage over self-pollination.

From: Dafni A, Eisikowitch D (2023).
Pollination in an Israeli Mirror. Pardes Publications, Haifa.

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# POLLINATION IN ISRAEL: PAST, PRESENT AND FUTURE

**Due to its unique location at the intersection of continents and its richness of habitats, Israel is blessed with rich biodiversity, including 2,300 species of plants and thousands of species of pollinating insects.**

The field of pollination in Israel has attracted countless studies in the fields of botany, entomology, ecology, evolution and agriculture. Even research on pollen grains, those same microscopic flakes that transfer the genome from one plant to another, provides us with invaluable information. For example, the presence of pollen grains in prehistoric sediments gives us a unique glimpse into the world of plants that existed tens of thousands of years ago in the Mediterranean Basin[1].

Bees are known to have been bred in hives in Israel for approximately 3,000 years. Analysis of beehive findings discovered in diggings at Tel Rehov revealed that Anatolian honey bees were bred in the Land of Israel; this is a sub-species that still exists in the modern region of Turkey. Today, commercial breeding uses bees from the Italian sub-species. In the Land of Israel there was also a local sub-species of honey-bee, known as the "Syrian bee", which was more aggressive and less easy to domesticate, but during the 20th century it disappeared from nature[2].

We note that in the world of flowers, insects and pollination, honey bees are not the whole story. The honey bee is one species of bee from among over 1,200 species of bees living in Israel. The list of bees in Israel keeps growing all the time following new discoveries in systematic research[3]. Many bee species "specialize" on a very limited group of plants, each bee species and its compatible plant. This specialization is significant; often, their pollination abilities are unique and sophisticated, unlike those of less selective bees, such as the honey bee.

Other groups of insects, in particular, flies, moths and beetles, are characterized by high species richness in Israel, and many species of plants are adapted to pollination by them (for example, black calla, sea daffodil and bossed poppy, respectively). Non-insect pollinators have barely been studied in Israel, but one of our country's birds – the Palestine sunbird – belongs to a group of tropical birds that feed mainly on plant nectar, and some even pollinate[4].

Nature in Israel demonstrates a unique richness of interactions between plants and pollinators. Here, we will mention just a few examples: the Persian cyclamen, whose floral structure is compatible with pollination by large bees, but in practice, is pollinated mainly by moths; the poppy anemone, which flowers in a range of colors, each of which varies in attractability to different pollinators; the squill, which attracts a wide spectrum of pollinators when everything around it has dried up and it has no competitors; and the coastal iris, which

1.
Langgut, D. et al. 2011. Vegetation and climate changes in the South Eastern Mediterranean during the Last Glacial-Interglacial cycle (86 ka): new marine pollen record. Quaternary Science Reviews, 30: 3960–3972.

2.
Soroker, V. et al. 2018. Apiculture in Israel. In: P. Chantawannakul et al. (eds.), Asian Beekeeping in the 21st Century. Springer.

3.
Pisanty et al. 2022. Twenty-five new species of mining bees (Hymenoptera: Andrenidae: Andrena) from Israel and the Levant. Zootaxa, 5185: 1–109.

does not provide its pollinators with nectar or pollen, but serves as a night refuge for male bees[4].

But the most unique examples in the world of pollination belong to the orchids. This family, represented by only 34 species in Israel, represents the epitome of sophistication in pollinator exploitation. Most orchid flowers in Israel are “deceivers”, attracting their pollinators without providing any reward in return. Some of them (such as the Israel orchid) do this by mimicking other flowers, while others (such as the bee orchid) do it by mimicking female bees, which attract the males for mating[4].

In a country that leads agricultural production, development and technology, many studies have been conducted in Israel to improve the pollination of a range of agricultural crops using different pollinators, mainly honey bees. It has been found that the location of the beehive and timing of the bees’ entrance into the field or plantation is critically important for pollination success. Another pollinator that has been used extensively in agriculture is the buff-tailed bumblebee. This species has strong wing muscles that allow optimal pollination of flowers from the nightshade family, such as tomato, pepper and eggplant, in a process known as “buzz pollination”[5].

Some additional species have been studied with respect to their pollination abilities and potential for commercial use in agriculture, particularly species of bees that nest in hollow stems, which can be installed in farmlands[5]. Studies from recent years have also emphasized the importance of populations of native pollinators living adjacent to farmlands, and even inside them, as making an important contribution to the pollination of crops, in addition to the contribution of commercial pollinators, even acting as a “safety net” in cases where the latter are lacking[6]. Other studies have tried to find ways to improve pollination through technological and mechanical means, independently of native agents[7].

4.
Dafni, A. and Eisikowitch, D. 2023. Pollination in an Israeli Mirror. Pardes Publications. [Hebrew]

5.
Dag, A. 2009. Interaction between pollinators and crop plants: The Israeli experience. Israel Journal of Plant Sciences, 57: 231–242.

6.
Pisanty, G. et al. 2016. Watermelon pollinators exhibit complementarity in both visitation rate and single-visit pollination efficiency. Journal of Applied Ecology, 53: 360–370.

7.
Bechar et al. 1999 Modeling and experiment analysis of electrostatic date pollination. Transactions of the ASAE, 42: 1511–1516.

What does the future hold for pollination in Israel? Nature conservation challenges in our crowded country are unrelenting, and the combination of shrinking natural areas, climate change and a range of local disturbances created by humans puts many species of plants, pollinators and even entire ecosystems in danger. When the natural areas shrink, competition forms between different actors in the world of pollination, particularly between commercial honey bees and native bees and other native pollinators. The difficulty in finding a balance between the needs of humans and agriculture and the needs of nature is expressed by increased invasion by commercial honey bees into natural areas at the expense of the native pollinators living in these areas[8]. Similarly, there are threats from various invasive species, such as the dwarf honey bee, which has invaded the Eilat region and is spreading northwards[9]. These challenges and many others require all of us to be proactive, but also to take a long-term perspective to protect the world of plants and pollinators and all its richness.

8.
Tourbez, C. et al. 2025. Commercial honey bee keeping compromises wild bee conservation in Mediterranean nature reserves. Apidologie, 56: 11.

9.
Moritz, R.F.A. 2010. Invasion of the dwarf honeybee Apis florea into the near East. Biological Invasions, 12: 1093–1099.

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# THE CONTRIBUTION OF **POLLEN GRAIN RESEARCH TO ARCHAEOLOGICAL RESEARCH**

Plant pollen grains are produced in the stamens, the male reproductive organs of the flower, and carry the male reproductive cells. They are transferred by wind, water or animals (mostly insects) to the style, the female reproductive organ of the flower, and thus reproduction takes place. Every plant has its own characteristic pollen shape; thus, pollen grains serve as the plant's "ID card". Pollen grains are tiny; their size ranges from a few microns (thousandths of a millimeter) to a few tens of microns, and they are identified mainly by light microscope.

Wind-dispersed pollen grains have a broader distribution than those dispersed by insects, and they reach significant distances more easily. Moreover, to increase the chance of pollination, wind-pollinated plants produce pollen grains in larger quantities than those produced by insect-pollinated plants.

## POLLEN GRAINS AND ARCHAEOLOGY

Pollen grains have very high preservability; they may be preserved as fossils for hundreds or even thousands of years, and can therefore assist the resolution of archaeological mysteries. The preservation conditions of pollen grains are particularly good in places where oxidation processes are very slow, such as sediments that accumulate at the bottom of the sea, lakes and swamps, as well as desert environments. By reconstructing ancient vegetation, researchers make conclusions about climate change. By identifying fossilized pollen grains at archaeological sites (a scientific field known as archaeobotany) it is possible to answer a wide range of questions about the lifestyle of the ancient residents of the region. For example, in what season was the site established, what was the residents' nutrition, what were their survival strategies – agriculture, grazing and so on – ritual customs, trade relationships, ancient botanic gardens etc.

The fossilized pollen grains at an archaeological site can be sampled from floors, ceramic vessels, plaster spread on walls, animal droppings and so on.

## THE PALACE AT RAMAT RACHEL

Recently in Israel, unique findings were discovered that spread new light on the study of ancient royal gardens in our region. Diggings at the Ramat Rachel site near Jerusalem revealed a magnificent architectural structure that was identified as the palace of the representative of the Persian Empire in our region, approximately 2,500 years ago. Diggings conducted in recent years around the palace by Prof. Oded Lipschits and Prof. Yuval Gadot (the directors of the archaeological dig) revealed an ancient royal garden. The archaeologists were very curious to discover what grew in this garden, but no botanical remains were preserved in the soil, and the riddle of the garden's vegetation remained unsolved. Therefore, it was clear to the researchers that less routine archaeobotanical techniques were required. They decided

to try to determine whether pollen grains had been trapped in the plaster of the garden buildings. Over the years, the buildings were plastered with several layers of plaster for maintenance purposes. The working assumption was that if one of the layers was plastered during the spring, when the garden was at peak flowering, then pollen grains in the air at that time should have stuck to the wet plaster and been sealed in it.

## RECONSTRUCTION OF THE PALACE GARDEN VEGETATION

Identification of plants that grew in the garden is based on the isolation of fossilized pollination grains from plaster that covered one of the ponds in the garden. The microscopic examination also identified a surprising, unique collection of fruit trees, ornamental plants and trees that do not grow in our region, but were brought to the royal garden from a great distance.

The most surprising finding discovered by this study was the citron (etrog). This was the most ancient direct botanical evidence for the cultivation of this tree in the eastern Mediterranean. The citron originates from eastern India and southern China, and it is the first species from the citrus family that spread westward, probably through Persia (modern day Iran). Its Hebrew name, etrog, even hints to its origin: in Persian, the citron is called “etronj”. Since the garden at Ramat Rachel was abandoned towards the end of the fourth century BCE, the identification of citron pollen in the garden teaches us that during the Persian Period, at the latest, the citron was already being cultivated in the Land of Israel.

Another tree that does not grow wild in Israel, and was identified in the pollen collection from the garden, is the cedar of Lebanon. The identification of pollen grains from the cedar in the garden at Ramat Rachel proves that it was grown in the garden.

The walnut too, does not grow wild in Israel. This plant originates in the cool temperate habitats of Persia and its surroundings, where it was probably originally cultivated. Pollen grains of this tree were also identified in the collection found in the plaster of the pond in the royal garden.

Among the fruit trees that grow naturally in the region, and were identified at Ramat Rachel, we must mention the grape and the fig. The existence of these trees in the garden plant collection is unique, since the pollen grains of these species have limited dispersal ability, as they are not carried over large distances. The cultivated grape usually self-pollinates, while the fig is pollinated by a wasp inside the fruit. Thus, the presence of pollen grains of these two plants in the pond plaster proves that they grew nearby.

Among the other plants identified through pollen grains in this study were poplars, fast-growing tall trees, which may have been used to make a perimeter fence; common myrtle, common in ornamental gardens because of its pleasant fragrance, its long flowering period and the fact that it can be easily pruned into eye-catching shapes; as well as duckweed and water lily, two species of water plants that were planted in the garden pond for ornamental purposes.

## SUMMARY

This study shows how the identification of fossilized pollen grains can shed light on archaeological questions that had remained hidden from the eye. The unique sampling method allowed the first accurate reconstruction of the vegetation components of the spectacular royal garden. Through an understanding of pollination mechanisms and other botanical parameters of the different plants identified in the garden, we can imagine how the garden looked. The collection of pollen grains identified in the royal garden at Ramat Rachel is unique in its rare composition and provides evidence of the desire of the local ruler, the palace resident, who

was probably the regional representative of the Persian Empire, to glorify in a spectacular garden for propaganda purposes, so that visitors to the garden and the region's subjects would see his grand abilities. Thus, he imported trees from distant locations in the kingdom, such as the citron, cedar of Lebanon and walnut, and planted plants that require irrigation and care – the willow, poplar and grapevine – which in their native habitats usually grow near water bodies, so their presence at the site provides evidence of their irrigation. We must also remember that the site is close to the desert transition zone, and the garden flowering in it most certainly was very prominent on the backdrop of the natural environment. The garden was designed, therefore, to present its resident as an all-powerful ruler who rules nature and shapes it at will, just as he rules his subjects.

# Pollination: **Unveiled**

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