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Insects in the service of humankind

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TECHNION
Israel Institute of Technology

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INSECTS IN THE SERVICE OF HUMANKIND

Review and Recommendations for the City of Afula as a Hub to Promote the Field

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Executive Summary

Insects are of fundamental importance to the ecosystem on Earth and their existence is critical for human survival. Insects play a variety of roles in the service of humankind, while the full potential of using this option is found in various stages of research. In general, it can be stated that the market for insect applications in the service of humans is on the rise worldwide, and has the potential for significant growth in the coming years. According to various estimates, about 150-300 companies are engaged in insect-related areas, most of them start-ups that were founded during the last two years, mostly in the US and Europe. However, the different areas are characterized by variable levels of maturity and different development timeframes, depending on the unique characteristics of the technologies and target markets. In this study, we classified the different aspects of insects in the service of humans into three main areas:

1. **Insects in agriculture and public health**
2. **Insects as a source of food and feed**
3. **Insect-based systems and materials**

The field of insects in agriculture and public health is divided into several sub-areas, including pollination, pesticides, extraction of medical materials, and waste treatment. While it seems that the fields of pollination and pest control are in a relative steady state, with about 10 world leading companies in these fields, the rest of the sub-areas (as well as more innovative approaches to pest control) are in advanced stages of research, on the verge of commercial breakthrough; the biodegradable waste market alone is estimated globally at approximately 750 billion dollars a year.

Insects as a source of food and feed is one of the most promising areas of insect applications in the service of humans, and recently has attracted increasing global interest, where most of the players are from the food industry and not necessarily from the field of insects in agriculture. According to some predictions, the market of edible insects may reach half to one and a half billion dollars within 5 to 8 years; the global animal feed market is estimated at approximately 460 billion dollars, so that this market also has a very significant potential. However, it should be noted that, although edible insects are not a new phenomenon, their cultivation as an agricultural activity for food is expected to face tightening food safety regulation – regulation which is mostly still in its early formation stages, and hence it is difficult to fully assess its potential implications on the growth of the sector.

Applications of insect-based systems and materials are not a distinct discipline, and almost always belong to much wider fields of science, such as robotics, electronics, software, biochemistry, and materials engineering, where they constitute one solution out of many for the scientific challenges presented by each academic school. Respectively, these applications are aimed toward a wide range of target markets: from industry and textile, to transportation and military systems, making it difficult to assess the full market potential today. Furthermore, most of the applications developments are still in the research stage and are not yet being used on a commercial scale, and some are military and still largely confidential.

In Israel, the interest in insects for the service of humankind is scattered across a number of small centers in the academia, industry, and the world of entrepreneurship. In the academia, there are a number of collaborations taking place between universities and various research institutions. It seems that these connections are founded mainly on a regional basis and there is no regular contact between the institutions in the north and those in the central and

southern parts of the country. This can be attributed to the broad areas of knowledge that relate to this field, but also to the lack of high-level scientific and professional conferences that bring together those who work in this field. On the industry side, most of the commercial activity is in the areas of pest control and pollination, which are the more traditional applications in agriculture, executed by mature companies. It seems that these companies are working to expand their operations with both additional geographic markets and new areas of activity, through active investment in research and development. In the field of entrepreneurship, the first signs of startups that focus on innovative applications in the fields of food and nutrition have appeared, and it seems that there is considerable interest and awareness of the subject on the part of venture capital entities, which are positive signs for the start of a full ecosystem formation in this field in Israel.

Mapping of the Ecosystem in Israel

	Agriculture **Pollination, pesticides, public health**	**Food** **Human food, animal feed**	**Systems** **Systems, materials**
Academia	· Hebrew University, Agriculture Faculty · Haifa University, ORANIM campus · Sapir College	· Hebrew University, Agriculture Faculty · The Technion · Tel-Hai College	· The Technion · Tel Aviv University
Research	· MIGAL · R&D North · Volcani Center	· MIGAL	-
Industry	· Bio-bee · Yad-Mordechai	· Bio-bee	-
Entrepreneurship	-	· Hargol Foodtech (Trendline) · Flying spark (The Kitchen)	-

The various applications of insects in the service of human are a good example of the connection of several foci of Israel's relative advantage, in that they require integration and synergy between the knowledge that was originally designed to serve the agriculture sector, for example, and the knowledge in chemistry and medicine. The ability to create such a connection is a characteristic strength of Israel, and can help Israel to become a global "game-changer" in the areas in which it will be implemented. In order to realize the business and scientific potential inherent in the development in Israel of the sector of insects in the service of humankind, there are recommended areas on which to focus in the short and medium term. The international review that has been conducted and the interviews that took place with key people in the field seem to indicate that **the areas of agriculture and of food and feed have the greatest potential in the immediate to medium term**. It should be noted that the food sector in Israel is expected to be commercially limited due to the Kosher limitations of most types of food made from insects.

As part of developing an action plan, we examined a number of possible alternatives for founding a center to promote insect activity in the service of humankind. Afula, as an urban center surrounded by agriculture, is suited to serve as a basis for activities related to insects in the service of humankind, and its leaders have even expressed a willingness and desire to promote this issue as part of the continued development of the Entrepreneurship Centre recently established there. Afula is a city that has been rapidly developing in recent years, with a number of local and regional assets that the hub can leverage for the benefit of its activities.

The global review shows that engagement in research and development of various aspects of insects in the service of humankind is on the rise, and in some areas even on the verge of a breakthrough, in view of the enormous potential of insects as a platform for creating solutions for a variety of challenges facing

humanity today and in the coming decades. Thus, the importance of this issue for the long term and the need to form a policy for its promotion are obvious.

At the national level, examination of the Israeli perspective shows that dealing with insects in the service of humans is gathering a positive momentum and shows preliminary signs of a healthy mix of research, development and industry. Although it is necessary to overcome the breakthrough phase, which may take several years, Israel is well positioned to build industry-leading capabilities in this area at the global level, in both the academic and business spheres.

In light of these conclusions, these are our recommendations for a national policy for Israel:

1. **In Israel, great importance and systemic attention should be devoted to promoting the activities on the subject of insects in the service of humans.**
2. **It is necessary to act to establish a national-global center in Israel to promote research and entrepreneurship on the subject of insects in the service of humans.**

Further to these policy recommendations, the proposed action plan, and the willingness of the municipality of Afula to promote this issue, the recommended strategy for Afula is to establish a knowledge center that should develop further into an entrepreneurship center. The vision is of **an entrepreneurship and industrial center that integrates the scientific and business knowledge in Israel in the field of insects to the service of humans.**

Introduction

Through four hundred million years of evolution, insects have evolved into the class with the greatest number of species in nature. Many species of insects have not yet been discovered, but the prevailing belief is that there are between six and ten million different species, representing more than 90% of all life forms on the planet. Out of the million known species of insects, only about five thousand could be harmful to humans, livestock, and crops (FAO, 2013).

Insects are fundamentally important in Earth's ecosystem and their existence is critical for human survival. They possess an exoskeleton that protects them from the environment, are cold-blooded, breed quickly, with resistance to high and low pressure, as well as to radiation (Delong, 1960). Insects play a central role in nature, such as in the process of plants reproduction – including food crops – where an absolute majority of 98% of pollinators belong to the class of insects (Ingram, Nabhan, & Buchmann, 1996). Insects play a vital role in the process of decomposition of waste: they feed on dead parts of plants and decompose organic molecules to a level at which they can be digested by fungi and bacteria, thus helping to return minerals and nutrients to the earth, and from there to the cycle of plants' nutrition. Insects also help in the decomposition of carcasses and of livestock manure, allowing the return of nitrogen, carbon, and various minerals to the soil as nutrients for plants.

Insects play a variety of roles in the service of humankind, yet the extent of their full potential is still being researched. In this study, the different aspects of insects in the service of humans were classified into three main areas:

1. **Insects in agriculture and public health**
2. **Insects for food and feed**
3. **Insect-based systems and materials.**

Global Review

The oldest and most characteristic applications of insects for human needs are for the production of honey and silk. Other products derived from insects include edible and fabrics colors, resilin (a protein with elastic properties) that is used in medicine for the restoration of damaged blood vessels, beeswax, and more. Other uses in the fields of engineering mimic natural solutions (a field called biomimicry) in a variety of applications, for example the imitation of the structure of termite mounds for optimizing temperature control in the design of buildings. Efficient and economic insect agriculture is an important and interesting field, both scientifically and commercially, for the development of the industry. The agriculture processes should enhance the quantity and quality of the product while considering factors such as the quality and cost of nutrition, temperature, air circulation, lighting, and other growing conditions, and therefore the mere agriculture of insects has potential for innovation and developments.

In general, it can be stated that the market of 'insects in the service of humans' applications is on the rise worldwide, and has the potential for significant growth in the coming years. According to various estimates, there are about 150-300 companies engaged in insects, most of them start-ups that were founded in the last two years, mostly in the US and Europe. However, the different areas are characterized by a varied level of maturity and development timeframes, depending on the unique characteristics of the technologies and the target markets.

The field of insects in agriculture and public health is divided into several sub-areas, including pollination, pesticides, medical materials extraction, and waste treatment. While it seems that the fields of pollination and pest control are in a relative steady state, with about 10 world leading companies in these fields, the

remaining sub-areas (as well as the more innovative approaches to pest control) are in the advanced research stages, on the verge of commercial breakthrough; the biodegradable waste market alone is estimated globally at approximately 750 billion dollars a year.

Insects as a source of food and feed is one of the most promising areas of insects' applications in the service of humans, and has recently begun to attract increasing global interest, where most of the players come from the food industry, and not necessarily from the field of insects for agriculture. According to some predictions, the market of edible insects may reach half to one and a half billion dollars within 5 to 8 years; the global animal feed market is estimated at approximately 460 billion dollars, offering a very significant potential. However, it should be noted that, although edible insects in themselves are not a new phenomenon, their cultivation as an agricultural activity for food is expected to face tightening food safety regulation. This regulation is still in its early formation stages, and therefore it is difficult to fully assess its potential implications on the rate of growth of the sector.

Applications of insect-based systems and materials are not a distinct discipline, and almost always belong to much wider fields of science, such as robotics, electronics, software, biochemistry, and materials engineering, where they constitute one solution out of many for the scientific challenges presented by each academic school. Respectively, these applications target a wide range of markets, from industry and textiles to transportation and military systems, making it difficult to assess today the full market potential. Furthermore, most of the applications developments are still in the research stage and are not yet being used on a commercial scale, and some are military and still largely confidential.

Insects in Agriculture and for Public Health

Pollination

Among the various services provided by insects to human beings, one of the most important is in the field of plant reproduction. Out of the 100,000 species of pollinators, 98% are insects, and more than 90% out of 250,000 flowering plants depend on pollinators for their reproduction, including about three-quarters of the 100 different species that constitute the majority of food crops (Ingram, Nabhan, & Buchmann, 1996).

Cultured bees are responsible for the pollination of about 15% of agricultural crops, but the acculturation of other species of insects for pollination purposes is also being examined. Commercial breeding of bees for the pollination of crops is an area of business with a global presence, consisting of major players (the leading companies in this field are Koppert and Bio best), which develop and market honeybees and bumblebees as part of the system of pollination services.

In recent years, the bee population in many regions of the world is in a state of crisis, in part due to the harmful impact of Neonicotinoids – a group of pesticides that acts on the central nervous system of insects and causes paralysis and death. This crisis threatens to affect directly the agricultural crops that rely on the pollination services of bees, as well as the production of honey. This crisis creates an additional incentive for further development of the field of pollination on the one hand, and on the other hand, for expanding the use of biological pest control as an alternative to that of chemical pest control.

Pest Control

Insects may cause damage to plants, but they can also be part of the solution. The damage caused by insects can be further divided into direct damage (insects' feeding) and indirect damage (pathogens such as bacteria, viruses and diseases transmitted by the insect).

The growing resilience of insects to pesticides, the changes occurring in the flora environment, including exposure to pests and new diseases, the tightening of regulations over the development and use of strong and residual substances, and the fact that the combination of different measures and mechanisms is more effective over time, raise the need for advanced strategies for pest control. An example of a strategy that is increasingly being used is IPM (Integrated Pest Management). This sustainable method focuses on long-term prevention of the need for pesticides and reducing the damage caused by pesticides, by incorporating measures such as biological control, environmental manipulation, changing and adapting methods of operation, and combining various preventative elements. An additional measure of IPM for crop protection is the use of insects. Biological control using insects is achieved by using pathogens, predators, or parasites that are spread by seeding redistribution and acclimatization or flooding.

The use of insects as a helpful agent in reducing pest populations is a trend that is gaining strength every year. This type of pest control uses a variety of techniques, including pheromone manipulation (an area considered commercially mature in the world), the use of sterile insects (SIT –sterile insect technique), and even genetically modified insects. The SIT area, which is less mature, is also growing and gaining momentum against the backdrop of the mosquito-borne Zika virus plague; this area has great potential, with an emphasis on the European market.

Other developments use insects as vectors bearing medicinal properties, or alternatively disabling disease vectors in attacking insects. Bacteria interacting with insects (symbionts) can be used as a basis for developing innovative methods to reduce damage by destroying the host or its ability to serve as a vector of plant pathology, as well as a source of beneficial bacteria.

Overall, it is evident that the aforementioned trends indicate significant potential for increasing the use of biological pesticides as a significant measure in the total pest control means being used.

Public Health

Another sub-sector closely related to agriculture is the use of insects in the context of public health. Insects are already being used in the manufacture of pharmaceutical products (a field called "Entomotherapy"). Examples include the production of propolis, a natural anti-bacterial, anti-fungal, and anti-viral substance produced by bees, the use of insect venom to treat infections, the use of resilin – a protein that allows insects to jump – to repair damaged arteries (Elvin, 2005), and more.

Insects are used for the benefit of public health also for their abilities in the field of organic waste treatment. The role of insects in treating hazardous and contaminated wastes is highly relevant in the field of public health and includes, for example, localized treatment of human excretions as an alternative to sewage and sanitation systems in space. In the treatment of agricultural waste, the common treatment solutions today include composting and anaerobic digestion. The regulatory requirements of environmental authorities are continuously tightening, which increases the investment required to implement these methods. In many places waste is landfilled, incinerated, or dispersed over agricultural land, causing environmental hazards, such as air and soil pollution, pests, etc. (Ostrowski, 2011), or transported to remote concentration sites. As

an alternative, insects-based solutions for organic waste (biomass) treatment are currently being examined. Waste is used as a nutrients source for insects in their larvae stage, a process resulting in a significant reduction in the waste volume and its transformation into a fertilizer, a reduction in the human-related pathogenic bacteria population, and insects that can serve as a food product rich in protein for animal feed (Diener, 2009; Lock, 2014; Yu, 2011).

Insects as a Source of Food and Feed

Edible insects are a source of food that has high nutritional value, both for humans as well as feed for beef, chicken, and fish. According to estimates, at least 2 billion people consume insects as food regularly, mostly in the developing world. In large parts of Africa, Asia, and South America insects are part of the regular diet and even considered a delicacy, rather than on account of scarcity of beef, chicken or fish. However, in Western culture eating insects is typically considered a taboo.

One of the most significant works in the field of insects as food in recent years was conducted by the Food and Agriculture Organization (FAO) of the United Nations (UN) in collaboration with the Laboratory of Entomology[1] at Wageningen University, the Netherlands, which is a world leader in this field. The published report outlines the use of insects as a major solution of the global food crisis (FAO, 2013). The trend of population growth and rising living standards, on the one hand, and the limited availability of agricultural land and water, on the other hand, coupled with climate change, are likely to further intensify the nutritional deficiency already experienced by one billion people and the need to find sustainable sources of food.

[1] http://www.wageningenur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Laboratory-of-Entomology.htm

Food for Humans

Over 1,900 species of insects were found to be edible, including species from families of beetles, caterpillars, bees, wasps, ants, grasshoppers, locusts, crickets, cicadas, termites, flies, and more. Eating insects is known to have health, environmental, and social benefits. Insects are a nutritious substitute for food of animal origin (chicken, beef, and even fish) and are rich in proteins, fats, and minerals. From the environmental aspect, insect agriculture is characterized by a much lower level of greenhouse gas emissions than cattle breeding, for example, and is less demanding in terms of consumption of land and other resources (both directly for breeding the insects themselves and for growing food to feed them); they can be fed by organic waste, and are especially efficient in food consumption. The agricultural breeding of insects as an economic sector (also called "mini livestock") has low entry barriers in light of the low investment required, and as such it can provide employment in both urban and rural areas; although traditionally this is "low-tech" farming, there is great potential for improving and introducing innovative and advanced practices into this sector.

Nutritional Values of Insects

Most edible insects possess good nutritional values for humans, including high levels of proteins, amino acids and fats, as well as minerals and vitamins:

- **Protein** – the protein concentration in insects is relatively high (with a broad range of 13%-77% on a dry basis, depending on the type of insect), and therefore can be used as a good dietary source of animal protein
- **Amino acids** - some species of insects are characterized by a considerable amino acids content
- **Fat** - insects constitute a significant source of fats, in particular mono-saturated fat, as well as omega-3 and omega-6, in particular in countries with limited access to fish and sea food
- **Minerals** - edible insects are a rich source of iron and zinc (most of them contain iron in an equal or superior amount to beef), as well as copper, magnesium, manganese, phosphor, selenium, and sometimes also folic acid
- **Vitamins** - while most insects contain vitamins essential to processes in the digestive system and to boost the immune system, most of them contain very low concentrations of vitamin B12, and therefore further research is needed to identify edible insects that are richer in the B vitamins
- **Nutritional fibers** - exist in high concentrations in insects

A study comparing the nutritional value of beef with those of mealworms (Finke, 2002) found that while mealworms have levels of copper, sodium, potassium, iron, zinc, and selenium similar to those of beef, they contain less fat and more vitamins, except for vitamin B12.

Source: (FAO, 2013)

Animal Feed

According to estimates, by 2050 the production of meat from different sources is expected to double (IFIF, 2012). The food for animal agriculture, usually composed of ingredients of meat, fish, and soy, not only constitutes about 60%-70% of the costs of breeding, but these costs are continuously rising against the background of increasing demand and limited availability. Fishmeal, for example, is in a continuous trend of rising prices and high volatility, among other reasons due to excessive fishing and climate change that affect the yields of the fish of which it is composed. The market environment and growing

demand provides an opportunity for the use of protein derived from insects as a sustainable alternative for animal feed. In nature, insects serve as a source of food for a great number of animals, and are particularly suitable for poultry and fish. In addition to their nutritional values, the chitin found in insects has a positive effect on the immune system of poultry and their integration into their diet might reduce the need for antibiotics. A wide variety of insects were found suitable for feed, and are partially in use in different parts of the world. Various attempts made to replace a certain percentage of feed with insects for feeding poultry and fish have shown good results, equaling and even exceeding the performance of regular food.

Insect-Based Systems and Materials

Systems

The scope of insect-based systems, which includes insect-inspired technology as well as insect-integrated technology (e.g. cyborg insects) is wide and spans over numerous branches of knowledge in research and the industry. It constitutes of studies that use the interface between brain, nervous system, or other body systems of insects and various technological elements, in order to collect information on insect activities or manipulate the insect to perform various tasks; developing technologies based on information acquired by observing the mechanics of various insects; and up to mathematical and algorithmic solutions inspired by the activity of an insect's nervous system. Another subsection belonging to a broader framework of research comprises attempts to link the sense of smell and robotics, that is, the investigation of the mechanisms of decision-making based on the sense of smell.

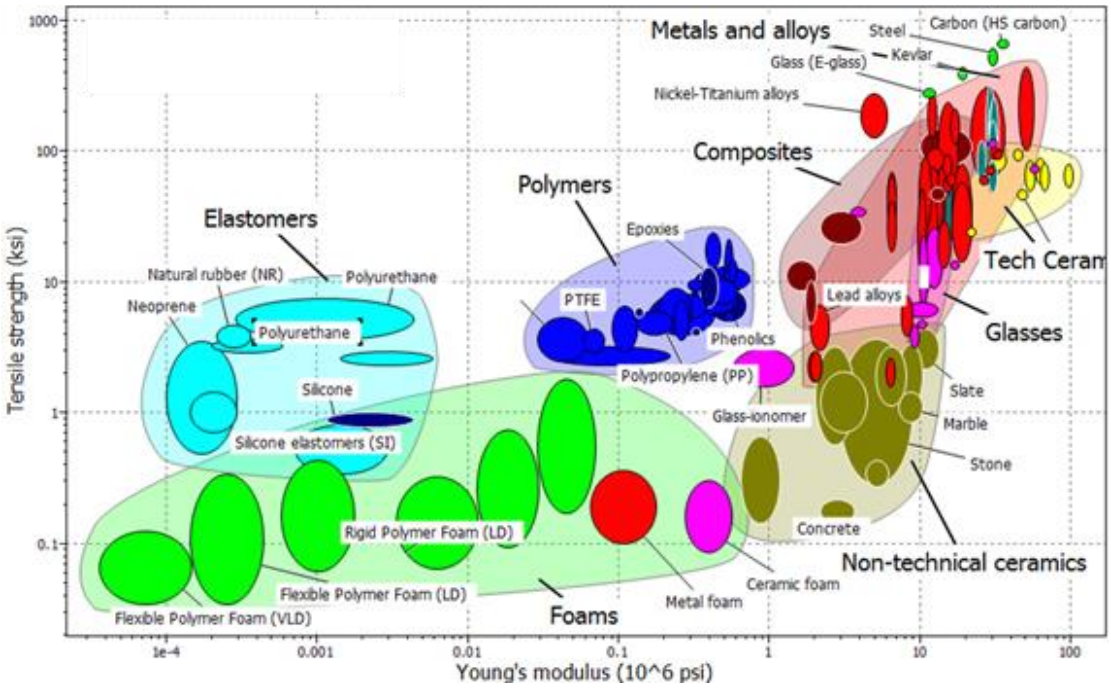
Potential applications include the development of aviation systems for the military, search and rescue purposes, agriculture (e.g., pollination), improvement of aviation control, the development of motion detectors and

algorithms associated with autonomous driving or autonomous flight, and more.

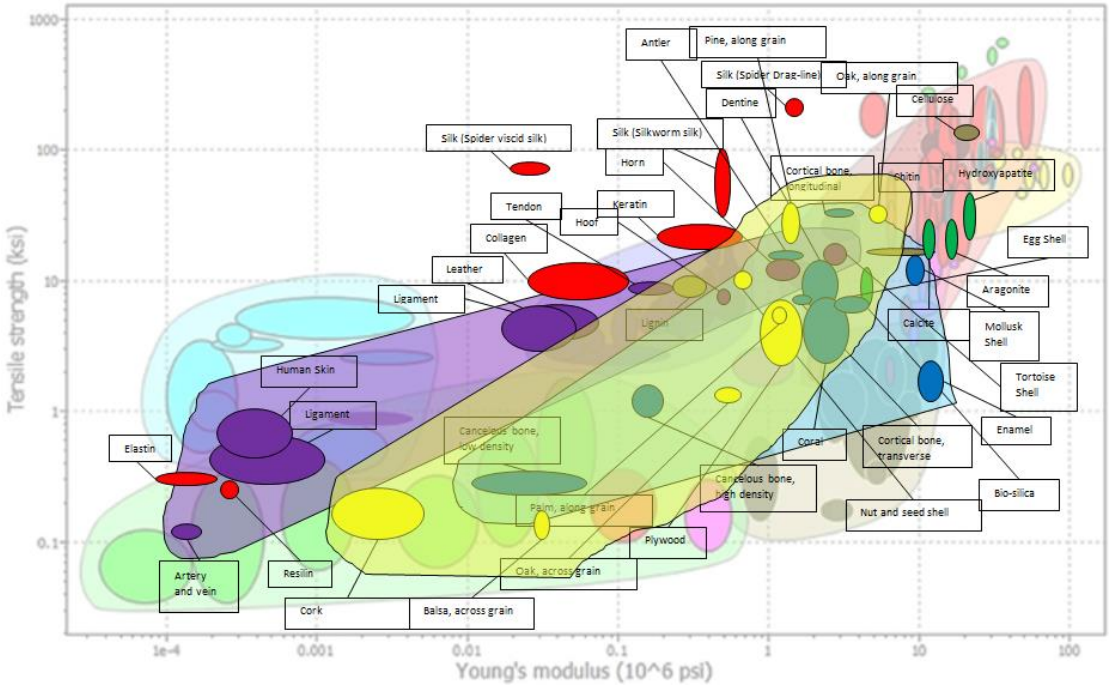
Materials

Unlike engineered materials that require considerable energy, heat, pressure, and the use of chemicals for their production, most biological materials are created by nature under normal temperatures and pressures, and in many cases in an aqueous environment. A comparison of the properties of engineered materials and biological materials makes it evident that in many cases the biological materials are equal to – or even surpass – the engineered materials, even though the former are not undergoing intensive processes to produce them (see figures below). The domain of materials made of insects is still in the basic stages of research and are premature for commercialization. Nevertheless, in the longer run, it is reasonable to estimate that with the development of industrial processes for creating biological materials, as well as developing the ability to mimic the properties of these biological materials, this application may become highly significant in a variety of applications and industrial sectors.

Properties of engineered materials



Properties of biological materials (laid over engineered materials)



Source: Karnstedt, P. https://insectsdiditfirst.com/2015/09/10/the-insect-cuticle-5-mild-synthesis-conditions/

Review of the Field in Israel

The field of insects in the service of humans in Israel is scattered across a number of small centers in the academia, industry, and the entrepreneurship scene.

In the academia, there are a number of collaborations taking place between universities and various research institutions. It seems that these collaborations are founded mainly on a regional basis and there is no regular contact between the northern institutions and those in the center and south of the country. This can be attributed to the broad areas of knowledge that are related to the field, but also to the lack of high-level scientific and professional conferences that bring together those who are working in this field. In other words, there is fragmentation in the research and the contacts between researchers; even when they exist, they are mostly not strong and not continuous, except for a few exceptions.

In industry, most of the commercial activities are in the areas of pest control and pollination, which are the more traditional applications in agriculture, executed by mature companies. It seems these companies are working to expand their operations with both additional geographic markets and new areas of activity, through active investment in research and development.

In the entrepreneurial field, there are first signs of emerging startups, focused on innovative applications in the fields of food and feed, and it seems that there is considerable interest and awareness on the part of venture capital entities. These are positive signs for the start of the formation of a full ecosystem in this field in Israel.

Academia

The major centers of research in Israel which were identified and reviewed are located in Tel Hai College (including MIGAL and Northern R&D), the Technion, Haifa University (ORANIM Campus), Tel Aviv University, the Faculty of Agriculture in Rehovot (The Hebrew University of Jerusalem), and the Agricultural Research Organization (ARO) - Volcani Research Center, including its two sites.

Agriculture

Dr. Yael Hefetz, of the **Faculty of Agriculture** in Rehovot, is a researcher in the field of green pest control, working to optimize the SIT (Sterile Insect Technique) methods by creating efficient transgenic insects to reduce the frequency and quantity of dispersion. The study involves the Mediterranean fruit fly that will soon be generic, being expanded later to other species. In addition, a preliminary research is being conducted in the faculty, in cooperation with Hargol Foodtech, concerning the improvement of insect cultivation and maximizing protein production using genetic methods.

At the **Volcani Center**, Prof. Eli Harari is investigating the use of disrupting communication between male and female insects through pheromones in order to reduce the mating choices and hence the reproduction of pests. Other researchers at the Institute are engaged in research in the field of green pest control, by applying various technologies, including genetic methods, symbiotic bacteria, physical barriers, fungi, endo-symbionts, natural enemies, and more. In the field of physical barriers, automated insect traps are being developed as part of the Institute's activities, including camera systems that enable counting trapped insects, to be used for giving appropriate guidance regarding pest control activities; other developments in the advanced stages are nets and covers for vegetation in colors and with reflection properties that repel insects.

Dr. Einat Zchory-Payne, of the **Newe Ya'ar Research Center of the Volcani Center** (ARO), focuses her research on the relationship between symbiont bacteria and their hosting insects, as a knowledge base for solutions to reduce the damage to agriculture. The damage that insects cause can be divided, as aforementioned, into direct (insect nutrition) and indirect (bacteria, viruses and fungi) damage. However, bacteria interacting closely with insects can be used to reduce the damage. One example from Israel is a cicada which transmits a disease to grapevines; from this insect a single bacterium was isolated that may serve as a biological pesticide. To date, there are no known commercial applications in this field in Israel, although there is an ongoing R&D project with an investment by a commercial fund, as well as cooperation of the Center with the industry for the microbiome analysis of commercially-used insects, for the identification of beneficial bacteria and pathogens. Dr. Eric Palewski, another researcher at the center, is studying predatory mites that are used for biological pest control in various systems (orchards, chicken coops, bees, and land).

Prof. Tamar Keisar, head of the Department of Biology and Environment at the **University of Haifa - Oranim campus**, is also involved in the field of biological pest control, as well as in the field of pollination. About fourteen researchers are engaged in the Department in studies related to insects in the service of humans, while research is conducted at the ecosystem level, as well as at the micro-cell and macro-molecules levels. For example, research on pollination is conducted on wild bees, and other studies are conducted in the field of biological pest control using parasitic wasps, the study of insect as vectors of diseases, and more.

Current research challenges in Israel in the field of agricultural:

- There are knowledge gaps (e.g., in the field of gene expressions) as well as a need for an information sharing platform
- There is a lack of infrastructure, including for insects breeding (climate cages)
- There is a lack of research funding
- SIT methods are costly to implement and rely on government support
- Solutions for biological pollination are feasible only in the case of failure of the present and natural solution, which is bees
- There is a conflict between industry and academia in view of intellectual properties (IP), since it is difficult or impossible to protect methods related to the development of life forms by patent. Moreover, working with research entities requires communication through their implementation units (TTOs)
- Regulatory uncertainty and potential barriers exist regarding leakage prevention on the issue of trans-genetics

Food

At the Faculty of Biotechnology and Food Engineering of the **Technion**, studies are being conducted on the subject of insects for food and feed. A research, being conducted in the laboratory of Prof. Avi Spiegelman, studies the processing of food proteins derived from insects and their quality and properties. Another research, in the laboratory of Prof. Uri Lazmas, studies a variety of edible insects and analyses aspects of nutritional composition of insect flours, changes that occur in them during cooking and baking, and the bioavailability of insect proteins to human in the resulted food.

A study on insects for food and feed is under way in the research laboratory of the **Tel-Hai Academic College**, in a collaboration between Dr. Ofir Benjamin, Dr. Isaac Martinez, and Dr. Adi Jonas of **Tel Hai** and **MIGAL**. The study was conducted on honey bees,[2] grasshoppers, and the black soldier fly (BSF). Dr.

[2] Growing bees for food has several advantages: first, the public image of bees in the Western world is better and easier "to digest"; second, the cultivation process is familiar, expected, and has been performed for centuries. The use of bees for protein can complement traditional products in the industry. Additionally, it integrates well with the developing trend of beekeeping in the urban space, as well as the need to support the bee population (which is in a state of crisis) by increasing their agricultural cultivation growing beyond the current capacity.

Martinez specializes in growing the insects and Dr. Benjamin in advanced sensory analysis and the functionality of the products, including through the use of advanced laboratory equipment such as a unique electronic "tongue" and an innovative food pilot device. Dr. Jonas is investigating the issue from the perspective of the biotechnology-biochemistry of food. Prof. Doron Lavi explores the economic aspects using life cycle analysis (LCA). Dr. Liora Shaltiel-Harpaz, in collaboration with the team of **R&D North**, is studying the subject of agricultural waste treatment using BSF and the usage of the output insects as poultry feed, where the remaining waste residues are to be composted, creating a complete ecosystem cycle.

Current research challenges in the field of food in Israel:

- There are knowledge gaps throughout the "farm-to-fork" chain
- A need to develop effective, hygienic and economic cultivation processes
- Specification and adjustment of the insects' nutrition to the nutritional values and their availability in the final product
- The development of efficient and economic extraction and processing methods
- Creation of functional food applications and components for the food industry, such as flours, emulsifiers, oils, etc.
- Examination of competitive gaps between agricultural growing for food and agricultural growing for feed

Systems

In the systems' area, most of the research involves the analysis, control, and mimicking the movement mechanisms of insects[3]. In the Zoology Department of the **Tel Aviv University**, in the laboratory of Prof. Gal Ribak, studies on comparative bio-mechanics are being conducted. Among other things, phenomena related to the structure and mechanics of different insects are being studied, for example, in the context of aerodynamic mechanics.

[3] This field is also called "Motion detection in insect orientation and navigation."

In a joint research conducted by Prof. Ribak and Prof. Daniel Weiss at the **Technion**, the flight and navigation systems of grasshoppers were manipulated. The ultimate goal may be to create a robotic insect or alternately to control insects ("cyborg insect") for various purposes, such as pollination, intelligence operations, and so on. Another study being conducted in Prof. Weiss' laboratory is inspired by the wings of small insects and the structure of the yellow-weed stamen to build airborne micro detectors. In another study, which focused on building air-guided detectors that can be flipped into the required position, a mechanism mimicking the mechanism found in the click beetle was designed. Another mechanism for controlling position during flight/landing was studied in scales. Furthermore, studies are being conducted around the world on cloaking and camouflage methods, inspired by the mechanisms used by insects.

Research challenges in the field of systems developments in Israel:

- Adjusting the energy source to the size and weight limitations of the micro-robot
- Miniaturization of the mechanical elements in the micro-robot, such as sensors, computing systems, communications components, and actuators
- The long time periods required for development and implementation
- The long training period of researchers, due to the multidisciplinary nature of this field in that it employs both biologists and engineers
- The efficient supply of the researched insect, frequently through a separate study and the implementation of its growing process in the laboratory (most insects for research are raised by the researcher himself)
- Regulatory challenges related to the subject of genetic manipulation of insects
- In general, robotics is a problematic area in terms of insect-related applications, since commerciality is limited and it is difficult to find a substantial market
- Knowledge of the aerodynamics of insects is lacking

Industry and Entrepreneurship

The number of companies that are commercially active in the field of insects in the service of humans in Israel is limited and divided into the established industry with two dominant players and the nascent industry that includes several innovative ventures in the preliminary stages of maturity.

BioBee

BioBee is a veteran and well-established Israeli company that produces insects for pollination and biological pest control, and is now expanding into additional areas. BioBee was founded in 1983 by Kibbutz Sde Eliyahu and operates in close cooperation with the Dutch company Koppert Biological Systems, a world leader in the development and marketing of biological solutions for the agricultural sector.

The company operates globally, through wholly- or partially-owned subsidiaries and other forms of cooperation, in Chile, Colombia, Russia, India, and South Africa. Considering the unique characteristics of each target market in terms of the agricultural and environmental aspects, as well as the domestic regulation, it can be assumed that penetration into any target market is preceded by considerable development and preparation work, beyond regular business development. About 280 people are employed by Bio-Bee, of which 220 are in Israel, including about 25 researchers and staff in its R&D department. About 70% of the company's sales are exported, to markets in 32 countries. Sterilization is performed using radiation, under the framework of nuclear energy for peaceful purposes.

The company has several main areas of activity:

- **Biological pest control:** reducing the need for pesticides spraying and using biological pest control by means of arthropods as a substitute for chemicals for crop protection, thus allowing farmers to meet the health standards of pesticide residue in agricultural produce; additionally, serving the field of organic farming. In general, insects and arthropods constitute a market share of approximately 5-10% out of the global biological pest control market of $2B, which is in itself a relatively small part of the total insecticide market, estimated at 50-60 billion dollars a year. Most of the activity is based on the production of the Mediterranean fruit fly, which undergoes a process of male sterilization by radiation, used for pest control under the concept of Sterile Insect Technique (SIT). In addition, the company has other solutions for specialized markets, such as a predator spider, designed to reduce harmful pests in roses growing in Colombia. The time required for the research and development of a new biological pest control product is about three years.
- **Pollination:** pollination using bumblebees, which are primarily suited to cold weather and greenhouses. The business model is divided into the provision of pollination services on the basis of acreage, and the sale of hives ready to provide pollination. The technological knowledge is mainly in the area of beekeeping in mass scale, with an emphasis on growing queens and their preservation along the distribution chain. Exporting bumblebees to countries where they are not an endemic species is prohibited, sometimes even limited to the presence of the specific sub-species in the target area. The subject of species and its interaction with native species is a fundamental issue when export is considered, given the regulatory restrictions. Furthermore, the technological solution is adapted for each subspecies.

- **Biologically based Integrated Pest Management (IPM) – resale:** Marketing and distribution of shelf products that complement the company's products, for example bio-pesticides, oils, plant-based pesticides, pheromones, microbial substances, etc.
- **Insects for food and feed:** Production of flies as protein source for fish (currently in a pilot study stage). The black soldier fly (BSF) can also be used to treat organic waste, thanks to its ability to reduce the volume of organic waste 10-fold in two weeks; it is possible to integrate organic waste digestion as part of the fly growing process for the purpose of food, if the waste is generated as part of controlled food production. According to current estimates, this method can turn 100 kg of degradable organic waste into 10 kg of fertilizer and 10 kg of BSF "flour."

Yad-Mordechai Pollination services

Yad-Mordechai Pollination Services (1995), located at Kibbutz Yad Mordechai, was established in 1992 (an independent company since 1995), specializing in the mass growing of colonies of land-bumblebees, provision of pollination services and advanced pollination solutions for a variety of agricultural crops. In addition, the company produces beneficial insects for biological pest control in greenhouse crops. Yad Mordechai Pollination Services is working in cooperation with Bio best, a Belgian company which is a leader in the pollination and biological control areas, the first company that began providing bumblebees commercially.

The company has two main areas of activity:

- **Pollination services** - about a third of the world's agricultural crops depend on pollination by insects, mainly bees, to produce fruit and vegetable crops for human consumption. Yad Mordechai Pollination Services specializes in providing pollination solutions for different crops, including unique crops, such as hybrid-seed production and more.
- **Green pesticides** – the company produces natural enemies to a number of pests and specializes in their application. The use of natural enemies for pest eradication in various cultural crops, usually agricultural crops, integrates well into the global trend to reduce the use of pesticides and to supply produce free of toxins.

Flying Spark

Flying Spark is a young company, engaged in the production of proteins from the larvae of the Mediterranean fruit fly, which are very rich in proteins containing a wide variety of important amino acids. This protein is ranked third in its quality, after egg protein and whey protein. According to the company, the larvae of flies also have many advantages as compared to other edible insect alternatives, including a higher protein to fat ratio, minimal ecological footprint, very short growing cycle, and resistance to extreme conditions. Therefore, this type of insect is particularly suitable for growing in a significant commercial scale. The end products that the company plans to produce are powders ("flour") at different processing levels, dried larvae, and oil.

Flying Spark operates within The Kitchen hub, a Chief Scientist's incubator managed by the Strauss Group and which is engaged in the food sector.

Hargol FoodTech (formerly **Steak TzarTzar**)

Hargol Foodtech is engaged in the development of advanced methods for commercial cultivation of grasshoppers and their processing into final products, including whole grasshoppers, powders ("flour") and food supplements. Grasshoppers have about 70% protein as compared to 20% -25% in fish, and the food conversion ratio in raising them is around 1.7 - 2 kg of food for 1 kg of edible product – superior to other "conventional" animal protein alternatives.

The grasshoppers, which today are eaten mostly whole (as is) in various countries in East Asia and Africa. They are often collected in the wild and there is no commercial agricultural cultivation, except for unskilled efforts at raising them. This is attributed to difficulties resulting from their sensitivity and potential susceptibility for food contamination, due in part to inefficient growing techniques and the lack of sanitation required to grow food for human consumption. Hargol FoodTech is currently focused on the development of cultivation processes, claiming to have already achieve a 30% efficiency gain as compared to US growers (mostly semi-amateur), and expecting an additional efficiency gain rate of 40% in the coming future.

The Company is examining three target markets for its products:

- **Animal feed:** mainly for aquaculture, as an alternative to animal protein in fishmeal. For this purpose, the most suitable are insects that are effective in producing the proteins by fat separation process, which is currently quite costly (currently the suitable insects are mainly flies and mealworms).

- **Food for humans:** either as a whole product (especially in the third world), or as a powder (for the developed world). As an indication of the market prices of grasshoppers, the price reaches about $12 per fresh kilo and $50 per kilo of flour, while in some countries the market price of grasshoppers may be 2 to 10 times the price of a kilogram of beef. The market of protein powder from insects is currently estimated at $20 million to $40 million a year in the US, and approximately $50 million in the world, and is mostly used as a niche product in the field of nutritional supplements and performance enhancers for athletes.
- **Pet food:** whole and living product (for feeding of reptiles, such as iguanas, etc.) or as raw material in dried food (for cats and dogs).

Trendlines Agtech

The venture capital fund Trendlines Agtech invested in Hargol FoodTech, and the company has recently won a prize in the Agro Innovation Lab competition.

Mapping of the Ecosystem in Israel

	Agriculture **Pollination, pesticides, public health**	**Food** **Human food, animal feed**	**Systems** **Systems, materials**
Academia	· Hebrew University, Agriculture Faculty · Haifa University, ORANIM campus · Sapir College	· Hebrew University, Agriculture Faculty · The Technion · Tel-Hai College	· The Technion · Tel Aviv University
Research	· MIGAL · R&D North · Volcani Center	· MIGAL	-
Industry	· Bio-bee · Yad-Mordechai	· Bio-bee	-
Entrepreneurship	-	· Hargol Foodtech (Trendline) · Flying spark (The Kitchen)	-

The Potential for Israel

Israel is endowed with a unique combination of virtues and limitations, which, throughout the years, created a fertile ground for developments and practices that surpass the obvious. Academic excellence and technology leadership, together with the limited land and water resources, as well as a small local market and limited regional trade, brought Israel over the years to the position of a global leader in knowledge in many fields. Relevant recognized fields are water treatment, advanced agriculture, information, communication, medical, computing, and trade systems. Although these areas seemingly originate from different disciplines, there is a potential overlap between them, which harbors a potential for creating innovative solutions and high-value products. The different applications of insects in the service of humans are a good example of the line linking multiple foci of Israel's relative advantages, by demanding integration and synergy between knowledge that was originally designed to serve the agricultural sector and the knowledge in biology, chemistry and medicine. The ability to create such a connection is a characteristic strength of Israel, and can help Israel to become a global "game-changer" in the areas in which it will be realized.

National Policy Recommendations

The global review shows that engagement in the research and development of various aspects of insects in the service of humankind is on the rise, and in some areas on the verge of a breakthrough. The enormous potential of insects as a platform for creating solutions for a variety of challenges facing humanity today and in the coming decades and in view of this review, the importance of this issue for the long term and the need to form a promoting policy are obvious.

At the national level, examination of the Israeli perspective shows that dealing with insects in the service of humans is gathering a positive momentum and shows preliminary signs of a healthy mix of research, development and industry. Although it is necessary to overcome the breakthrough phase, which may take several years, Israel is well positioned to build leading capabilities in this area at the global level, in both the academic and business spheres.

In light of these conclusions, here are our recommendations for a national policy for Israel:

1. **In Israel, great importance and systemic attention should be devoted to promote activities on the subject of insects in the service of humans.**
2. **It is necessary to act to establish a national-global center in Israel to promote research and entrepreneurship on the subject of insects in the service of humans.**

Further to these conclusions, the required steps are:

1. Form a preliminary action plan.
2. Locate a stakeholder to assume ownership over the subject, who will be dedicated and committed.
3. Implementation.

Action Plan

Effective promotion of the field of insects in the service of humankind in Israel requires a coherent action plan.

The plan should balance the need to provide free space for developments in different directions and the necessity to focus on a limited number of paths that are more likely to succeed.

The program should also describe a practical action plan that can be implemented with a reasonable investment and in a manner that will provide qualitative solutions to the needs of the relevant parties in the emerging industry.

Moreover, the program should consider both the immediate time frame and the more distant one, while outlining a horizon of several years.

Focusing on Areas of Activity

In order to realize in Israel the business and scientific potential inherent in the development of the insects in the service of the human domain, there are recommended areas of activity that are best to focus on in the short and medium term. From the global review conducted and the interviews that took place with key people in the field, it is evident that **the areas of agriculture and food have the greatest potential in the immediate to medium term**.

Agriculture, and especially pest control and pollination, is the most mature domain in the world commercially and employs rich academic knowledge and a well-developed ecosystem of established companies, corporations and innovative companies. However, there is still considerable potential for further development, in particular of other pest control solutions.

The food sector is still taking its first steps, but is already attracting great interest. The immediate potential is in the development of solutions for livestock feed, in light of the escalating costs of existing alternatives to feeding and the lower barriers to introducing insect-based products. Insects as a source of protein for humans, too, is a field that raises scientific and commercial interest, but we believe that its applications are still in their infancy. It should be noted that the food sector in Israel is expected to be commercially limited due to the Kosher limitations of most types of food made from insects.

Insect-based systems constitute an area of considerable potential, but largely fall under different areas of expertise, both in the scientific and industrial aspects. Since the wide commercialization of these applications is expected only in the much longer term, it is not recommended to put an emphasis on this area as part of the Action Plan.

Possible Alternatives

As part of formulation of an action plan, a number of possible alternatives for establishing a center for the promotion of insects in the service of humankind were considered.

The alternatives were examined by evaluating the chances of success, the investment required and the expected added value for each of the selected models.

The success of such a center clearly depends on creating a successful connection between academia, funding sources and industry, and of course on choosing the appropriate leader.

Each of the alternatives offered below highlights one of these aspects and represents a different mix of risk, required investment, and potential outputs.

Alternative 1. Knowledge Center

- **Goals**: initiating research collaborations between the various parties in the field, coordinating the activities of stakeholders, creating a meeting place for formulating and holding conferences on the subject, supporting partnerships, encouraging the transfer of knowledge from the academia to the industry, regulatory counseling
- **Method**: leading project manager, small office space with a small staff, information and consulting services
- **Budgetary sources**: at the initial phase, mostly from the municipality, calls for proposals and research grants, donations
- **Advantages**: cost and risk are relatively low
- **Disadvantages**: slow pace of development, limited production of strategic assets, limited geographical anchor

Alternative 2. Entrepreneurship Center

- **Goals**: creating an interface between knowledge and applications, starting an entrepreneurial ecosystem in this field, serving as lodestone for projects, providing support, mentoring and guidance
- **Method**: an ideological and physical structure of an accelerator and/or incubator, led by a managerial staff and a system of professional counseling
- **Budgetary sources**: the municipality, venture capital, national incubator plans, Chief Scientists offices, international funds
- **Advantages**: high potential for the development of start-ups and young industry, significant positive image impact, synergies with regional assets in terms of research and development
- **Disadvantages**: possible competition with venture capital funds and existing incubators, difficulty in creating sufficient volume of attractive deal-flow of in the short term, medium risk level

Alternative 3. Applied R&D Center

- **Goals**: provide R&D infrastructure as a service to the industry and entrepreneurship in the field, establish the center as a combined center of knowledge and applied research activity, grant access to advanced laboratory services that could serve as a consolidating nucleus to create entrepreneurial and industrial activity
- **Method**: build chemical and biological laboratories (including equipment for testing protein profiles, GCMS, analytical equipment, process equipment, and GRAS), build insect cultivation infrastructures (habitats for insects, insulation facility, greenhouses for growing nutrients), establish a food pilot (with equipment for development of processes, materials processing, production methods, and food analysis), the formation of a team of experts with applicative orientation and technical staff to operate the laboratories and the equipment
- **Budgetary sources**: investment funds, strategic investments from stakeholders, government grants, donations, revenues from the provision of laboratory and research services
- **Advantages**: significant geographic anchor, infrastructural assets, practical boost to the field as a whole
- **Disadvantages**: high cost of building and operation, direct competition with other research institutions in the region, higher risk level

Afula as a Research-Entrepreneurship Hub in the Field of Insects

Afula, being a municipal center surrounded by agriculture, is suitable to become a center of activity on the subject of insects in the service of humankind, and has expressed a willingness and desire to promote this issue as part of the continued development of its recently established Entrepreneurship Centre. Afula is a city that has been rapidly developing in recent years. The city has

several local and regional assets that the Center can leverage for the benefit of its activity:

- Afula is located in a **strategic location** in northern Israel, with good access to major traffic routes to the center of the country. It is situated between the industry and research centers in central Israel (led by the Volcani Center) and major research centers nearby (headed by the Technion's) and in the far north (Tel Hai and MIGAL).
- Afula is located at the heart of the Jezreel Valley, **surrounded by extensive agricultural activity**, which makes it a natural destination for examining agricultural applications on the subject of "Insects in the service of humankind."
- The area hosts an **extensive and established food industry** consisting of the largest Israeli food companies, serving as a fertile ground for generating collaborations.
- **Emek Medical Center** hospital is situated in Afula and is a source of knowledge, on the one hand, and a center that allows access to a variety of laboratories and clinical trials, on the other hand.
- The **Yezreel Valley College** is located on the outskirts of the town of Afula. Given that relevant study and research tracks are developed in the future, the college may become an additional academic party that will be a source for high-quality and highly-educated manpower.
- **Afula has expressed interest in developing an innovative and unique area of activity** and is committed to investing the necessary resources and attention for the long term. The Center for Entrepreneurship inaugurated about six months ago in Afula provides the basic infrastructure to jump-start leading activities.
- **Afula's location will allow integration of the Arab population in northern Israel**, as part of leveraging the capabilities in these fields among the Arab population into a unified economy.

The Proposed Work Plan

Further to the policy recommendations, the proposed action plan and the interest expressed by the municipality of Afula to promote this issue, followed is the recommended strategy for Afula to establish a center of Insects in the Service of Humankind. The plan is to establish a knowledge center that would be developed further into an entrepreneurship center, under the vision of **an entrepreneurship and industry center that integrates the scientific and business knowledge in Israel in the field of insects in the service of humans.**

In light of the substantial investment required and the still premature level of the field, it is not recommended to build R&D infrastructure as a first step, but only after the establishment of the center and in accordance with the actual needs of the projects that will be developed. Such a gradual development limits the risk at each step and allows the assets of the Knowledge Center to be realized and leveraged for commercial applications and the creation of a national ecosystem down the road.

The following are the main tasks for each step in the Center's development, over the period of the first two years of its activity:

Founding: preliminary requirements

- **Designating a physical space to operate the center** – except for the office space, the place has to accommodate meetings, seminars and conferences (even if by access to a space shared with another nearby activity), including all the necessary equipment.
- **Recruiting a leader for the center** - an experienced senior person has to be located for the management and leadership of the Center for a period of at least two years. This leader will be a key factor in the Center's development and promotion in the country and abroad, and as such

hiring should be assured in advance at least for two years, as the minimum period required to set a successful development path.

- **Securing budgetary resources** – raising and ensuring funds for the budget required to operate the Center for a minimum period of two years, in accordance with the planned budget.

First year: establishing the Knowledge Centre

- Establish an interdisciplinary center that brings together the knowledge in the field at the national level.
- Ongoing review and mapping of the field in the world and in Israel.
- Forge an evolving and growing nucleus of knowledge.
- Build a platform that coordinates the field and allows the exchange of knowledge and ideas, the creation of partnerships, and the promotion of the field within decision-making forums and round tables, hold conferences, invite experts from the field to give lectures and seminars, host delegations, and work hand in hand with the Israel Export Institute on relevant topics.
- Work to establish a consortium under the MAGNET program in cooperation with the academia (e.g. Volcani Center, Tel Hai College, the MIGAL Institute and R&D Centre North, the Agriculture Faculty in Rehovot) and industrial entities, such as food companies, companies in the field of agriculture and industrial research institutes. The consortium will be in charge of knowledge infrastructures development, which will serve all the participating parties or solve specific problems in the manufacturing process. Examples of research topics include the effect of insects' feed on their nutritional value, development of organic waste treatment processes using insects, and optimization of the separation processes of fat and protein.

- Submit calls for research proposals in the areas of food and agriculture, in collaboration with research institutes, independent researchers, consulting firms, and manufacturing companies.
- Prepare and submit proposals for research and development tracks abroad, including the Horizon 2020 program and binational funds
- Create connections with strategic players overseas - local government officials, major companies, leading research institutes, and the like.
- Lobby in the field of regulation and standards of food safety, including establishing a connection with government ministries, first and foremost to the Ministry of Health.

Second year: promotion of entrepreneurial activity

- Allocate a place for the center of entrepreneurship with separate and common work spaces.
- Management of investor relations: attract optional investors - venture capitalists, angel investors, investment funds, and strategic investors – and expose them to the active projects in this field.
- Formulate a guiding team of mentors from universities, research institutes, the industry and the world of entrepreneurship, who will provide guidance, assistance and support to young entrepreneurships.
- Participate in exhibitions and conferences.
- Assist in creating industrial relations in order to identify suppliers, customers and potential partners for projects.

Upon the formation of a significant deal-flow, it would be possible to consider switching to a technology incubator model, based on a combination of public and private capital.

Complementary Activities

The center has to act as a collaborating and connecting agent with overlapping activities, in order to enhance and support other initiatives in the region, rather than compete with other entities.

- **Food Institute**: if and when such an institute is established, it could be assisted by the center in Afula in its activities in the field of insect-based food.
- **Volcani Center:** it is desirable that the activity of the Institute engaged with the field of insects will be based in its northern extension - Newe Ya'ar Research Center.
- **Ministry of Agriculture:** the need for calls for research proposals regarding aspects of insects in agriculture has to be raised, in terms of both entrepreneurship and the management of an information center (this can also be done in cooperation with the Volcani Center).
- **The Galilee Society:** an excelling regional research and development center in Shfar'am, specializing in health, plants, water, and the environment, allowing for an opportunity to introduce academic experience into the Arab population.
- **The Samuel Neaman Institute:** can provide experience in the field of information science services, management of MAGNET consortiums, entrepreneurship, connections with financing funds, and identifying potential partners.

Budgetary Estimation

Below are the details of the minimal budget needed to run the center, under the work plan presented, for the period of its first two years of activity. Cost estimation is unchanged between the first and second year, since no changes are expected in the volume of activity (in terms of personnel, travel, events, etc.), only in content and focus.

Annual Cost Estimate

Activity	Cost
Salaries and benefits	$100,000
Office and accounting services	$25,000
Office rental	$15,000
Hosting	$5,000
Domestic travel and participation in conferences	$15,000
Travelling abroad	$10,000
Holding events	$10,000
Consulting	$15,000
Incidental expenses	$5,000

Annual total : **$200,000**

According to the details of this budget, the total budget required for the first two years amounts to 1.52 million NIS (in a ratio of 3.8 ₪ to $1).

It is estimated that revenues from additional budgetary sources, including research grants such as MAGNET and responses to the call for research proposals, will allow the introduction of the first ventures into the center of knowledge and entrepreneurship to be supported. At the end of the first two years of the center's activity, its achievements and development barriers should

be re-assessed, as well as the changes in assumptions regarding global trends, and consequently decide on the future path of the center.

Indicators for Success

The center's success will be measured in relation to the attainment of the following objectives:

1. The subject of insects in the service of humankind will be recognized as an essential field for the sector of agriculture and food in Israel, and the resources necessary to promote it businesswise will be attained.
2. The center will prove to be the main catalyst for promoting the business success in this field in Israel and will be perceived as a key factor by the other centers active in this field.

After two years, the degree of success can be measured based on several qualitative criteria:

- The expansion of research and projects in Israel on this subject.
- The establishment of a MAGNET consortium and the integration of new knowledge acquired of its defined topics.
- The number of projects that were integrated into the center.
- Successful conferences that attract the best practitioners.
- Presence as a leading center in the field in the eyes of the existing industry.
- Recognition by and cooperation with research institutions in the country.
- Recognition as a focus of attraction for entrepreneurship and availability of resources to support their development.

It is proposed that with the decision on the establishment of the information center, quantitative values for success will also be set.

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Appendix I: List of Interviewees

Dr. Avi Perl, Ministry of Agriculture

Prof. Avi Spiegleman, the Technion

Dr. Ofir Benjamin, Tel-Hai College

Prof. Uri Lazams, the Technion

Dr. Isaac Martinez, MIGAL

Prof. Eli Harari, Volcani Institute

Prof. Gal Ribak, Tel Aviv University

Dr. David Nini, The Kitchen Greenhouse

Prof. Dan Weiss, the Technion

Prof. Yigal Elad, Volcani Institute

Dr. Yael Hefetz, Agriculture Faculty

Dr. Liora Shatiel-Harpaz, R&D North

Yakob Mualem, Volcani Institute

Dr. Nitza Kardish, Trendlines Agtech

Dr. Einat Tzahor-Fein, Neve Yaar, Volcani Institute

Dr. Shimon Steinberg, Biobee

Dror Tamir, Hargol FoodTech

Prof. Tamar Keisar, Oranim College

Appendix Ii: Research and Industry Centers Around the World

General

International Symposium on Insects as Feed, Food and Non-Food.

The symposium deals with the forefront of insect technology, and the feasibility of using insects for human consumption, animal feed, and other uses. It reviews the technical, commercial, ecological, political, and ethical aspects in the European context. The conference covers the topics of production/growing systems, various applications of food, food safety, consumer perceptions, economic and environmental evaluations, legislation, bio-polymers, waste treatment, and more.

Application 1. Food and feed

- **Vageningen** – a food research institute in the Netherlands.
- **DIL** – a research institute in Germany.
- **IFR –** Englnad
- **The Insecta conference -** http://www.insecta-conference.com/
- Danish Technological Institute (DTI)

  A Technological Institute in Denmark with an infrastructure for insect growing and laboratories for analyzing insects and insect-based products. The Institute is experienced in the development of insect manufacturing processes toward an industrial level, and is engaged in providing business development services, analysis of food sources for insects made of industrial byproducts, optimizing processes through automation and computerization, analysis of the nutritional value and functionality of insects as food, micro-biology and food safety, regulatory aspects, assessments of toxins and allergens, and sensory perception among consumers.

- AgriProtein technologies

  AgriProtein is a large company in the feed area:

AgriProtein is leading a new industry called nutrient recycling. Using fly larvae fed on abundant waste nutrient sources, AgriProtein has developed and tested a new large scale

and sustainable source of natural protein. The nutrient recycling bioconversion process utilizes waste food as raw materials and generates valuable feed components: an insect based protein meal - MagMeal™, an extracted fat - MagOil™ and a nutrient rich soil conditioner - MagSoil.™
AgriProtein has been developing its insect based protein feed, extruded oil, and fertilisers since 2009. Following five years of parallel academic and manufacturing research, AgriProtein has raised $11 million from strategic partners to commercialise and globalise its IP. The company broke ground on its first industrial scale factory 'F1' in May 2014. The plant will come on line in 2015 and produce 7 tonnes of MagMeal™, 3 tonnes of MagOil™ and 20 tonnes of MagSoil™ per day. Locations for the second factory are currently under evaluation.

- **IPPIF – Food/Feed**

Application 2. Agriculture

- **IBMA –** biologic pest control
- University of Padova – Italy
- Helmholtz Jena research institute **–** Germany
- Oxford – England

Application 3. Systems

- Boston Dynamics
- DARPA
- Robo-bee, Ron Wood, Harward
- Mike Dicenston

General (unclassified into specific applications)

- **Oxitech –** a British company that uses genetically engineered insects. Was purchased by intrexon**, as well as** EnviroFlight
- **LAYI –** wrote an important paper on the subject
- **ICIPE –** a Research institution on insects in Kenya

Industry & Innovation

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