The Wide Array of Defense Mechanisms of Insects

Introduction

Most species of insects are the prey for many animals, so the ability to avoid predators and defend themselves is significant for the preservation of life and survival of individuals in the general population. Most (80-99.99%) of individuals born do not survive to reproductive age. Predation causes 50% of mortality among insects. Insects had to evolve a wide range of defense mechanisms because of the ongoing escapist battle. Despite the small size, weaknesses, numerous enemies, and loss, this class of insects is an active living one, which is ranked in the world's sustainable ecological niches. It is caused by the fact that insects, similar to all living beings, are genetically provided with everything necessary for the preservation of life. Only the best defense mechanisms have been passed down from generation to generation through the survival of the fittest insects. Such behavior includes passive and active defensive reaction to protect themselves, their homes and territory. The principal protective devices and processes are different types of defensive coloration and shape of a living being, as well as production of poisonous substances and pigments and bodies of their allocation. Among the diverse means of protection from the enemy, the most often used mechanisms are running (for example, ground beetle larvae due to numerous legs), jumping (a flea beetle), and a fast rise (horse-flies, borers). The ability to fall from plants with bent limbs and to play dead (ladybugs), camouflage coloring, spraying caustic or odorous liquid are other common features of insects. All of these defense mechanisms have proven to be effective since these species of insects continue to exist today. The research paper focuses on the defense mechanisms of insects, discovers their nature and emphasizes the significance of the class in the world.

Defense Mechanisms of Insects

Insects belong to the most numerous class of arthropod invertebrates. According to various estimates, their number reaches 3 million species. To date, about 1 million of described species of insects represent about 70% of the total number of known fauna. The representatives of the class of insects are ubiquitous in most ecological communities and play an important role. All living beings on Earth have special mechanisms needed to protect themselves from danger, ensuring the survival of their offspring. Insects have different kinds of defense mechanisms that allow them to hold a significant place among the inhabitants of the planet.

Hiding Mechanism

Hiding is one of the best defense mechanisms of insects because if they cannot be seen then they cannot be killed. One of the protective measures insects are using is obliterative coloration. There are three types of protective coloration and body shape: camouflage, mimicry, and demonstration. Insects, similar to many animals, do not just hide from predators in shelters, but use the protective coloration to mask and hide their eyes. It makes them less noticeable in the habitat, allowing merging with the background. Conversely, the brightness of the colors and the specificity of the figure serve as warnings to the enemy of poisonous insects. Color and shape of the insect's body mainly correspond to features of its habitat. Biological, physiological and morphological characteristics of the species that are in accordance with the environment are called a life form. For example, life forms of locusts are combined into two classes: the inhabitants of the plants (phytophils) and residents of the open areas on the surface of the soil (geophiles). Thus, individuals living in the green area have the green coloration as well as the ability to miraculously change to yellow as the drying vegetation.

Cryptic morphology. Certain insects have the ability to hide in the environment while changing their coloration according to the circumstances. With the help of the evolved specialized cryptic morphology, some insects became an integral part of the general background because of their resemblance to the environment. Other types invented the way of pretending to be an inedible object. Walking sticks (*Order Phasmatodea*), moths (*Order Lepidoptera*) and many katydid species (*Family Tettigoniidae*) are only small part of the class representatives that succeeded in evolution of these skills. Walking sticks are the great masters of disguise. They often look exactly like the surrounding vegetation. The ability to blend into the environment was inherited in them from birth. For example, the walking stick hatched from eggs lying on the ground will be brown in order to blend into the fallen leaves and branches. Later, as it climbs to the green plant, it can change the color to the appropriate shade of green. Another walking stick, which lives on a tree trunk, becomes mottled. Even if the walking stick from time to time moves or just rocks from side to side, it looks more like a twig in the wind than a living being. However, if the stick insects have wings, they can have a bright color. Under ordinary conditions, the wings are completely hidden under the elytra. The walking stick opens them when something disturbs it. Scientists call this phenomenon "a flash of color"; the walking stick uses this ability to frighten an approaching predator. List of camouflage colors of walking sticks seems to be endless.

Camouflage as another type of cypsis. Color and shape of the body of caterpillars are closely related to their way of life. Caterpillars often have protective coloration in order to be in harmony with the surrounding background. Moreover, the effectiveness of such color is enhanced by the specificity of the figure. For example, hawk moth caterpillars are green, while other species have oblique stripes laid on the gray background. They seem to be divided into segments of the caterpillar's body, making it even less noticeable on the colorful greenery. It can be similar to some part of the plant or home track, and the combination of

protective coloration increases with the characteristic shape of the body. This way, moth caterpillars resemble dry twigs.

Patterns and unique morphologies of camouflage. Insects have protective coloration and body shape similar to the leaves, twigs and even bird droppings, and often combine it with particular instinctive behavior. They are able to assess the situation and accordingly locate in relation to surrounding objects, taking a variety of camouflage postures. For instance, grasshopper sheets in order to protect itself from predators, sits still with tightly closed wings, mimicking the stem, or holds wings outstretched, looking like a leaf. Protective coloration and camouflage posture may contribute to both the passive conservation of insect life, and better opportunities for hunting. For example, mantis is a predator, which, due to the effect of disguise can sit still for a long, waiting for the prey. Furthermore, it can well camouflage for protective purposes.

Butterflies as a good example of defense. Some species of insects are endowed with colorful demonstration (threatening color). It is a signal to their enemies that they are dangerous. For example, a bird that tasted inedible ladybird or stinging insect remembers the unpleasant lesson and brightly colored insect well. Many species are also endowed with body painting demonstration, which is an evidence of their inedibility. For example, the effect of butterflies (*Order Lepidoptera*) is a good example of the defense balance between advantages and disadvantages of the protective coloration. Moth color also depends on the color of hair. This caterpillar has a bizarre appearance with bright red and black spots on a light background and with a bunch of black and yellow hairs of different lengths. The moth can escape from predators when they look at its light cryptic coloration.

Aposematism. Warning color may be an individual constant, which is typical of stinging insects. However, it can appear in the dangerous moment, when the insect needs to embody threat. The markings help to attract conspecifics or warn predators (*Aposematism*).

At the same time, the absence of color helps this insect to absorb adequate solar radiation. These special features play key roles in survival process.

Mimicry

Mimicry is the effect of imitative resemblance in body shape and color of representatives of vulnerable species of insects with more secure ones. Mimicry is another mystery of the inscrutable complexity and feasibility of the device behavior of organisms and species. Many scientists believe that it could not be the result of trial and error. It works when the predator discovers the inedibility of an insect.

Three types of mimicry. There are three main types of mimicry – protective, aggressive and conscious. Protective mimicry has similarity with the object type of environment – animal, vegetable or mineral origin. This type of mimicry is divided into many smaller categories due to the variety of objects. Aggressive (warning) mimicry is an imitation of the shape and color of the body in order to avoid predators by the presence of special protection or unpleasant taste. It is found in the larvae, nymphs, adults and even pupae. Conscious mimicry or stain may occur in species with sexual dimorphism. Imitation of inedible species helps them to be either male or female. Thus, females sometimes mimic several different colored species, found either in the local area during different seasons or in various parts of the range type simulator. Darwin believed that this type of mimicry is a result of sexual selection, in which defenseless form is becoming more similar to the protected one in the process of destroying the less perfect imitator's natural enemies. Those who manage to copy someone else's appearance rather survive because of this similarity and produce offspring.

Automimics. Automimics are individuals that can protect themselves through their visibility in the circle of identical relatives. Butterfly species have some bright spots on the wings in the form of eyes, scaring predators. Usually, wings of a seated butterfly are folded,

but when one touches it, they immediately disclose. Figure eyes deter small birds. Some caterpillars have a false eye and are also endowed with the ability to wriggle the body. Demonstration of such a behavior of the caterpillar usually deters it from small birds and other predators. Although it is edible, butterfly survives thanks to ultrasound mimicry. This butterfly is endowed with an amazing ability to emulate clicky high-frequency sounds that are needed for their protection from the tiger moths. The bats that prey on the principle of echolocation prefer to avoid insects with a clicking sound. Their ancestral knowledge, sometimes supplemented by lessons learned, indicates that, as a rule, that sound production indicates poisonous or unsavory insects. The secret is simple. The poisonous insects use ultrasonic warning signals because of the bats that hunt at night, while bright color does not matter. At the same time, the bats do not touch quite a delicious moth, imitating its inedibility.

Müllerian mimicry. Müllerian mimicry is used by the group of insects. It helps them to educate the predator over more than one species. That is why it benefits all the members of the group. For example, many species of wasps have black and yellow alternating bands on the abdomen. One example of such a manifestation of mimicry is the external semblance of some kinds of butterflies, such as whiteflies, *Heliconiinae*, *Rhopalocera species* of South American butterflies. Many *Heliconiinae* individuals have a pungent odor and unpleasant taste so that they are not touched by the birds. A whitefly butterfly is endowed with a whole set of imitative opportunities to remind their prototypes. They closely resemble flying or resting *Heliconiinae*, having not only similarities with the shape and color of the wings, but even with the nature of the flight. In South America, one bush can be the home for almost five species of butterflies of the same color. However, if there are poisonous representatives of only one of the species, it will make the birds avoid that bush.

Behavioral Mechanisms of Protection

It is the type of protection that gives insects the opportunity to escape predation. It includes the cycle of life when the insect is active only in a restricted period of the day and borrowing into the substrate. To avoid predators, the main passive-defensive reactions are fading, escaping, hiding in shelters, and other suitable behavioral techniques. Many species of beetles use thanatosis as a means of protection. It is the immobility time at which an insect pretends to be dead. In the cases of possible danger beetles usually fade and fall from the plant to a bed. This behavior is characteristic of many groups of insects, including weevils, beetles, and other byrrhidae. For example, in cases of the alarm, the bug apple weevil instantly puts its legs and falls from the tree to the ground, where it lays still for a while. The fall of the tree provides faster protection than moving by paws while escaping from the enemy. A gray color and motionless position with folded legs make a small weevil indistinguishable from soil aggregates.

Thanatosis. Thanatosis is also characteristic of a ladybug. Even though it is an active hunter aphid, adjusting to the amount of pests, it is very well protected from the encroachment of any predators. An important way of self-defense is its ability to play dead. It falls to the ground and lays there motionless. Once the danger has passed, the bug instantly comes to life. However, if the threat remains, ladybug releases a yellowish liquid, unpleasant odor and taste that deters the enemy. Then the mottled coloring of the insect confirms that the bug is toxic and is not suitable to be eaten.

Crickets are completely silent when fighting an enemy. Only those who are given the ability to capture ultrasonic signals will be able to rescue. Unusually sensitive receptors help to reveal the danger when it is in the distance. This miniature live device is built into the nervous system of a cricket. It reacts to the sound frequency emitted by the bat in order to orient in space. Cricket’s receptor, driven by this frequency, emits pulses. They are the alarms that cause the insect to rapidly remove from the sound source. This unique receptor has

another feature that surprises entomologists. It turns out that it is only activated when the cricket is in flight, becoming vulnerable to nocturnal predators. At a time when the insect is safe, the receptor is silent, without disturbing the owner in vain. However, in cases of danger, the device is once again ready to respond to the ultrasonic signals of the predator to raise the alarm and save the insect. It manifests a perfect appropriateness and elegance of protective mechanisms and devices of the insect.

Bright colors as the mechanism of defense. Mantises are given special hearing and excellent vision to avoid meetings with bats. Those organs are located on the chest between the legs, serving for sensing ultrasound. In some species of praying mantis, except ultrasonic hearing organ, there is a second ear, which senses a much lower frequency. Its function is unknown. In case of extreme danger, deters enemies and Apollo butterfly are falling to the ground, scraping legs and hissing threateningly. This effect enhances plowing its warning bright wings. After all, red spots on the hind wings are *Apollo*'s conventional sign for the birds that the insect is poisonous. Many species of *Mantis* can not only hide well due to its protective coloration, but they know how to fend for themselves in case of danger. This insect rises, assumes a threatening attitude, magnificently dissolves rear wings, and shows its bright color. Then mantis creaks and emits a menacing sound of clacking prehensile feet. Caterpillars use other ways to deter predators. Some of them adopt an emergency threatening posture, and occasionally emit a variety of sounds. In such cases, a big caterpillar harpy immediately dangerously rises up the tip of the abdomen with a sort of "plug" formed by the two strong-smelling threads.

Mechanical Defenses

Cuticle as a defense tool. Insect protection from the numerous enemies is carried out not only by the passive-defensive reactions and the different types of stains. In case of danger, many of them have the capacity to actively defend. Typically, insects use a whole

range of different protective devices. A characteristic feature of insects is their chitinous cuticle, which consists of a complex organic substance-related tissue. The carapace of insects protects them from adverse environmental factors and primarily the threat of drying, as it prevents the loss of water by evaporation. This chitinized clothing of insects is closely related to their hairs, spines, scales, iron, tactile, olfactory and gustatory organs. At the same time, their coloration can have a variety of colors and drawings which far exceed the diversity of shades of whimsical flowers.

Additional tools for physical defense. A variety of horns and their carriers gives scientists an excellent material for the study of mechanisms of occurrence, development and changes. When they grow in the wrong place, very old genetic mechanism normally regulates the development of limbs in insects. Horns appear in five areas of the body formation: three usually occur on the head and two in the thoracic region, but the combination of them can be any. The males use the horns for the tournament battles. The small insects have no chance to defeat a stronger opponent. In this case, the horns help to defend insect predation.

The behavior of blister beetle is unique. In a moment of danger, it runs very quickly, timidly takes wing and flies away swiftly. It is almost impossible to catch. However, if one still manages to grab a blister beetle legs, it begins to struggle desperately and furiously, biting with its crescent-shaped jaws. There are biting insects, such as bees, wasps, ants and some other who are provided with a sting to inject venom. It is used in a dangerous moment for the insect or to paralyze its prey. In honey bees, sting is jagged and stuck in the body of the animal that attacked it. Despite the fact that after pulling the sting, the bee dies, this protective reaction does not remain unnoticed. Animals receiving a painful injection forever remember the lesson learned and will no longer attack stinging insects or those externally similar to them. Such defense mechanism shows not individual but social protection on which

the security of the whole species depends. In contrast to the bee sting, wasp does not get stuck in the body of the animal, but this quite a painful sting can occur multiple times.

The striking color pattern as a surviving tool. Coloration of wasps and bees (a combination of black and yellow stripes) is also a warning, especially for those who have previously experienced the effects of the poison. Biochemical funds for this purpose are made at the right time, according to the body of the insect. This way, genetic program controls a complex of protective means and mechanisms for the survival of the individual.

Autotomy

Autotomy is the technique used by insects in order to escape from the predator. It is the process of shedding appendages. Some representatives of the class have limbs due to which they can escape from a predator. Legs of certain types of arachnids, centipedes and *Orthoptera* insects break off. In most cases, autotomy is done by the reflex contraction of certain muscles and is usually associated with subsequent regeneration. Autotomy was developed in the course of evolution, primarily as a safety feature.

The use of the mechanism by the walking stick. This regeneration ability of many insects, such as stick insects, is considered to be a real advantage. When a predator is enough for one of their parts, the limb falls away and continues to twitch for some time. Meanwhile, the walking stick (order *Phasmatodea*) goes away using the remaining five legs. If the specimen of stick insects has not yet reached adulthood, he restores severed limbs during the next molt (replacing outer cover), while the new limb may be smaller in size.

Chemical Defense

One of the main tools for defense and attack in the living world are poisons. Poisonous substances, which are able to scare, paralyze or kill the enemy, are located in special glands. The poison of the insects has relative toxicity. Some bites are practically painless. At the same time, there is the poison that causes severe allergic reaction, fatal for

small animals. Toxic substances are used in different ways: they are either injected into the body of the enemy or sprayed with the jet. They can also be shot with the explosion and the formation of acrid clouds.

Aposematism. To scare predators away, insects do not only produce toxic releases, but simply unpleasant smelling substances. Moreover, special glands bugs, beetles and caterpillars have a smelly secretion that makes the enemy remember the meeting with its victim for a long time. Thus, predators have a conditioned reflex to avoid smelly insects of certain types and colors. However, some insects are not always safe.

The examples of the long-lived insect with mechanical kind of protection. For example, Darkling beetles of the family *Tenebrionidae,* which is the largest in our fauna, persistently react to the approach of a dangerous object standing on the front foot and releasing unpleasant-smelling liquid. Still, Darkling beetles are slow, so the mouse has time to grab it before the appearance of a defensive reaction. Then, the mouse eats everything except its tip. Such expedient behavior of the mouse can be instinctive, and may be the result of learning and experience, after obtaining the unpleasant lessons of interaction with these beetles.

The body of some insects is able to create poison mixtures that contain more than 50 different chemicals. They cause itching pain, cramps, and even destruction of the skin cells or shell animals. It is found that members of certain ant species, after spraying their enemy with formic acid, pour over a mixture of two of its complex chemical compounds. These substances, which are specifically synthesized by the body of an ant, can have a pleasant smell of lemon, but carry certain toxicity. In addition, they have an important feature. Formic acid promotes penetration through the integument of an animal. Studies have also shown that the chemical laboratory of the ant runs an innate program and creates many other protective

substances. Among them, there are even those who kill cholera, typhoid, and tuberculosis. Scientists are working on the possibility to use these substances for medical purposes.

It is hard to imagine a consistent appearance of all elements of this technological chain in the body of the beetle. For example, complex processes of compounds' synthesis are first developed which, when combined, produce an explosive mixture. Then chemicals, failing to appear in small quantities, once connected to its body, create an explosive mixture. It would be better to create multiple generations simultaneously for production and storage of chemicals and separate chambers.

Apparency as a tool for the life longevity. Toxic and malodorous substance in foam forms is also a defensive reaction of some wingless grasshoppers-bumpkins. In case of danger, they release the foam with a whistling hiss from their mouths and breasts. It consists of a mixture of quinine phenol and air bubbles. The origin of the toxic substances is required to plant food, which feeds the grasshopper. The larvae of all the cicadas, endowed with musical talent, are able to defend with the help of such foam. For example, spittlebug dribbling derives its name from the fact that after the usual consumption of large amounts of plant sap it secretes it into foam. These secretions are an excellent protection of its organism from both drying out and the attack of birds and other enemies. It collects pine needles and clumps of resin in special bags associated with the intestines. The most dangerous moment is when caterpillar allocates the lump of resin, and then inflates it and shoots. The shot glues foot, for example, of ants. The enemy becomes disarmed and motionless, and the caterpillar uses instinctive behavior and special protective devices of the body to save its life.

The representatives of some of the ant species have a poisonous mixture, which splashes into the enemy who is at a greater distance. It is typical of the worker ants from the *Formicidae* subfamily. Half of them have huge abdominal glands that produce formic acid. It is surrounded by a powerful muscular bag. In case of emergency, the muscle contracts, and

the poison is thrown to a distance of half a meter. It is striking that the distance which a poisonous substance can reach is 500 times greater than the length of the ant's body. Specific secretions protect many beetles, for example, leaf beetles and their larvae. They produce droplets of highly poisonous and sharp-smelling yellow-orange liquid through the joints of the body. Investigation of secretions of beetles showed that the introduction of the blood of their microscopic dose causes the death of small animals. It is interesting to observe insectivorous hunters who try this bug. A lizard that accidentally grabbed it has to throw it immediately out of the mouth and then wipe the long snout of the various items. Frog, in this situation, is trying as much as possible to stick its tongue, carefully wiping it on the plants. Even more poisonous little bugs belong to the family *Meloidae*. Even large animals can be killed by eating them with grass. Previously, dried *Meloidae* were used in the drug store business for making blister. Bombardier beetle from the family of ground beetles is endowed with the amazing system of self-defense. In case of danger, it throws poison from the end of their abdomen and skillfully directs the enemy jet, literally boiling (1000C) caustic liquid. In the air, it evaporates with a bang, forming a cloud of the malodorous chemical. Studies have shown that this explosive reaction of the bug that has500 - 1000 emissions per second leaves severe burns on the body of an animal while attacking him.

Gullan and Cranston Division of Chemicals. The protective chemicals have a two-class division. It was proposed by scientists Gullan and Cranston who were working on this issue for many years.

Class I. Chemicals of the Class I annoy, injure, poison, and drug some predators. The further development divides them into immediate or delayed substances. The type of poison is defined according to the period of time needed for the effect evaluation. When a predator insect treats and delays chemicals that are usually contained in its tissues, they induce vomiting and bubbles. Chemicals include bufadienolides, cardenolides, cyanides,

cantharidin, and alkaloids from Class I. Vertebrate is more affected by the use of these substances. The most widespread defensive compound of insect is alkaloids.

Class II. Chemicals of the Class II are substantially harmless. They stimulate the olfactory and taste receptors to inhibit feeding. They usually have a low molecular weight and are volatile and reactive, including acids, aldehydes, ketones, aromatic, and others. Furthermore, they can be aposematic, which indicates the odors' presence through chemical protection. It is significant to note that insects can use poisons of both classes at the same time.

Conclusion

A man in his daily life and practice is constantly faced with a variety of insects. Some of them bring positive effects, while others negatively impact the environment. Under the influence of human population, many species of insects have been reduced and become rare, and some are on the verge of extinction. All the insects are in need of protection. Due to the enormous variety of insects, their large number and wide distribution, their role in nature is extremely important. The development of the protective mechanisms of insects had taken centuries. However, this amazing evolution made them use different techniques, such as mimicry, coloration, autotomy, chemical defense, and others. Some insects have developed chitin as a means of defense, whereas others have horns. Some insects even shed their appendages as a distraction in order to prevent their predators from chasing them. It is significant to study mechanisms of protection in order to avoid the extinction of insects. They have evolved along with the development of the planet. All these tools used by insects are helping them to protect their existence in the world. Today, not all species are studied and many still remain a mystery indeed. Meticulous study of defense mechanisms will not only enlighten the concept of how the body of insects is built, but also help to understand the basic principles of evolution.