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THE EFFECT OF INSULIN SIGNALING PATHWAY ON HONEY BEE GROOMING BEHAVIOR

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Abstract

The insulin signaling pathway is a highly conserved mechanism in vertebrate and invertebrate that regulates many physiological processes such as metabolism, growth and development. Insulin becomes functional after binding to insulin receptors in most tissues. Any disorder in the regulation of insulin release or downstream signaling leads to a variety of metabolic diseases including diabetes and obesity. In general, researchers have focused on the role of insulin signaling in metabolism, cell proliferation, development, growth and ageing, but the role of insulin in regulating insect behavior and interactions between neural circuits has been an interesting and neglected issue. In this review we focused on the possible effects of the insulin signaling pathway on grooming behavior in honey bees.

Keywords: Grooming behavior, Honey bee, Insulin signaling pathway, Nerve circuit

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1. Introduction

Animals may perform the various behavior in response to their environment and internal state, and many movements are selected from a repertoire of stereotyped motor patterns (Hampel et al., 2015). This repertoire can include movements for different purposes, such as feeding, grooming, song production, locomotion, and even coordinated facial poses for expressing different emotions (Grillner and Wallen, 2004; Grillner et al., 2005). Many of these movements are produced by nerve circuits (Pearson, 1993; Kiehn and Kullander, 2004). Because most of the interaction between neurons in the nervous system occurs in synapses, changes in behavior are ultimately followed by changes in nature and the number of interneuronal synaptic contacts (Sweatt, 2016).

Grooming is a common behavior for getting rid of ectoparasites among vertebrates and arthropods (Aumeier, 2001). This behavior of bees has evolved to protect both individual and colony health (De Figueiró Santos et al., 2016). Grooming behavior is the ability of adult honeybees to remove mites from themselves or other bees (Kurze et al., 2016). Grooming behavior is named in two ways according to the way it is performed: auto-grooming or self-grooming and allogrooming or social grooming. Auto-Grooming is the self-cleaning behavior with the movement of mouthparts or pro- /

mesothoracic legs. Allogrooming can be one-on-one, or socially involving several bees acting together. During social grooming, bees use their mouthparts to remove mite and debris of mite from the wing bases and other body parts of other bees (Milum, 1947).

Some studies have shown that grooming behavior provides resistance to against tracheal mites in European honey bees (Pettis and Pankiw, 1998; Danka and Villa, 2003; Villa, 2006) and Varroa mites in African bee populations (Moretto et al., 1993; Guzman-Novoa et al., 1999; 2002; Arechavaleta-Velasco and Guzman-Novoa, 2001; Mondragon et al., 2005; 2006).

In this study, the possible role of the insulin signaling pathway in grooming behavior was examined.

2. Insulin Signaling Pathway and Effects on Insect Behavior

Insulin plays a critical role in a wide range of biological processes, including stimulation of glucose uptake, glycogen, lipid and protein synthesis, anti-lipolysis, activation of transcription of specific genes, and modulation of cellular growth and differentiation (Taha and Klip, 1999).

The Insulin Signaling Pathway (ISP) agonists in insects are generally termed “insulin-like peptides” (ILPs) or “insulin-related peptides” (IRPs) (Badisco et al., 2013). The Insulin-like peptides (ILPs) of invertebrates have been described as functionally homologous to insulin and insulin-like growth factor 1 (IGF 1) ligands in mammals (Flatt et al., 2005). In mammals, insulin is produced by beta-pancreatic cells and in insects, ILP is produced in neurons (Nilsen et al., 2011). Studies on insulin signaling in insects have covered the considerable distance with the identification of eight insulin-like genes in the fruit fly (Drosophila melanogaster) genome (Brogiolo et al., 2001; Grönke et al., 2010; Colombani et al., 2012). Although different ILPs are produced in different cell types and tissues at different stages of development, in all insects examined, at least one of the ILPs is produced by nerve cells in the brain (Nässel and Broeck, 2016).

Such as feeding and locomotor behavior are modulated through the insulin pathway by IPCs. Reduced insulin production from brain IPCs results in decreased downstream insulin signaling, leading to increased ethanol (EtOH) sensitivity and motivated foraging. With the decrease in insulin signaling in sNPFR (short Neuropeptide F receptor) expressing odor receptor neurons (ORNs) and NPFR (Neuropeptide F Receptor) expressing neuron enhances the sensitivity of ORNs to odors and increases the attractiveness of flies to harmful food sources. In locomotion, octopaminergic neurons signal to stimulate wake through IPCs. However, this effect is independent of insulin signaling. Insulin signaling in the corpus allatum (CA), an endocrine gland, triggers sexual dimorphism of locomotor structures. Finally, the insulin signaling in circadian small ventrolateral neurons (sLNVs) alters resting sensitivity (Figure 1) (Erion and Sehgal, 2013).

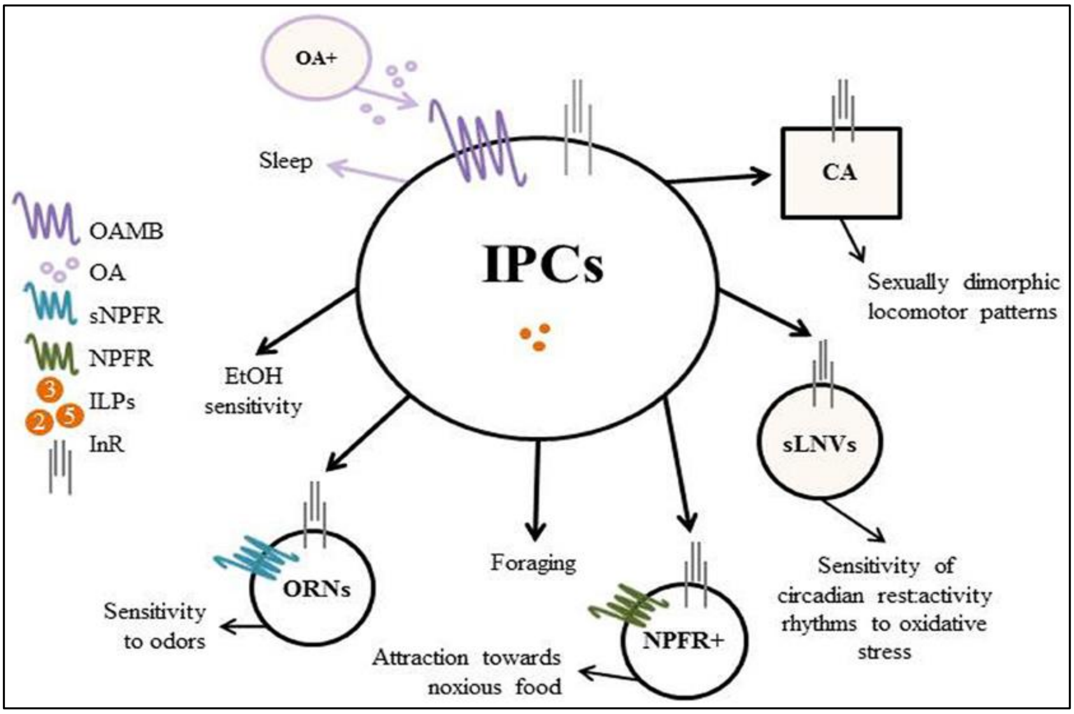

Figure 1. Regulation of behavior by insulin-producing cells (IPCs) in Drosophila (Erion and Sehgal, 2013).
CA= Corpus Allatum, ILPs= Insulin-Like Peptides, INR= Insulin Receptor, NPFR= Neuropeptide F Receptor, OA= Octopamine, OAMB= Octopamine Receptor, ORNs= Odorant Receptor Neurons, sLNVs= Small Ventrolateral Neurons, sNPFR= Short Neuropeptide F Receptor.

Octopamine is an analog of norepinephrine found in invertebrates. The biogenic amine octopamine can act as a neurotransmitter, a neurohormone, and a neuromodulator (Farooqui, 2012). Neuromodulators can serve a specific behavioral context or a specific physiological state and establish mutual interactions between nerve tissues in metabolic or physiological states. Also, octopamine is activated energy sources in living organisms and causes an increase in activity in general (Roeder, 2005).

Octopamine has a great effect in regulating insect behavior, such as locomotion and grooming behavior in locusts, dance and sting behavior in honey bees, discrimination of nestmates from non-nestmates in honeybees and fire ants, division of labor and foraging preference in honey bee, visual responses in locusts and honey bees, learning and memory processes in honey bees, Drosophila melanogaster and Gryllus bimaculatus (Farooqui, 2012).

3. Results and Discussion

Mechanical or chemical stimuli cause movements that aim to remove foreign matter from the body surface (Newland, 1998; Page and Matheson, 2004; Reingold and Camhi, 1978; Canal et al., 1998; Honegger et al., 1979; Hensler, 1986; Phillis et al., 1996; Reingold and Camhi, 1977). In addition to environmental stimuli, different neurotransmitters and neural genes have been associated with the modulation of this behavior.

Fussnecker et al. (2006), in order to investigate the effect of biogenic amines on honey bee motor behavior, the honey bee workers have injected with octopamine, tyramine, mianserin and yohimbine in different concentrations. They followed the bees over a period of time to observe the effects of these treatments on walking, grooming, fanning and flying. Grooming behavior, at least to some degree, showed increased expression in four biogenic amine treatments.

Novikova and Zhukovskaya (2015), reported that octopamine generally did not affect the locomotor activity of cockroaches, but increased grooming behavior in the first half of the trial. In another study reported, increased levels of tyramine and decreased octopamine in Drosophila larvae cause abnormal locomotion (Saraswati et al., 2004). However, this abnormality is thought to be caused by defects in motor pattern formation (Fox et al., 2006).

Luo et al. (2014), found that knockdown of OAMB in IPCs affects certain physiological properties that may lead to a decrease in systemic IIS (Insulin/IGF Signaling), such as increased starvation and oxidative stress resistance and increased food intake in Drosophila.

When the studies are examined, octopamine appears to have a positive effect on the honey bee grooming behavior. It can be said that the effect of the insulin signaling pathway on grooming behavior may have an octopamine-dependent effect. However, it should be noted that there are difficulties in testing grooming behavior and that there are very few neurotransmitter studies related to grooming behavior.

It is clear that more information is needed about the interactions between insulin and the nervous system, which are responsible for the regulation of behavior. At the same time, more studies are also needed to understand the neurological basis of grooming behavior. Thus, the effect of insulin on grooming behavior will be more easily understood.

Conflict of interest

The authors declare that there is no conflict of interest.

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