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Review

Neuroendocrine System and its Hormonal Activities in Silkworm *Bombyx mori*

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Abstract

Neuroendocrine system of the silkworm *Bombyx mori* consists of nervous system and endocrine glands. The nervous system has 3 parts namely central nervous system, visceral nervous system and periphery sensory nervous system. The endocrine glands include neurosecretory cells of the brain, subesophageal ganglion (SG), corpora cardiaca (CC), corpora allata (CA) and prothoracic gland (PG). The neurosecretory cells (NSC) are divided into 3 parts such as A, B and C cells. In silkworm *Bombyx mori*, the prothoracic gland is present in the prothorax just behind the head. The prothoracic gland produces moulting hormone, called ecdyson. Corpora cardiaca (CC) secretes prothoracicotropic hormone and copora allata (CA) secretes juvenile hormone. This review mainly focuses on neuroendocrine system and its hormonal activities in silkworm *Bombyx mori* and also covers the function and role of these hormones in the insect system.

Keywords: Neuroendocrine system, silkworm, *Bombyx mori,* neurohormones, insect system.

Introduction

A hormone is a chemical substance secreted by specialized cells/glands of the body and it is used by insects to regulate physiological, developmental and behavioural activities. Hormones are produced in very small quantities and hormonal effects may be stimulatory or inhibitory (Chapman, 2013). The Neuroendocrine system of the silkworm *Bombyx mori* consists of the nervous system and the endocrine glands. The nervous system of the silkworm is divided into three parts such as central nervous system, namely visceral or sympathetic nervous system and periphery sensory nervous system (Droste, 1974). Endocrine glands, consists of neurosecretery cells of the brain, subesophageal ganglion (SG), corpora cardiaca (CC), corpora allata (CA) and prothoracic gland. Various types of neurosecretery cells are present in the brain and produce neurohormones. They secrete five types of neurohormones such as prothoracicotropic hormone (PTTH), allatotropic hormone, eclosion hormone (EH), melanization and reddish hormone (MRCH) and Bursicon. Subesophageal ganglion secretes diapause hormone (DH) from its neurosecretory cells and corpora cardiaca secretes an adipokinetic hormone (AKH). Moreover corpora cardiaca secretes juvenile hormone (JH) and prothoracic gland secretes moulting hormone (Akai, 1988). These moulting and juvenile hormone are very much important, especially during moulting period and metamorphosis. Ecdyson and JH are maintained by the neurohormones.

The main function of the endocrine system is metabolism, growth and development, sexual function and reproduction, appetite, heart rate and regulation of body temperature (Gullan and Cranston, 2000).

Nervous System

The basic functional unit of the nervous system is the nerve cell or neuron, composed of a cell body with two projections (fibers), the dendrites that receive stimuli and the axon that transmits information, either to another neuron or to an effector organ such as a muscle. There are different types of neurons on the basis of structure and function (Wiggeslesworth, 1972). On the basis of structure, it includes monopolar (neuron with a single axon), bipolar (cell body bears an axon and a single, branched or unbranched dendrites), multipolar (neuron with aproximal axon and many distal dendrites). On the basis of function, it includes sensory neuron (it conducts impulse from sense organs to central nervous system), motor neuron (it conducts impulse from central nervous system to effector organs), inter/association neuron (inter-links sensory and motor neurons) (Wiggeslesworth, 1972). Nervous system can be divided into three major parts such as central nervous system, visceral nervous system and peripheral nervous system (Droste, 1974).

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Central Nervous System

Central nervous system (CNS) composed of a double chain of ganglia connected by longitudinal connectives (Takeda et *al.,* 1986). It includes Brain. It is formed by the fusion of first three cephalic neuromeres. It is consists of prtocerebrum, deutocerebrum and tritocerebrum (Kobayashi, 1957). All behaviors of the insect are controlled by the brain. Ventral nerve cord is formed by a series of ganglia. It is present in the thorax and abdomen below the alimentary canal (Takeda *et al.,* 1986). Subesophageal ganglion is formed by the last three cephalic neuromeres which includes innervate mandible, maxillae and labium (Kobayashi, 1957). Thoracic ganglia have three pairs and present in the respective thoracic segments. Abdominal ganglia have maximum eight pairs and number varies due to fusion of ganglia (Chapman, 2013). Thoraco abdominal ganglia produce single compound ganglia (Wiggeslesworth, 1972).

Visceral or sympathetic nervous system (VNS)

Visceral or sympathetic nervous system (VNS) is formed by an oesophageal sympathetic and a ventral sympathetic system. The oesophageal sympathetic system is directly connected with the brain innervating the fore and mid gut, dorsal vessel and other parts (Wiggeslesworth, 1972). Ventral sympathetic system is formed by a pair of transverse nerves connected with the ventral nerve cord ganglia. Ventral nervous system consists of three different systems such as stomodeal/stomatogastric, ventral visceral, and caudal visceral.

Peripheral nervous system (PNS)

The peripheral nervous system consists of all the motor neuron axons. These nerves are associated with the sensory structures (Chapman, 2013).

Endocrine glands

Neurosecretory cells of the brain: In case of silkworm, *Bombyx mori* neurosecretory cells are present in the brain and neurosecretory cells are specialized to produce hormones. It is divided into 4 groups, two medials in the intercerebalis and two laterals in protocerebrum (Akai, 1988). Generally the medials neurosecretory cells are found at early larval stage though pupa to moth. As well as lateral neurosecretory cells are present in the fifth instar larvae to moth. Neurosecretory cells are large in size and it has large nuclei compare than other nerve cells (Kobayashi, 1957). On the basis of cytological feature, neurosecretory cells are of two types A-cells and B-cells (Tembhare and Barsagade, 2000). In A-cells, Vacuole is present, elliptical in shape and it measures about 40 µM to 70 µM. In B-cells, Vacuole is absent, round in shape and it measures about 18 µM to 25 µM.

The brain hormone is produced by the neurosecretory cells of the brain. It is called neurohormone, as well as activation hormone. In brain, various types of neurosecretory cells are present and produce neurohormones like prothoracicotropic hormone (PTTH), allatotropic hormone, eclosion hormone (EH), melanization and reddish hormone (MRCH) and bursicon hormone. Brain hormone activates corpora allata and prothoracic gland to produce their hormones. Brain hormone stimulates the prothoracic gland to secrete moulting hormone. Ichikawa and Ihizaki (1961) extracted an active substance from insect brain, which is water soluble, heat soluble and non-dialyzable. Later they found that these substances resistant to pepsin and trypsin and suggested that this brain hormone may be mucopolysaccharide. Yamzaki and Kobayashi (1969) purified brain hormone extracted from the brain of *Bombyx mori*. The brain hormone purified from the brain of *Bombyx mori* at the larval pupal apolysis using decapitated larva of the fourth instar.

Prothoracic glands (PG): It is one of the most important endocrine organs for whole neuroendocrine system. A pair of prothoracic gland found in the prothorax just behind the head. Each gland has a rich tracheal and nerve supply (Akai, 1988). The prothoracic gland produces the moulting hormone called ecdysone. Ecdyson is one type of pheromone and it is converted into active hormone. Ecdyson is very essential for post-embryonic development of the insect, especially in larval moult and metamorphosis. The ovary of the adult female insect produced ecdysteriods is involved in ovarian maturation (Akai and Kiuchi, 1987). Maekawa *et al*. (1984) reported that there is an increase in both r-RNA due to the application of 20E which results in changes in shape and structure of nuclei and development of nuclei and development of organelles related to protein synthesis. Kobayashi *et al*. (1967) reported the influence of moulting hormone on ovarian development in pupal stage and showed that the injection of large amount of 20E into normal female silkworm pupae resulted in production of large sized eggs along with normal eggs. Chinzei (1975) reported that the silk gland of the silkworm broke down when exposed to ecdysterone. This suggests that it is an important factor inducing histolysis of specific larval tissues.

Corpora cardiaca (CC): The corpora cardiaca, a pair of endocrine organs located on the walls of the aorta, just behind the brain. Generally corpora cardiaca secretes a prothoracicotropic hormone (PTTH). The corpora cardiaca acts as signal amplifier, sending out the PTTH to the body, after they receive a signal from neurosecretory cells in the brain. They serve as a neurohemal organ for different hormones (Akai, 1988).

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Corpora allata (CA): The corpora allata, another pair of endocrine organs, is situated just after the corpora cardiaca. They secrete juvenile hormone (JH) and there are different types of juvenile hormone such as JH-1, JH-2, JH-3 and JH-0. Juvenile hormones are very much essential for post-embryonic development of the insects. These hormones are controlled by the neurohormone from neurosecretory cells in the brain (Akai, 1988). Neurosecretory cells are stimulating corpora cardiaca to secrete juvenile hormone and secretes sesquiterpene compound. Juvenile hormone has some specific roles, generally metamorphosis and regulation of reproduction development controlled by juvenile hormone. As well as larval characteristics are maintained and metamorphosis is inhibited. Fukuda (1956) demonstrated the presence of a second substance with juvenile hormone activity in Cecropia extract. The material comprised of 1/4th to 1/7th of the total juvenile hormone activity and is identical to first juvenile hormone. Fukuda (1956) demonstrated that in silkworm, the silk gland is more sensitive than epidermal cells to the juvenile hormone by means of reimplantation of corpora allata. Raabe (1982) in *Bombyx mori* showed that the larval coloration and the pigmentation of larval markings are controlled by juvenile hormone secreted from corpora allata during moulting process.

Subesophageal ganglion (SG): Subesophageal ganglion is elliptic in shape and they are different from other endocrine organs which are present in the brain. The neurosecretory materials present is more in the subesophageal ganglion during the pupation stage to the day before emergence and after that these material slowly decreases. During the larval stage, the amount of material is less than in the pupal stage. Generally the subesophageal ganglion secretes a diapause hormone (DH). Some insects living in certain area where climatic condition is very low in temperature and generally diapausing larvae may stop feeding, but some species feed periodically (Yamashi, 1996). Sonobe and Ohnishi (1971) reported that a protein fraction of silkworm adult head showed diapauses hormone activity. Diapause hormone consist of 2 µg of DH-B per pupa induce diapauses in 50% of the eggs. The glycogen content in diapauses eggs increases from 0-24 h after oviposition, then decreases until the end of diapause. On the other hand, the amount of sorbitol and glycerin became large with decrease of glycogen content, suggesting the conversion of glycogen to sorbitol and glycerin through trehalose.

Conclusion

Insect hormones are generated and used by insects for various activities. Nervous system and the endocrine gland constitute neuroendocrine system and they produce various hormones which functions in regulating physiological, developmental and behavioural activities in silkworm *Bombyx mori*.

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