Press Release

Shining light on the 100-year mystery of birds sensing spring for offspring

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Biologists at ITbM, Nagoya University have identified for the first time, a key photoreceptor cell deep inside the brain of birds, which takes the role of eyes in humans by directly responding to light and regulates breeding activity according to seasonal changes.

Nagoya, Japan – Professor Takashi Yoshimura and colleagues of the Institute of Transformative Bio-Molecules (WPI-ITbM) of Nagoya University have finally found the missing piece in how birds sense light by identifying a deep brain photoreceptor in Japanese quails, in which the receptor directly responds to light and controls seasonal breeding activity. Although it has been known for over 100 years that vertebrates apart from mammals detect light deep inside their brains, the true nature of the key photoreceptor has remained to be a mystery up until now. This study led by Professor Yoshimura has revealed that nerve cells existing deep inside the brains of quails, called cerebrospinal fluid (CSF)-contacting neurons, respond directly to light. His studies also showed that these neurons are involved in detecting the arrival of spring and thus regulates breeding activities in birds. The study published online on July 7, 2014 in Current Biology is expected to contribute to the improvement of production of animals along with the deepening of our understanding on the evolution of eyes and photoreceptors.

Figure 1. Photo of Japanese quail taken by Professor Takashi Yoshimura

Many organisms apart from those living in the tropics use the changes in the length of day (photoperiod) as their calendars to adapt to seasonal changes in the environment. In order to adapt, animals change their physiology and behavior, such as growth, metabolism, immune function and reproductive activity. "The mechanism of seasonal reproduction has been the focus of extensive studies, which is regulated by photoperiod" says Professor Yoshimura, who led the study, "small mammals and birds tend to breed during the spring and summer when the climate is warm and when there is sufficient food to feed their young offspring," he continues. In order to breed during this particular season, the animals are actually sensing the changes in the seasons based on changes in day length. "We have chosen quails as our targets, as they show rapid and robust photoperiodic responses. They are in the same pheasant family as the roosters and exhibit similar characteristics. It is also worth noting that Toyohashi near Nagoya is the number one producer of quails in Japan," explains Professor Yoshimura. The reproductive organs of quails remain small in size throughout the year and only develop during the short breeding season, becoming more than 100 times its usual size in just two weeks.

In most mammals including humans, eyes are the exclusive photoreceptor organs. Rhodopsin and rhodopsin family proteins in our eyes detect light and without our eyes, we are unable to detect light. On the other hand, vertebrates apart from mammals receive light directly inside their brains and sense the changes in day length. Therefore, birds for example, are able to detect light even when their eyes are blindfolded. Although this fact has been known for many years, the photoreceptor that undertakes this role had not yet been clarified. "We had already revealed in previous studies reported in 2010 (PNAS) that a photoreceptive protein, Opsin-5 exists in the quail's hypothalamus in the brain," says Professor Yoshimura. This Opsin-5 protein was expressed in the CSF-contacting neurons, which protrudes towards the third ventricle of the brain. "However, there was no direct evidence to show that the CSF-contacting neurons were detecting light directly and we decided to look into this," says Professor Yoshimura.

Yoshimura's group has used the patch-clamp technique for brain slices in order to investigate the light responses (action potential) of the CSF-contacting neurons. As a result, it was found that the cells were activated upon irradiation of light. "Even when the activities of neurotransmitters were inhibited, the CSF-contacting neurons' response towards light did not diminish, suggesting that they were directly responding to the light," says Professor Yoshimura excitedly. In addition, when the RNA interference method was used to inhibit the activity of the Opsin-5 protein expressed in the CSF-contacting neurons, the secretion of the thyroid-stimulating hormone from the pars tuberalis of the pituitary gland was inhibited. The thyroid-stimulating hormone, so-called the "spring calling hormone" stimulates another hormone, which triggers spring breeding in birds. "We have been able to show that the CSF-contacting neurons directly respond to light and are the key photoreceptors that control breeding activity in animals, which is what many biologists have been looking for over 100 years," elaborates Professor Yoshimura.

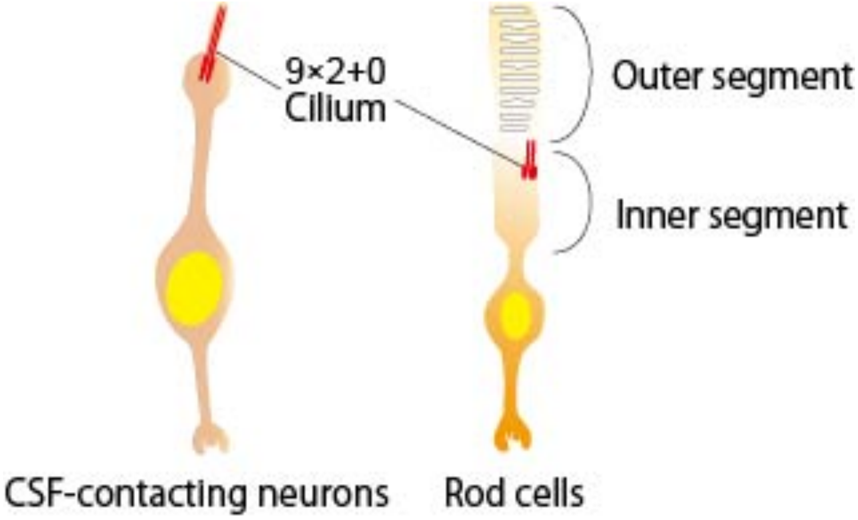

Figure 2. CSF-contacting neurons do not possess outer segments present in the rod cells of the eye's retina but have cilia in the same manner as visual cells.

There have been many theories on the role of CSF-contacting neurons in response to light. "Our studies have revealed that these neurons are actually the photoreceptors working deep inside the bird's brain. As eyes are generated as a protrusion of the third ventricle, CSF-contacting neurons expressing Opsin-5, can be considered as an ancestral organ, which shares the same origin as the visual cells of the eyes. Opsin-5 also exists in humans and we believe that this research will contribute to learning how animals regulate their biological clocks and to find effective bio-molecules that can control the sensing of seasons," says Professor Yoshimura. Professor Yoshimura's quest to clarify how animals measure the length of time continues.

This article "Intrinsic photosensitivity of a deep brain photoreceptor" by Yusuke Nakane, Tsuyoshi Shimmura, Hideki Abe and Takashi Yoshimura is published online on July 7, 2014 in Current Biology, Volume 24, Issue 13, Pages R596-597.
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About WPI-ITbM (http://www.itbm.nagoya-u.ac.jp/)
The World Premier International Research Center Initiative (WPI) for the Institute of Transformative Bio-Molecules (ITbM) at Nagoya University in Japan is committed to advance the integration of synthetic chemistry, plant/animal biology and theoretical science, all of which are traditionally strong fields in the university. As part of the Japanese science ministry's MEXT program, the ITbM aims to develop transformative bio-molecules, innovative functional molecules capable of bringing about fundamental change to biological science and technology. Research at the ITbM is carried out in a "Mix-Lab" style, where international young researchers from multidisciplinary fields work together side-by-side in the same lab. Through these endeavors, the ITbM will create "transformative bio-molecules" that will dramatically change the way of research in chemistry, biology and other related fields to solve urgent problems, such as environmental issues, food production and medical technology that have a significant impact on the society.

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