Paleoneurology: A Sight for Four Eyes

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The ‘third eye’ of the pineal complex is a curious component of the vertebrate brain associated with light sensation and melatonin production. A fossil lizard with a ‘fourth eye’ now calls for a reinterpretation of pineal evolution.

“...a certain very small gland [the pineal organ] situated in the middle of the brain’s substance...”
René Descartes, The Passions of the Soul, 1649 [1]

It’s perhaps understandable that our knowledge of the function and evolution of the pineal organ has been murky, because, as Descartes noted, it is indeed a very small structure buried deep within the brain of humans and other mammals. Although perhaps few people today subscribe to Descartes’ view of the pineal organ as the ‘seat of the soul’, it retains an almost mystical quality in some quarters. Pop cultural references abound, suggesting ways (and selling products, of course) to ‘activate the pineal’ with cannabis or ‘harmonic sound wave technology’ to achieve enlightenment (psychedelic or spiritual). Fortunately, there is also a rich scientific literature on the neuroscience and clinical neuroendocrinology of the pineal gland, revealing that the organ may have less to do with the soul and enlightenment and more to do with responding to light/dark cycles and mediating circadian and seasonal rhythms via production of the hormone melatonin [2]. The mammalian pineal organ is complicated enough, but when other vertebrates are taken into account, we now speak of a ‘pineal complex’ involving multiple organs that emphasize the photosensory component. That is, they often are ‘eyes’ with structures comparable to the cornea, lens, retina, and visual pigments (opsins) that we typically associate with our normal, lateral eyes and which breach the skull to appear on the top of the head [3,4]. In fact, when considering the pineal complex of vertebrates we now need to distinguish between ‘lateral eyes’
Regardless, both pineal and parapineal always separate midline structures [8]. The pineal among invertebrates and vertebrates, and sense, visual organs) are widespread beginnings of vertebrates [6]. The pineal organ, and the pineal organ sits behind it organ, and the pineal organ sits behind it organ, and the pineal organ sits behind it complex is comprised of a pineal organ whereas lizards emphasize pineal gland whereas lizards emphasize the parapineal gland. The kicker is that there is a huge diversity of extinct tetrapods (land vertebrates), such as the famous sail-backed Dimetrodon, that often show a single large midline parietal foramen in their skull roofs [9–11]. Is this ‘third eye’ opening for a parapineal (parietal) eye or a pineal eye? Both ideas have been proposed [10,12].

Enter Saniwa ensidens, the 49-million-year-old fossil lizard that sparked Smith and colleagues’ [5] re-exploration — and indeed revision — of pineal-complex evolution in this issue of Current Biology. Fossils of this outwardly routine species, a close kin of extant monitor lizards (Varanus), have long been known and have been well studied recently [13,14]. Smith and colleagues [5], however, noticed a couple of specimens that showed something remarkable, which is not one midline opening in the skull roof as in other lizards, but two. These fragmentary fossil specimens had sat in the Yale Peabody Museum collection, barely noticed, for almost 150 years, but these authors had the insight to wonder whether they were facing a ‘four-eyed’ animal. Indeed, at the end of their exhaustive studies, Smith and colleagues [5] came to the conclusion that the larger normal-looking parietal foramen in the front must have been for the parapineal organ as in other lizards, and the smaller ‘accessory’ foramen behind must have been for the pineal organ. Moreover, the cup-like bone surface on the outer part of the accessory foramen is consistent with the presence in life of cornea- and lens-like structures. In other words, Saniwa ensidens had both parietal (parapineal) and pineal eyes!

This completely unexpected finding has a number of important implications. For example, there is no longer any debate that it is the parapineal component of the pineal complex that forms the parietal eye in lizards, and that the parapineal/parietal opening should no longer be termed the ‘pineal foramen’ in lizards as it still is sometimes. It also tips the scales toward the notion that the pineal complex probably is natively a midline system rather than a paired system that got evolutionarily tugged into its midline alignment. But, although it’s good to clean up the nomenclature and nail down the original anatomy, the truly remarkable point is that Saniwa had a photoreceptive pineal eye that peered out of the top of its
Such a feature was thought to have been lost hundreds of millions of years ago back when the earliest vertebrates with jaws evolved, at which point the pineal gland sunk deeper into the brain cavity and lost its eyelike function. In 1893, Belgian paleontologist Louis Dollo formulated the Law of the Irreversibility of Evolution, which simply states: that which is lost shall not be regained [15]. Some laws are meant to be broken, and the re-evolution of a pineal eye in Saniwa is not the first atavism to be reported. Still, it’s not a common occurrence, and it’s so rare in this case that it raises new questions. How could a pineal eye simply re-evolve? Few details of the developmental genetics of the pineal complex are known, but the similarities in the tissue types and visual pigments between the lateral eyes and pineal complex perhaps reflect commonalities in genetic regulation [6] such that slight modification of regulatory pathways could change their developmental fates. Minimally, Saniwa seems to demonstrate the latent capability of the system to generate a true pineal eye. But why Saniwa? What’s special about this lizard? Nothing is special, as far as we can tell. Smith and colleagues [5] offer some suggestions, but it’s fair to say that the functional benefit of having both parapineal and pineal eyes remains obscure. This finding also means that all of a sudden we’re no longer sure which organ — pineal or parapineal eye — was peeking through the parietal foramen of a host of extinct ancient tetrapods. As is often the case in science, we progress by changing our search image, and the analysis of Saniwa requires that change for both paleontologists and developmental neuroscientists. While the pineal may not be the seat of the soul, it still has some mysteries to reveal.

REFERENCES