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a tail of protection

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Movement is essential to all organisms. Long before the advent of legs for instance, Nature had devised cilia to satisfy the essential need of mobility – both self-mobility and the capacity to create mobility. These tail-like protrusions, which appear on the surface of many eukaryotic cells and are known as motile cilia, are capable of propelling protozoans forward, for example, or of pushing an ovum along the fallopian tube towards the uterus. A second type of cilium also exists. These are the sensory cilia, such as those that belong to our taste buds for example, and which convey the sense of taste to our brain. However, since the beginning of this new century, scientists have discovered yet a third type of cilium. Indeed, there is growing evidence that some motile cilia can also be sensory. Or vice versa. By way of illustration, researchers have demonstrated that motile cilia located in the lungs can actually sense noxious substances, thanks to the existence of "taste" receptors on their surface, and then whip them away to clear the airways.

"Washed-up", by Mateo Dineen

Courtesy of the artist

Over many millions of years, organisms have learned that noxious substances are usually the ones with a bitter taste. Instinctively, an animal will spit out bitter-tasting food in case it might turn out to be life-threatening. Conversely, we know that most sweet-tasting substances are probably alright because these are the substances that are usually full of sugar, hence full of energy. Besides actually tasting toxic substances, we also inhale them. Our lungs react by coating the toxins – that can also be produced by pathogenic bacteria for example – with mucus, which is subsequently cleared away by way of cilia found on the surface of epithelium cells that line the lungs.

Cilia were first observed by the man who invented the microscope, the Dutch tradesman, Antonie van Leewenhoek (1632-1723). An instrument he first devised so that he could detect faults in linen fabric. He observed bacteria, protists and spermatozoa, and his observations were published in the Royal Society of London's journal "Philosophical Transactions". Indeed, he is said to have been the first ever to have described single-celled organisms – a notion not readily welcomed by the Royal Society at the time. Almost 200 years later, the Swiss anatomist K.W. Zimmermann described cilia on the surface of mammalian cells for which he suggested a sensory role but this was largely ignored, and it was only in the late 1960s that the existence of sensory cilia were finally acknowledged. Now, almost 50 years later, scientists are beginning to realise that there are cilia which can be both sensory and motile.

There is no real "first" discovery. More often than not, a scientific discovery depends on painstaking observations that eventually lead up to a revelation – which may be qualified as ground-breaking. Such has happened with the recent affirmation that cilia can be both sensory and motile. In truth, it has been in the air for some time, and was largely hinted by Zimmermann over 100 years ago.

So how are cilia capable of sensing substances in the first place? Unlike prokaryotic cilia, eukaryotic cilia are surrounded by a membrane on which can be found sensory receptors. Sensory receptors were recently observed on epithelium cells which line the lungs. In particular, four different types of receptor were identified – which all belong to the bitter taste receptor family, also known as the T2R family. The four receptors are G-protein coupled receptors. In taste buds, when such proteins are stimulated, they trigger off a signal transduction pathway that ultimately reaches the brain. In turn, the brain informs the organism that what it is consuming is bitter and, hence, probably not good for it. It is fairly easy to understand when it comes to taste buds but how does such a system work in the lungs? Especially when, instinctively, we do not have the impression that our airways can smell anything at all, let alone sense danger…

The system is ingenious and completely bypasses the central nervous system, unlike the olfactory or the tasting systems. Indeed, observations suggest that when the airway cilia recognise a noxious compound, a – still unknown – signal transduction pathway is triggered off, bringing about an increase in cellular calcium. This increase causes the cilia to wiggle faster. Consequently, the toxins – wrapped up in mucus – are whipped away faster, and the lungs are eventually cleared. What is more, the combination of four different types of T2R on the surface of the cilia should ensure the "tasting" of a large variety of noxious compounds.

Hence our lungs may prove to be capable of not only "tasting" harmful compounds but also getting rid of them. There has been some discussion as to which function appeared first. Were cilia originally sensory and then, with time, became motile? Or were they first motile and ended up becoming sensory? It could be that the whole thing started with the existence of a polarised gathering of sensory receptors on a cell, which eventually grew into a sort of antenna making the structure more effective in terms of receiving and signalling. As motility requires a multi-protein apparatus, the motility factor may have emerged a little later. Consequently, the passing of time has caused some types of cilia to lose one of the capacities – motility or sensory – rather than acquire one or the other. But does it really matter? Is it not heart-warming to know that there are so many different systems at work within us just to keep us alive?

N.B. Also read Protein Spotlight issues 17, 55 and 61

Cross-references to UniProt

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