

Figure 1 Coloured transmission electron micrograph of a cross-section of cilia in the lung. Microtubules are shown in orange $\times 200\,000$

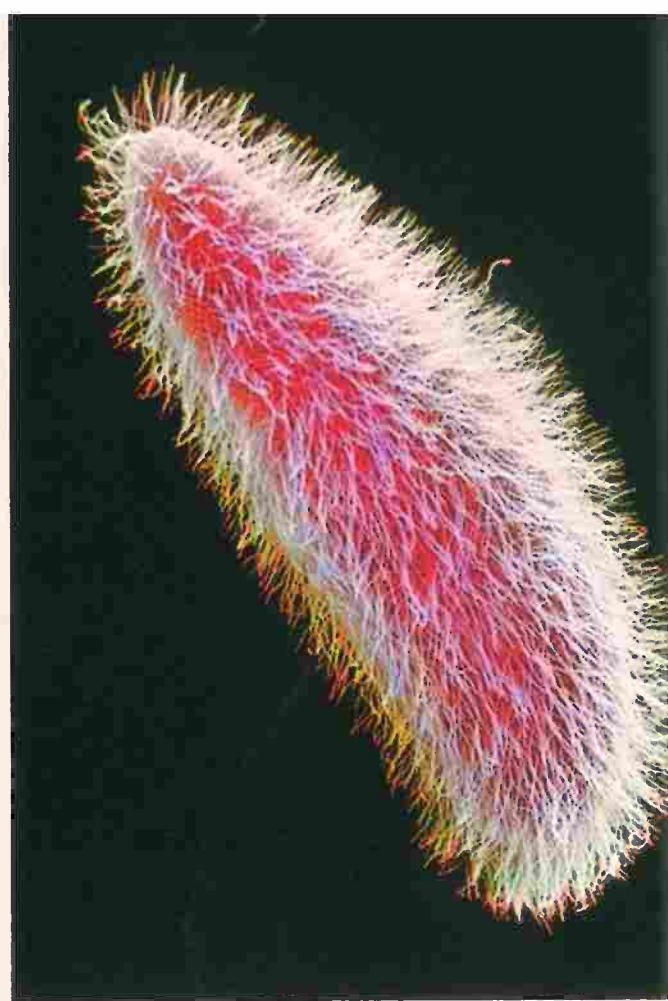


Figure 2 Coloured scanning electron micrograph of the freshwater, single-celled organism *Paramecium*, covered with cilia, which beat to propel it through the water $\times 650$

Cilia and flagella

Cilia and flagella (singular: cilium and flagellum) are fine, hair-like structures found on the surface of a wide range of cells. In eukaryotic cells, the structure of cilia and flagella is similar. In cross-section they show a '9+2' arrangement, comprising nine pairs of protein microtubules in a ring, with two further microtubules in the centre (see Figure 1), all enclosed by the cell-surface membrane. Movement — bending — is caused by protein arms that link adjacent pairs of microtubules and make them slide past each other. This process uses energy from the hydrolysis of ATP.

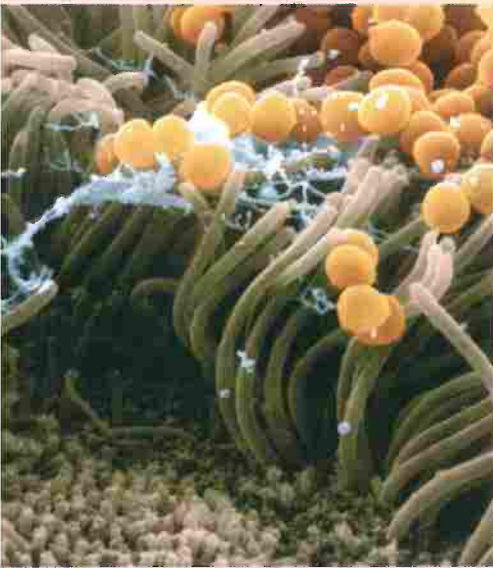
The most obvious difference between cilia and flagella is their length. Cilia are short (2–10 micrometres) and occur in large numbers, making the cell appear hairy. Flagella are longer (up to more than 1000 micrometres) and there are only a few per cell. Their most obvious function is to generate movement, but they also move differently. Cilia beat like oars, at about 5–10 beats per second, and usually in phase with each other. This leads to coordinated movement of the whole cell (see Figure 2 and

<http://tinyurl.com/pnodyjo>) or moves fluids or particles across the cell surface (see Figures 3 and 4). Flagella move individually in an undulatory pattern, with a wave of bending passing along the length. An example is the tail of sperm (see Figure 5).

Cilia are adapted for many purposes in addition to movement — for example, in sense organs. The hair cells of the inner ear have cilia arranged in rows according to their length. They bend in response to a sound wave, and bending is converted into a generator potential in the cell.

The flagella of prokaryotes, such as bacteria, are different in structure from those described above. They are again used for movement and may be present singly, in pairs, or as a group at one end of the cell (see Figure 6, <http://tinyurl.com/noh22m7> and <http://tinyurl.com/o47yyfd>). Movement is due to a wheel-like structure at the base, which rotates, causing the flagellum to act like a propeller.

Catherine McCrohan



Coloured scanning electron micrograph of cilia in a respiratory tract. These move mucus (blue) and harmful bacteria (orange) up to the back of the throat where they are swallowed $\times 9500$

Coloured scanning electron micrograph of ciliated inner surface of the fallopian tube. Beating cilia move a primary oocyte from ovary to uterus $\times 900$

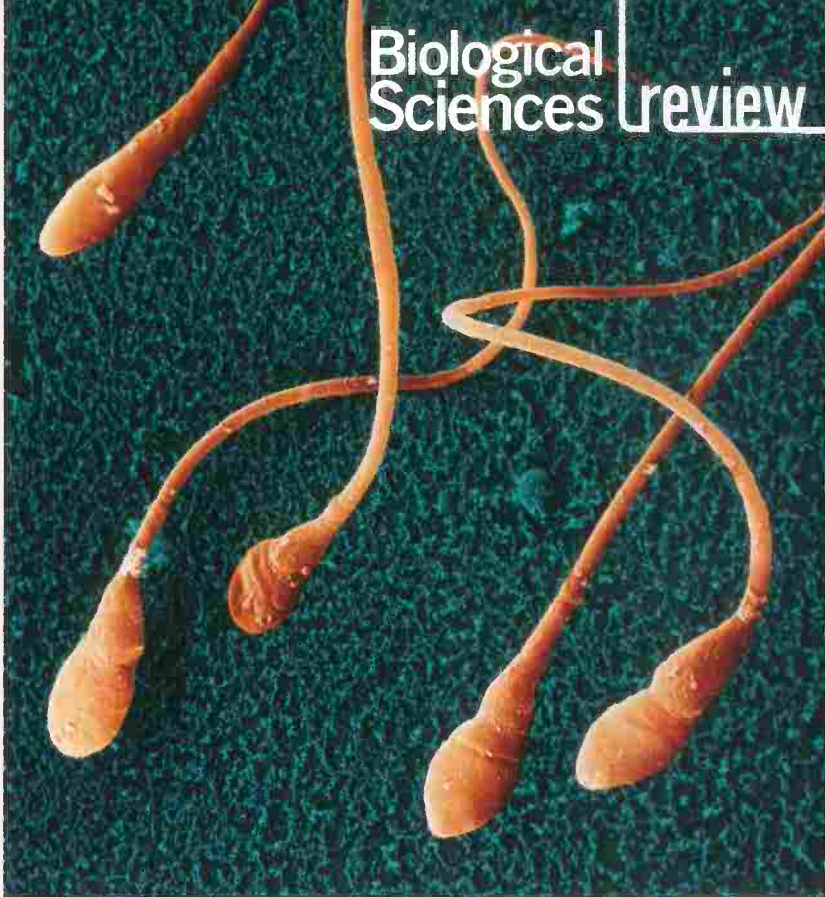


Figure 5 Coloured scanning electron micrograph of human sperm cells, which swim using their whip-like flagella $\times 2400$

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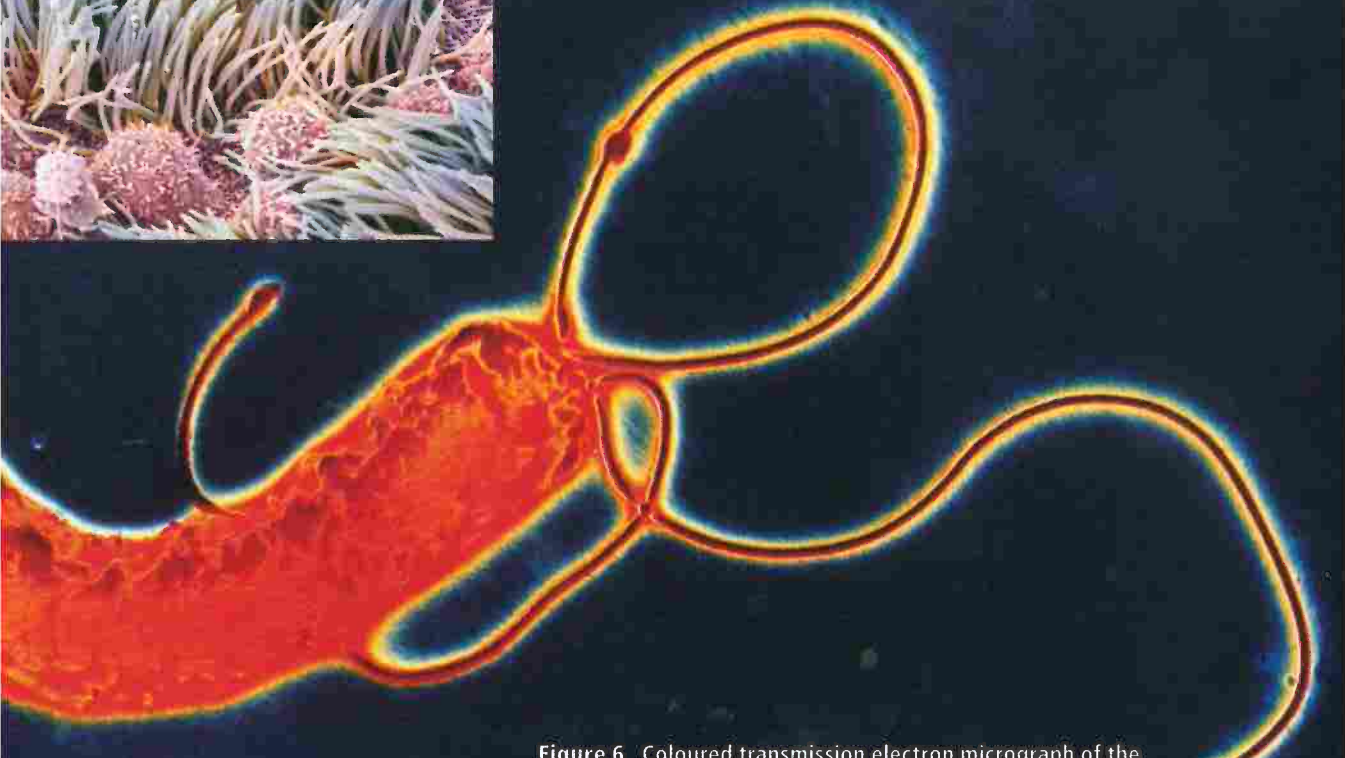


Figure 6 Coloured transmission electron micrograph of the