Life and death of cells

The life expectancy of the cell

The lifespans of different cells vary greatly

Cells can last a human lifetime, but not many do. Some, such as the white blood cells that hunt down bacteria, are gone in less than a day, while cells in the lining of the gut hang around for nearly a week. Most, though, last a good deal longer – liver cells for a year or so, bone cells for perhaps ten years.

Just a few kinds of cell can endure from birth to their owner's death. They include cells inside the lens of the eye (which become inert once they are in place in the embryo), cells in heart muscle and, perhaps most importantly, neurons in the brain.

Counting all the cells a person ever has would take several lifetimes. The average turnover of all human cells in different tissues is seven to ten years, so the lifetime cell count is perhaps ten times the adult total – at least several tens of trillions of cells. That ignores many other cells, like the 180 or so types of bacteria and other microorganisms that live in and on our bodies. This microbiota has a significant impact on human health, and it's thought that each of us carries ten times as many of these cells as we have our own, human cells, which can account for 3 per cent of our body mass.

Under development

Controlled cell division is a key part of development

Perhaps the most remarkable fact in biology is that the several tens of trillions (1 trillion = 10^{12}, or 1,000,000,000,000) of cells that make you develop from a single cell – a fertilised ovum, or zygote. Controlled cell division is crucial for development.

In the early stages of embryogenesis, the zygote undergoes cellular division to create two cells, which then go on to make four cells, and then eight (and so on). Each division takes between 12 and 24 hours, so the eight-cell stage is usually reached at around day 3. Once the embryo has between 16 and 32 cells, the dividing cells can begin to differentiate and form structures that fold, get reshaped or even migrate to different locations. Disrupting just one of the many genes involved in controlling all these subtle shifts increases the risk of developmental defects. The effects of these defects may be felt much later on in adult life, not just at birth.

Waste disposal

How do cells dispose of their unwanted parts?

Cells are continually making new molecules, while old ones are broken down and recycled. This is especially important in cell signalling, where old signals need to be stopped in order for new signals to be responded to. The main site for this breakdown is the lysosome, which acts as a cellular stomach.

A typical human cell has about a hundred lysosomes, each containing a collection of potent hydrolytic (digestive) enzymes, which break down substances by hydrolysis, enclosed in a membrane. Old organelles, other cellular waste and, in immune system cells, old red blood cells or bacteria engulfed by the cell are all wrapped in membranes of their own. These then fuse with the lysosome, where they are quickly broken down into small molecules that can then be reused.

In cases where one of the lysosomal enzymes fails, the cell cannot keep up with removing waste. In the rare genetic condition Tay–Sachs disease, for example, an enzyme that mops up a fatty chemical in neurons is defective. This chemical, a ganglioside, then accumulates and eventually destroys cells in the

brain and spinal cord, causing a progressive loss of mental and physical function that usually results in death before the age of five.

The right packaging is also crucial for recycling and disposal. Cells constantly pinch off bits of outer membrane, turning a small pit in the membrane into a vesicle, which is brought inside (endocytosis). Larger vesicles import material from outside. The vesicles then fuse with an extensive network of tubes and bags, known as endosomes, which sort incoming material.

New vesicles can also bud off from here, and shift designated contents onward – to other parts of the cell, back to the outer membrane (through exocytosis) or to the lysosomes. Cell surface receptors are recycled as part of this process, too.

Ageing cells have a number of tell-tale signs

Over time, the waste disposal system in the cell can get clogged up. Old, tangled proteins and other bits of cellular junk defy the lysosomal enzymes. Remnants of fatty acids are a particular problem and they make up a big portion of the yellowish pigment granules known as lipofuscin, the appearance of which is a sure sign of an ageing cell.

Other signs of cell ageing, such as shortening of the telomeres on the ends of the chromosomes, are related to how many times the cell has divided. Most, though, are the result of normal wear and tear. Mitochondria age faster than other organelles. Their job of energy release through aerobic respiration exposes them to reactive chemicals – free radicals – that can damage DNA.

Mitochondria have some essential genes in their own DNA, and the proportion of them that have serious defects increases as the person and their cells grow older; this can cause a decline in mitochondrial function.

Cells die in a variety of ways

Cells, like people, die if they are starved or poisoned. Blockage of the coronary artery in the heart causes death of heart muscle cells in a heart attack, for instance. A similar obstruction in the carotid artery, which supplies the brain, leads to the destruction of brain cells in a stroke. This kind of death is called necrosis, but a cell’s life can also end in other ways.

One is programmed cell death, or apoptosis. Cells have an inbuilt self-destruct routine that keeps them poised on the brink of suicide. Normally, signals from neighbouring cells keep them from doing themselves in, but if the signals change, the cell pushes the suicide button.

This is a neat and tidy death. Whereas necrotic cells swell and burst, spilling lysosomal enzymes and damaging surrounding cells, apoptosis involves the orderly dismantling of organelles and proteins: the cell shrinks and ends up as a few vesicles, which are cleared up by other cells.

Apoptosis happens in different places at different times. The developing embryo uses it to sculpt fingers from a web-shaped hand, by removing the cells in between the fingers. Cells with damaged DNA may sense the damage and sacrifice themselves for the common good, as in the case of sunburn. In this way, apoptosis may prevent skin cancer. Viruses may also set off apoptosis in infected cells. Triggering apoptosis is one way that HIV depletes the immune system of vital defensive cells.