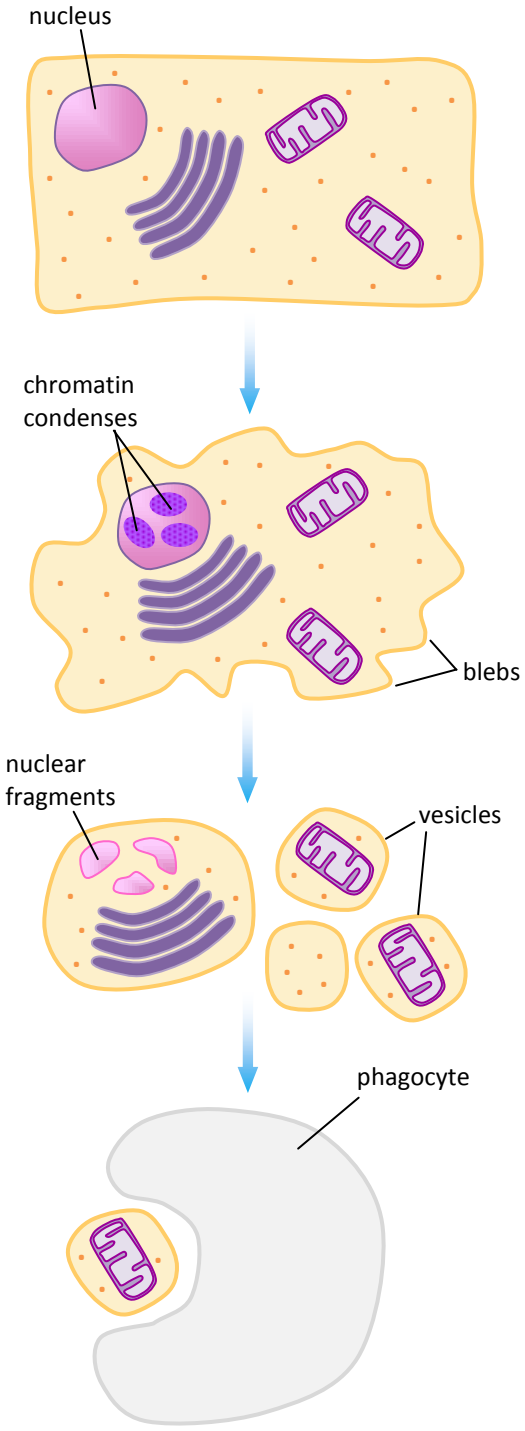
5.4 Apoptosis

Programmed cell death: a series of biochemical events leading to a tidy, healthy cell death

Programmed cell death

The term **apoptosis** literally means "programmed cell death". This is a process which occurs in almost all multicellular organisms, and is essentially a small series of biochemical events which lead to a tidy and clean cell death which causes no harm to the overall organism (described as sacrificing the one cell for the greater good of the organism). Generally speaking, cells should normally undergo around fifty mitotic cell divisions before apoptosis *should* dispose of the cell.

Apoptosis is considered the 'healthy' way to remove cells: as opposed to **cell necrosis**, which is the unexpected or improper death of cells. Necrosis is always caused by external factors which the cell does not influence, such as pathogens or trauma. Whilst apoptosis is actually beneficial to the organism, necrosis often can prove harmful, or fatal.



The stages of apoptosis are as follows:

- enzymes break down the cell's cytoskeleton
- the cytoplasm becomes densely packed as all the tiny organelles bundle together
- the cell surface membrane alters in shape, giving the appearance of a flaccid cell, with many 'inland' and 'bay' shapes (the parts that stick out are called **blebs**)
- chromatin from within the nucleus condenses, and the nuclear envelope breaks down
- as the nuclear envelope breaks down, DNA also breaks into fragments, and **nuclear fragments** become separated into smaller chunks that will be split into separate vesicles
- the cell packages its contents into **vesicles**
- vesicles are taken up by **phagocytes** and the cellular debris is disposed of, and by this apoptotic method no other cells are damaged or harmed

The process of apoptosis is very speedy. The process is controlled by a range of cellular signals, both intracellular and extracellular. These signals include **cytokines** made by the cells from the immune system, hormones and nitric oxide. Nitric oxide, for example, can induce apoptosis by making the mitochondrial membrane more permeable to hydrogen ions, removing the carefully maintained concentration gradient which drives *chemiosmosis*.

If cells have damaged DNA, including a mutation to genes involved in regulating mitosis, they do not respond to certain signals from surrounding cells. This means they do not undergo apoptosis, and keep on dividing by mitosis, forming a *tumour*. If cells from the tumour break away, enter the bloodstream or lymph system, and travel to another part of the body, they can set up *secondary cancers*. This is called **metastasis** and the cancerous tumour is malignant.

Apoptosis is a particularly important process during development, where mitotic divisions are very regular. During development, it is apoptosis which causes the fingers and toes to separate from each other (those with webbed feet have improper apoptosis during early development). The rate at which cells undergo mitosis and apoptosis should be balanced to prevent tumours (not enough apoptosis) or cell loss and degeneration (too much apoptosis).