Terence Allen & Graham Cowling

# THE CELL

## A Very Short Introduction

OXFORD

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# Chapter 1
# The nature of cells

## What makes a cell?

A cell is the smallest unit of life. Everything living is formed of cells, from single-celled organisms, familiar to us as bacteria, to the most complex of creatures such as ourselves, formed of mind boggling numbers of cells, but trivial in comparison to cell numbers in two hundred tons of blue whale. In its role as the basic building block of life, a cell might be considered a relatively simple collection of components, gently 'ticking over' to maintain itself and occasionally dividing to create a new cell. Nothing could be further from the truth. Each and every cell, from the simplest to the most complicated, is a self-contained molecular factory working frantically throughout every minute of its lifespan, whether this is the half hour of unique existence of most bacteria before they divide, or the self maintenance and day-to-day activity of our nerve cells, living for several decades. The analogy of a cell as a factory falls somewhat short because, to match cellular activity, the factory itself and much of its machinery would have to be dismantled and rebuilt on a daily basis, without any slowing of production levels. Both animal and plant cells are around a thousand-fold larger than bacteria with a much more complicated and intricate internal organization.

Just what sort of chemistry can support the extreme levels of synthesis that allow the simpler cells to double themselves in minutes, and more complicated cells within a day? At the fundamental level, life is based on the atoms of only six of the 117 known elements: carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur. Hydrogen and oxygen, combined as molecules of water, make up 99 out of every 100 molecules in the cell. This might appear to make life a rather dilute affair, but some of this water is tightly bound into the structure of larger molecules, and does not occur as actual liquid. Life at the molecular level is based on a restricted set of small carbon-based molecules common for all cells, which include sugars (providing chemical energy), fatty acids (forming cell membranes), amino acids (the units of all proteins), and nucleotides (the subunits of informational molecules such as RNA and DNA). All proteins are formed from just 20 different amino acids, which are common to every living thing. This 'alphabet' of amino acids is combined in a variety of different ways similar to the use of letters to make words, forming a massive 'vocabulary' of proteins. Proteins exist in a remarkably diverse variety of forms, providing the structural materials, chemical catalysts, and molecular motors that support and drive the processes of life. The code for each unique protein is stored in another code, this time of four letters, which makes up the genes in our DNA and which is passed from mother cell to daughter cell at each division. Each of the 24,000 or so individual genes in our DNA is specific for a single protein, but our bodies may have many times this number of proteins, produced by modifying the original genetic message. Proteins are combined to form multi-protein complexes, the cogwheels and bearings that drive the motors of production and maintenance within the cell. This level of complexity works perfectly for the simpler cells such as bacteria, but in larger and more complex cells such as our own, specific tasks are undertaken in separate sites in the cell termed organelles, which are separated from other components within the cell by their own membranes. Adding yet a further layer of complexity, our own bodies contain 200 or so different cell types.

This book attempts to provide an introduction to the massive diversity undertaken by cells in order to go about their business, and why any (cellular) shortcoming may result in disease.

## Basic cell characteristics

Everything that lives on the surface of the planet is cellular in nature. At this point we should exclude viruses, as they are unable to reproduce themselves without hi-jacking the synthetic processes of the cell they infect. Their non-vital nature is emphasized by the capacity to make crystals of purified viruses in solution. The cell is the basic unit of life, and as such must fulfil three requirements: (1) to be a separate entity, requiring a surface membrane; (2) to interact with the surrounding environment to extract energy in some way for maintenance and growth; and (3) to replicate itself. These parameters are the same for all living beings, from the smallest bacterium, to any one of the 200 different cell types that create a human being. Many organisms live as single cells, whereas a human has some 100 trillion cells in all. This number can be compared with the total number of people on Earth today (6–8 billion), or even the total number of people estimated to have ever been on the planet (106 billion). As an aid for the perception of these extremely large numbers, we can perhaps use an analogy based on time. One trillion seconds ago equates to approximately thirty thousand years, a time when the Neanderthals were roaming around Europe.



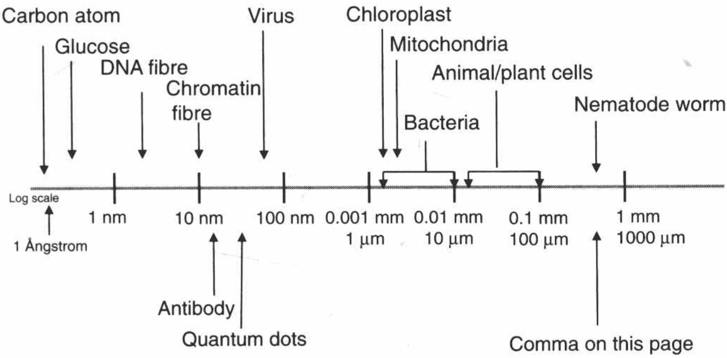
A cell can function perfectly well as a single entity or, alternatively, one cell may be an infinitesimally small part of a massive community of cells that work together to make a single being such as ourselves. In multicellular organisms, groups of cells form tissues and tissues come together to form organs. Multicellularity requires cells with a complex internal architecture (as we shall see in Chapter 2), whereas the single-celled existence of a bacterium allows for a relatively simple organization (essentially a membranous bag containing the necessary chemical mix to maintain life). When life began, some four billion years ago, the first cells would have been similar to the bacteria of today. However, simplicity doesn't necessarily indicate primitive or unsuccessful, as bacteria are the most numerous and widespread of cells, and a branch of the bacterial family called Archaea can flourish in the most extreme environments on the planet, where nothing else can survive. In optimal conditions, some bacteria can reproduce every 20 minutes—a rate that will produce 5 billion bacteria in 11 hours, a number equivalent to the world's total human population. We ourselves are colonized by bacteria to the point where we house ten times the number of bacterial 'guests' (mainly in the gut, and weighing around one kilogram) than the number of actual cells in our own bodies.

## Membranes and cell walls



As the basic unit of life, every cell must be a discrete entity and consequently requires its own boundary. This boundary is common to all life forms and consists of a thin membrane built from two layers of fat molecules (lipids) and coated and pierced with proteins that control the molecular traffic between the cell and its surroundings. Animal cells are usually combined to form tissues (for example, our skin), involving large numbers of different cell types. The membranes of these cells are in direct contact, held together at specific attachment sites, with other membrane areas modified to allow communication between adjacent cells. Unicellular organisms such as bacteria usually have an extra 'cell wall' outside of the membrane, often incorporating adhesive materials to 'glue' them to other cells or to surfaces (such as our teeth). Plant cells have a rigid cell wall woven from long molecules of cellulose. This major difference between plant and animal cell structure is largely the reason why animals move and plants (generally) do not.

Plant cell walls provide a strong mechanical framework as well as protection against pathogens and dehydration. Plant cell walls are

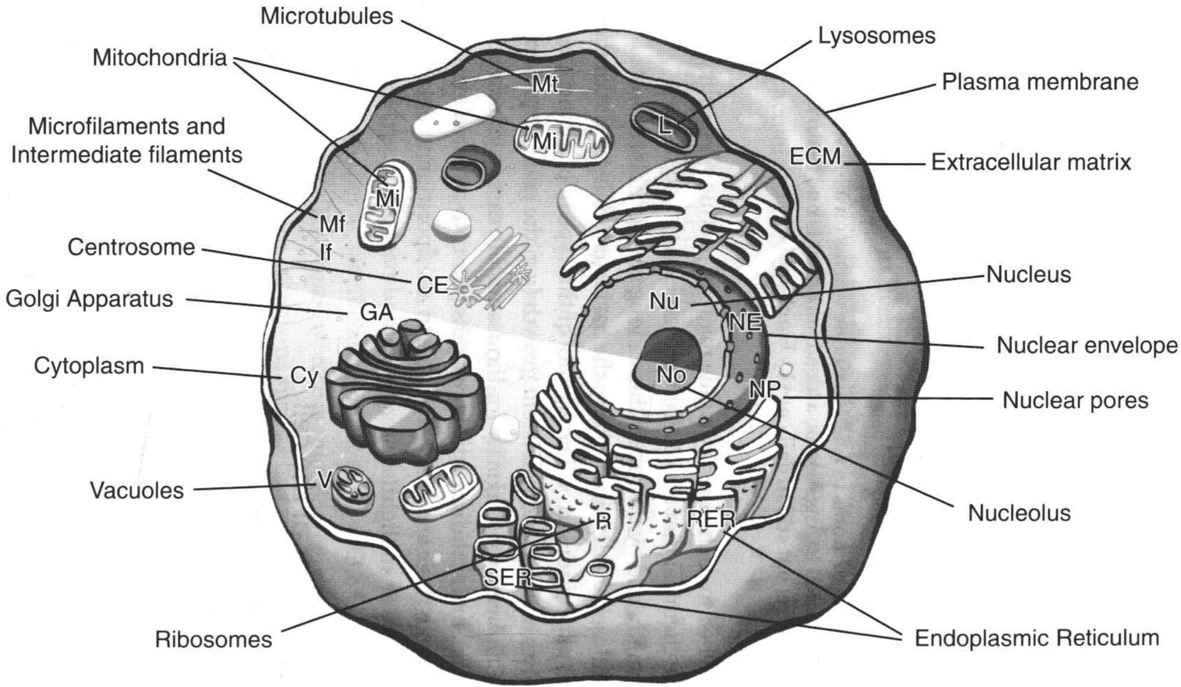



**1. The sizes of atoms to relative simple worms on a log scale. Atoms are measured in Ångstroms, a 'dead' unit that is one tenth of a nanometre, but still in daily use by biophysicists**

attached to each other by a glue made of pectin polysaccharides (the chemical that makes fruit preserves set), and further strengthened by the deposition of long strong molecules of celluloses and lignins that are the basic materials for the timber and paper industries. The rigidity of this type of construction allows massive and persistent growth (e.g. the giant sequoia trees of California) or longevity for thousands of years (e.g. bristlecone pines), but at the same time restricts plants to a rooted existence, although their leaves are well able to alter position to optimize exposure to sunlight.

## The interior of the cell

In comparison to bacteria, plant and animal cells are massive, about one thousand times the volume. Figure 1 shows the scale of cells in the units they are measured in: nanometres (one millionth of a millimetre) cover the molecular sizes of cell components, and whole cells are usually tens of micrometres (one thousandth of a millimetre) in length. Plant and animal cells are also infinitely more complicated, containing a variety of structural elements built from proteins and several types of internal membrane-bound bodies called organelles (Figure 2). Individual organelles have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Mitochondria
Microfilaments and
Intermediate filaments
Centrosome
Golgi Apparatus
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