

Essay 1

All cells are descended from the same common ancestor. Thus, there are many similarities between prokaryotic and eukaryotic cells in structure and basic processes. However, since the split between pro- and eukaryotes 3.5 billion years ago, eukaryotic species have adaptively radiated into new niches by developing complex cellular machinery.

The most essential functions of a cell are regulated by a group of highly conserved genes. Over 200 gene families span all three domains of life, mainly involved in DNA transcription, translation and replication. Thus, the basic building blocks of life are common to both pro- and eukaryotic cells.

Yet there are also basic differences between these cell types, in addition to the defining existence of a nucleus in eukaryotes. These stem mainly from genome size. Prokaryotes have significantly smaller genomes than eukaryotes; usually consisting of 1000 to 6000 genes with minimal amounts of regulatory sequences in between. Conversely, human (eukaryotic) cells consist of around 24,000 genes and 10,000 times more DNA than *Escherichia coli*, a model prokaryotic cell.

The difference in DNA has a fundamental impact on the lifestyle of these two cell types. Prokaryotes can divide in as little as 12 minutes (where eukaryotes take at least 12 hours) due to the small (and usually haploid) nature of their genome. This high reproductive rate, combined with the horizontal transfer of plasmid DNA between prokaryotes, can afford more DNA mutations during replication: changes that allow for a relatively rapid pace of evolution. This advantage enables prokaryotes to dominate eukaryotes on our earth, both in species number and total quantity.

Still, eukaryotes have some advantages. Gene redundancy – resulting in homolog and eventually ortholog processes within one species – and non-coding DNA – allowing regulation of gene expression – together create an environment in which specialisation can flourish. Both within a single cell and between cells in a multicellular organism, this is unprecedented among the prokaryotes.

The key is organelles. These membrane-bound structures in eukaryotic cells compartmentalise processes and can keep their own stable internal environment. Organelles such as the golgi apparatus and endoplasmic reticulum, involved in transporting products within and out of cells, allow eukaryotes to be larger than prokaryotes by a factor of 2000. A prokaryote of that size could not efficiently

transport nutrients in and waste out of the cell because of the low surface area to volume ratio.

However, some of these useful organelles were once prokaryotes. Chloroplasts and mitochondria, for example, are clearly prokaryotic endosymbionts, with telltale small and exclusively freefloating ribosomes (70s, compared to normal eukaryotic 80s), and a plasmid DNA. This illustrates both a contrast of size and function between pro- and eukaryotes, but also of the hazy division between their respective defining properties.

Close collaboration between pro- and eukaryotic cells is only possible because of their shared basic characteristics, like the plasma membrane. This phospholipids bilayer holds many proteins and molecules which define the membrane properties. Though the pro- and eukaryotic membranes can interact, they have different compositions. *E. coli*, for example, is to 70% composed of phosphatidylethanolamine. Eukaryotic cells (here, a liver cell), on the other hand, consist of a diverse cocktail of molecules, like cholesterol, glycolipids and sphingomyelin: all of which are nonexistent in *E. coli*'s membrane. *E. coli* does not need these structural membrane molecules because it, as opposed to liver cells, relies on cell walls for stability and rigidity

A final difference between prokaryotes and eukaryotes lies in their different metabolic processes. Many eukaryotes use aerobic respiration in favour of anaerobic respiration, as it releases 20-fold more ATP than (≤ 40 as opposed to 2). Prokaryotes, however, do not have mitochondria to facilitate aerobic respiration – they mostly use anaerobic respiration or specialise in nitrogen fixation, the latter which is unheard of for eukaryotes.

Despite differences in complexity and function, eukaryotes remain closely related and linked to prokaryotes in many vital life processes. As such, prokaryotes can provide a relatively simple and accurate model for eukaryotic processes, as well as supplying us with cellular products compatible to with eukaryotes for treatment and research. Nevertheless, the complex system of cell specialisation, intercellular cooperation and other 'higher' processes common in eukaryotes are unmatched in the prokaryotic range of life.