How big is a yeast cell?

The budding yeast *Saccharomyces cerevisiae* has served as the model eukaryote in much the same way that *E. coli* has served as the representative prokaryote. Due to its importance in making beer and baking bread (explaining why it is also called Brewers' or Bakers' yeast) this easily cultured and accessible organism was also an early favorite of scientists (Beginnings of microbiology and biochemistry: the contribution of yeast research James A. Barnett). Given that these cells are significantly larger than common bacteria they are a convenient single-celled organism to study under the microscope. In large part due to the ease with which its genome can be manipulated, it has remained at the forefront of research and in 1996, was the first eukaryotic organism to have its genome completely sequenced.

As a prerequisite to reasoning about the concentrations of the molecular machines "typical" of eukaryotes and how they work, we first need to get an impression of the size of a yeast cell and its organelles. One of the ideas that we will emphasize in a quantitative way repeatedly is the idea of cell-to-cell variability and its role in establishing the different behaviors of cells in response to different environmental cues. To begin, we note that a simple rule of thumb for the dimensions of a haploid yeast cell is to think of these cells as spheres with a diameter of roughly 5 μm (BNID 101796, fig. 1, an electron micrograph of a yeast cell budding). Thus if we think of a world in which *E. coli* is the size of a human, then yeast is about the size of an elephant (nice point, the relative linear dimensions sort of match as well! Ie. we are rod-like). If we assume that such a cell has the same density as that of water, this implies that the mass of such a yeast cell is roughly 60 pg (pico=10^{-12}). As most cellular substances are denser than water (proteins, RNA, DNA), the buoyant mass of yeast ranges from 3-10pg. That is, because of these dense substances, yeast cells have an actual mass ~10% heavier than the equivalent volume of water.

Yeast cell size is subject to much variability. As yeast replicate by budding off small daughter cells from a larger mother, any population has a large range of cell sizes spread around the median. For instance, the S288C strain has a median cell volume of $42\pm2\mu m^3$ (42 fl, BNID 100450) for a haploid cell and a 25^{th}-75^{th} percentile range of ~30-60 fL. But median cell size is also highly malleable, being subject to genetic and environmental controls. A diploid cell is almost twice as big ~$82\mu m^3$ (BNID 100490) as its haploid progenitors because DNA content is directly correlated with median cell size. Furthermore, the median cell size can differ by as much as 150% in different strains of *S.cerevisiae*. Finally, like *E.coli*, median cell size in yeast is correlated with growth rate – the better the environmental conditions and growth rate, the larger the cells. Interestingly, recent measurements (Jorgensen et al., Science 2002) have probed how sensitive yeast cell size is to single gene deletions(Fig. 2, adapted from Jorgensen et al., XY medium with 2% glucose, 30^o C). In some of these deletion mutants, the median size was only 40% of the wild type size whereas in others it was larger by >70% than wild type revealing an intriguing coupling between size regulation and the expression of critical genes and also the tight-coupling of wild type cell size to the cell cycle itself. It remains largely unknown

how genetic and environmental changes shift the median cell size in yeast. More intruiging is the question of what evolutionary advantage shifting cell size in response to environmental conditions brings to the yeast.

Prominent components of the cell volume are the nucleus which takes about 10% (100491, 103952), the cell wall with a mass equal to 10-25% (104593, 104592) of the total dry mass (which often overlooked when thinking about the yeast world) and the endoplasmic reticulum and vacuole that are the largest organelles.

Figure 1: Electron micrograph of budding yeast cells (from www.microbiologyonline.org.uk/yeast1.htm)

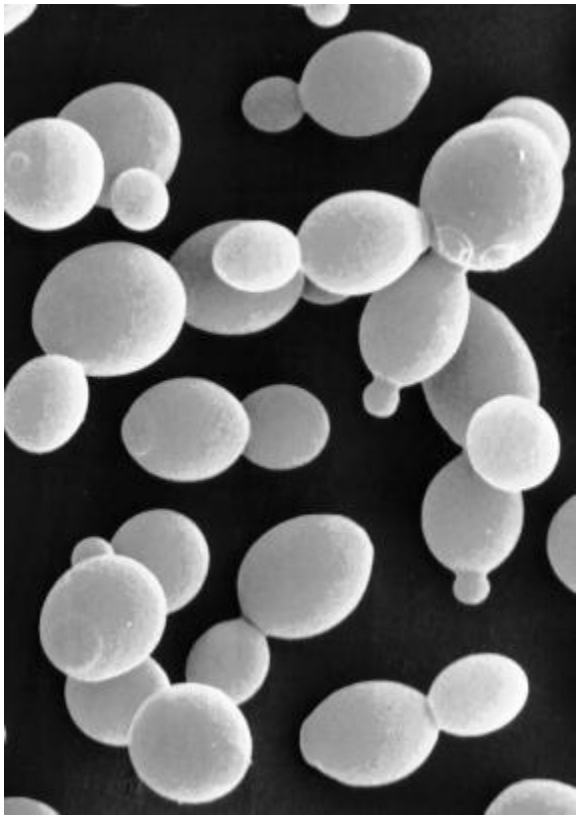

Figure 2: Histogram of distribution of cell sizes for wild type (WT) and different mutants. The label WT refers to the wild-type strain while the graphs with other labels refer to particular interesting mutants. (from Jorgensen et al. Science 2002)