

to make proteins) of cells varies from 10% to 20% of dry weight. However, viruses may contain nucleic acids up to 50% of their dry weight. Typically, the lipid content of most cells varies between 5% to 15% of dry weight. However, some cells accumulate PHB up to 90% of the total mass under certain culture conditions. In general, the intracellular composition of cells varies depending on the type and age of the cells and the composition of the nutrient media. Typical compositions for major groups of organisms are summarized in Table 2.7.

Most of the products formed by organisms are produced as a result of their response to environmental conditions, such as nutrients, growth hormones, and ions. The qualitative and quantitative nutritional requirements of cells need to be determined to optimize growth and product formation. Nutrients required by cells can be classified in two categories:

1. *Macronutrients* are needed in concentrations larger than 10^{-4} M. Carbon, nitrogen, oxygen, hydrogen, sulfur, phosphorus, Mg^{2+} , and K^{+} are major macronutrients.
2. *Micronutrients* are needed in concentrations of less than 10^{-4} M. Trace elements such as Mo^{2+} , Zn^{2+} , Cu^{2+} , Mn^{2+} , Ca^{2+} , Na^{+} , vitamins, growth hormones, and metabolic precursors are micronutrients.

TABLE 2.7 Chemical Analyses, Dry Weights, and the Populations of Different Microorganisms Obtained in Culture

Organism	Composition (% dry weight)			Typical population in culture (numbers/ml)	Typical dry weight of this culture (g/100 ml)	Comments
	Protein	Nucleic acid	Lipid			
Viruses	50–90	5–50	<1	10^8 – 10^9	0.0005 ^a	Viruses with a lipoprotein sheath may contain 25% lipid.
Bacteria	40–70	13–34	10–15	2×10^8 – 2×10^{11}	0.02–2.9	PHB content may reach 90%
Filamentous fungi	10–25	1–3	2–7		3–5	Some <i>Aspergillus</i> and <i>Penicillium</i> sp. contain 50% lipid.
Yeast	40–50	4–10	1–6	1 – 4×10^8	1–5	Some <i>Rhodotorula</i> and <i>Candida</i> sp. contain 50% lipid.
Small unicellular algae	10–60 (50)	1–5 (3)	4–80 (10)	4 – 8×10^7	0.4–0.9	Figure in () is a commonly found value but the composition varies with the growth conditions.

^aFor a virus of 200 nm diameter.

With permission, from S. Aiba, A. E. Humphrey, and N. F. Millis, *Biochemical Engineering*, 2d ed., University of Tokyo Press, Tokyo, 1973.