CELL NUTRIENTS

Cell Nutrients

- Cell's composition differs greatly from its environment.
- A cell must selectively remove desirable compounds from its extracellular environment and retain other compounds within itself.
- Semipermeable membrane is the key to this selectivity.

Organism	Composition (%) Dry Weight: Protein	Nucleic Acid	Lipid	Typical Population in Culture (cells/L)	Typical Dry Weight of the Culture (g/L)	Comments
Viruses	50–90	50–50	<1	10^{11}–10^{12}	0.005[a]	Viruses with a lipoprotein sheath may contain 25% lipid
Bacteria	40–70	13–34	10–15	2×10^{11} –2×10^{12}	0.2–29	PHB content may reach 90%
Filamentous fungi	10–25	1–3	2–7		30–50	Some *Aspergillus* and *Penicillium* sp. contain 50% lipid
Yeast	40–50	4–10	1–6	$1–4 \times 10^{11}$	10–50	Some *Rhodotorula* and *Candida* sp. Contain 50% lipid
Small unicellular algae	10–60 (50)	1–5 (3)	4–80 (10)	$4–8 \times 10^{10}$	4–9	Numbers in () are commonly found values but the composition varies with the growth conditions
Mammalian cells[b]	60	5	16	10^{9}–10^{11}		Mammalian cells are about three magnitudes bigger than *E. coli* in volume

Intracellular composition if cells varies depending on the **type and age** of cells, and the composition of **nutrient media.**

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Cell Nutrients

- Nutrients required by cells can be classified in two categories:
  - **Macronutrients** are needed in concentrations larger than 10^{-4} M.
    C, N, O, H, S, P, Mg^{2+}, and K^{+}.
  - **Micronutrients** are needed in concentrations less than 10^{-4} M.
    Mo^{2+}, Zn^{2+}, Cu^{2+}, Mn^{2+}, Ca^{2+}, Na^{+}, vitamins, growth hormones and metabolic precursors.

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MACRONUTRIENTS
C, N, O, H, S, P, MG^{2+}, K^{+}

Macronutrients
Carbon

- **Carbon compounds** are the major sources of cellular carbon and energy.
- Microorganisms are classified in two categories on the bases of their carbon sources:
  1. **Heterotrophs** use organic carbon sources such as carbohydrates, lipid, hydrocarbon as a carbon and energy source.
  2. **Autotrophs** can use carbon dioxide as a carbon source. They can form carbohydrate through light or chemical oxidation.

Macronutrients
Carbon

Carbon sources:

- **In industrial fermentation**, the most common carbon sources are molasses (sucrose), starch (glucose, dextrin), corn syrup, and waste sulfite liquor (glucose).
- **In laboratory fermentations**, glucose, sucrose and fructose are the most common carbon sources.
- Ethanol, methanol and methane also constitute cheap carbon sources for some fermentations.

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Macronutrients
Carbon

Fermentation:

- **In aerobic fermentations,** about 50% of substrate carbon is incorporated into cell mass and about 50% of it is used as energy sources.
- **In anaerobic fermentation,** a large fraction of substrate carbon is converted to products and a smaller fraction is converted to cell mass (less than 30%).

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Macronutrients
Nitrogen

- **Nitrogen compounds** are important sources for synthesizing proteins and nucleic acid.
- Nitrogen constitutes 10% to 14% of cell dry weight.
- The most commonly used nitrogen sources are:
  - ammonia (NH_3) or ammonium (NH_4^+) salts such as ammonium chloride, sulfate, and nitrate
  - protein, peptides, and amino acids
  - urea may also be used as a source by some microorganissms

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Macronutrients
Nitrogen

- In industrial fermentation, commonly used nitrogen sources are
  - soya meal
  - yeast extract
  - distillers solubles
  - cottonseed extract
  - dried blood
  - corn steep liquor

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Macronutrients

Oxygen

- **Oxygen** constitutes about 20% of the cell dry weight.
- **Molecular oxygen** is required as terminal electron acceptor in the aerobic metabolism of carbon compounds.
- **Gaseous oxygen** is introduced into growth media by sparging air or by surface aeration.
- Improving the mass transfer of oxygen in a bioreactor is a challenge in reactor control.

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Macronutrients

Hydrogen: 8% of dry cell weight

- Major source: carbon compounds such as carbohydrates.
- Some bacteria can utilize hydrogen as an energy source!

Sulfur: 1% of cell dry weight

- present in protein and some coenzymes.
- **Sources:**
  - Sulfate salts (e.g. $(NH_4)_2SO_4$
  - Sulfur containing amino acids
- some autotrophs can use S^0 and S^{2+} as energy sources.

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Macronutrients

Phosphorus

Phosphorus constitutes 3% of cell dry weight.

- Present in nucleic acids and in the cell wall of some gram-positive bacteria
- A key element in the regulation of cell metabolism
- Sources:
  - Inorganic phosphates (most common).
  - Organic phosphates such as glycerophosphates
- The phosphate level should be less than 1 mM for the formation of many secondary metabolites such as antibiotics.

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Macronutrients

Potassium:

- a cofactor for some enzyme and is required in carbohydrate metabolism.
  - **cofactor:** any of various organic or inorganic substances necessary to the function of an enzyme.
- **Source:** potassium phosphates.

Magnesium:

- a cofactor for some enzyme and is present in cell walls and membranes.
- Ribosomes specifically requires Mg^{2+} .
- Sources: Magnesium sulfate or chloride

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MICRONUTRIENTS

MO^{2+}, ZN^{2+}, CU^{2+}, MN^{2+}, CA^{2+}, NA^{+}, VITAMINS, GROWTH HORMONES AND METABOLIC PRECURSORS

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Micronutrients

- Micronutrients could be classified into the following categories (required less than 10^{-4} M):
  - Most widely needed trace elements.
  - Trace elements needed under specific growth conditions .
  - Trace elements that are rarely required.

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Micronutrients

1. **Most widely needed elements** are Fe, Zn and Mn. Such elements are:
   - **important cofactors** for some enzyme
   - play **regulatory role** in fermentation processes and metabolisms
   - Play a role in excretion of primary metabolites
2. **Trace elements needed under specific growth conditions** are Cu, Co, Mo, Ca, Na, Cl, Ni, and Se.
   - For example, copper is present in certain respiratory-chain components and enzymes.

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Micronutrients

3. **Trace elements that are rarely required** are B, Al, Si, Cr, V, Sn, Be, F, Ti, Ga, Ge, Br, Zr, W, Li and I.
   - These elements are required in concentrations of less than 10^{-6} M and are toxic at high concentration.

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Micronutrients
Growth factors

- **Growth factor** is also micronutrient.
- Growth factor stimulates the growth and synthesis of some metabolites.
- Vitamin, hormones and amino acids are major growth factors.
- They are required in concentrations of less than 10^{-6}M.

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Growth Media

- There are two major types of growth medium:
  - **Defined media**
    contain specific amounts of pure chemical compounds with known chemical compositions
  - **Complex media**
    contain natural compounds whose chemical composition is not exactly known

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Defined Growth Media

- *specific amounts with known compositions*
- **Examples:**
  - Glucose (30g/L), $(NH_4)_2HPO_4$ (6g/L), NH_4Cl (1.32 g/L), $MgS0_4.7H_2O$ (0.6 g/L), $CaCl_2$ (0.05 g/L), KH_2PO_4 (10.0 g/L)
- **Advantage:**
  - Results are more reproducible
  - The operator has better control of the fermentation.
  - Product recovery and purification processes are easier and cheaper than complex media.

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Complex Growth Media

- *natural compounds whose chemical composition is not exactly known*
- **Example:**
  - yeast extract, peptone, molasses or corn steep liquor.
- Usually can provide necessary growth factor, vitamins, hormones, and trace elements resulting in ***higher cell yields*** compared to defined medium
- Often ***cheaper*** than defined medium
- More complex separation

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