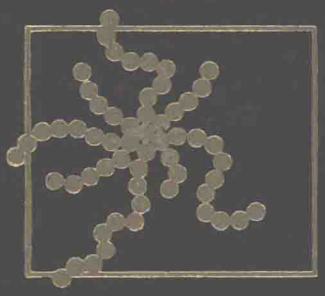
ADVANCED NUTRITION and HUMAN METABOLISM



Second Edition

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DEDICATION

To Gerda for a level of spousal support and understanding above and beyond the call during this adventure.

Jim

To Michelle Lauren and Michael James Gropper, the little readers in my house, and to Daniel for his patience and support.

Sareen

PREFACE

We conceived the first edition of *Advanced Nutrition and Human Metabolism*, published in 1990, to fill the need that teachers expressed for a text on normal metabolism, designed for upper-division nutrition students. The positive response to the first edition has encouraged us to maintain the same general scope, level, and organization of material in this edition. Most of the changes we have made concern new discoveries and reshaped concepts in the field. We have also used more examples, to help students better relate the printed word to current nutritional practice. In addition, helpful suggestions from reviewers and from both student and instructor users of the first edition have helped us revise the sequence of topics to provide a more natural flow of information.

Because this book focuses on normal human nutrition and physiologic function, students majoring in nutrition science and in dietetics can use it with equal effectiveness. As an advanced nutrition text, the book has been written for students at a level that presumes a sound background in the biological sciences. However, we review basic sciences—particularly biochemistry and physiology, which are important for understanding the material—at an appropriate level and scope, to rekindle faded memories. The text broadly applies biochemistry to nutrient use from consumption through digestion, absorption, distribution, and cellular metabolism, and is thus a valuable reference for health care workers. Health practitioners often want to refresh their memory of metabolic and physiologic interrelationships, or they want a concise update on current scientific discoveries or concepts related to human nutrition.

We have represented nutrition as the science that integrates life processes from the cellular level on through the multisystem operation of the whole organism. Our primary goal has been to give a comprehensive picture of cell reactions at the tissue, organ, and system levels. Subject matter was selected for its relevance in meeting this goal. The annotated bibliography familiarizes students with current research on each subtopic. We have also introduced a generous amount of cross-referencing, to strengthen the reader's access to indepth discussions of each topic.

Each of the 17 chapters begins with a topical outline followed by a brief introduction to that chapter's subject. Each chapter has a brief summary that ties together the ideas presented and concludes with an annotated bibliography. Fifteen of the chapters have as their final section one or two *Perspectives.* These relate chapter subject matter to a currently important aspect of human nutrition and health, and have their own annotated bibliographies.

We divided the text into five sections. Section I (Chapters 1, 2, and 3) focuses on the structure, function, and nourishment of the cell, and reviews energy transformation. Section II (Chapters 4 through 8) discusses the metabolism of macronutrients. In this section, we review primary metabolic pathways for carbohydrates, lipids, and proteins, emphasizing reactions that have particular relevance for health. We include a chapter on dietary fiber, and a chapter on the interrelationships among the macronutrient metabolic pathways as well as the metabolic dynamics of the feeding–fasting cycle.

Section III (Chapters 9 through 12) concern nutrients considered regulatory in nature: the vitamins (water- and fat-soluble), and the minerals, both macro and micro. These chapters cover nutrient features such as digestion, absorption, transport, function, metabolism, excretion, deficiency, and toxicity. We also discuss Recommended Dietary Allowances (RDAs) for each.

Section IV, "Homeostatic Maintenance," includes Chapters 13 through 16. We discuss, in order, body fluid and electrolyte balance, body composition, energy balance and weight control, and nutrition and the central nervous system. We singled out the central nervous system for discussion because of the current popular interest in relationships between nutrition and human behavior.

The last chapter (17) constitutes Section V. It is supplementary to the rest of the book. Titled "Experimental Design and Critical Interpretation of Research," this chapter discusses the types of research and the methodologies by which research can be conducted. The chapter is designed to familiarize the student with research organization and implementation, to point out problems and pitfalls inherent in research, and to help him or her critically evaluate scientific literature.

The appendices that round out the book include the following:

- Recommended Dietary Allowances 1989
- Calculation of available dietary iron
- Forms for estimating total energy expenditure
- Food exchange lists

A Glossary of Abbreviations follows.

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This textbook could not have been written without the helpful comments, encouragement, and patience of those close to us, both at the workplace and at home. Our special thanks to our colleagues at Georgia State University and Auburn University for recognizing the size of the task, and showing the interest and understanding that "kept the wind at our backs."

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BRIEF CONTENTS

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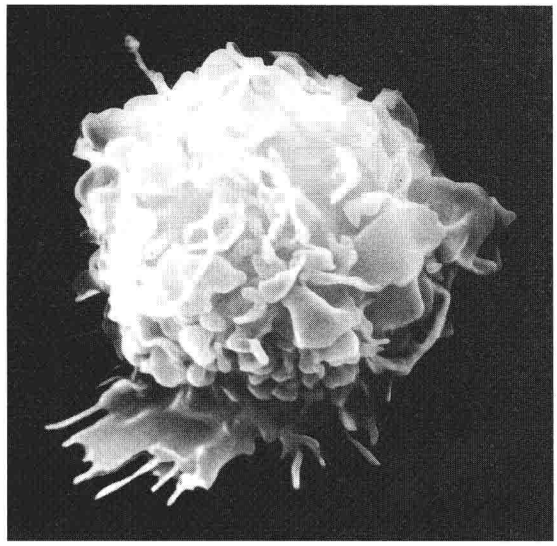
SECTION I

CELLS AND THEIR NOURISHMENT



CHAPTER 1

THE CELL: A MICROCOSM OF LIFE

Components of Typical Cells
- Plasma Membrane
- Cytoplasmic Matrix
- Mitochondrion
- Nucleus
- Endoplasmic Reticulum and Golgi Apparatus
- Lysosomes and Peroxisomes

Cellular Proteins
- Receptors
- Transport Proteins
- Catalytic Proteins (enzymes)

Perspective: **The Glucose Transporters**

Photo: A human scavenger cell

Life is impossible without cells. Cells, individual units of life, group together to form a living human body. Cells vary greatly in size, chemical composition, and function, but each one is a remarkable miniaturization of human life. Cells move, grow, ingest food and excrete wastes, react to their environment, and even reproduce.

Cells of all multicellular organisms are called *eukaryotic cells* (from the Greek *eu*, meaning "true," and *karyon*, "nucleus"). By their having a defined nucleus, eukaryotic cells are distinguished from other, more primitive cell types called *prokaryotic cells*, from which they are known to have evolved. Eukaryotic cells are also larger and much more complex structurally and functionally than the prokaryotes. Because this text addresses human metabolism and nutrition, all discussions of cellular structure and function in this and subsequent chapters pertain to eukaryotic cells.

Specialization among cells is a necessity for the living, breathing human, but cells in general have certain basic similarities. All human cells have a plasma membrane and a nucleus (or have had a nucleus), and most of them contain endoplasmic reticulum, Golgi apparatus, and mitochondria. For convenience of discussion, a so-called typical cell is considered so that the various organelles and their functions, which characterize cellular life may be identified. Considering the relationship between the normal functioning of a typical cell and the health of the total organism—the human being—one is reminded of the old rule: "A chain is only as strong as its weakest link."

Figure 1.1a shows the fine structure of a typical animal cell (hepatocyte), while Figure 1.1b gives a schematic view of a typical animal absorptive cell (such as an intestinal epithelial cell), showing its major components or organelles. The discussion begins with consideration of the plasma membrane, which forms the outer boundary of the cell, and then moves inward to examine the organelles held within this membrane.

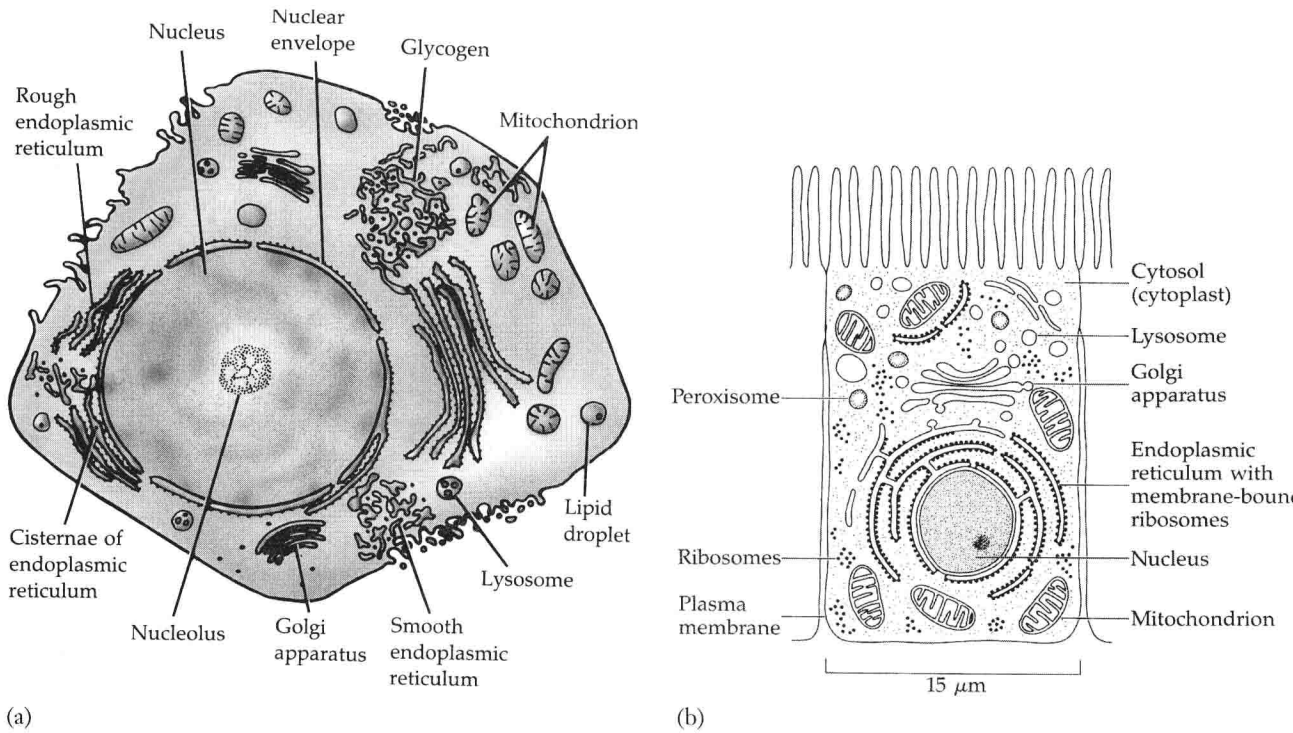


FIGURE 1.1 The fine structure of a typical animal cell (hepatocyte) is shown in (a) while (b) depicts a typical animal absorptive cell.

COMPONENTS OF TYPICAL CELLS

Plasma Membrane

The plasma membrane is the membrane encapsulating the cell. By surrounding the cell, it lets the cell become a unit by itself. The plasma membrane, like other membranes found within the cell, has distinct functions and structural characteristics. Nevertheless, all membranes share some common attributes:

- Membranes are sheetlike structures composed primarily of lipids and proteins held together by noncovalent interactions.
- Membrane lipids consist primarily of phospholipids, which have both a hydrophobic and hydrophilic moiety. This structural property of phospholipids lets them spontaneously form bimolecular sheets in water, called *lipid bilayers*, as shown in Figure 1.2. These bilayer sheets, because of their hydrophobic core, retard the passage of many water-soluble compounds into and out of the cell. Although such an arrangement requires transportation systems across the membrane, it allows retention of essential water-soluble substances within the cell.
- Phosphoglycerides and phosphingolipids (phosphate-containing sphingolipids) compose most of the membrane phospholipids. Of the phosphoglycerides, phosphatidylcholine and phosphatidylethanolamine are particularly abundant in higher animals. Another important membrane lipid is cholesterol, but its amount varies considerably from membrane to membrane. Molecular structures of these lipids are detailed in Chapter 6.
- Membrane proteins confer on biological membranes their functionality: they serve as pumps, gates, receptors, energy transducers, and enzymes. Figure 1.3 schematically illustrates the functions and positioning of some membrane proteins.
- Membranes are asymmetric. The inside and outside faces of the membrane are different.
- Membranes are fluid structures in which lipid and protein molecules can move laterally with ease and rapidity.