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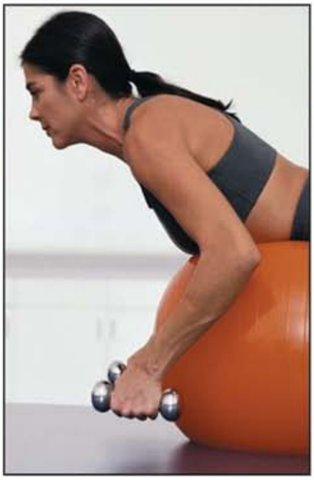
THE NUTRITIONIST

Food, Nutrition, and Optimal Health



ROBERT WILDMAN, PhD, RD

Robert E. C. Wildman, PhD, RD

The Nutritionist
Food, Nutrition, and Optimal Health

Pre-publication REVIEWS, COMMENTARIES, EVALUATIONS . . .

"*The Nutritionist: Food, Nutrition, and Optimal Health* is refreshing in its approach to the subject. The organization of this text is clear and logical, particularly tables and figures which are self-explanatory without constant reference to the text. A salient defining aspect of this text which separates it from other introductory texts in nutrition is the organization of each chapter. In this book, rather than having the usual academic subheadings as topics, the subheadings are articulated as questions. For instance, the chemical nature of carbohydrates is discussed under the subheading 'Where do carbohydrates come from?'

The manner in which the text is written is user friendly and largely devoid of technical jargon. The major nutrients are discussed in terms of need and how they optimize health and prevent certain diseases. Applications to physical activity, pregnancy, and weight control issues, for example, are discussed from a consumer perspective. The content is accurate and up-to-date. Academicians will find this useful as a text for an introductory nutrition class and nonacademicians will find it useful in their home libraries. The reader of this book will discover significant information for personal use on how to lead a healthy lifestyle."

Denis M. Medeiros, PhD, RD
Professor and Head,
Department of Human Nutrition,
Kansas State University, Manhattan

More pre-publication
REVIEWS, COMMENTARIES, EVALUATIONS . . .

"Nutrition is perhaps one of the most confusing topics for students, health professionals, and the general public. A large part of the confusion stems from the fact that nutrition is a relatively `young' field of study and, as such, new information is being generated every day. In *The Nutritionist,* Dr. Wildman has taken a complex topic and distilled it down to its most fundamental elements—the result being a highly useful and easy-to-understand overview of nutrition from theory, to science, to practice. *The Nutritionist* uses a friendly question and answer format to focus the reader on the primary elements necessary for understanding first the basic concepts of general nutrition and then the subtler nuances of nutrition and health. Using this format, *The Nutritionist* provides value for nonscience majors with an interest in nutrition as well as for science majors looking for practical nutrition knowledge."

Shawn M. Talbott, PhD
Senior Scientist,
Pharmacology and Clinical Affairs,
Pharmanex, LLC,
Provo, UT

"This book will certainly be of interest and use to the general public as well as an introductory course in nutrition with no prerequisites. The book covers the basics and later uses and integrates this information to discuss topics such as exercise nutrition, lifespan nutrition, and nutrition and disease. It covers not only material on nutrition for our well-being but also nutrition to enhance the quality of our lives. The text is amply complemented with easily understood tables and figures. Dr. Wildman writes in a snappy, yet authoritative, style. He gives us much food for thought."

Ira Wolinsky, PhD
Professor of Nutrition,
University of Houston, TX

"This book would be a very good text for use in an introduction to nutrition course, and an excellent text for a general education requirements (nonmajor) class in nutrition. The text will also be very helpful for professionals engaged in the fitness and wellness areas (for example, personal trainers). It also would be very digestible for the layperson wanting to learn more about nutrition and how it affects the human body.

The question/answer style of the text makes it easy to read and engages the reader. The introductory chapters do a nice job of laying the groundwork for later discussions. In general, it is a very nice read for understanding the 'nuts and bolts' of human nutrition while still including more technical information. It also presents nutrition information relative to the lifespan, which will reach a broader audience."

Barry Miller, PhD
Assistant Director, Recreation;
Assistant Professor, Department
of Health and Exercise Science,
University of Delaware,
Newark

More pre-publication
REVIEWS, COMMENTARIES, EVALUATIONS . . .

"Dr. Wildman has truly compiled a one-stop primer into the basic chemistry, biology, and physiology related to human nutrition. He has presented a most excellent and painless description of human nutrition along with an outstanding complement of figures and tables to further aid in one's understanding. In fact, the title of this book is most appropriate, since Dr. Wildman presents the information as answers to commonly asked questions. He has demonstrated the admirable quality of synthesizing difficult material and concepts into straightforward and comprehensive explanations. After presenting a general, but thorough, overview of the science of nutrition, he demonstrates the application of these concepts in exercise and sport, the life cycle, and in disease states. His description of nutritional factors and their role in cardiovascular disease and cancer are particularly pertinent in a society where these disease states are leading causes of death. Along the way, he addresses popular nutritional myths and misconceptions with scientific evidence and sound nutritional advice.

In reality, this text allows anyone from the student to the enthusiast to learn the basics of nutrition without years of schooling. In Dr. Wildman's text, the science of nutrition is packaged for ready consumption. This book should be mandatory reading for every basic nutrition course and for every dietary program. An excellent reflection of his scientific understanding and his teaching capabilities."

Arny A. Ferrando, PhD
Associate Professor, Surgery, Metabolism,
Shriners Hospital for Children,
Galveston, TX

"I wish I could persuade everyone who wants to learn about nutrition to read this book instead of picking up one of the many popular books published every year that are full of gimmicks, hype, and self-promotion. In one comprehensive text, Dr. Robert Wildman presents modern nutrition science in a user-friendly package suitable for those with a personal interest and beyond. The major strength of this book is the deft use of examples and analogies to both entertain and educate readers while maintaining an easy-to-read and personalized writing style. In fact, reading this book feels like having a one-on-one conversation with the author.

Readers, you will learn about nutrition as it truly is, a science residing at the interface between biology, chemistry, and medicine. Best of all, a background in science isn't required as *The Nutritionist* does a splendid job of explaining any relevant science that comes up in the reading. You will find tools in this book that will empower you to make important decisions regarding optimal health and disease prevention. If you want to learn more about nutrition and health, then this book is for you."

Thunder Jalili, PhD
Director of Nutrition Science,
Division of Foods and Nutrition,
University of Utah

NOTES FOR PROFESSIONAL LIBRARIANS AND LIBRARY USERS

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Robert E. C. Wildman, PhD, RD, LD
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The Nutritionist: Food, Nutrition, and Optimal Health by Robert Wildman

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Robert Wildman, PhD, RD, is the Director of Nutrition for the Bally Total Fitness Corporation, Chicago, Illinois. He is co-author of *Advanced Human Nutrition* and *Sport & Fitness Nutrition* and editor of *The Handbook of Nutraceuticals and Functional Foods.*

Preface

The seeming simplicity of our daily activities is greatly contrasted by the complexity of our true nature—quite a paradox, no doubt. We appear simple in that, on the outside, the goals of our body may appear few. We internalize food, water, and oxygen, while at the same time ridding ourselves of carbon dioxide and other waste materials. These operations support reproduction, growth, maintenance, and defense. Yet on the inside our body seems very complex, as various organs participate in a tremendous number of complicated processes intended to meet the simple goals previously mentioned.

Nutrition is just one part of the paradoxical relationship mentioned. The objective of nutrition is simple: to supply our body with all of the necessary nutrients, and in appropriate quantities, to promote optimal health and function. However, in practice, nutrition is far from that simple. Too many nutrients, controversial nutrients, and different conditions such as growth, pregnancy, and exercise are involved to allow nutrition to be a simple topic.

Although we have long appreciated food, it has only been in more recent years that we have really begun to understand the finer relationship between food and our body. Most nutrients have been identified only within the past century or so, and right now nutrition is one of the most prevalent areas of scientific research. However, our understanding of nutrition is by no means complete. It continues to evolve in conjunction with the most current nutrition research. Discoveries in nutrition occur seemingly on a weekly basis.

Just a few decades ago the *basic four* food groups were pretty much all the nutrition information known by the average American. Today, nutrition deeply penetrates many aspects of our lives including preventative and treatment medicine, philosophy, exercise training, and weight management. Diet has been linked to cardiovascular health, cancer, bowel function, moods, and brain activity, along with many other health domains. Humans no longer eat merely to satisfy hunger. Nutrition has become a matter of great curiosity and/or concern for most of us today.

A few problems have developed along with this most recent illumination of nutrition. One such problem is that we may have generated too much knowledge too fast. Even though we, as humans, have been eating throughout our existence, the importance of proper nutrition seems to have been thrust upon us suddenly. We did not have time to first wade into the waters of nutrition science, slowly increasing our depth. The reality is that we may be in over our heads, barely treading water to keep up with the latest recommendations. Sometimes, all we can do is try our best to follow the latest nutrition recommendations without really having the background or accessibility to proper resources to truly understand the reasons behind the recommendations.

Although nutrition has become a very complex subject, many authors still try to present it in an oversimplified manner. Perhaps they believe that people are not interested in the scientific details and merely wish to be told what to do. This book attempts to break that pattern. We will spend time laying a foundation with some of the basic concepts of science and the body in hope that this effort will make nutrition a simpler subject.

I believe that deep down a scientist lurks within each of us. Every day we ponder the effects of certain actions before performing them. This is the so-called *cause and effect* relationship, the very basis of scientific experimentation. Furthermore, since most of us give at least some thought to the foods we eat, humans are all a special breed of scientist. We are nutrition scientists! A nutrition scientist is one who ponders the relationship between food components and the body. One does not have to work in a laboratory to be a nutrition scientist. All one needs is simple curiosity and the dedication of his or her time to pursue a greater understanding of nutrition. This book is written in a question and answer format to satisfy the reader's curiosity.

Fundamental questions regarding nutrition and our body will be posed and then answered based upon the most current research. If your educational background includes a solid foundation of biology and chemistry you may wish to skip the first few chapters. However, if your science background is weak or far in the past, you may find the first few chapters of service. So, here we go. Good luck and good science!

Acknowledgments

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The author would also like to acknowledge the following facilities and people for their assistance in the development of *The Nutritionist.* Research assistants: Carol Haas, Melissa Guillory, Jody Williams, Jennifer Gautreaux, Denise Darjean, Gena LeMaire, Dolly Zeringue, Dani Marsh, Jennifer Zimmerman, Sara Myers, Christine Lister, and Charity Humphrey. Exercise photo models: Mark Doyle, Noelle LeJeune, Ashley Martin, and Barrett Richard. Facilities: Red Lerille's Health and Racquet Club, Lafayette, Louisiana, and the Exercise Laboratory of the Department of Kinesiology at the University of Louisiana at Lafayette.

Chapter 1

The Very Basics of Humans and the World We Inhabit

OUR MOST BASIC OBJECTIVES

We humans are just one of millions of different species inhabiting this planet. Like our planetmates we must abide by the basic objectives of life. These are to

1. function independently or self-operate,
2. defend ourselves (externally and internally),
3. nourish ourselves, and
4. reproduce, which is without question the ultimate objective.

Yet we humans enjoy a relatively massive brain and intellectual capability. This quality allows us to try to understand ourselves and in accordance how to nourish ourselves.

What is nutrition?

We will start out as simple as possible. The shortest definition for nutrition is the science pertaining to the factors involved in nourishing our body. Nutrition hinges upon the special relationship between our body and the environment that we inhabit. It is this environment that dictates our nourishment needs as well as provides the substances that will do the nourishing. These nourishing substances are called *nutrients,* which are chemicals that are used by our body for energy or other human processes.

From the moment of conception to the waning hours of advanced age, we find ourselves in a continuum to nourish our body. Nourishment supports body businesses such as growth, movement, immunity, injury and disease recovery, and, of course, the ultimate business at hand for all life-forms, reproduction. All that we are, ever were, or are going to be is actually borrowed from the environment that we inhabit. This unique state of indebtedness is primarily attributed to our nutrition intake.

We must be grateful to the earth's crust for lending us minerals that strengthen our bones and teeth and allow us to be electrical. We must also pay homage to plants for the carbohydrate forms that power our operations and for the amino acids that make the protein in our muscle.

All too often we do not truly appreciate the relevance of nutrition to our basic being. But again, please keep in mind that nearly everything we are and are able to do is either a direct or indirect reflection of our past and current nutrition intake. No matter how oversimplified nutrition may seem in television commercials and on cereal boxes, it is without a doubt one of the most complex and interesting sciences out there.

How do we begin to understand nutrition?

Certainly any great building must be constructed upon a solid foundation. So let us go ahead and commit ourselves to building our own scientific foundation for nutrition as well. Before we try to learn how to nourish our body we should have a better understanding of what needs to be nourished. Our body is the product of nature and being so it must adhere to the basic laws of nature. In fact, the science of nutrition is really an offspring science, with chemistry and biology being the proud parents. Therefore, understanding the whats, whys, and hows of nutrition will be a lot easier once a few basic areas of chemistry and biology are appreciated. Following are some basic principles of chemistry and biology and a description of their relevance to nutrition and the body.

ATOMS AND MOLECULES MAKE THE HUMAN, NOT CLOTHES

What is the most basic composition of our body?

Let's say that we had access to fancy laboratory equipment capable of determining the most fundamental composition of an object. If we used this equipment to assess a person it would spit out data on our most basic level of composition, *elements*. Elements are substances that cannot be broken down into other substances. Scientists have determined that there are 100 or so of these elements in nature. Some of the more recognizable elements include carbon, oxygen, hydrogen, nitrogen, iron, zinc, copper, chromium, calcium, nickel, silver, aluminum, helium, gold, sodium, potassium, and chlorine. All of the elements known to exist can be found on the Periodic Table of Elements, which we have all come across at one point or another in our schooling. A Periodic Table of Elements is included as Appendix A in case you feel the need for another peek. Now, imagine, if you will, that everything that you can think of is merely a skillful combination of these same elements. This includes cars, boats, buildings, clouds, oceans, trees, and of course our body. In fact, our body employs about twenty-seven of the elements (see Table 1.1 and Appendix A).

The great Carl Sagan in his personal exploration of the cosmos believed that we are made up of the stuff of stars. He was alluding that our body is made up of many of the very same elements that make up planets and other celestial bodies in the universe. We humans as well as other life-forms on our planet have simply borrowed these ele-

TABLE 1.1. Elements of Our Body

Major Elements	**% of Body Weight**	**Minor Elements**	**% of Body Weight**
Oxygen (O)	63.0	Iron (Fe)	< 0.1
Carbon (C)	18.0	Selenium (Se)	< 0.1
Hydrogen (H)	9.0	Copper (Cu)	< 0.1
Nitrogen (N)	3.0	Cobalt (Co)	< 0.1
Calcium (Ca)	1.5	Fluorine (F)	< 0.1
Phosphorus (P)	1.0	Iodine (I)	< 0.1
Potassium (K)	0.4	Molybdenum (Mo)	< 0.1
Sulfur (S)	0.3	Manganese (Mn)	< 0.1
Sodium (Na)	0.2	Vanadium (V)	< 0.1
Chlorine (Cl)	0.2	Chromium (Cr)	< 0.1
Magnesium (Mg)	0.1	Boron (B)	< 0.1
		Zinc (Zn)	< 0.1
		Aluminum (Al)	< 0.1
		Tin (Sn)	< 0.1
		Silicon (Si)	< 0.1
		Arsenic (As)	< 0.1

ments. Interestingly, four of these elements, namely oxygen, carbon, hydrogen, and nitrogen, make up greater than 90 percent of our body weight. Since the majority of these elements are found in our body as part of substances such as water, proteins, carbohydrates, fats, and nucleic acids (DNA and RNA), it only makes sense that these substances must be the major chemicals of our body. For example, a lean, young adult male's body weight may be approximately 62 percent water, 16 percent protein, 16 percent fat, and $<$ 1 percent carbohydrate. Most of his remaining weight (about 5 percent) would be attributed to minerals. We will spend a lot more time talking about the finer details of body composition in later chapters.

What is the relationship between elements and atoms?

Atoms are the building blocks of everything that exists. From the clothes on your back to the car you drive to the food you eat—everything is comprised of atoms. Each individual atom belongs to only one element. This is to say that even though there are an incomprehensible number of atoms on this planet and the universe making up everything we know and are yet to know, all of these atoms belong to only one of 100 or so elements (see Appendix A). This is similar to each one of the billions of people living on this planet being native to only one of a hundred or so countries.

In a world where size is judged relative to the size of humans, the size of the atom is indeed miniscule. It has been said that if we could line up a million atoms end to end they would barely cover the distance across the period that follows this sentence. However, they do indeed exist even though you cannot see them with the naked eye.

All atoms have a similar blueprint to the image displayed in Figure 1.1. There are three principal particles called *neutrons, protons,* and *electrons*. Because they are smaller than the atom that they come together to form, they are often called *subatomic* particles. Two of these particles (protons and neutrons) are found in the tightly packed center region of the atom, referred to as the *nucleus,* which literally means "the center." Protons bear a positive charge (+). Meanwhile, neutrons do not bear any charge at all and are thus deemed neutral. Revolving around the nucleus of the atom at the speed of light is the third type of subatomic particle, the electron. Electrons bear a negative charge (–). By design, there are the same number of electrons revolving around

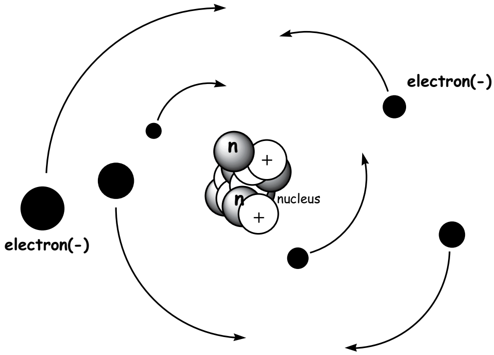


FIGURE 1.1. This is a carbon atom. Protons (white [+]) and neutrons (shaded [n]) are in the nucleus. Electrons (black [–]) orbit the nucleus at the speed of light.

the nucleus as there are protons within the nucleus. This balances the *net charge* of the atom.

We classify an atom as belonging to a specific element based on the number of protons it has. In fact, the Periodic Table organizes the elements in order of increasing proton number. Hydrogen atoms have only one proton; helium atoms have two protons; carbon six; calcium twenty; and so forth. Again, the general design of an atom is to have an equal number of electrons as protons, thereby "balancing" the electrical charge, creating a neutral atom. Meanwhile, the number of neutrons can vary for a given atom.

It is the electrons that generally dictate how atoms will behave in relation to one another. Electrons are the interacting portion or "business portion" of an atom and will be involved in many nutrition aspects to follow.

Is it possible for certain atoms to become charged?

Atoms of certain elements do possess the ability to lose or gain electrons. Since electrons bear a negative charge, this results in the development of a net electrical charge on that atom. It is a matter of simple algebra. If an atom gives up an electron, it will develop a single positive charge (1^+). This is shown in Figure 1.2. If an atom concedes two electrons it will develop a double positive charge (2^+). On the contrary, if an atom gains an electron, it develops a single negative

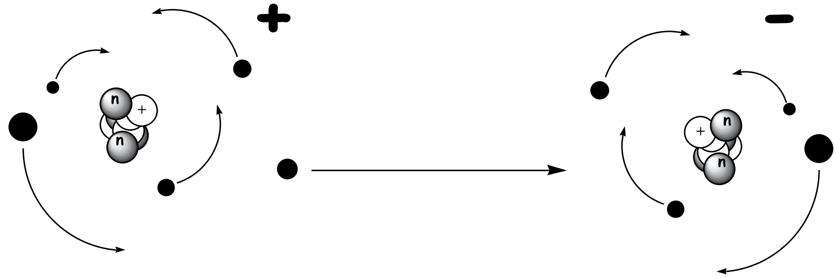


FIGURE 1.2. An electron is lost by the atom on the left (yielding a positive charge) and gained by the atom on the right (yielding a negative charge).

charge (1–) and if an atom gains two electrons it develops a double negative charge (2–). Charged atoms (and molecules) are called *ions*.

The processes of losing and gaining electrons are interrelated, as is also displayed in Figure 1.2. As one atom gains an electron, it is actually removing the electron from another atom which was willing to donate it. This activity is referred to as *oxidation* and *reduction*. Oxidation refers to the loss of an electron while reduction refers to the gain of an electron. Perhaps you were thinking that this may have something to do with antioxidant (antioxidation) nutrients, such as vitamins C and E and a whole host of others such as beta-carotene and lycopene. Well, were you? If you were, then you are accurate in your thought and have the mind of a scientist. We will get to free radicals and begin to talk about antioxidant protection later in this chapter. Also, you may have heard the term oxidation in reference to energy operations in our body (e.g., oxidation of fat). Again, you would be on the right track. But we are getting ahead of ourselves.

Many elements important to nutrition and the proper functioning of our body exist naturally in a charged state. These elements include sodium, chlorine, potassium, iodine, magnesium, and calcium. The charge associated with an atom will be displayed in superscript next to the element's symbol. As a rule, sodium (Na^{+}) and potassium (K^{+}) will give up one electron, while calcium (Ca^{2+}) and magnesium (Mg^{2+}) will give up two electrons. On the contrary, chlorine (Cl^{-}), flourine (F^{-}), and iodine (I^{-}) will take an electron from another atom. Actually, we tend to refer to chlorine, fluorine, and iodine as chloride, fluoride, and iodide with respect to this electrical state. Some of these charged atoms are commonly referred to as *electrolytes* because of their electrical state and properties, which will be discussed later on as well.

How do atoms combine with each other?

A couple millennia ago, the Greeks believed that water was one of the four elements of nature, along with fire, air, and earth, and that all things were made from combinations of these elements. Today, we of course know that there are a hundred or so basic elements. In fact, water is not a single element but a combination of atoms of two elements, hydrogen (H) and oxygen (O). When two or more atoms of the same or different elements combine together, *molecules* are formed. Therefore, water is a molecule. The chemical formula for a water molecule (H_2O) is probably the most widely quoted of all *chemical formulas*. A chemical formula is merely a molecule's element recipe. Thus, for each molecule of water, two hydrogen atoms (subscript 2 behind H) are bound to one oxygen atom (no subscript, so 1 is implied).

From our previous description of the size of atoms you can imagine then that an ordinary glass of water must contain millions of H_2O molecules. In fact, we can use water to tidy up our understanding of elements, atoms, and molecules. If we have an 8 ounce (oz) glass of pure water, we can say that the container is accommodating millions of molecules of water, and thus millions of atoms; however, only two elements are present, oxygen and hydrogen.

In general, atoms can link together or *bond* by two means. First, charged atoms can interact with oppositely charged atoms. Remember, as in so many aspects of life, opposites attract. Perhaps the best example of this kind of bonding is sodium chloride (NaCl) or common table salt. Here, the negatively charged chloride ions (Cl^-) are attracted and electrically stick to positively charged sodium ions (Na^+). You can also check your toothpaste for sodium fluoride (NaF) or toothpaste salt. By the way, the term *salt* is actually a general term that describes these types of electrical interactions.

Na^+ ↯ Cl^-	**Na^+ ↯ F^-**
sodium chloride (table salt)	**sodium fluoride (toothpaste salt)**

Another way that atoms can bond with each other is by sharing electrons. This is a fascinating event whereby atoms share electrons between them to form a stable union. In Figure 1.3 and throughout

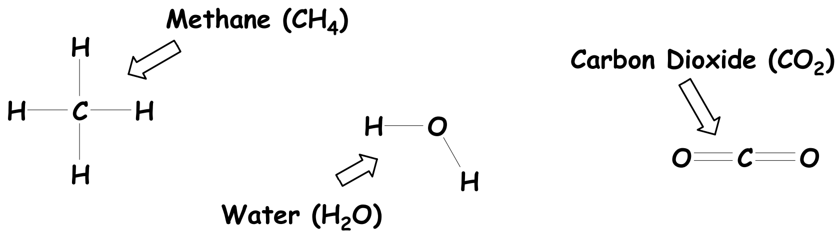


FIGURE 1.3. Methane and carbon dioxide are organic molecules while water is not.

this book you will see a straight line connecting atoms that are bonded in this manner. Probably the best examples of this type of bonding are the so-called *organic* molecules, which refers to those molecules that are based on carbon atoms. Organic also refers to that which is living. Therefore, the most important molecules of life must be carbon based. In fact, a large portion of this book discusses organic molecules, such as proteins, carbohydrates, fats, cholesterol, nucleic acids, and vitamins. These are all carbon-based substances.

What is the design of molecules?

One limitation of an ink-and-paper representation of molecules is that it often fails to truly capture the three-dimensional beauty of molecules. For example, DNA molecules exist in a spiral staircase design, while many protein molecules appear to be all bunched (or globbed) up. The three-dimensional design of a molecule helps determine what that molecule can do (its properties). Furthermore, we will see that many of the important molecules in our body are actually combinations of smaller molecules. For instance, proteins are made from amino acids, and fat molecules are made from fatty acids and glycerol.

How do molecules interact with one another?

Molecules in our body, or anywhere else in nature, can mingle among one another. If things are right, they can also interact. When molecules interact the process is called a *chemical reaction.* For instance, in the reaction below, A and B are substances that react *(reactants)*. As a result of this chemical reaction different substances are produced *(products),* namely, C and D. In a more realistic reaction, carbon dioxide (CO_2) reacts with water to form carbohydrate ($C_6H_{12}O_6$) and oxygen (O_2). This is photosynthesis, the process whereby plants make carbohydrates.

$$A + B \longrightarrow C + D$$

or

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

The reaction arrow ($\longrightarrow$) separating the reactants and products merely shows which way the chemical reaction will proceed. A reaction may proceed in only one direction or it may be reversible, whereby the reaction will proceed in either direction. A reversible-reaction arrow looks like you might expect: $\longleftrightarrow$. If there is a number (coefficient) in front of reacting or produced substances this merely tells us how many molecules of a substance must react or be produced in order for the chemical reaction to make sense or be "balanced."

What are enzymes?

Life itself would be impossible without *enzymes*. Enzymes are proteins whose job is to regulate and accelerate most chemical reactions. You may remember from a high school or college chemistry lab that when you performed an experiment using two or more chemicals, another chemical was often added to help the reaction to take place or to speed it up. That chemical was an enzyme.

Enzymes are called *catalysts,* meaning they speed up the rate of a reaction between two or more chemicals. A given chemical reaction between two chemicals may take place without an enzyme, but the rate of the reaction may be incredibly slow. It might take hours, days, weeks, or even years to happen. This would be simply unacceptable, as the proper functioning of our body may require that same chemical reaction to take place numerous times in a fraction of a second. So enzymes speed up the rate at which chemical reactions occur. Another important feature of enzymes is that they are extremely specific. Most enzymes will work on only one reaction, just as a unique key will fit into a certain lock.

Is it possible for chemical reactions to be linked together?

In various situations in our body, many chemical reactions actually occur in series. One or more products of a chemical reaction become reactants in the next chemical reaction as part of a series. These reaction series are more commonly referred to as *pathways,* as depicted in Figure 1.4. We will discuss many pathways throughout our exploration.

ENERGY IS EVERYTHING

What is energy?

Energy may be best understood as a potential or presence that allows for some type of work to be performed. Some of energy's more recognizable forms are heat, light, mechanical, chemical, and electrical energy. Without energy we would not exist, and the universe if it existed would be a frigid, barren, motionless void.

According to the laws of thermodynamics, energy can be neither created nor destroyed. However, energy can be converted from one form to another. The total amount of energy in the universe remains constant while the quantity of the different forms can change relative to one another. For instance, you are probably reading this book by the light of a nearby lamp. Take a moment and turn off the lamp. Without touching the bulb, look at the thin filament inside. The filament transforms the electrical energy running from the wall socket and through the cord and eventually along the filament in the bulb into two other forms of energy—light and heat. As the filament illuminates, there is a reduction in electrical energy and an increase in

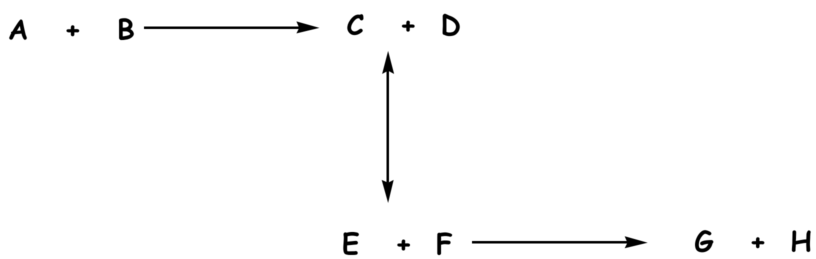


FIGURE 1.4. Here A and B are the initial reactants and G and H are the end products of the pathway.

light and heat energies. So energy is not lost but transformed to other forms.

A little bit closer to nutrition, food contains chemical energy in the form of carbohydrates, proteins, fats, and alcohol. Once inside our body the chemical energy of these substances can be transformed into mechanical energy to power muscular movement and other activities as well as heat to maintain our body temperature. Furthermore, we can store these energy molecules when we cannot immediately use them.

Is energy involved in chemical reactions?

In general, two types of chemical reactions take place—those that release energy *(energy releasing)* and those that require the input of energy *(energy requiring)*. When a chemical reaction takes place, the bonds between atoms are disrupted. This process releases energy as shown in Figure 1.5. Some of the released energy can be harnessed to create the new bonds found in the product(s).

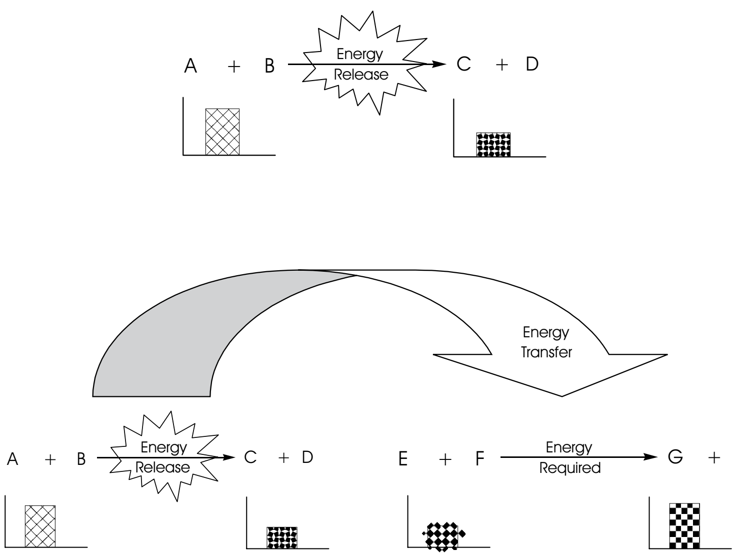


FIGURE 1.5. (Top) Energy is released from this chemical reaction. The bar graphs below the reactants and products present the energy in the bonds. There is less energy in the products thus energy was released in this reaction. (Bottom) Energy released by the first chemical reaction is utilized in the second chemical reaction.

If the energy associated with the bonds of the products is less than the energy associated with the initial energy in the reactants bonds, then the reaction can proceed without a need for outside energy input. In this situation, the fate of the leftover energy depends on whether the energy-releasing reaction was coupled with an energy-requiring reaction. In energy-requiring reactions, where the energy associated with the bonds of the products is greater than the energy associated with the reactants, the energy input is derived from a energy-releasing reaction coupled to it (see Figure 1.5).

Beyond those chemical reactions that either release or require appreciable amounts of energy there are many chemical reactions that take place without a release of or requirement for energy. Here the energy associated with the bonds of the reactants and products of chemical reactions is the same. These would be the reversible reactions we discussed earlier, where one enzyme catalyzes the reaction in both directions.

How does food energy become our body's energy?

On a daily basis we acquire energy from foods in the form of carbohydrates, protein, fat, and alcohol. However, we cannot directly use these molecules for energy. These substances must first engage in chemical reaction pathways that allow for us to capture their endowed energy in a form that we can use. Generally, when energy molecules are broken down some of their energy is captured in so-called "high-energy molecules." By far, the most important high-energy molecule is *adenosine triphosphate* or, more commonly, ATP. Figure 1.6 displays a simplified version of ATP. When energy is needed to power an event in our body an enzyme breaks the bonds between the phosphates releasing energy, which can be utilized to power that event. If ATP was "A" in Figure 1.5 (bottom) then its energy would be used in building new molecules in our body.

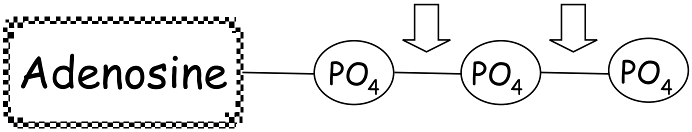


FIGURE 1.6. Adenosine triphosphate (ATP) is the principal "high-energy molecule" in our body. A lot of energy is harnessed in the bonds (arrows) between the phosphates (PO_4).

Interestingly, not all of the energy released in the breakdown of carbohydrates, protein, fat, and alcohol is incorporated in ATP. It has been estimated that we are able to capture only about 40 to 45 percent of the chemical energy available in those molecules in the form of ATP. The remaining 55 to 60 percent of the energy is converted to heat, which helps us maintain our body temperature (see Figure 1.7). The final product of the chemical reaction pathways involving carbohydrates, proteins, fat, and alcohol is primarily carbon dioxide (CO_2), which we then must exhale, and water (H_2O), which helps keep our body hydrated.

If we bear witness to the ATP molecule, we notice what looks like a *phosphate* tail (see Figure 1.6). Phosphate is made up of phosphorus (P) bonded to oxygen (O) and, as indicated in its name, ATP contains three phosphates. The energy liberated during the breakdown of energy nutrients is used to link phosphates together to make ATP. These phosphate links are thus little storehouses of energy. When energy is needed, special enzymes in our cells are able to break the links between adjacent phosphate groups. This releases the energy stored within that link, which can be harnessed to drive a nearby *energy-requiring* reaction or process.

WATER SOLUBILITY DETERMINES HOW CHEMICALS ARE TREATED IN OUR BODY

Why do some things dissolve in water while others do not?

On the average, adults will maintain about 60 percent of their body weight as water. Since water is the predominant substance in the body, it is important to understand how other substances interact with

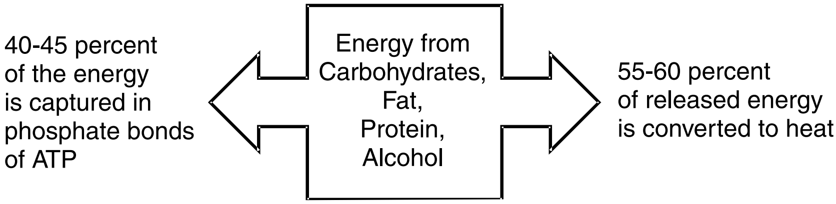


FIGURE 1.7. Only about 40 to 45 percent of the energy released from carbohydrates, protein, fat, and alcohol is captured in the phosphate bonds of ATP and other high-energy molecules; the remaining energy is converted to heat.

it. What we are really talking about is a substance's ability or inability to dissolve into water.

If a substance dissolves easily into water it is referred to as *water soluble.* Conversely, if a substance does not dissolve into water it is referred to as *water insoluble.* As a general rule, water-insoluble substances will dissolve in lipid substances, such as oil (fat). Therefore, we can call these substances either water insoluble, lipid soluble, or fat soluble. Examples of water insolubility are often obvious. We have all been frustrated by the inability of traditional salad dressings, such as vinegar and oil, to stay together and not separate into two layers. We have also witnessed oil tanker spills whereby the oil does not dissolve into the body of water but rather forms a layer on top of the water, posing a threat to the aquatic life. As many water-insoluble substances, such as the oil from the tanker or in the salad dressing, are less dense than water, they tend to float.

The key to understanding water solubility requires a closer look at the bonds between hydrogen and oxygen atoms in a water molecule. As Figure 1.8 demonstrates, two very small hydrogen atoms share electrons with one relatively large oxygen atom. Hydrogen atoms have but one proton in their nucleus, while oxygen atoms have eight protons. As a result, oxygen tends to pull the shared electrons closer

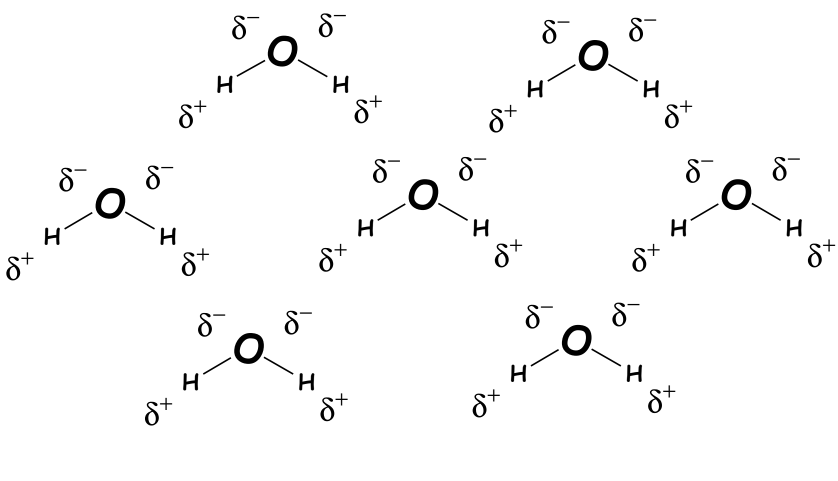


FIGURE 1.8. Water molecules are attracted to one another and other charged chemicals because of the partial positive charges on the H atoms and partial negative charges on the O atoms.

to it because it has a greater positive charge in its nucleus. This leads to a partial negative charge associated with oxygen atoms and a partial positive charge associated with hydrogen atoms. It is an electron tug-of-war, with hydrogen atoms having a weaker pulling force. It is important to see that the charges that develop are not full charges, as the electrons are technically still being shared. The charge is only a partial charge and will be designated with the Greek lowercase letter delta in superscript (δ^+ or δ^-).

Therefore, water is somewhat electrical in nature. Partially charged water molecule atoms can then interact with other water molecules due to opposite charge attraction. This is the glue that holds water together. This glue helps us understand the concept of surface tension, especially when the water level exceeds the capacity of a glass. The water molecules at the top of the glass are attracted to the other water molecules beneath them and they sort of hold on electrically, which keeps the too-full glass from overflowing, to a point.

Since atoms in a water molecule bear partial charges it only makes sense that they can interact with other substances that have a charge. This includes sodium (Na^+), potassium (K^+), and chloride (Cl^-). When these atoms (and other charged chemicals) are dissolved in water, the resulting fluid is able to carry an electric current. Scientists began to refer to them as *electrolytes* which means "electricity loving." Sodium and chloride are the electrolytes in sports drinks such as POWERade. These beverages are often called fluid and electrolyte replacements.

Lipids, such as fats and cholesterol, do not have a significant charge and as a result they are water insoluble. The partial charges of water atoms do not find lipid molecules electrically attractive. Therefore, the two substances do not mix. Or, from another perspective, the partial charges of water molecules are more attracted to water and other charged substances and basically ignore lipid substances.

Since lipid molecules fail to dissolve into water, they tend to clump together. As mentioned previously, because lipids are generally less dense than water, they tend to sit on top of water. This explains why some salad dressings separate with the oil on top. Also, it explains why oil spills lay on top of water and can be cleaned up by using a corralling device called a boom.

ACIDS AND BASES CONTRIBUTE TO THE CHEMISTRY LAB OF OUR BODY

What are acids and bases?

The world is filled with *acids* and their counterparts, *bases*. These substances are in our foods and beverages, as well as throughout nature. An acid is any molecule that has the potential to release a hydrogen ion (H^+) when mixed into a water-based fluid. Therefore, when an acid is added to water, the free-hydrogen-ion content of the water will probably increase. Conversely, a base is any substance that when dissolved in water will bind free hydrogen ions also dissolved in the water-based fluid. A base will decrease the concentration of free hydrogen ions in that fluid. Therefore, acids and bases are opposites.

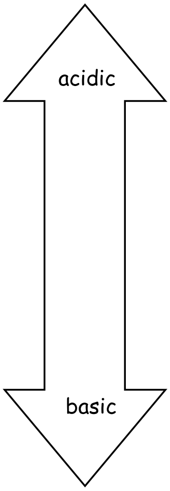
So we see that *acidity* simply refers to the amount of free hydrogen ions dissolved in water or a water-based fluid. Our body can be considered a container of water-based fluid, and, as will become more obvious soon enough, the concentration of hydrogen ions in our body fluid will greatly influence function and health.

How do we measure acidity or alkalinity?

Acidity, or alkalinity (basicity) for that matter, is measured on a basis of the hydrogen ion concentration on what is called the pH scale. The pH scale ranges from 0 to 14, with 0 being the most acidic and 14 being the most basic. Thus, a pH of 7 is said to be neutral because it splits the two extremes. The more acidic a fluid is the greater the hydrogen ion concentration and the lower the pH. The pH scale was conceived by Sören Sörensen who was a pretty good biochemist and an excellent brewer of beer! (So I am told.)

Back in the days before sophisticated pH meters, one could speculate as to whether a fluid was acidic or basic based on taste. Acidic substances tend to have a sour taste (lemon juice, orange juice), while more alkaline substances taste bitter.

So what is the big deal about pH? Our body has but a narrow pH range at which it can function appropriately. As noted on the scale in Figure 1.9, the pH of our circulating blood is about 7.4. This means that the pH of our body is slightly basic. If the pH falls below or above 7.4 these conditions are referred to as *acidosis* and *alkalosis,* respectively. Nearly all chemical reactions in our body are catalyzed by en-



0
1
2 Stomach acid (2.0), lemon juice (2.3)
3 Wine (3.5), orange juice (3.7)
4 Tomato juice (4.2)
5 Coffee (5.1)
6 Milk, urine, saliva (6.5)
7 (Neutral) - pure water (7.0), human blood (7.4)
8 Egg white (8), baking soda, sea water (8.4)
9 Borax (9.2)
10 Milk of Magnesia (10.5)
11 Household ammonia (11.7)
12
13 Lye, caustic soda (13.0)
14

FIGURE 1.9. The pH of common substances, including human blood (7.4).

zymes, most of which function in our best interest at a pH around 7.4. Thus, when our pH falls or climbs, the efficiency of many enzymes is significantly affected. This can compromise normal function and possibly our vitality.

Inherent to our body are systems that help us maintain the pH of our body fluid (e.g., blood) around 7.4. These systems are called *buffering systems* and they act either to soak up excessive H^+ or to release H^+ when pH is subject to change. Thus pH can be maintained at the 7.4 ideal despite changing internal factors.

FREE RADICALS ARE BIOLOGICAL BULLIES; ANTIOXIDANTS ARE CELLULAR SUPERHEROES

What are free radicals and antioxidants?

Over the past decade or so, more and more attention has focused upon *free radicals* or *oxidants* and their counterparts, *antioxidants*. Once we understand free radicals, it is easy to appreciate the importance of nutrients associated with antioxidant activities such as vitamins C and E, β-carotene, lycopene, selenium, copper, iron, manganese, and zinc. A free radical is a substance that endeavors to interact with other molecules and either steal an electron from them or force an electron upon them. Most of the time it is the former. You will remember that earlier we called the process of losing an electron oxidation and the process of gaining an electron reduction. The major difference between proper oxidation and reduction and the damaging activity of free radicals is a matter of desire. You see, free radicals often interact with molecules that do not want to give up an electron. Therefore, free radicals are sort of biological bullies that will interact with other molecules without regard for the stability of these molecules. Typically free-radical substances include oxygen, such as the following:

- Superoxide (O_2^-)
- Hydrogen peroxide (H_2O_2)
- Hydroxyl radicals (OH^-)

One obvious feature of the free radicals just listed is that they closely resemble the oxygen (O_2) we breathe. So how abnormal could they be? The presence of free radicals in our body is not necessarily a disease and seems to be unavoidable. Free radicals are normally produced in the process of making ATP in cells and detoxifying some chemicals as well. In addition, certain immune processes purposely generate free-radical substances to attack foreign entities or debris in our body. However, free radicals can certainly lead to disease if their presence becomes too great and they are left to their own devices. This tends to happen when we allow free radicals access to our body via the foods we eat and the substances we breathe. Cigarette smoke is loaded with free-radical substances, probably greater than 100 different kinds.

Free radicals can cause damage within the human body by attacking extremely important molecules such as DNA, proteins, and special fatty acids. If these or other molecules are attacked by free radicals and have an electron removed from their structure (oxidation) it is like pulling a bottom card from a house of cards. The victimized molecule is rendered weak and unstable and subject to breakdown. An example of this oxidative damage can be demonstrated by leaving vegetable oil out in an open container exposed to sunlight. The presence of oxygen and energy from sunlight leads to the formation of oxygen-based free radicals, which attack the fat causing them to break down in smaller molecules. Some of these molecules can produce an offensive odor and taste. Throughout time we have accepted the presence of free radicals, and our body has evolved to meet the challenge. We are armed with a battery of antioxidants to keep the free radicals in check. The term *antioxidant* implies that these molecules will prevent free radicals from pulling electrons (oxidation) from other molecules. They may do so by donating their own electrons to a free radical. This pacifies a free radical and spares other molecules. Antioxidants are different from nonantioxidant molecules in that they remain relatively stable after giving up an electron. They are designed to handle this process.

Hey, you made it through Chapter 1. For many people these concepts may seem easy; however, for others, they may present more of a challenge. One thing is certain: if you have at least a general comprehension of these concepts, nutrition becomes a lot easier to understand. In Chapter 2 we discuss some of the finer aspects of the structure and function of our body.

Chapter 2

How Our Body Works

CELLS ARE LIFE

It is obvious that humans are not the only life-form or *organism* residing on this planet. In fact, we are only one of several million different species of organisms. Organisms include everything from mammals, birds, reptiles, and insects, to plants, bacteria, fungi, and yeast. But bear in mind that even though organisms such as a tomato plant and an octopus may seem completely different, they have numerous similarities which strongly suggest a common ancestry for all life-forms hanging out on Earth, which includes you and me.

Among the millions of species on this planet, the *cell* is the common denominator. Cells are the most basic living unit. In many species, such as bacteria and amoeba, the entire organism consists of a single isolated cell. But for plants and animals, including us, the organism exists as a compilation of many cells working together. In fact, every adult human is a compilation of some 60 to 100 trillion cells.

As a rule of nature life begets other life and thus all cells must come from existing cells. This is to say that in order to create a new cell, another cell has to divide into two cells. It also suggests that all life-forms on Earth may be derived from the same cell or type of cell. The process of cell division is tightly regulated and, as we will discuss in later chapters, when this regulation is lost and cells divide out of control, cancer can arise.

When you and I were conceived, an egg (ovum) from our mother was penetrated by our father's sperm. This resulted in the formation of the first cell of a new life. Therefore, everyone you know was only a single cell at first. That cell had to then develop and divide in two cells, which themselves divided to create four cells, and so on.

What are cells?

The term *cell* implies the concept of separation. Each cell has the ability to function on its own. In multicellular organisms such as humans, individual cells are also sensitive and responsive to what is going on in the organism as a whole. Therefore, these cells survive as independent living units and also cooperatively participate in the vitality of the organism to which they belong.

Human cells can differ in size and function. Some are bigger and some longer, some will make hormones while others will help our body move. In fact, there are roughly 200 different types of cells in our body. Although these cells may seem unrelated most of the general features will be the same from one cell to the next. Therefore, we can discuss cells by describing the features of a single cell. Unique characteristics of different kinds of different cell types (e.g., red blood cells [RBC] and muscle and fat cells) will be described as they become relevant later in this chapter and book.

A wall or, more scientifically, a plasma membrane encloses every cell in our body. As shown in Figure 2.1, the plasma membrane separates the inside of the cell from the outside of the cell. The watery environment inside the cell is called the *intracellular fluid*. Meanwhile, the watery medium outside of cells is called the *extracellular fluid*. Previously, it was noted that our body is about 60 percent water. Of this 60 percent, roughly two-thirds of the water is intracellular fluid while the remaining one-third is extracellular fluid, which would include the plasma of our blood.

What types of substances are found in the intracellular and extracellular fluids?

In our body fluids we would find small dissolved substances such as ions, amino acids, and the carbohydrate glucose, as well as larger proteins. The major ions (electrolytes) would include potassium (K^+), sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), phosphate (PO_4^{3-}), and bicarbonate (HCO_3^-). As demonstrated in Figure 2.2, all of these and other substances will be found in both the intracellular and extracellular fluids. However, there are basic differences between the concentration of substances dissolved in

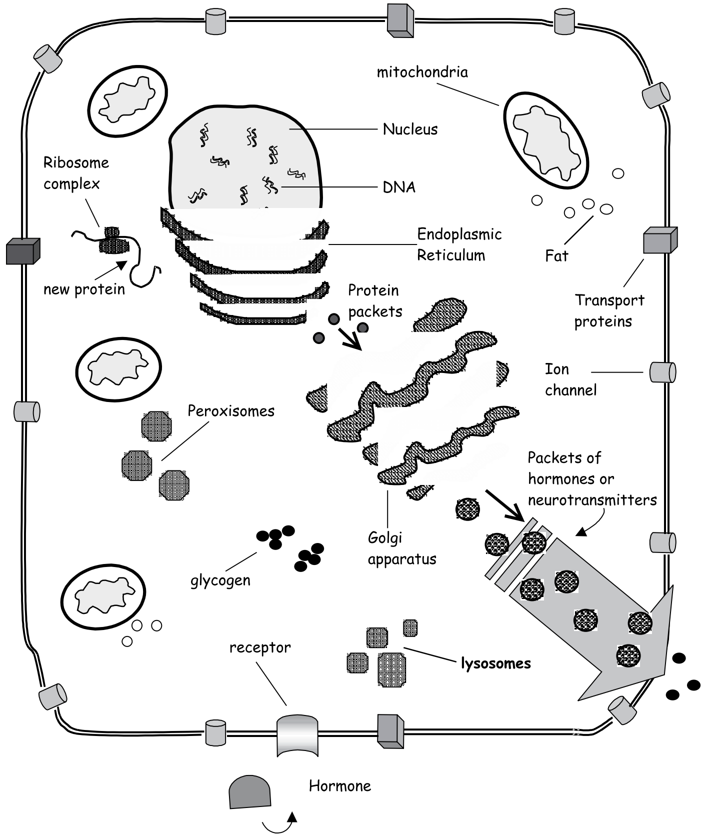


FIGURE 2.1. This is a model of a human cell. Cells contain DNA, the instructions for bonding proteins, and organelles that perform specific functions.

either fluid, and the plasma membrane is bestowed with the awesome responsibility of functioning as a barrier between the two mediums.

What would we expect to find inside of our cells?

Immersed in and bathed by the intracellular fluid are small compartments called *organelles*. The word organelle means "little organ." Two of the more recognizable organelles are the *nucleus* and *mitochondria*. Other organelles include *endoplasmic reticulum, Golgi apparatus, lysosomes,* and *peroxisomes* (see Figure 2.1). The various organelles are little operation centers within cells. Each type of

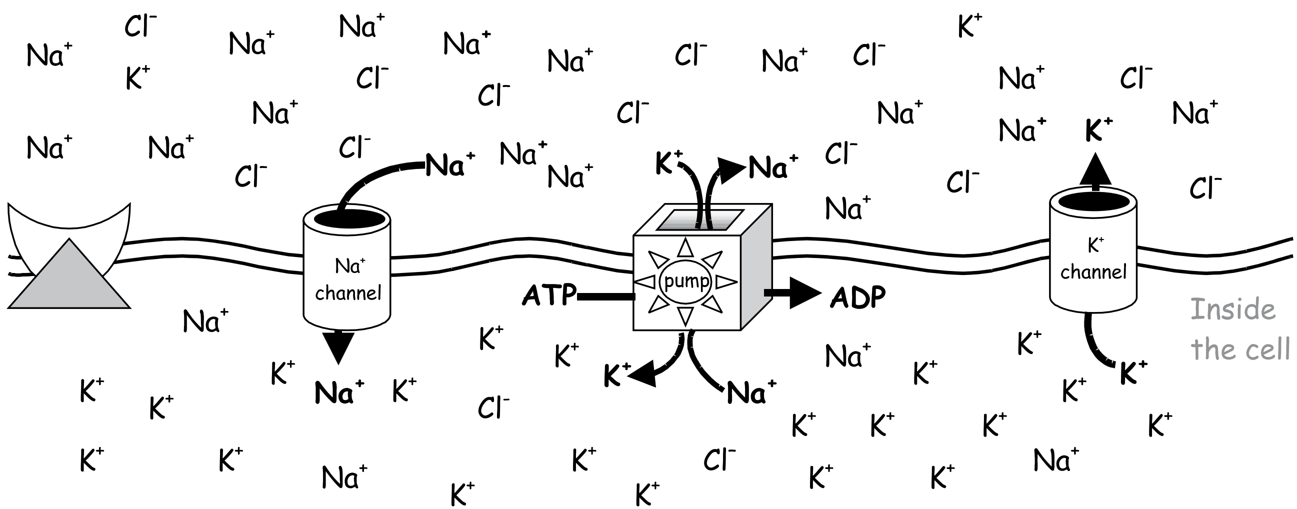


FIGURE 2.2. The concentration of sodium (Na+) and chloride (Cl–) is greater in the extracellular fluid while potassium (K+) is more concentrated in the intracellular fluid. These electrolytes move down their concentration gradients through channels and are pumped against their concentration gradient by energy (ATP)-requiring pumps.

organelle performs a different and specialized job (see Table 2.1). Each organelle has a membrane with many similarities to the plasma membrane. Therefore, as we discuss the nature of the plasma membrane below you can keep in mind that some of these features also pertain to organelle membranes as well.

Also within the intracellular fluid of certain cells we would expect to find some energy reserves in the form of *fat droplets* and *glycogen* (carbohydrate) (see Figure 2.1). The amount of glycogen and fat will vary depending on the type of cell. Another important component of cells is *ribosomes*. Ribosomes are the actual site where proteins are constructed.

Do individual cells and our body as a whole attempt to maintain an optimal working environment?

Just as you clean your apartment or house and determine what kind of stuff is found within your living area, so too will our cells clean and regulate the contents in their intracellular fluid. This allows each cell to maintain an optimal operating environment. Scientists often use the term *homeostasis* to describe the efforts associated with the maintenance of this optimal environment. Furthermore, just as it is the responsibility of each cell to maintain its own ideal internal environment, at the same time many of our organs work in concert to regulate the environment within our body as a whole (see Box 2.1). These or-

TABLE 2.1. Overview of Organelle Function

Organelle	**Function and Specialized Features**
Nucleus	Houses almost all of our DNA
Mitochondria	The site of most ATP manufacturing in cells; houses some DNA
Lysosomes	Involved in breaking down unnecessary or foreign substances; contains acidic environment and digestive enzymes
Endoplasmic reticulum	Involved in making proteins and lipid substances destined to be exported from a cell
Peroxisomes	Like lysosomes but with a different assortment of enzymes; site of detoxification
Golgi apparatus	The final packaging site for substances due to be exported from a cell

gans include the kidneys, lungs, skin, and liver. Many of our most basic functions, such as breathing, sweating, urinating, digesting, and the pumping of our heart, are actually functions dedicated to homeostasis. Therefore, homeostasis is the housekeeping efforts of all our cells working individually as well as together to provide an environment conducive to optimal function.

BOX 2.1. General Mechanisms of Homeostasis

- Regulation of the ion concentrations inside and outside of cells
- Blood pressure regulation
- Regulation of optimal levels of blood gases (O_2 and CO_2)
- Maintaining optimal body temperature
- Regulating blood glucose and calcium levels
- Maintaining an optimal pH level

What is the nature of the plasma membrane?

Each cell is enveloped by a very thin membrane measuring only about 10 nanometers (nm) thick. A nm is one-billionth of a meter—pretty thin indeed. The makeup of the plasma membrane is a very clever combination of mostly lipids and proteins with just a touch of carbohydrate. Interestingly, plasma membranes use the basic principle of water solubility to allow for its barrier properties. Actually, it is the lipid portion that provides this character. Molecules that are somewhat similar to triglycerides (fat) called *phospholipids* are arranged to provide a water-insoluble capsule surrounding cells. What that means is that water-soluble substances such as sodium, potassium, and chloride, carbohydrates, proteins, and amino acids are restricted from moving freely through the membrane. Some lipid substances and gases seem to freely move across the plasma membrane. The plasma membrane will also contain the lipid substance cholesterol. Cholesterol appears to increase the stability of the plasma membranes.

If we were to weigh all of the components of the plasma membrane we would find that it is about half protein. However, this is a bit misleading as the much smaller lipid molecules of the plasma membrane actually outnumber protein molecules by about fifty to one. Since the plasma membrane functions as a barrier between the outside and inside of the cell, there must be a means or doorways whereby many water-soluble substances can either enter or exit a cell. One of the roles of proteins in the plasma membrane is to function as doors, thereby allowing substances such as sodium, potassium, chloride, glucose, and amino acids to enter or exit a cell. This is shown in Figures 2.1 and 2.2.

Proteins are truly the more functional component part of the plasma membrane, as phospholipids and cholesterol provide more structural support. Let us go into a little more detail about just how some of the proteins function as doorways in our plasma membranes. Some of these proteins function as channels or pores that will allow the passage of only one specific substance across the membrane. This is like opening the stadium doors for fans before a concert. The concentration of fans outside the stadium is much higher than within and the natural flow is for the general movement of people into the stadium, an area of lower concentration.

Plasma membrane channels mostly allow the passage of ions such as sodium, potassium, chloride, and calcium down their concentration gradient. However, the movement will be in mass amounts resulting in a sudden and significant change in a cell's environment. As an example, *ion channels* are especially important in nerve and muscle cells, and drugs often prescribed for people with cardiovascular concerns are calcium-channel blockers, which will be discussed more in just a bit and also in Chapter 13.

We should stop for a moment and emphasize a very important concept. In nature, when provided the opportunity, things will tend to move from an area of higher concentration to an area of lower concentration. This type of movement is called *diffusion* and it can be applied to so many aspects of nature. The movement of substances across our plasma membranes is an excellent example of diffusion. Simply put, diffusion is when a substance moves from an area where it is found in higher concentration to an area of lower concentration. For example, muscle cells are told to contract by calcium. Thus when muscle cells want to relax (not contracted) they must pump out nearly all of the calcium. This sets up a huge diffusion gradient. In fact, the calcium concentration outside the muscle cell will be greater than ten times that inside during relaxation of that muscle cell. However, when that muscle cell is told to contract, calcium channels open, calcium diffuses, and that cell contracts. Calcium-channel blockers attempt to inhibit the opening of channels and the subsequent contraction of muscle cells in the walls of certain blood vessels. This is an attempt to relax the muscle and allow the vessels to dilate a bit. This then would lower the pressure associated with the blood (blood pressure).

Channels or pores are not the only types of proteins found in our plasma membranes. Other proteins can function as *carriers* that can physically relocate or "transport" substances across the membrane. Here again substances would be moving along their concentration gradient. These carrier proteins tend to transport larger substances than channels can, and the movement tends to occur only one or two substances at a time. Substances that utilize carrier proteins include carbohydrates and amino acids. Perhaps the most famous example of a carrier protein is the glucose transport protein (GluT) which is the primary concern in type 2 diabetes mellitus. We will spend much more time on glucose transporters later on.

Not all substances move across our plasma membrane down their concentration gradient. Like trout swimming upstream, substances moving across the plasma membrane in this manner go against the natural flow of nature. To perform this operation, certain membrane proteins can function as *pumps*. Quite simply, pumps will move substances across the membrane against their concentration gradient. Said another way, substances can be pumped across the membrane from the area with a lower concentration of that substance through the plasma membrane to the side with a higher concentration. As this goes against the natural flow of things, it will require energy to make it happen. (You can bet the trout are tired.) The energy is derived from splitting ATP. In fact, a very respectable portion of the energy that humans expend every day is attributed to pumping substances across cell membranes. We will go into much more detail about this later on in this chapter and other chapters.

Last, but certainly not least, not all proteins in the plasma membrane function in transport operations. Some proteins function as *receptors* for special communicating substances in our body such as *hormones* and *neurotransmitters*. Typically, receptors will interact with only one specific molecule and ignore all other substances. In a way, then, these proteins are involved in the transport processes. Here, however, the transported item is not a substance but information.