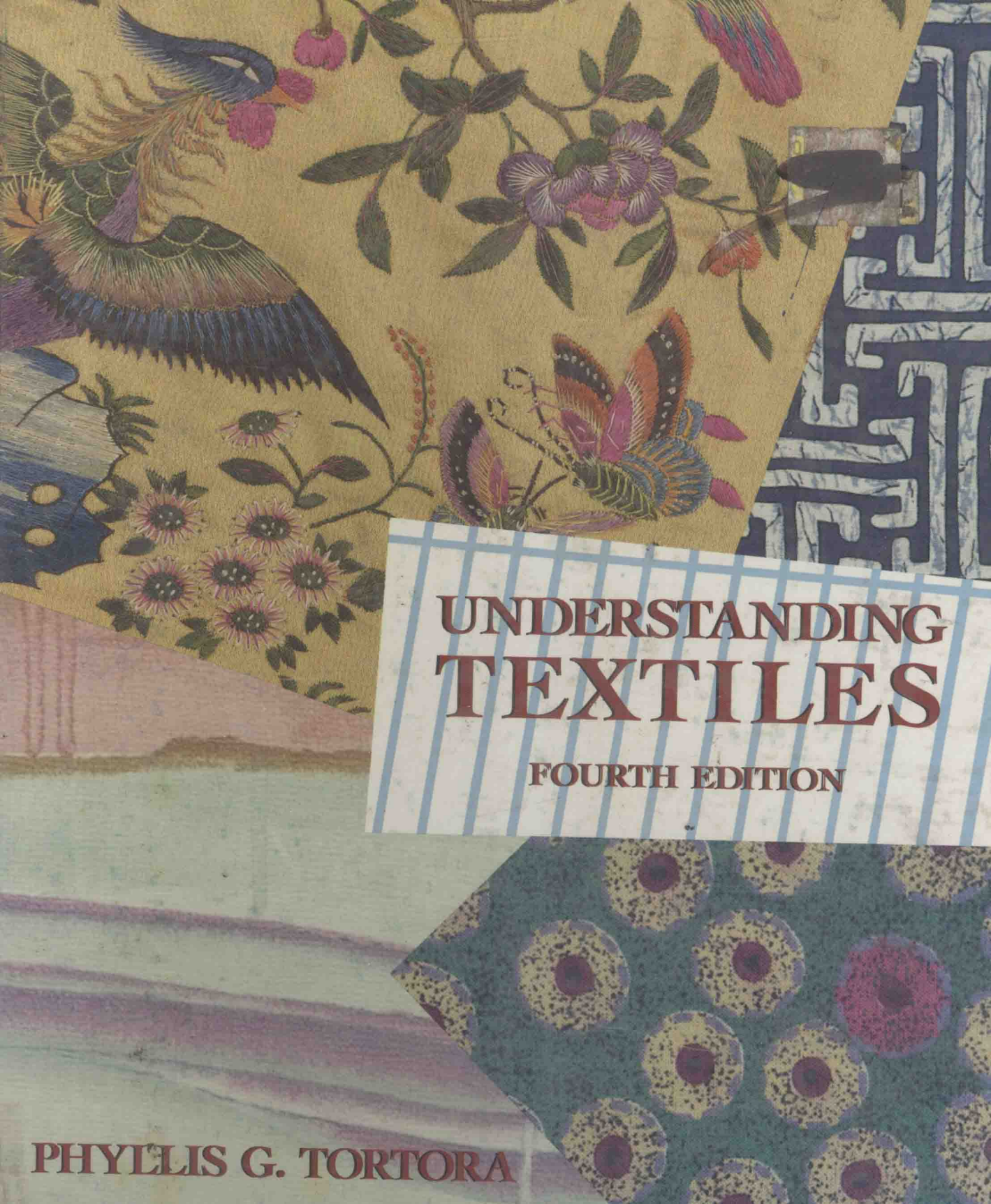

UNDERSTANDING TEXTILES

FOURTH EDITION

PHYLLIS G. TORTORA

4th Edition

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PHYLLIS G. TORTORA
QUEENS COLLEGE

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PREFACE

The purpose of this book is to provide a common background for students who are making a study of textiles. Some students may be planning to enter one of the many career areas that require some knowledge about textiles. Others may be interested in becoming better informed consumers. Whatever may motivate students to enter an introductory course in textiles, certain basic concepts are essential to their understanding of the subject. It is my hope that these concepts are presented in a clear, logically developed format.

The text begins with an overview of the textile industry. The majority of students are likely to begin their study of textiles without any prior knowledge about the origin, manufacture, and distribution of the wide variety of textile products they use daily. The first chapter presents an overview of the journey of textile products that begins with fiber production and goes on to manufacture of yarns or other components, to fabric production, to design, and to manufacture of the final product. It is my intention to set a context for the chapters that follow in which basic processes, rooted in science and technology, are explored in depth, beginning with the basic building blocks of fabrics: fibers. In subsequent chapters emphasis is placed on the interrelationships of fibers, yarns, fabric constructions, and finishes. What is known about each of these components is applied to the understanding of textile behavior and performance.

To this end, diagrams and photographs have been selected with care to illustrate the concepts and processes described in the text. Many students study in parts of the country where they have no access to field trips to textile manufacturing sites; therefore, photographs of various types of machinery are included.

The recommended references at the end of each chapter have been selected to complement the subject matter of the chapters. I have made a conscious effort to include both relatively elementary and highly technical material so as to introduce students to the variety of resources in

the field. I have also tried to include readings from the most widely used periodicals in the field. An extensive bibliography, broken down under special subject headings, is appended to the book.

After Chapter 1 introduces the reader to the various elements from which textiles are made, their historical development, and the present-day organization of the textile industry, Chapters 2 and 3 establish the relationship of fiber properties to fiber behavior. Chapter 2 focuses on physical properties of fibers, and Chapter 3 deals with the chemical and physical concepts basic to understanding the behavior of textile fibers. Chapter 3 is written for the reader who has had no previous chemistry training. The student should be able to gain some understanding of these elementary concepts and to appreciate not only the integral role that chemistry plays in the manufacture and finishing of textile products, but also the role of chemistry in the use and care of textiles by consumers. Often this kind of material is integrated into varying parts of a text. I have not done so here because a separate chapter on the subject offers a better opportunity to explain elementary chemical terminology and concepts and to relate these concepts to the science of textiles. Some teachers may prefer to emphasize this chapter a great deal, whereas others may wish to discuss it briefly. Either approach may be taken.

The chapters on textile fibers (Chapters 4 to 13) have been reordered in this fourth edition. This material now begins with wool and other natural protein fibers in Chapter 4, continues with natural cellulosic fibers in Chapter 5, and then introduces students to the various manufactured fibers in Chapters 6 to 13. Each of the chapters dealing with textile fibers is organized in much the same way, with the same topic headings being used in each chapter. These topic headings are also used in the introductory chapter dealing with textile fiber properties—to facilitate comparisons between fibers. Each chapter ends with a table summarizing some of the more important characteristics of the major fiber groups discussed in that chapter.

From fibers the text moves to yarns and their production (Chapter 14), and from yarns the text goes on to fabric structures. Those who have used previous editions of this text will note that the content of Chapter 15 has been narrowed to focus only on woven fabrics, that knitted fabrics are covered in Chapter 16, and that multicomponent textiles (laminated fabrics, quilted fabrics, and the like) are now included in Chapter 17 after a discussion of non-woven textiles. These chapters deal with processes ranging from traditional methods of manufacture to innovations in the production of materials such as high technology textile composites.

The various methods of adding color and giving special finishes to fabrics are discussed in Chapters 18 to 21. Much of the appeal of textile fabrics results from the color and decoration that are applied to them. A number of photographs selected for Chapter 18 and 19 are of historic

textiles and are meant to provide a special emphasis on the aesthetic qualities of textiles.

Each of Chapters 22 to 25 fulfills a special purpose in the organization of the book. Chapter 22, "The Care of Textile Products," is included as a separate chapter, even though some material about the care of textiles is also included in preceding chapters, because of the importance of care in relation to consumer satisfaction with textiles.

Chapter 23 deals with textiles and the environment, a topic of concern to both the consumer and the textile industry. The chapter is addressed not only to ways in which textile production and use affect the environment but also raises questions about the complex "trade-offs" between environmental quality and increased costs of consumer goods.

Chapter 24 provides a brief introduction to the subject of textile testing. Many colleges and junior colleges have little or no textile testing equipment. Others may have extensive and elaborate textile laboratories. For the former, this chapter provides photographs of basic equipment and some brief discussion of types of equipment used in testing, as well as descriptions of some simple tests that can be performed in the classroom or at home. For the latter, this chapter provides a very general introduction to the subject of textile testing that may be expanded in other courses. This chapter does not serve as a substitute for technical or laboratory manuals.

The last chapter provides a summary for the text. It explores some of the ways in which fiber, yarn, fabric construction, and finishes contribute to the total structure of the fabric, and how the structure of the fabric is, in turn, related to its performance.

Each college or university organizes its course work in unique ways. While it is not possible for a single text to meet the needs of all programs, I believe that this book includes all the information essential to an introductory textiles course and offers the student and the teacher neither too much nor too little. It will be up to the faculty and students who use this book to tell me whether I have indeed reached that goal.

The contributions of individuals to the preparation of previous editions continue to be basic to the structure and form of the fourth edition, and those contributions are still very much appreciated. My husband Vincent, my son Christopher, and my daughter Giulia continued to provide constant encouragement, assistance, and support throughout the process.

Colleagues and students who have used the third edition of this text provided a number of useful suggestions. I found the careful and consistent feedback from Dr. Elizabeth Lowe of the Queens College faculty especially noteworthy, as were the comments provided by Janice Stellato.

Dr. Robert Merkel of Florida International University, a reader of

the manuscript for previous editions, proved once again to be exceptionally helpful in reviewing the third edition and providing a great many valuable comments and suggestions which were incorporated into this fourth edition. These, I believe, added very considerably to the quality of the final manuscript. Other readers selected by the publisher were also most helpful. They included Professor Joanne Eckstein of Macomb Community College, Professor Lucille Golightly of Memphis State University, and Professor Ardis M. Rewerts of University of Texas.

Gail Ronnerman of the Queens College library staff assisted in locating materials and in keeping alert to useful references. I thank the Fashion Institute of Technology library staff for allowing access to their periodical collection.

As always many individuals in the textile industry were helpful, providing information, photographs, and illustrative materials. Particular thanks are due to Fisher Rhymes and the technical committee of the American Fiber Manufacturers Association, Inc. for their review of the chapters on manufactured fibers, and James Morrissey of the American Textile Manufacturers Institute, Inc. for his assistance and suggestions.

P. T.

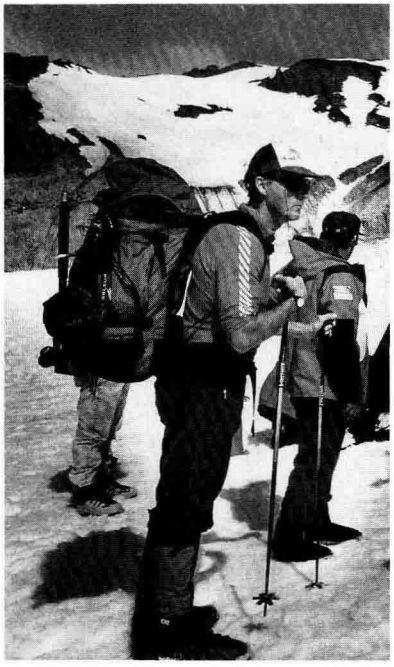
CONTENTS

1

INTRODUCTION

Each day each of us makes decisions about textiles. From the simplest choice of what clothes to wear to the commitment of a major portion of the family budget to buy a new carpet, judgments about the performance, durability, attractiveness, and care of textiles are consciously or unconsciously made. The economic implications of decision about fibers, yarns, and fabrics obviously increase if someone is involved professionally with textiles. But whether or not understanding textiles is required for personal or for professional purposes, the key to informed decision making is knowledge about fibers, yarns, fabrics, and finishes and the ways in which these are interrelated.

Textiles fulfill so many purposes in our lives that their study can be approached in a number of ways. Textiles may be seen as being purely utilitarian, in relationship to the numerous purposes they serve. On awaking in the morning, for example, we climb out from under sheets and blankets and step into slippers and a robe. We wash our faces with washcloths, dry them with towels, and put on clothing for the day. We even brush our teeth with toothbrushes, the bristles of which are made from textile fibers. If we get into a car or bus, we sit on upholstered seats and the machine moves on tires reinforced with strong textile cords. We stand on carpets, sit on upholstered furniture, and look out of



(a)

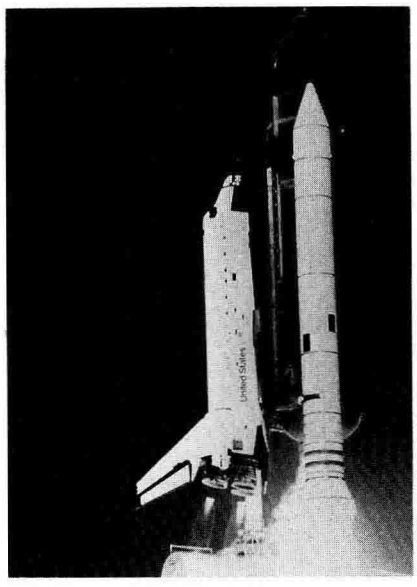
(b)

Figure 1.1. Fibers are used in applications that range from apparel to high technology. (a) Mountain climber in active wear made from polypropylene fiber. Courtesy of Helly-Hanson; (b) sofa upholstered in fabric made from olefin fiber. Courtesy of Amoco Fabrics and Fibers/ Westpoint Pepperell; (c) industrial oil boom of the type used to contain oil spills at sea. Courtesy of Himont/S. Mednick; (d) exhaust nozzles of trident missile made with carbonized rayon fiber. Courtesy of Avtex Fibers Inc.

curtained windows. Even the insulation of our houses may be glass textile fiber. Not only are golf clubs, tennis rackets, and ski poles reinforced with textile fibers, but so are roads, bridges, and buildings. Strong, heat-resistant textile fibers in the nose cones of space ships travel to distant planets. Physicians implant artificial arteries made of textiles or use fibers for surgery that gradually dissolve as wounds heal. Few of our manufactured products could be made without textile conveyor belts. Even our processed foods have been filtered through textile filter paper. There is truly no aspect of modern life that is untouched by some area of textiles. (See Figure 1.1.)

Some individual or some group of persons will be the ultimate consumer of each textile product. The ultimate consumer selects the product for a particular end use, whether that use be a fashionable garment or the fabrics used to reinforce high technology building materials. In all cases consumers want to select products that will perform well in the projected end uses. Most also seek to minimize cost. The ways in which textiles are produced affect their costs. Some steps in manufacturing are more expensive than others. Manufacturers may be able to choose one procedure instead of another. When alternatives are available, manufacturers are likely to select processes that will maximize their profits while making products that will sell at competitive prices

(c)



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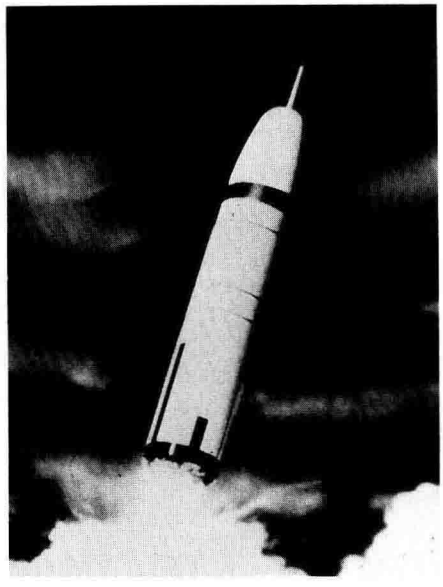

Figure 1.1 *(continued)*

and also fulfill customers' desire for satisfactory performance. Many products must also meet the demands of current fashion.

Even though we all personally experience textiles at home, at work, and at play, we usually encounter only the complete product; rarely do we deal with the individual components. But each finished product makes a long journey from its beginnings in the laboratory or on the farm to the place where it is acquired by the ultimate consumer. An introductory course in textile study can be a sort of road map or itinerary of that journey; therefore, this text is organized to begin with the first steps in the long progress from fiber to completed fabric and goes on to examine subsequent steps in a generally chronological sequence.

If you were to take the shirt or sweater that you, the reader, are wearing at this moment and break it down into its components, you would have to work backward, taking apart the fabric structure. Most likely your garment is woven or knitted. Weaving and knitting are the two most common means of creating fabrics for apparel, although other methods do exist. Both weaving and knitting are subject to a great many possible variations, and these differences contribute to the enormous variability in appearance, drapability, texture, crease recovery, handle, and the many other qualities of fabrics.

To take a woven or knitted structure apart requires that the fabric be unraveled into the yarns from which it was constructed. The yarns (with some few exceptions) are likely to have been made from short or long

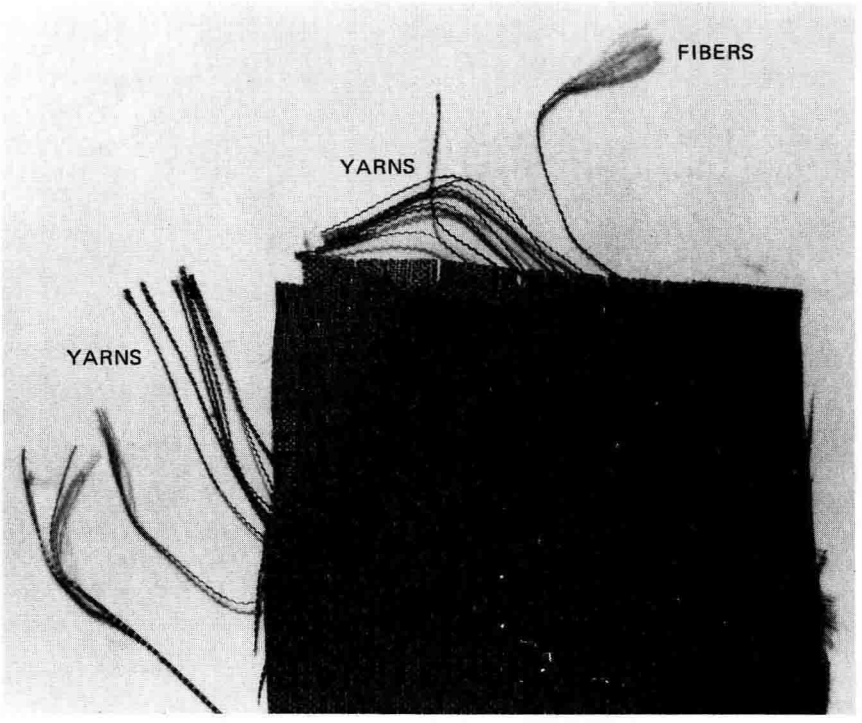

Figure 1.2. Fabric unravels into separate yarns. Yarns untwist into individual fibers.

continuous fibers that are twisted together. By untwisting the yarns, it should be possible to separate the yarn into a number of small, fine, hairlike fibers. These fibers are the basic units that make up the majority of textile products that are encountered in apparel and home furnishings. (See Figure 1.2.)

FIBERS

Textile fibers exist in nature or are created through technology. Technical definitions of the term *textile fibers* tend to stress their dimensions. For example, a textile fiber may be defined as "a unit of measure of hairlike dimensions with a length at least one hundred times greater than the width." [1] Although this may explain how a fiber looks, some materials that do fit this definition are not suitable for use in textiles. The fibrous structure of an overcooked pot roast, for example, is obviously not suitable for use in a textile. Fibers appropriate for use in textiles must have not only fineness and flexibility, but also sufficient strength and durability to withstand conditions encountered in use.

[1] A glossary of technical terms is provided in Appendix B.

In order to understand and evaluate suitability of different fibers for particular products, professionals in the textile field and consumers need to understand the physical and chemical properties of fibers. Particular fibers may be suitable for use in some textile applications, but not in others. Carbon fiber, excellent for use in high technology products and sports equipment, is not useful for wearing apparel. Even among those fibers used in many apparel and home furnishing items, some are preferred for particular applications. Nylon has become synonymous with sheer women's hosiery—women may refer to their stockings as

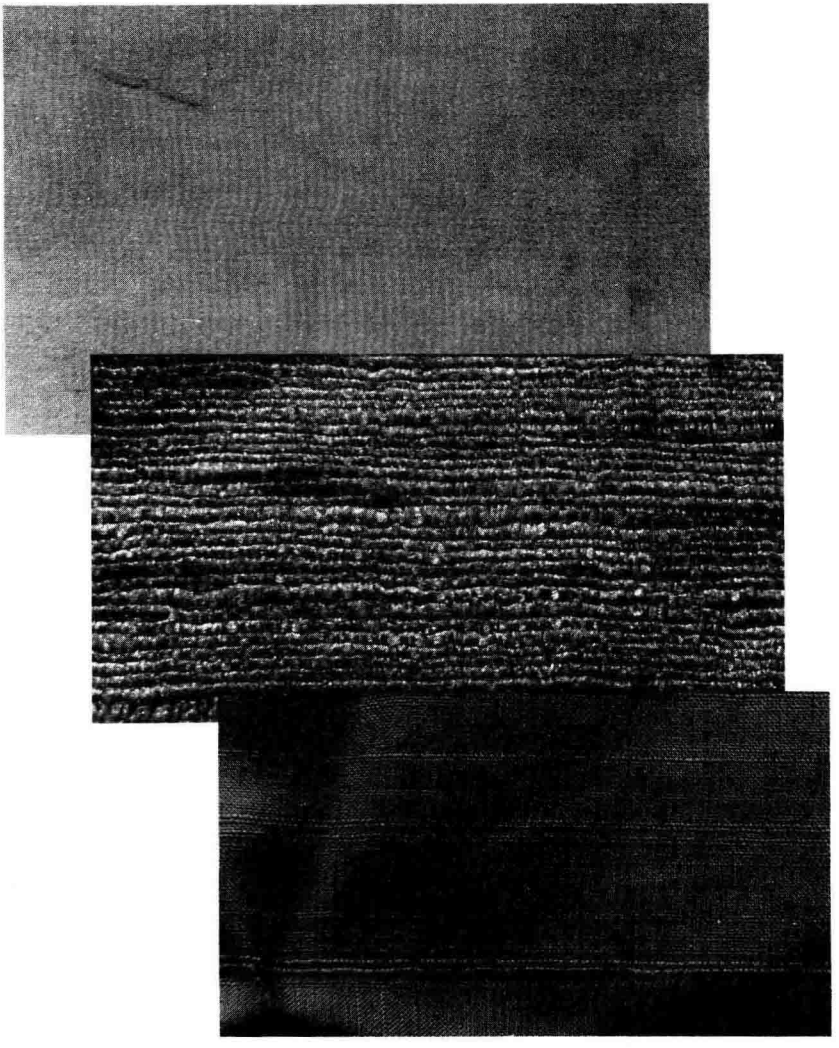

Figure 1.3. Fabrics made from the same fiber and in the same (plain) weave look different because different kinds of yarns are used.

"nylons" — although in fact, in the past, fibers such as silk or rayon were used to make women's dress hosiery. On reflection, then, it is obvious that we tend to prefer some kinds of fibers for certain uses because those particular fibers offer some special advantages. For example, a particular fabric may seem to be more comfortable in warm or cool weather, may soil less easily, may dry more quickly, or may have an appearance that is best suited to a particular kind of occasion. The reasons for these differences among fibers reside in the specific properties of each fiber. If we are to have a clear understanding of the finished products and what qualities are to be expected of them, we need to know the fibers from which the product is made — and the characteristics of those fibers.

YARNS

Fibers alone cannot make a textile. Although it is possible to entangle groups of fibers or to bond them together in some way to create a textile (as is done with felt, for example), most of the cloth that is made into wearing apparel is formed from yarns. Yarns are assemblies of fibers twisted or otherwise held together in a continuous strand. An almost endless variety of yarns can be created by using different fibers, by twisting fibers more or less tightly, by combining two or more individual yarns to form a more complex yarn, or by giving yarns a wide range of other special treatments.

Just as different fibers will vary in their individual properties, different kinds of yarns have varying characteristics. (See Figure 1.3.) And to complicate matters still further, two yarns of the same structure will have different properties if they are made from markedly different kinds of fibers.

FABRIC STRUCTURES

Yarns must be united in some way if they are to form a cohesive structure. The transformation of individual yarns into textile fabrics can be accomplished by an individual with a pair of knitting needles, a crochet hook, or a hand loom or through the use of powerful machines that combine yarns by weaving, knitting, or stitch-bonding to produce thousands of yards of completed fabrics. As with fibers and yarns, the potential for variations in the structure is enormous, and a walk through any department store will reveal to even the most casual observer the almost endless variety of textile structures produced and consumed by the public in the form of apparel or household textiles.

And, once again, if the construction being used is varied, the resulting properties will differ. Furthermore, even when the same weave or knit construction is used, the end product will be distinctive if the fiber or yarn type is varied. (See Figure 1.4.)

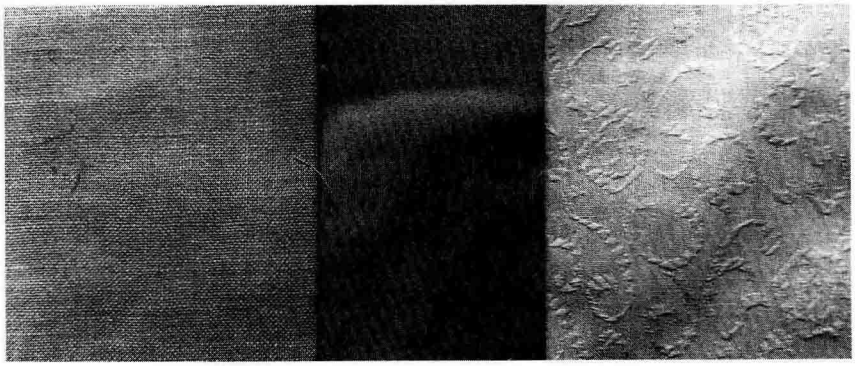

Figure 1.4. Fabrics made from the same fiber and from similar types of yarns look different because different types of weaves were used in their construction.

FINISHING AND COLORING

As the reader will learn, certain properties are inherent to each fiber, yarn, or fabric structure. Consumers find some of these properties desirable, while others are not valued. For example, fabrics of manufactured fibers dry quickly after laundering. Most consumers value this quality. But the same fabrics may tend to build up static electric charges, producing small electrical shocks or "static cling." Consumers do not like this quality. When a fiber, yarn, or fabric has unacceptable properties, special treatments called "finishes" may be applied to the fiber, yarn, or fabric to overcome undesirable properties. Finishes may be used to give to the fibers, yarns, or fabrics some properties that they do not normally possess but that will enhance performance. The aforementioned static cling of some manufactured fibers can be decreased or overcome by giving fibers, yarns, or fabrics special finishing treatments. Most of you know about durable press finishes, for example, or you may have purchased upholstered furniture with soil-resistant finishes. Other examples will be discussed in the chapters dealing with finishes.

Appearance — color, pattern, or texture — is one of the major factors that leads consumers to purchase one product over another. Most textile fabrics intended for personal, household, or architectural use have been decorated in some way, by dyeing the fabric, printing designs on it, or weaving with varicolored yarns. Large segments of the textile industry are devoted to dyeing and/or printing fabrics, yarns, or fibers.

TEXTILE HISTORY

The place of textiles in the world economy is enormously complex. How the production of textiles moved out of the home to become the business of huge multinational corporations is a part of the evolution of modern society. The origin of textile production is lost in prehistory.

No one knows exactly when the spinning and weaving of textiles began, but archeologists tell us that woven plant fiber fabrics were made

more than eight-five hundred years ago in Catal Huyuk, a hunting village in what is today the country of Turkey, and that a number of Mexican textiles date between 7000 and 5000 B.C.[2] For most of the time that people have made fabrics, the only fibers available for use were found in nature, and the processes used to make these fibers into cloth were carried out by hand.

In spite of limited technology, people created a wide variety of fabrics for themselves and for use in their homes. Some of these fabrics, such as the simple, plain homespun cloth used for every day were strictly utilitarian. Others were elaborately patterned, printed, or dyed in order to satisfy the universal human need for beauty.

As the complex social and political organizations of people evolved, some of the small hunting villages were replaced by larger towns, and eventually by cities and urban centers. Along with the growth of cities, nations, and empires, there were improvements in technology and the development of international trade, both of which involved textiles. Changes in textile technology and trade had come about as early as the time of the Roman Empire. The Romans not only traded actively with nearby Egypt to import cotton, but they had developed trade in silk with faraway China by the year A.D. 1. Close to storehouses in Roman settlements excavated in India, archeologists have found facilities for dyeing and finishing cotton fabrics. In the remains of many Roman towns there is evidence of installations for finishing and dyeing fabrics.

During the Middle Ages the production and trading of the plant called *woad,* an important source of dye, was a highly developed industry. Returning Crusaders brought luxurious silk and cotton fabrics from the Middle East to their homes in Europe, and these "foreign novelties" became an important item in trade. During the fifteenth century, the trade fairs of southern France provided a place for the active exchange of wools from England and silks from the Middle East. The economic activities surrounding these events gave rise to the first international banking arrangements.

Even the discovery of America was a result of the desire of Europeans to find a faster route not only to the spices but also to the textiles of the Orient. Once the American colonies had been established, the colonists sold native dyes such as indigo and cochineal to Europe and bought cottons from India. At the time when textiles were assuming an increasingly important role in international trade, advances were being made in the technology of textile production. Even so, the manufacture of cloth was still essentially a hand process. By 1700, in Western Europe spinning was still being done on a spinning wheel, by hand. Fabrics were woven by hand on looms for which the power was provided by the weaver.

[2] Mary Elizabeth King, "Archeological Textiles," in the *Proceedings of the Irene Emery Roundtable on Museum Textiles* (Washington, DC: The Textile Museum, 1974), p. 10.