# TEXTILES: FIBER TO FABRIC

FIFTH EDITION

CORBMAN

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FIFTH EDITION

**DR. BERNARD P. CORBMAN**
Dean of Academic Affairs
and Professor of Business and Commerce
Bronx Community College
City University of New York

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**Textiles: Fiber to Fabric**



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# PREFACE

*Textiles: Fiber to Fabric*, Fifth Edition, blends both the revolutionary new developments in the textile field and the traditional background information necessary for a full understanding of this complex and fast-moving industry. This edition provides the basic information needed by (1) students who are preparing for careers in the textile industry—in manufacturing, retailing, purchasing, or promoting; (2) beginning workers who are employed in any phase of the textile complex; (3) consumers and home economists who need sound guidance in the selection and care of textile products; (4) teachers who need a complete basic text on textiles, adaptable to a variety of curricula and student needs; and (5) specialists who need an up-to-date reference book.

## SCOPE OF THE BOOK

*Textiles: Fiber to Fabric*, Fifth Edition, continues to serve as a comprehensive survey of the textile field. It stresses consumer concerns with regard to comparison, selection, usage, and care of fabrics and merchandise as well as to the theory and processes underlying their manufacture.

New finishing processes such as shrink resistance and shrink-proofing, stain repellency and soil resistance, flame retardancy, and water repellency are surveyed. The discussion of permanent press finishes has been expanded. The wide application of "stretch" in fabrics is given considerable attention through discussions of stretch fibers, yarns, finishes, and the resultant stretch fabrics. The use of optical brighteners and their value are considered. New dyeing and decorating techniques are examined and their merits noted.

The several major strains of cotton fibers are identified, evaluated, and compared, as are the various forms of established, improved, and new varieties of rayon, nylon, polyester, acrylic, modacrylic, spandex, polypropylene, saran, and glass. A chapter on aramid has been added. The chapter on textured and stretch yarns has been updated, and more illustrations have been added.

In addition to the advancements made in weaving, such as the use of shuttleless looms, special attention is given to the continued growth of fabric construction by other methods. The chapter on knitting now includes the advances made in electronic techniques that increase the versatility of knitting. Nonwovens, tufting, Mali, Arachne, and Doweave are also covered.

In this edition, fabrics of all types are compared by performance, durability, care requirements, and related characteristics. Thus the student can develop an ability to select goods wisely. Discussions of the Permanent Care Labeling Rule and the Flame Retardancy Regulations have also been added.

Detailed descriptions and information are provided on apparel, such as sweaters and hosiery, and on home furnishings, such as rugs and carpets. The discussion of hosiery, for example, covers evaluation of various knitted constructions. The discussion of the various types of rugs and carpets, their methods of construction, the fibers used in their manufacture, and their merits have been expanded.

## ORGANIZATION OF THE BOOK

The organization of *Textiles: Fiber to Fabric*, while following a distinct line of development, is by no means rigid. Each chapter is an entity unto itself, so that instructors may adapt the text to an outline appropriate for their particular textile course of study or group of students.

The sequence of chapters of the previous edition, which was based upon many years of teaching experience has been retained. The book opens with an introduction to the various fibers and tells how to identify them. Then the reader is taken through the logical, related sequence of chapters from fiber to finished fabric. For example, a chapter is devoted to spinning the fiber into various types of yarn. This is followed by treatment of fabric construction in a chapter on weaving, an expanded chapter on knitting, and a separate chapter on the less predominant, but growing, minor fabric constructions. Subsequent chapters review the many types of finishes, dyes and dyeing methods, and printing and flocking techniques.

Also included are the history of textile development, the methods of manufacture, and the characteristics, evaluations, and care of each type of textile. Comparative characteristics of all major fibers are presented in a summary chapter. Subsequent chapters of the book cover minor textile fibers, rugs and carpets, and care of fabrics, thus rounding out the reader's acquaintance with the field of textiles.

## SPECIAL FEATURES

*Textiles: Fiber to Fabric* does not require a previous knowledge of textiles or a background in science. Its vocabulary is simple and direct. Where technical or chemical terminology is necessary, it is presented clearly and in an understandable manner. Technical theory, concepts, and methods are intermingled with practical information that the lay person needs and understands readily. The student is also provided with trademarks of fibers and finishes and with glossaries of significant fabrics.

Specific facts to be considered when purchasing such items as hosiery, sweaters, sheets, towels, and carpets are organized and presented for ready reference. The general care of fabrics is fully discussed, including detailed information on stain removal.

***Illustrations.*** Illustrations help to make the more technical material understandable. A substantial number of photographs and diagrams are used to clarify new materials and to simplify complex industrial processes. Summary charts quickly identify and review the principal points covered and compare the specific items discussed.

***Cross-References.*** Information in the text is organized so that the book can be used as a reference source as well as a classroom text. Although each topic is treated independently, cross-reference notations minimize repetition and enable the reader to find specific information, such as properties of fibers, description of fabrics and finishes, and the like.

***End-of-Chapter Activities.*** There are two kinds of end-of-chapter activities. Review Questions provide an opportunity for classroom discussion and review and are based on the text material. Suggested Activities are also provided for selected chapters as appropriate. They give the student direction for enriching activities that will further increase his or her understanding of the subject.

***Instructor's Manual and Key.*** The instructor's manual contains the answers to all Review Questions in the text. This manual also contains an extensive bibliography of reading and reference sources for independent study. Listed are current books, periodicals, trade journals, and brochures covering the entire textile area. Names and addresses of textile companies and other organizations that have educational material available are also provided. In addition, the manual offers helpful suggestions for teaching the course. It also contains an objective test that can be duplicated and used as a final examination, as well as a key to this test.

*Bernard P. Corbman*

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# 1

# TEXTILE FIBERS

*under the microscope*

Textiles have such an important bearing on our daily lives that everyone needs to know something about them. From earliest times, people have used textiles of various types for covering, warmth, personal adornment, and even to display personal wealth. Today, textiles are still used for these purposes and everyone is an ultimate consumer. You use textiles in some form even if you are not the direct purchaser. Included among consumers are merchandisers of many types, from the wholesale textile manufacturer and merchant to the sales force in any retail store. Many industries, such as the automobile industry, are important consumers of textiles in various forms. Some other consumers are homemakers, dressmakers, interior decorators, and retail-store customers, as well as students who are studying for these and various other occupations and professions in which a knowledge of textiles is of major importance.

The merchant, particularly, and all those who work for him must be thoroughly familiar with the merchandise they are handling if they wish to be successful. Only thorough knowledge will prevent the mistakes that are too often made in buying and selling.

## REASONS FOR STUDYING TEXTILES

A study of textiles will show, for example, why certain fabrics are more durable and therefore more serviceable for specific purposes. It will explain why certain fabrics make cool wearing apparel as well as give an impression of coolness when used as decoration. The matter of cleanliness and maintenance must also be estimated before purchasing, when that is an important factor.

Complete knowledge of textiles will facilitate an intelligent appraisal of standards and brands of merchandise and will develop the ability to distinguish quality in fabrics and, in turn, to appreciate the proper uses for the different qualities. As a result, both the consumer merchant and consumer customer will know how to buy and what to buy, and salespeople will know how to render good service to those consumers who have not had the advantage of a formal course in textiles.

In recent years, great strides have been made in the textile industry that have markedly influenced our general economic growth. The prosperity and growth of related industries, such as petroleum and chemistry, and dependent industries, such as retail apparel stores, have produced broader employment opportunities. Competition for the consumer's dollar has fostered the creation of new textile fibers with specific qualities to compete with well-established fibers. New fiber blends have been created to combine many of these qualities into new types of yarns with new trademarks. There are also new names for the fabrics made of these new fibers and yarns. New finishes have been developed to add new and interesting characteristics to fibers, yarns, and fabrics.

This welter of creativity and the myriad of trademarks present a challenge to the consumer, who is sometimes knowledgeable but frequently confused. Yet he need not be. Without being overly technical, this information can be easily understood and consequently very useful to the consumer in his business and personal life. All of this information can be adopted for such utilitarian benefits as economy, durability, serviceability, and comfort, as well as for such aesthetic values as hand (or feel), texture, design, and color.

In the study of textiles, the students' initial interest will become an absorbing interest when they discover the natural fascination of fabrics and their cultural associations, particularly when factual study is supplemented by actual handling of the textile materials. The subject will seem worthwhile as they become familiar with illustrative specimens and fabrics and begin to handle and learn to compare the raw materials of which fabrics are made as well as the finished consumers' goods.

## SEQUENCE OF FABRIC CONSTRUCTION

In beginning the study of textiles, you should have in your hand a sample of a woven fabric. Note that it is constructed by interlacing sets of yarns that run lengthwise and crosswise. It is from the interlacing, or weaving, of yarns that such textile materials are made. A close examination of any one of these yarns will reveal the fibrous substance from which the yarn is made. Such yarns comprise a multitude of fine, hairlike fibers or filaments that have been separated, made parallel, overlapped, and twisted together by various processes.

There is a logical development of raw material into finished consumers' goods. Studying textile materials in the interesting sequence of "fiber to yarn to fabric" will help you understand the construction and ultimate qualities of the fabrics with which you will become familiar. Here are the steps in the manufacture of fabrics from raw material to finished goods:

1. Fiber, which is either spun (or twisted) into yarn or else directly compressed into fabric

2. Yarn, which is woven, knitted, or otherwise made into fabric
3. Fabric, which by various finishing processes becomes finished consumers' goods

## KINDS OF FIBERS

The textile industry uses many different kinds of fibers as its raw materials. Some of these fibers were known and used in the earlier years of civilization, as well as in modern times. Other fibers have acquired varied degrees of importance in recent years. New fibers are being produced and tested daily. The factors influencing the development and utilization of all these fibers include their ability to be spun, their availability in sufficient quantity, the cost or economy of production, and the desirability of their properties to consumers.

Before 1960, the development of new fibers caused difficulty in the textile industry in terms of nomenclature, classification, and identification. The confusion was compounded by the trend of manufacturers to identify each of their fibers with a different trademark. Consumers became confused by these names and found it difficult and sometimes impossible to identify the fiber content of the products they saw in the stores. Often they did not know whether an identifying name represented a particular *kind* of fiber or a *trademark* for some kind of newly created fiber. Subsequently, the United States Congress enacted the Textile Fiber Products Identification Act, which became effective on March 3, 1960. This act requires that the labels of all textile products must show the fiber contents for amounts above 5 percent, both by fiber name and generic (or family) name, and that all fibers must be listed in descending order of their predominance, with the amount of each fiber indicated in percent by weight of the total fiber content. (The label must also indicate the name or registered number of the person or company marketing or retailing the product and, if the product is imported, the name of the country where it was manufactured.) To standardize this identification procedure, the Federal Trade Commission (FTC) assigned generic groups of manmade fibers according to chemical composition.

While this arrangement has brought about some standardization, clarification, and easier identification of fibers, the generic types do not provide for related groupings. Indeed, it has been found difficult by many authorities to arrange them into logical groupings by characteristics of types. One such grouping, as suggested by the Man-Made Fiber Producers Association, Inc., is cellulosic, synthetic long-chain polymers, and nonfibrous natural substances.

Table 1-1 identifies all fibers by type, name, and source or classification. It includes the author's suggested extension or modification of the association's grouping of nonfibrous natural substances into their derivations.

*Natural fibers* that occur in nature can be classified as *vegetable, animal,* and *mineral.* Vegetable fibers, found in the cell walls of plants, are cellulosic in composition. Animal fibers, produced by animals or insects, are protein in composition. The mineral fiber, asbestos, is mined from certain types of rock.

*Table 1-1*

| CLASSIFICATION OF FIBERS | | |
|---|---|---|
| TYPE | NAME OF FIBER | SOURCE OR COMPOSITION |
| NATURAL FIBERS: | | |
| Vegetable | Cotton | Cotton boll (cellulose) |
| | Linen | Flax stalk (cellulose) |
| | Jute | Jute stalk (cellulose) |
| | Hemp | Hemp or abaca stalk (cellulose) |
| | Sisal | Agave leaf (cellulose) |
| | Kapok | Kapok tree (cellulose) |
| | Ramie | Rhea or China grass (cellulose) |
| | Coir | Coconut husk (cellulose) |
| | Pina | Pineapple leaf (cellulose) |
| Animal | Wool | Sheep (protein) |
| | Silk | Silkworm (protein) |
| | Hair | Hair-bearing animals (protein) |
| Mineral | Asbestos | Varieties of rock (silicate of magnesium and calcium) |
| MAN-MADE FIBERS: | | |
| Cellulosic | Rayon | Cotton linters or wood |
| | Acetate | Cotton linters or wood |
| | Triacetate | Cotton linters or wood |
| Synthetic Long-Chain Polymers | Nylon | Aliphatic polyamide |
| | Aramid | Aromatic polyamide |
| | Polyester | Dihydric alcohol and terephthalic acid |
| | Acrylic | Acrylonitrile (at least 85%) |
| | Modacrylic | Acrylonitrile (35–84%) |
| | Spandex | Polyurethane (at least 85%) |
| | Olefin | Ethylene or propylene (at least 85%) |
| | Saran | Vinylidene chloride (at least 80%) |
| | Vinyon | Vinyl chloride (at least 85%) |
| | Novoloid | Phenol based novalac |
| | Fluorocarbon | Tetrafluoroethylene |
| | Alginate* | Calcium alginate |
| | Anidex* | Monohydric alcohol and acrylic acid |
| | Lastrile* | Acrylonitrile (10–50%) and a diene |
| | Nytril* | Vinylidene dinitrile (at least 85%) |
| | Vinal* | Vinyl alcohol (at least 50%) |
| Metallic | Metal | Aluminum, silver, gold, stainless steel |
| Rubber | Rubber | Natural or synthetic rubber |
| Protein | Azlon* | Corn, soybean, etc. |
| Mineral | Glass | Silica sand, limestone, and other minerals |
| | Ceramic | Minerals |
| | Graphite | Carbon |

*Not presently in commercial production in United States; not covered in text.

*Man-made fibers* are derived from various sources. For instance, man has taken the natural material of cellulose from cotton linters and wood pulp, processed it chemically, and changed its form and several other characteristics into fibers of various lengths. These are classified as *man-made cellulosic fibers*. He has also taken the protein out of such products as corn, processed it chemically, and converted it into *man-made protein fibers*.

*Synthetic fibers* are another *group of man-made fibers*. Sometimes confusion exists regarding the terms "synthetic" and "man-made," and they may be incorrectly used interchangeably. All synthetic fibers are man-made; but not all man-made fibers are synthetics (as noted above, for example). Synthetic fibers have been and are still being created by research chemists as companies strive to imitate properties of other fibers, to develop other characteristics, or to combine certain properties. These fibers are synthesized by combining carbon, oxygen, hydrogen, and other simple chemical elements into large, complex molecular combinations or structures called *polymers*. Chemists, in fact, discover new chemical compositions and invent new substances that they form into fibers having certain desired characteristics.

Man-made fibers created from other sources are *mineral fibers*, *metallic fibers*, and *rubber fibers*. Glass fibers are produced by combining silica sand, limestone, and certain other minerals. Metallic fibers are produced by mining and refining such metals as aluminum, silver, and gold. Rubber fibers are made from the sap tapped from the rubber tree.

## COMPOSITION AND STRUCTURE OF FIBERS

Each textile fiber has its own distinctive structural shape and markings that, under a microscope with a magnification of at least 100, provide aid in the identification of the fiber. Certain general observations also help to identify fibers without the use of a microscope. These differences in structure determine the various characteristics of the different fibers and explain why some fibers are to be preferred to others for certain uses. The illustrations in this chapter show cross-sectional and longitudinal photomicrographs of the various fibers.

## THE NATURAL FIBERS

### Vegetable Fibers

Of the several vegetable fibers, each derived from a different plant, two are recognized as major textile fibers. They are cotton, which grows in the seedpod, or boll, of the cotton plant, and linen, which grows in the stalk of the flax plant. (The minor vegetable fibers are discussed in Table 1-1 and Chapter 27.)

***Cotton.*** Unlike other fibers obtained from plants, the cotton fiber is a single elongated cell. Under the microscope, it resembles a collapsed, spirally twisted tube with a rough surface. The thin cell wall of the fiber has from 200 to 400 turns of natural twists, or convolutions, to the inch. The fiber appears flat, twisted, and ribbonlike, with a wide inner canal (the lumen) and a granular effect. Chemically, the fiber contains

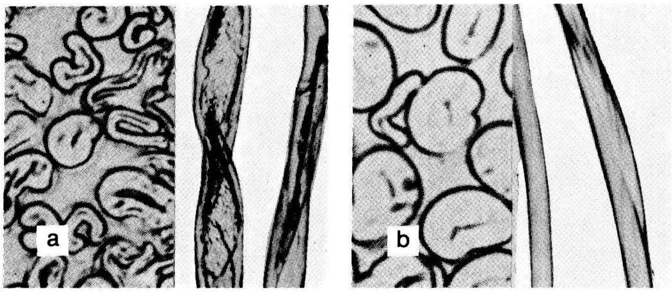


Figure 1-1 Cross-sectional and longitudinal views of cotton fibers under a microscope: *(a)* natural cotton fiber *(Courtesy U.S. Testing Co.)* and *(b)* mercerized cotton fiber. *(Courtesy U.S. Department of Agriculture)*

about 90 percent cellulose and about 6 percent moisture; the remainder consists of natural impurities. The outer surface of the fiber is covered with a protective waxlike coating, which gives the fiber a somewhat adhesive quality (see Figure 1-1*a*).

Because of the natural twist in cotton fiber, it may easily be spun into yarn. Some cotton fibers, however, look different under the microscope and do not have this natural twist. Such fibers have been subjected to the commercially important process of mercerization, which causes the naturally flat, twisted cotton fiber to swell and become straight, smooth, and round. The straightness of the fiber causes light to be reflected on the smooth surface and produces a lustrous effect that is commercially valuable. The resultant fabric is called *mercerized cotton* (see Figure 1-1*b*).

***Flax.*** Under the microscope, the hairlike flax fiber shows several-sided cylindrical filaments with fine pointed ends (Figure 1-2). The filaments are cemented together at intervals in the form of markings, or nodes, by a gummy substance called *pectin*. The long flax filaments contain a lumen, or inner canal, which appears as a narrow line. The fiber somewhat resembles a straight, smooth bamboo stick, with its joints producing a slight natural unevenness that cannot be eliminated. Chemically, the flax fiber is composed of about 70 percent cellulose and about 25 percent pectin; the remainder consists of ash and woody tissue. From such fibers, linen yarns are produced. To the naked eye, linen yarns appear smooth, straight, compact, and lustrous. Flax fibers are more brittle and less flexible than cotton fibers.

### Animal Fibers

There are several animal fibers, each obtained from a different source, but only two are recognized as major textile fibers. They are *wool*, which grows from the skin of sheep, and *silk*, which is unwound from the cocoon of a moth caterpillar known as the silkworm. (Minor *hair* fibers, such as camel, llama, alpaca, mohair, cashmere, vicuña, guanaco, and rabbit, are discussed in Chapter 13.)

***Wool.*** Wool fiber is irregular and roughly cylindrical, tapered at the end, and multicellular in structure. Under the microscope, a cross section shows three fundamental layers—the epi-

Figure 1-2 Cross-sectional and longitudinal views of linen (flax) fiber under a microscope. *(Courtesy U.S. Testing Co.)*

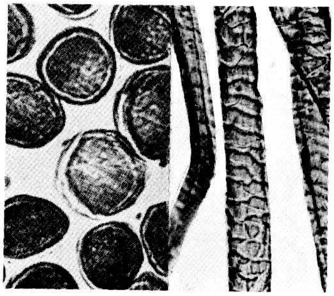

Figure 1-3 Cross-sectional and longitudinal views of wool fiber under a microscope. *(Courtesy American Woolen Co.)*

dermis, the cortex, and the medulla (Figure 1-3). The epidermis, or outer layer, consists of scales or flattened plates ranging from 1,000 to 4,000 to an inch. These scales give the fiber its cohesive quality. They vary in type, from those having smaller, finer scales with smoother edges to those having coarser scales with irregular edges. The finer, softer, warmer fibers have more numerous and smoother scales. The thicker, coarser, less-warm fibers have fewer and rougher scales. The better fibers with more and finer scales are duller in appearance than the poorer quality wool fibers with fewer scales.

The second layer, the cortex, is the main fiber body. It gives the fiber strength and elasticity and consists of intermediate cells that hold the color pigment.

The innermost layer is the medulla, which consists of large spiral-shaped, air-filled cells. The medulla is discernible only in coarse and medium wools and only under high magnification. It is the central canal, varying in appearance from a narrow to a broad line or from a continuous to an interrupted line. Some wool fibers that have no cortical layer are compensated with a larger proportion of medullary cells. This fact lessens the affinity for dyes, because the medulla has more fat than has the rest of the fiber. The finer wools, having no medulla, absorb dyes more readily.

Two striking characteristics of wool fiber are its susceptibility to heat and its felting property, which is caused by the horny epidermal scales. Because of this felting property, only pressure, heat, and moisture are required to make wool fibers into the type of fabric called *felt*.

Chemically, wool is the only natural fiber that contains sulfur. It is composed of the following basic elements in these approximate proportions: carbon, 49 percent; oxygen, 24 percent; nitrogen, 16 percent; hydrogen, 7 percent; sulfur, 4 percent. These elements combine to form a protein known as *keratin*.

***Silk.*** Raw silk fiber as it comes from the cultivated cocoon is called *bave*. Under the microscope, this bave appears somewhat elliptical. It is composed of the *fibroin*, consisting of two filaments, each of which is called a *brin*, held together by *sericin*, a gummy substance that gives the bave a rather uneven surface. As the sericin is removed by hot water, the two brin filaments appear clearly as fine and

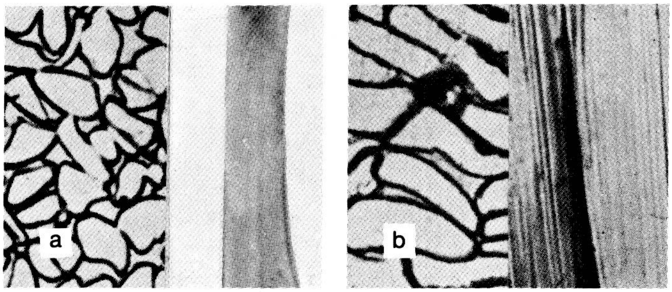


Figure 1-4 Cross-sectional and longitudinal views of silk fibers under a microscope: *(a)* cultivated silk fiber *(Courtesy U.S. Testing Co.)* and *(b)* wild, or tussah, silk fiber. *(Courtesy U.S. Department of Agriculture)*

lustrous, somewhat triangularly shaped transparent rods.

Wild silk, or tussah silk, may be distinguished from cultivated silk by its coarse, thick form, which appears flattened. Cultivated silk is a narrow fiber with no markings. Wild silk is a broader fiber with fine, wavy, longitudinal lines running across its surface, giving it a dark hue under the microscope (Figure 1-4).

Chemically, the silk fibroin and sericin are composed of approximately 95 percent protein and about 5 percent wax, fat, salts, and ash.

### Mineral Fibers

***Asbestos.*** Asbestos is a natural fiber obtained from varieties of rock. It is a fibrous form of silicate of magnesium and calcium, containing iron, aluminum, and other minerals. It is discussed in detail in Chapter 27.

## THE MAN-MADE FIBERS

### Cellulosic Fibers

The three types of man-made cellulosic fibers—rayon, acetate, and triacetate—are derived either from the cellulose of the cell walls of short cotton fibers (called linters) or, more frequently, from pine wood. Pure cellulose appears as a formless white substance that is converted by chemical treatment and produced into fiber form. Paper, for instance, is almost pure cellulose.

***Rayon.*** There are three varieties of rayon now commercially produced: viscose, cuprammonium, and high wet-modulus. These fibers have a glasslike luster under the microscope and appear to have a uniform diameter when viewed longitudinally. (The appearance of fine pepperlike particles on a cross-sectional view is an indication that the rayon has been delustered.) The rayon filaments differ in appearance according to the process used in their manufacture (Figure 1-5).

*Viscose rayon*, although produced in several forms, basically has a cross-sectional view under the microscope that is very irregular. These irregularities or wrinkles run the length of the fiber and appear as striations or fine lines in the longitudinal view on an otherwise glossy surface.

Viscose rayon is also produced in modified forms. A *high-tenacity* rayon fiber can be produced by causing the