MINISTRY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF
TECHNICAL AND VOCATIONAL EDUCATION

TE - 02016

TEXTILE FIBRE MICROSCOPY

A.G.T.I. (Second Year)

Textile Engineering
Part One
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CHAPTER 1
INTRODUCTION TO TEXTILES

1.1 Introduction

Food, shelter, and clothing are the basic needs of everyone. All clothing is made from textiles and shelters are made more comfortable and attractive by the use of textiles. Everyone is surrounded by textiles from birth to death. We walk on and wear textile products; we sit on fabric-covered chairs and sofas; we sleep on and under fabrics; textiles dry us or keep us dry; they keep us warm and protect us from the sun, fire, and infection. Clothing and household textiles are aesthetically pleasing and vary in colour, design, and texture. They are available in a variety of price ranges.

The industrial and medical uses textiles are many and varied. The automotive industry uses textiles to make tire cords, upholstery, carpeting, head liners, windows runners, seat belts, and shoulder harnesses. Man has traveled to the moon in a 20-layer, space suit that has nylon water-cooled underwear. Life is prolonged by replacing worn-out parts of the body with woven or knitted fabric such as polyester arteries and velour heart valves. Disposable garments are worn by doctors and nurses. Bulletproof vests protect hunters and soldiers, and safety belts make automobile travel less dangerous.

Textiles are always changing. They change as fashion changes and to meet the needs of changing life-styles of people. New developments in production process also cause changes in textiles, as do government standards for safety, environmental quality and energy conservation. All of these elements are interdependent and contribute to the beauty and texture, the durability and serviceability, and the comfort of fabrics. Textile fabrics can be beautiful, durable, comfortable, and easy to care for. They can satisfy the needs of all people at all times.

The word textile comes from the Latin term textilis, "woven" and the verb textere, "to weave". Today the word textile is more generalized to refer to products made from fibres. The word textile originally meant a fabric produced by weaving, but its application has greatly broadened. Now this term is used for a wide range of products made from fibres or filaments, including not only woven, knitted, and felted fabrics, but also lace, nets, yarn, cord, and many other materials. The variety of these products and their uses is so enormous that
textiles have applications in almost all our activities. Textiles used in engineering range from insulating fabric 2.5 hundredths of a millimetre thick to very thick and strong industrial fabrics such as conveyor belting. Household fabrics range from the simplest white cotton cloths used for sheets to the highly decorated materials of complicated construction that may be used in furnishing. Whatever their purpose and method of manufacture, these materials all have one property in common - a certain degree of flexibility which suits them to their various purposes and which arises from the fineness of the ultimate unit of construction - the fibre.

1.2 The Textile Industry: Its Range and Markets

The textile industry is very complex. At this point, only an introduction can be given so as to provide a brief overview for some insight. It begins in agriculture with fibre production of cotton, flax, and other fibrous plants; in husbandry of sheep, other animals and silkworms; in mining of metals and minerals; in forestry for wood; in chemical research and production of synthetics. These fibres are processed into yarn and/or fabrics. The yarns are made into fabrics for industrial and consumer uses by various means, such as weaving and knitting. The fabrics are converted into finished cloths, which provide particular appearances and performances. These fabrics are made into end-use products, including apparel, home furnishings, and various industrial applications. These products are then merchandised and sold. Every one of these aspects of the textile industry is a field in itself, and there is an interdependency with multiplying effects on other industries.

As one learns about the various aspects of the production of textiles and textile products, it becomes apparent that these activities play a major role in the economy. The industry has so many facts that it is possible that the student's interests may develop in the pursuit of a career in one of them. For example, consumers require the services of teachers of textiles, home economics, and interior decoration. The retailer who serves them requires salespeople, buyers, merchandise managers, and related personnel who deal with textile products. The manufactures of these products need fabric buyers, designers, production managers, sales persons, etc. The fabric manufacturers, yarn producer, and fabric finishers need knowledgeable people. All of these fields utilize marketing and advertising specialists to promote textiles and textile-related products.
1.3 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 fibres 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 "fibre 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) Fibre, 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.

A fibre is defined, in a very general way, as any product capable of being woven or otherwise made into a fabric. It may be thought of as the smallest visible unit of textile production.

Fibres, the usual starting place for a study of textiles, may be agricultural products (such as cotton or wool) or units (such as nylon or polyester) manufactured in a chemical plant. Fibres then serve as the raw material in the next stage of textile manufacturing. They may be spun into a strand, called a yarn, that can be used to knit a sweater, to sew two pieces of fabric together, or to weave a fabric. Fibres also may be made directly into a broad range of nonwoven fabrics such as felt for hat or the underlayment for a modern highway.

Fabrics is a planar structure produced by interlacing yarns in processes such as weaving, knitting, knotting, and braiding, or by binding fibres together to form a structure. Fabrics are produced in such forms as the flat sheets for a bed, the tubular body of a T-shirt, or the shaped nose cone of a rocket. Many of these fabrics are not pleasing during the early stages of their manufacture. To enhance their appearance and improve their functional performance, fabrics can be dyed or printed, then treated with special finishes. The result is called dyed and finished fabric.
CHAPTER 2
FIBRE TYPES AND PROPERTIES

2.1 Kinds of Fibres

The basic unit of a textile structure is fibre. Examination of any fabric shows that it is made of fibres. The first essential of a fibre is that it must be hundreds of times longer than it is wide to enable it to be spun into a thread for weaving. It must also be strong and flexible and elastic enough to withstand the strain of the processes required to produce a cloth that wears well. If the fibre is a very coarse one, it produces a cloth resembling sacking. For comfort in weaving, all fibres need to be able to absorb moisture. Lustre may be desirable for appearance, and weight and flexibility can affect draping.

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

In order to simplify the study of textile fibres, materials with similar properties must be grouped in some logical order. Each country has developed its own system for naming fibres. The two major groups, or families, of fibres specified by the act are natural fibres and manmade fibres.

Natural fibres that occur in nature can be classified as vegetable, animal, and mineral. Vegetable fibres could be further subdivided according to the part of the plant that produces the fibre: the leaf, a hair produced from a seed pod, or the stem. These are cellulosic in composition. Animal fibres, produced by animals or insects, are protein in composition. They could be further subdivided into those fibres from the hair of an animal and those from an extruded web. The mineral fibres, asbestos, is mined from certain types of rock. Each of the natural fibres is produced in several varieties which differ in quality. Pima Cotton and Merino Wool are examples of good quality varieties that are sometimes mentioned on labels. Natural fibres are subject to lack of uniformity due to weather conditions, nutrition or soil
fertility, and disease. Because it is possible to control the entire production process, man-made fibres are more uniform in size and in other characteristics.

**Manmade** fibres are derived from various sources. For instance, the natural material of cellulose has been taken from cotton linters and wood pulp, processed chemically, and changed in form and several other characteristics into fibres of various lengths. These are classified as **manmade cellulosic fibres** (Regenerated Cellulose).

**Noncellulosic Polymer** fibres are another group of manmade fibres. These synthetics have been and are still being created by research chemists as companies strive to imitate properties of other fibres, to develop other characteristics, or to combine certain properties. These fibres are synthesized by combining carbon, 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 fibres having certain desired characteristics.

The protein from such products as corn and milk has been processed chemically and converted into manmade protein fibres. However, they have not been commercially successful.

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

To be spinnable, a fibre must have sufficient length, pliability, strength, and cohesiveness to form a yarn. Kapok is an example of fibre that is too brittle to spin into yarns; but it is usable for padding material. Fibres must also be inexpensive, available, and constant in supply to be economically suitable for production. There are two classes of fibres according to length; (a) filament, and (b) staple.

(a) **Filaments** are of a continuous length measurable in yards or metres. The only filament fibre that occurs naturally is silk. All other filament fibres are manmade. Yarns made from filament fibres are of two types; multifilament and monofilament.

**Multifilament yarns** are made of a number of tiny filament twisted together. The size and number of the filaments can vary. Yarns of this type give pleasant surface texture,
softness, lustre, and luxurious drape. They are used in blouses, lingerie, and silk-type dresses. Monofilament yarns are composed of a single, solid strand of great strength and smoothness. Very sheer hosiery is made from very fine monofilaments. Sheer blouses, veils, and gowns are other examples of monofilament use. Large monofilaments are used in car set-covers, screenings, webbing for furniture, and similar materials.

(b) Staple fibres are short in length, measured in inches and range from three-quarters of an inch to 18 inches in length. All the natural fibres, except silk, are staple fibres. Any filament fibre can be cut into staple of a length determined by the end-use desired.

Manmade fibres are spun out through very fine holes in a spinnerette. Manmade filament and staple are not spun on the same equipment. To make staple fibre, several thousand filaments are spun out of one spinnerette in a long rope-like strand called tow. However, to make filament yarns, only enough fibres are spun out by one spinnerette to make the size of yarn desired.

2.2 Fibre Properties

A serviceable fabric is one which is properly designed for intended use. This intended use is spoken of as the “end-use”. The end-use of a fabric may be a beautiful partly dress, a long-wearing pair of overalls, a soft warm blanket, or a house dress that won’t shrink.

To make such a fabric the manufacturer chooses fibres, yarns, weaves, and finishes with a combination of properties which will give the type of serviceability the consumer wants. The consumer, for her part, needs a knowledge and understanding of these properties so she can successfully select, use, and care for the article she buys.

2.2.1 Physical Properties Related to Hand and Appearance

The physical structure of a fibre includes length, diameter, surface contour, crimp, and shape. These properties help determine the roughness, smoothness, softness, and soil-resistance of a fabric.

Crimp refers to the waves or bends that occur along the length of a fibre. Wool has natural crimp. Manmade fibres may be given a permanent crimp. Fibre crimp increases cohesiveness, resiliency, and resistance to abrasion. It helps fabrics maintain their thickness.

Lustre is the shine, sheen or brightness of a fibre caused by reflection of light. Smooth fibres reflect more light than rough or serrated fibres; round fibres reflect more light than flat
fibres. Filaments which are laid together with little or no twist reflect more light than short fibres which must be twisted together to form yarns. Manmade fibres can be delustered by adding oil or pigments to the solution from which the fibre is spun.

Density and specific gravity are measured of the weight of a fiber. Density is the weight in grams per cubic centimetre. Specific gravity is the ratio of the mass of the fibre to the mass of an equal volume of water at 40°C. The weight of a fabric is determined by the density or specific gravity of the fibres.

2.2.2 Physical Properties Related to Durability

Strength of a fibre is the ability to resist strains and stresses. It is expressed as tensile strength which is measured in pounds per square inch (p.s.i.) or as tenacity which is measured in grams per denier. Some fibres gain strength when wet, some lose strength, and some are unaffected by water.

Abrasion resistance is the ability of a fibre to withstand the rubbing or abrasion it gets in everyday use. Inherent toughness, natural pliability, and smooth filament surface are fibre characteristics that contribute to abrasion resistance.

Cohesiveness is the ability of fibres to cling together. This is important in staple fibres, but unimportant in filament fibres.

Pliability or flexibility is the ease of bending or shaping. Pliable fibres are easily twisted to make yarns. They make fabrics that resist splitting when folded or creases many times in the same place.

Stiffness or rigidity is the opposite of flexibility. It is the resistance to bending or creasing. Rigidity and weight together make up the body of the fabric.

Elasticity means the ability of a stretched material to return immediately to its original size.

Resiliency is the ability of a fibre or fabric to recover, over a period of time, from deformation such as stretching, compressing, bending or twisting. A resilient fabric has good crease recovery, hence requires a minimum of ironing. Resilient fabrics also retain high bulk.

2.2.3 Physical Properties Related to Stability, Care, and Comfort

Stability is the retention of size, shape, or form. A stable fabric does not stretch, sag, shrink, beyond stated limits with moisture, heat, or strains.
Absorbency is the ability of a fibre to take up moisture and is expressed as percentage of moisture regain, which is the percentage of moisture that a bone-dry fibre will absorb from the air under standard conditions of temperature and humidity. The ability of a fibre to absorb moisture is directly related to washability, dyeing, shrinkage, absorption of aqueous finishes, comfort on humid days, and soiling. Staple fibres hold more water than filament fibres since they pack less compactly and create a sponge-like condition in the yarn and fabric. For this reason staple fibre fabrics require a longer drying time.

Wicking or wetting refers to the conduction of moisture along the fibre or through the fabric, although the fibre itself does not absorb much moisture. This property is related to surface wetting and is not the same as absorbency.

Plasticity is that property of a fibre which enables the user to shape it semi-permanently or permanently by moisture, heat, and pressure or by heat and pressure alone.

Electrical conductivity is related to the build-up of static electricity charges on a fabric. A good conductor does not build-up static.

Chemical resistance ... The chemical reactivity of each fibre depends on the arrangement of the elements in the molecule and the reactive groups it contains. Dry-cleaning solvents, perspiration, soap, synthetic detergents, bleaches, atmospheric gas, soot, and sunshine may all cause chemical degradation on some or all of the fibres.

Resistance to moths, and mildew is due to the chemical composition of the fibre. These properties are important to the consumer because they indicate the type of care needed during storage as well as during use. Fibres without natural resistance must have protective finishes added or have their chemical composition changed to make them resistant.

Flammability or inflammability refers to the ease of ignition and the speed and length of burning. Non-flammable fibres will not burn. Flammability depends not only on the chemical composition but on the air incorporated in the yarn or fabric. Combustible finishes or dyes may take a non-flammable fibre burn. Finishes can also be added to make fibres non-flammable.
### 2.3 General Classification of Textile Fibre

<table>
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<tr>
<th>TYPE</th>
<th>NAME OF FIBER</th>
<th>SOURCE OR COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Fibers:</td>
<td>Cotton</td>
<td>Cotton boll (cellulose)</td>
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<tr>
<td></td>
<td>Linen</td>
<td>Flax stalk (cellulose)</td>
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<td></td>
<td>Jute</td>
<td>Jute stalk (cellulose)</td>
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<td></td>
<td>Hemp</td>
<td>Hemp or abaca stalk (cellulose)</td>
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<tr>
<td></td>
<td>Sisal</td>
<td>Agave leaf (cellulose)</td>
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<td></td>
<td>Kapok</td>
<td>Kapok tree (cellulose)</td>
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<td></td>
<td>Ramie</td>
<td>Rhea or China grass (cellulose)</td>
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<td></td>
<td>Coir</td>
<td>Coconut husk (cellulose)</td>
</tr>
<tr>
<td></td>
<td>Piña</td>
<td>Pineapple leaf (cellulose)</td>
</tr>
<tr>
<td>Vegetable</td>
<td>Wool</td>
<td>Sheep (protein)</td>
</tr>
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<td></td>
<td>Silk</td>
<td>Silkworms (protein)</td>
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<td></td>
<td>Hair</td>
<td>Hair-bearing animals (protein)</td>
</tr>
<tr>
<td></td>
<td>Asbestos</td>
<td>Varieties of rock (silicate of magnesium and calcium)</td>
</tr>
<tr>
<td>Animal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral</td>
<td></td>
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<tr>
<td>Manmade Fibers:</td>
<td>Rayon</td>
<td>Cotton linters or wood</td>
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<tr>
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<td>Acetate</td>
<td>Cotton linters or wood</td>
</tr>
<tr>
<td></td>
<td>Triacetate</td>
<td>Cotton linters or wood</td>
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<tr>
<td>Cellulosic</td>
<td>Nylon</td>
<td>Aliphatic polyamide</td>
</tr>
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<td></td>
<td>Aramid</td>
<td>Aromatic polyamide</td>
</tr>
<tr>
<td></td>
<td>Polyester</td>
<td>Dihydric alcohol and terephthalic acid</td>
</tr>
<tr>
<td></td>
<td>Acrylic</td>
<td>Acrylonitrile (at least 85%)</td>
</tr>
<tr>
<td></td>
<td>Modacrylic</td>
<td>Acrylonitrile (35–84%)</td>
</tr>
<tr>
<td></td>
<td>Spandex</td>
<td>Polyurethane (at least 85%)</td>
</tr>
<tr>
<td></td>
<td>Olefin</td>
<td>Ethylene or propylene (at least 85%)</td>
</tr>
<tr>
<td></td>
<td>Vinyon</td>
<td>Vinyl chloride (at least 85%)</td>
</tr>
<tr>
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<td>Saran</td>
<td>Vinyldene chloride (at least 80%)</td>
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<tr>
<td></td>
<td>Novagloid</td>
<td>Phenol based novalac</td>
</tr>
<tr>
<td></td>
<td>Polycarbonate</td>
<td>Carbonic acid (polyester derivative)</td>
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<tr>
<td></td>
<td>Polybenzimidazole</td>
<td>Tetraminobiphenyl and diphenyl isophthalate</td>
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<td></td>
<td>Alginate</td>
<td>Calcium alginate</td>
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<td></td>
<td>Fluorocarbon</td>
<td>Tetrafluoroethylene</td>
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<td></td>
<td>Graft</td>
<td>Molecular graft of polymers</td>
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<tr>
<td></td>
<td>Matrix</td>
<td>Mixture of polymers</td>
</tr>
<tr>
<td></td>
<td>Anilox*</td>
<td>Monohydric alcohol and acrylic acid</td>
</tr>
<tr>
<td></td>
<td>Lastri*</td>
<td>Acrylonitrile (10–50%) and a diene</td>
</tr>
<tr>
<td></td>
<td>Nytril*</td>
<td>Vinyldene dinitrile (at least 85%)</td>
</tr>
<tr>
<td></td>
<td>Vinal*</td>
<td>Vinyl alcohol (at least 50%)</td>
</tr>
<tr>
<td>Noncellulosic Polymers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Azlon*</td>
<td>Corn, soybean, etc.</td>
</tr>
<tr>
<td>Rubber</td>
<td>Rubber</td>
<td>Natural or synthetic rubber</td>
</tr>
<tr>
<td>Metallic</td>
<td>Metal</td>
<td>Aluminum, silver, gold, stainless steel</td>
</tr>
<tr>
<td>Mineral</td>
<td>Glass</td>
<td>Silica sand, limestone, other minerals</td>
</tr>
<tr>
<td></td>
<td>Ceramic</td>
<td>Alumina, silica</td>
</tr>
<tr>
<td></td>
<td>Graphite</td>
<td>Carbon</td>
</tr>
</tbody>
</table>

* Not presently commercially available in United States; not covered in text.
CHAPTER 3
COTTON

3.1 The Seed Fibres

The seed of plant is often attached to hairs which are constructed in the main from cellulose. Many of these fibres are used in the textile industry, one of them-cotton-has become the most important textile fibre in the world.

Cotton is a fibre that grows from the surface of seeds in the pods, or bolls, of a bushy mallow plant. Each fibre is a single elongated cell that is flat, twisted, and ribbonlike with a wide inner hollow (lumen). It is composed of about 90% cellulose and about 6% moisture; the remainder consists of natural impurities. The outer surface of the fibre is covered with a protective waxlike coating, which gives the fibre a somewhat adhesive quality. This characteristic combined with its natural twist contributes to making cotton an excellent fibre for spinning into yarn. Cotton yarn is used to make fabrics that are universally used for all types of apparel, home furnishings, and industrial applications.

In common with other natural fibres, cotton is available in a great variety of fibre qualities, which are determined particularly according to fibre length and fibre fineness. The West Indies produces a small quantity of cotton compared with world production, but its supreme excellence is well known and it is commonly known as Sea Island. Its length of about 6cm. (which is very long for cotton), lustre, fineness, and accompanying softness make it suitable for fine, best quality yarns and fabrics. A very short, coarse cotton which is only suitable for coarse yarns and fabrics could be, for instance, an Indian cotton known as Bengals.

Generally speaking, it can be said that all cotton fibres exhibit good moisture absorption, good wet and dry tensile strength and resistance to abrasion, and that they withstand frequent laundering at a high temperature. Fabric finishing is necessary to achieve minimum-care properties, pleat-retention, and minimum shrinkage.

Cotton is put to a wide range of uses, such as underwear, blouses, dresses suits, overalls, rainwear, sewing threads. Fabrics which may be made from cotton are voile, poplin, denim, satin, winceyette, corduroy, velveteen, lace and a host of others. Fortunately, cotton is an inexpensive fibre.
3.2 Kinds and Types of Cotton

Raw cotton is creamy white in colour. The fibre is a single cell, which, during growth, pushes out of the seed as a hollow cylindrical tube over one thousand times as long as it is thick. Different kinds and types of cotton are grown in various parts of the world. Some of their basic characteristics differ. Variations among cotton fibres also occur because of growth conditions including such factors as soil, climate, fertilizers, and pests. The quality of cotton fibre is based on its colour (degree of whiteness), length (staple), fineness, and strength. Usually, the longer fibres are finer and stronger.

The cotton of commerce can be classified into three general groups on basic of fibre length, fibre fineness, and geographical region (country) of growth as follows:

*Type 1 Long, fine cotton* ... Long staple, fine strong fibre of good lustre, which form the top quality cotton. The fibres are generally of 10-15 microns diameter, staple length from 1 to 2½”. It includes Sea Island, American Pima and Egyptian cotton. They are not easy to grow, they are expensive and are used only for high quality, fine cloths, and hosiery yarns.

*Type 2 Standard cotton* ... Intermediate staple, coarser texture, and shorter length. The fibres are generally of 12-17 microns diameter, staple length from 1 to 1 5/16”. The principal member of this group is American Upland. They are used for standard fabrics.

*Type 3 Coarse, shorter cotton* ... Short staple, coarser fibres of no lustre and low in strength that range in staple length from 3/8 to 1”. The fibres are generally of 13-22 microns diameter. These are mainly the Indian or Asiatic cottons. It is used for lower quality fabrics (sometimes blended with wool, for cotton blankets and carpets).

3.3 Production of Cotton

Cotton grows in any part of the world where the growing season is long. The United States, China, and Russia lead in cotton production. Cellulose will not form if the temperature is below 70°F. Cotton grows on bushes, 3 to 6 feet high. The blossom appears,
falls off, and the *boll* begins its growth. Inside the boll are seeds from which the cotton fibres grow. Thus cotton is classified as a seed-hair. When the boll is ripe, it splits open and the fluffy white fibres stand out like a powder puff (a boll contains seven or eight seeds). Each cotton seed may have as many as 20,000 fibres growing from its surface and a single boll will contain 150,000 fibres or more.

Cotton is picked by hand or by machine. After picking, the cotton is taken to a cotton *gin* to remove the fibres from the seed. The fibres, called *lint*, are pressed into bales weighing 500 pounds (227 Kg.), ready for sale to a spinning mill. The average yield is 2 ½ bales per acre.

The seeds, after ginning, look like the buds of the pussy willow. They are covered with short fibres – 1/8 inch in length – called *linters*. The linters are removed mechanically from the seeds and are used to a limited extent as raw material for the making of rayon, acetate, film, and lacquers. The seeds are crushed to obtain cottonseed oil.

### 3.4 Byproducts of Cotton

The raw cotton passes through several cleaning processes before it is baled as well as after it is unbaled at the cotton mill. As a result, the grower obtains valuable byproducts that amount approximately to one-sixth of the entire income derived from the cotton plant. Cotton is therefore important because of its contributions to other industries as well as to the textile industry.

#### 3.4.1 Cotton Linters

Cotton linters are the short, fuzzy hairlike fibres that remain on the seeds after they have been separated from the fibre in the cotton gin. The cotton linters are removed by a second ginning process. They are used in the manufacture of rayons and acetates, plastics, shatterproof glass, photographic film, and fast-drying lacquers, and for other purposes.

#### 3.4.2 Halls

The halls, which are the outside portion of the cotton seeds, are obtained after the linters have been removed. The halls are rich in nitrogen, an important plant food, and are used as fertilizer, in the manufacture of paper, plastics, and cattle feed, and as a base for explosives.
3.4.3 Inner Seeds

The meat of the seed inside the hull yields cottonseed oil, which is used in cooking oils and compounds and in the manufacture soap. The residue of the inner seed becomes cattle feed.

3.5 Physical and Chemical Properties of Cotton

3.5.1 Strength

Cotton fibres are quite strong because the long-chain cellulose molecules have a high degree of orientation within the fibre. However, much of the fibre strength is lost in the yarn because under strain the fibres slip past one another instead of breaking. Cotton's strength increases approximately 25% when wet. This is important in washing and ironing. Fabrics which are stronger when wet can be handled with less care. The strength of cotton is improved by treating with caustic soda. This process, called mercerization, also increases its lustre and affinity for dyes.

3.5.2 Elasticity

Elasticity refers to the extent to which a fibre can be elongated by stretching and then returning to its former condition of size or length. Cotton fibre has very little natural elasticity. This characteristic can be altered to varying extents by hand-twisting fibres into creped yarns and by using fabric construction techniques such as knitting.

3.5.3 Resilience

Resilience refers to the extent to which a fabric can be deformed by compression or crushing and return to its original condition. The tendency of cotton fabrics to wrinkle easily may be offset by finishing processes that give a wrinkle-resistant quality. Like all cellulose fibres, cotton is low in resiliency.

3.5.4 Drapability

The ability of a fabric to hang easily and fall into graceful shape and folds indicates its drapability. The characteristic is dependent upon the kind of fibre, yarn, and construction of the fabric as well as finish given to it. Cotton does not intrinsically have the body and
suppleness required for good drapability. However, the nature and compactness of the fabric construction can improve it. This can be enhanced further by sizing and other finishes.

3.5.5 Heat Conductivity

The extent to which heat can be conveyed through a fabric or a fabric indicates its heat conductivity. Cotton has a relatively high degree of heat conductivity. Therefore it is, basically, a cool fibre. Cotton can be made into excellent summer clothing because it is a good conductor of heat. Crisp, clean, lightweight cotton fabrics look cool as well as feel cool. When warmth is required, cotton yarn made into napped or pile weave fabrics will have decreased heat conductivity.

3.5.6 Absorbency

The ease and extent to which moisture can penetrate into a fibre determines its absorbency. Once the outer protective cuticle of the cotton fibre is broken down by finishing processes, the fibre becomes very absorbent. Cotton fibre is composed primarily of cellulose, which is very absorbent. Its hollow centre, or lumen, aids in conveying moisture. Such factors as the amount of twist in the yarn will also affect the absorbency, since a low-twisted yarn will be more absorbent than a high-twisted one. Fabric structure, such as a pile weave, will affect absorbency.

Cotton makes very comfortable skin contact fabrics because of its absorbency. It is lacking in any surface characteristics which might be irritating to the skin. Cotton has a moisture regain of 8.5%. When cotton becomes wet, the fibres swell and become somewhat plastic. This properly makes it possible to give a smooth, flat finish to cotton fabrics when they are ironed, and makes high cotton woven fabrics water repellent.

3.5.7 Cleanliness and Washability

Although cotton attracts dirt particles because of its roughness, this disadvantage is offset by the washability of the fibre. Cotton fabrics are not injured even in very hot water with strong soaps or detergents, they launder well and withstand rough handling.
3.5.8 Shrinkage

When cotton fibre is wet, it tends to contract or shrink as it dries. As a result, cotton yarns and fabrics can shrink considerably, particularly those that are loosely constructed. However, preshrinking finishing processes minimize shrinkage in cotton fabrics.

3.5.9 Effect of Heat

Cotton will withstand moderate heat. If pressed with an iron that is too hot or if a hot iron is allowed to remain too long in one place on the fabric, it will scorch and ultimate burn. It is therefore best to either iron cotton material that has been dampened or use a steam iron.

3.5.10 Effect of Light

Cotton fibre oxidizes, turning yellow and losing strength from exposure to sunlight over a protracted period of time. Cotton fabrics should be shaded from direct sunlight.

3.5.11 Resistance to Mildew

Cotton fabrics, especially sized fabrics, mildew readily when permitted to remain in a damp condition. Small greenish-black or rust coloured spots caused by mildew fungus develop and a musty odor may be detected. Therefore, cotton material should be kept in a dry atmosphere.

3.5.12 Reaction to Alkalies

Cotton contains carbon, hydrogen and oxygen. Its cellulose content varies from 88% to 96%. Scoured and bleached cotton fabrics are approximately 99% cellulose. Cotton is not harmed by alkalies. In fact, a solution of sodium hydroxide is used to mercerize cotton, making it stronger, smoother and more lustrous. Bleaching of cotton is usually done with sodium hypochlorite, which is harmful to cotton if too much is used. The bleach is used to destroyed colouring-matter; but after the colouring-matter has been destroyed, the bleach will oxidize the cotton, causing it to lose strength. Hydroxide peroxide is the least harmful bleach to use on cotton goods.

3.5.13 Reaction to Acids

Cotton is not damaged by such volatile organic acids as acetic acid (vinegar). However, it is tendered if such nonvolatile organic acids as oxalic and citric are allowed to
remain on it, particularly if heat is also applied. They should be rinsed with cool water as soon as possible. Concentrated cold or diluted hot mineral acids, such as sulphuric acid, will destroy cotton.

3.5.14 Affinity for Dyes

Cotton has a good affinity for dyes. It is dyed best with vat dyes, but oxidation bases, azoic, and reactive dyes may also be effectively used. Colourfastness is generally good, but specific conditions should be considered.

3.5.15 Resistance to Perspiration

Perspiration may be alkaline or acidic, depending upon the individual’s metabolism. Since cotton is resistant to alkali, alkali perspiration does not deteriorate cotton. However, acid perspiration has a slightly deteriorating effect. In either case, discolouration may occur.

3.6 End Uses

Cotton is used in apparel, home furnishing, and industrial fabrics. Its comfort and hand are usually given as reasons for its preference by consumers of apparel and household fabrics. The fact that it is a “natural” product is a factor cited by many who select cotton products.

Apparel fabrics of all styles and weights are being used. Knit cotton T-shirts and cotton underwear are preferred for their absorbency and ease of care. Men’s shirts and summer suits contain cotton, and the fibre is predominant in women’s and children’s wear.

The domestics market -sheets and towels- is dominated by cotton. Most sheets and pillowcases are blends of cotton and polyester, but 100% cotton sheets are available once again. Polyester is occasionally blended with cotton in towels to provide strength and durability to the base fabric, but the surface pile remains cotton for absorbency.

Upholstery and slipcover fabrics of cotton and cotton blends are widely used, as are braided rugs, other flat woven rugs, and small pile rugs. Cotton is blended with other fibres to improve fabric properties and to provide design features. The fibre most often blended with cotton is polyester. A blend of 65% polyester and 35% cotton is traditional. Blend levels are subject to change when fibre prices change, and blends of more then two fibres are becoming more common.
3.7 Care

Cotton fibres are stable. They do shorten a bit when wet but on drying their original length is restored. Cotton is harmed by acids. It is not greatly harmed by alkali. Cotton can be washed with strong detergents and under proper conditions. It will withstand chlorine bleaches. Cotton is resistant to organic solvents so that it can be safely dry-cleaned. Cotton is attacked by fungi especially in starched fabrics.

Cotton oxidizes in sunlight, which causes white and pastel cotton to yellow and all cotton to degrade. Some yellow dyes are especially sensitive to sunlight and when used in curtain fabrics the dyed areas disintegrate. Cotton is not thermoplastic, it can safely be ironed at high temperatures. Cotton burns readily.

Finishes and dyes can alter the laundry performance of cotton fabrics, so it is wise to read care labels carefully. Most cotton and cotton-blend fabrics are machine washable and may be dried in the dryer. The easy-care fabrics require some special attention if ironing is to be avoided. Avoid overdrying cotton fabrics and remove them from the dryer promptly to prevent wrinkle from forming.
CHAPTER 4
FLAX (LINEN)

4.1 The Bast Fibres

Flax is the most important bast fibres. Bast fibres come from the stem of the plant. Hard labour is required to process bast fibres, so that production of these fibres has flourished in countries where labour is cheap. Harvesting is done by pulling or cutting the plants. Flax is usually pulled either by hand or by machine. After harvesting, the seeds are removed from the plants.

Flax is one of the oldest textile fibres. The fibres are extracted from the stem of the annual plant *Linum Usitatissimum*. When flax is converted into yarn and fabric it is known as linen. When flax fibre is first removed from the stem it is about one metre long, but during processing some reduction in fibre length occurs. By the time it is ready for spinning, the best quality flax will be about 40 centimetre long. The length of the fibres contributes to the lack of hairiness and to the lustre of the fabric. Flax forms only a small part of the world’s textile fibre production, but its interesting texture and thready “linen-look” have prompted users of manmade fibres to develop the effect in other fabrics. Up to now it has been easier to bleach the linen fabric after it has been woven rather than bleach the fibres alone, and this has made fibre blending a little difficult. A recent development in processing now enables the flax fibre to be bleached and provides opportunity for the fibre to be blended with a wide variety of fibres. This specially processed flax is known as “Linron”. Examples of fine linen fabrics are batiste, lawn, and handkerchief cambric. Heavier weights of fabrics are used for dresses and suits. Linen sewing thread is used for heavy-duty anchoring of some buttons.

Flax is a *prestige fibre* as a result of its limited production and relatively high cost. The term *linen* refers to cloth made from flax. This term is, however, often misused today in referring to fabrics that look like linen-fabrics that have thick-and-thin yarns and are fairly heavy or crisp. The term *Irish linen* always refers to fabrics made from flax.

The unique and desirable characteristics of flax are its body, strength, and thick-and-thin fibre bundles, which give texture to fabrics. The main limitations of flax are low resiliency and lack of elasticity. Most dress and suiting linens are given wrinkle-resistant finishes.
The fibre obtained from the stem of the flax plant was probably the first textile to be used. Linen has always been considered the fabric of luxury. In some ancient countries, linen was used only for ceremonial purposes, as the symbol of purity. The descriptive phrase "pure linen" is customarily used to describe all-linen fabrics. Linen always looks cool, crisp and clean, and gives an attractive and immaculate appearance to the persons and objects it adorns.

Fine-quality linens still retain the reputation of luxuriousness and expensiveness. The flax plant must be grown in countries where there is plenty of cheap labour as well as natural facilities for extracting the fibre. Even the manufacture of the fibre into fabrics requires unusual care throughout each process to retain the strength and beauty of the fibre.

The seed of the flax plant is valuable as the source of linseed oil, which is used in the manufacture of paints, varnishes, linoleum, patent leather, and oiled silk. To obtain the seed, flax must be allowed to overripen. As overripening destroys the value of flax as a textile fibre, the method of raising the plant is influenced by the purpose for which it is required.

4.2 Processing Fibre-Flax (From Field to Mill)

4.2.1 Cultivating

The flax plant requires deep, rich, wellplowed soil and a cool, damp climate. Prematurely warm weather affects the growth and the quality of the fibre. Level land with a plentiful supply of soft, fresh water is essential. As the soil in which flax is grown must be enriched for six years before it will yield a good harvest, only one crop in seven years can be raised on a specified portion of land. The crop must be carefully rotated. Shorter periods of rotation have been tried with some success.

The flaxseeds are sown by hand in April or May. When the plants are a few inches high, the weeds must be pulled by hand with extreme care to avoid injury to the delicate sprouts. In three months, the plants become straight, slender stalks from 2 to 4' (60-120 cm.) in height, with tapering leaves and small blue, purple, or white flowers. The plant with the blue flower yields the finer fibre. The other produce a coarse but strong fibre.

4.2.2 Harvesting

By the end of August, the flax turns a brownish colour, which indicates that the plant is about to mature, it is ready for harvesting. There must be no delay at this stage; otherwise, the fibre will lose its prized lustre and soft texture. The plants are pulled out of the ground
either by hand or efficiently by machine. If the stalk is cut, the sap is lost; this loss affects the quality of the fibre. The stalks are tied in bundles, called beets in preparation for extraction of the fibre. The seeds are removed at the mill by passing the seed end of the flax through a deseeding machine. About one-quarter of the stem consists of fibre.

4.2.3 Preparation of the Fibre (Retting)

The seed and the leaves are removed from the stems of the flax plant by passing the stalks through coarse combs. This process is called rippling. The bundles of plants are then steeped in water so that the tissue or woody bark surrounding the hairlike flax fibre will decompose, thus loosening the gum that binds the fibre to the stem. This decompositions is called retting. Retting is the step that loosens the fibre bundles from the stalk. The word "retting" comes from a German word meaning "to rot". Retting is not a rotting of the fibre, but it is rather bacterial action which hydrolyses the pectin around the fibres. Retting is one of the most important steps in flax preparation since it determines the colour and quality of the finished fabric. If flax is not retted enough, the removal of the stalk without injury to the delicate fibre is difficult. If flax is overretted, the fibre is weakened. The retting operation, as well as all other processes for producing linen fabric, therefore requires great care. Retting may be carried out in one of several ways:

4.2.3.1 Dew Retting

Dew retting is a method used in Belgium and the U.S.S.R. The flax straw is spread on the grass (ground) and is exposed to the atmosphere for three to four weeks. This method produces strong flax, dark gray in colour.

4.2.3.2 Pool, or Dam Retting

Pool, or Dam retting method is used in Belgium and Ireland. It requires less time than dew retting from ten to fifteen days. As stagnant pools of water are used, this method sometimes causes overretting, which is responsible for brittle and weak flax fibres. Pool retting darkens the flax, giving it a bluish gray colour.

4.2.3.3 Stream Retting

Stream retting method is used for producing high-quality flax fibre.
4.2.3.4 Vat, or Mechanical Retting

This method shortens the retting process and is used primarily in Belgium, France, Northern Ireland, and the United States. The flax is immersed in wooden vats of warm water at temperatures ranging from 75 to 90°F (25-30°C), which hastens the decomposition of the woody bark. The flax is removed from the vats and passed between rollers to crush the decomposed bark as clean water flushes away the pectin or gum and other impurities.

4.2.3.5 Chemical Retting

Chemical retting can shorten the retting process (within a few hours), but chemicals will affect the strength and colour of the flax fibre. The process must be monitored carefully to prevent damage to the fibre. Soda ash, oxalic soda and caustic soda (sodium hydroxide, sodium carbonate, dilute sulphuric acid) in warm water or boiling in a dilute sulphuric acid solution are the chemical methods used.

4.3 Processing Fibre-Flax (Manufacturing Processes)

4.3.1 Breaking

Once retting is completed, the fibre is rinsed and dried. The stalk becomes partially separated from the fibre when the wet plants are placed in the fields to dry. When the decomposed woody tissue is dry, it is crushed by being passed through fluted iron rollers. The breaking operation reduces the stalk to small pieces of bark called shives.

4.3.2 Scutching

The scutching machine removes the broken shives by means of rotating wooden paddles, thus finally releasing the flax fibre from the stalk. This operation can be done by hand as well as by machinery.

4.3.3 Hackling (Combing)

The scutched fibres are combed to separate the long fibres (line) from the short fibres (tow). The fibres are drawn through a series of combs that separate the fibres and leave them in a parallel arrangement. For very fine linen, hackling is done by hand. For faster and more efficient combing, hackling is done by machine. The fibres are then ready for spinning into yarn.
4.3.4 Spinning

The short-staple flax fibres, called tow are used for the spinning of irregular linen yarns. Tow is put through a carding operation, similar to the carding of cotton staple, which straightens the fibres and forms them into a sliver ready for spinning into yarn. The long-staple fibres are used for fine linens. These are called line, sometimes dressed flax. Line fibres are form 12 to 20” (30-50cm.) in length. They are put through machine, called spreaders, which combine fibres of the same length, laying them parallel so that the ends overlap. The sliver thus formed passes through sets of rollers, making a rove for the final spinning process, which inserts the necessary twist.

The standard measure of flax yarn is the cut. If one pound of flax fibre is drawn out to make 300 yards, the yarn is known as Ne 1. When drawn out to make twice 300 yards, it is labeled Ne 2. The higher the yarn count, the finer the yarn. Although flax is one of the strongest fibres, it is inelastic and requires a carefully controlled, warm, moist atmosphere for both methods of spinning.

4.3.4.1 Dry Spinning

Dry spinning does not use moisture. It produces rough, uneven yarns, which are not especially strong. These yarns are used for making coarse, heavy, and inexpensive linen fabrics.

4.3.4.2 Wet Spinning

This method requires a temperature of 120°F (50°C), which is conductive to the production of soft, fine, even yarns. By passing the roving through hot water, the gummy substance on the fibre is dissolved, permitting drawing out the roving into a fine yarn of high yarn count.

4.4 Physical and Chemical Properties of Flax

4.4.1 Strength

Flax is one of the strongest fibres. It is especially durable being two to three times as strong as cotton. Among the natural fibres, it is second in strength to silk. In linen, weight may be considered a criterion of durability. Flax also increases about 20% in strength when wet.
4.4.2 Elasticity

Linen has no significant elasticity. It is the least elastic of natural fibres. In order to fit comfortably, linen garments should neither bind nor pull at the seams.

4.4.3 Resilience

Linen is relatively stiff and has little resilience. Therefore, it wrinkles easily, which somewhat offsets its otherwise excellent qualities as a fabric for summer apparel. Due to its stiffness, linen fabrics should not have creases pressed firmly into them.

4.4.4 Absorbency

When absorbency is the main consideration, linen is preferable to cotton. It absorbs moisture and dries more quickly. This fabric takes up water rapidly. It has very good wicking properties. This makes the fibre comfortable to wear but difficult to dye and finish. It is therefore excellent for handkerchiefs and towels.

4.4.5 Density

Flax is one of the heavier cellulosic fibres with a density of 1.5 g/cc.

4.4.6 Lustre

Flax has a silky lustre due to the natural waxes found in the fibre. If this wax is removed by chemicals or solvents, the fibre becomes brittle and harsh.

4.4.7 Effect of Light

Flax has good resistance to sunlight. Flax is more resistant to light than cotton, but it will gradually deteriorate from exposure.

4.4.8 Effect of Heat

Linen scorches and flames in a manner similar to cotton. Linen may be safely ironed at 204°C (400°F).

4.4.9 Drapability

Linen has more body than cotton and drapes somewhat better.
4.4.10 Resistance to Mildew

Dry linen has good resistance to mildew, but fabrics stored in a warm, humid atmosphere support the rapid growth of the fungus. Most insects do not damage linen. It is more resistant to attack by insects and micro organisms.

4.4.11 Heat Conductivity

Linen is most suitable for summer apparel, as it allows the heat of the body to escape.

4.4.12 Cleanliness and Washability

Linen launders well and gives up stains readily. Some linen apparel requires dry cleaning because of construction and fabric finish. Care label instructions should be observed.

4.4.13 Shrinkage

Linen does not shrink a great deal; in fact, it shrinks less than cotton. But preshrinkage finishing is desirable.

4.4.14 Reaction to Alkalies

Linen, like cotton, is highly resistant to alkalies. Linen may also be mercerized.

4.4.15 Reaction to Acids

Linen is damaged by hot dilute acids and cold concentrated acids.

4.4.16 Affinity for Dyes

Linen does not have good affinity for dyes. However, it is possible to obtain dyes on linen that has good colourfastness. When buying coloured linens, look for the words “Guaranteed Fast Colour” on the label or get a guarantee of colourfastness from the store.

4.4.17 Resistance to Perspiration

Acid perspiration will deteriorate linen. Alkali perspiration will not cause deterioration. But in either case discolouration may occur.
4.5 End Uses

For many years flax was the traditional fibre for household items such as sheets, tablecloths, and napkins, but today it is a luxury fibre. Linen sheets and pillowcases are still available, and firm linen terry towels are preferred by some for a brisk rub down. Linen towels are preferred for drying glassware because they do not leave lint on the glass.

Decorative openwork casement cloths of linen are used in homes and offices for windows decoration. Linen draperies, upholstery, and slipcovers are also used. Fine damask table cloths and napkins are still made of linen. Some men's and women's apparel is made of linen. The fibre is confined primarily to spring and summer apparel. It is used alone and in blends with cotton, polyester, acrylic, wool and rayon. Two-and three-fibre blends are used.

4.6 Care

Linen items may be laundered, but reading the care instructions is essential, because dyes and finishes can alter fibre properties. Hot water, alkali detergent, and properly diluted chlorine bleaches do not damage the fibre. Linen fabric may be difficult to iron. It is usually recommended that it be ironed while still damp to achieve the maximum crispness and hand that are preferred for this fabric.

Table linens and other linen items stored for long period should be stored flat or rolled to prevent cracking and breaking of the fibre. Linen is fairly brittle fibre, and older linen fabrics that have been folded repeatedly in the same place may break along the crease line. Breakage of yarns along crease lines in garments has been noted as well.
CHAPTER 5
MINOR NATURAL FIBRES

5.1 Jute

Jute is a bast fibre that has been used since the dawn of civilization, but it did not attain economic importance until the latter part of the eighteenth century. Jute can be grown in any country that has enough warmth and moisture. India, Pakistan, Bangladesh and Thailand are the principal producers of jute.

Jute is the cheapest textile fibre used and is the second most widely used vegetable fibre, ranking next to cotton. The plant is cultivated in a manner similar to flax. Seeds are planted close together, and plants grow to a height of 15 to 20’ (4.6 to 6.1 metres). The fibres are extracted from the stem by retting; that is followed by breaking and scutching. The quality of jute varies according to the variety grown.

5.1.1 Properties of Jute

Good quality jute is coloured yellowish-white and silver-gray and has a lustrous appearance. Jute is usually brownish or greenish and has a unique lustre.

The individual cells in jute are shorter than those of any of the other bast fibres. Jute is the weakest of the cellulose fibres when dry and must therefore be spun into coarse yarns.

The average strength of jute is about 3.5 gm/denier. Resiliency is poor, and fabrics do not return to shape after deformation without treatment such as washing and ironing. Jute has low sunlight resistance and poor colour fastness. It is also brittle and subject to splitting and snagging. It is readily damaged by the action of weather, moisture and abrasion.

Jute can not be bleached white since disintegrates in strong bleaches; hence it is most often used in its natural colour. Chemical finishes can be used to overcome the natural odor of jute and to make it softer. Jute is similar to other cellulosic fibres in its reactions to heat and chemicals.

5.1.2 Uses of Jute

Jute is most widely used in the developing nations, as an apparel fabric as well as a household and industrial fabric.
The greater part of the jute goes into bagging for sugar, coffee, cotton and wool, where cheapness is a major factor. Large amounts are used as the binding threads in carpets and rugs, carpet backing and furniture. In carpet construction, it has been used as the primary backing for tufted carpets and for the secondary backing, which covers the tufting stitches and provides stability. It is also used in twine, cordage and ropes. Olefin fibres are now competing with jute in these areas.

This also limits its use for clothing. Occasionally it is used for fashion merchandise where texture and something different are desired. Burlap is often a fashion fabric for apparel and decorative home furnishings. Jute wastes are used as a paper making material.

5.2 Hemp

Hemp is a bast fibre that probably was first used in Asia. Today hemp is grown in most regions of the world and it is grown as an annual in warm or hot climates. The history of hemp is as old as that of flax. Because hemp lacks the fibre fineness of the better quality flax, it has never been able to compete in the clothing field. Some varieties of hemp are, however, very difficult to distinguish from flax. They look very much alike under the microscope, and when the hemp fibre is properly processed and spun it is a good substitute for flax in some of the larger yarn sizes.

Hemp production and manufacture are very similar to that of flax. The plant is retted, and the fibre scutched, hackled, and drawn to make yarn. Its high strength and light weight make it particularly suitable for hemp twine, cordage, and threads. Thread was used for stitching the soles of soldiers’ shoes. After the war the use of hemp declined, and at the present time it is one of the less important fibres.

5.2.1 Properties of Hemp

Hemp is coloured yellow or grayish-brown. Bluish-white and lustrous ones are excellent. Fibre length is variable, as is diameter. Both elongation and elasticity are low. Hot concentrated alkalies dissolve hemp, but cold concentrated alkalies and dilute alkalies do not damage. Cool dilute mineral acids do not harm the fibre, but hot dilute acids and concentrated acids reduce its strength and eventually destroy it. Hemp is stronger and withstands water better than flax. It is a hygroscopic fibre.
5.2.2 Uses of Hemp

Hemp is an industrial fibre; its primary use is in cordage. In developing nations the fibre is sometimes used in apparel and other end uses. It is too coarse for fabrics. Since hemp is strong, durable and good at water-resisting property, high grade yarns are used for hoses and canvases.

5.3 Ramie

Ramie has been used for several thousand years in China. For this reason fabrics made of ramie are often referred to as China grass, grass cloth, or Chinese linen. Small amounts of ramie have been used in the United States in towels, table coverings, and handkerchiefs. The many advantages of ramie would indicate that it should be a major textile fibre. The chief reason for limited production has been the need for an efficient mechanical decorticator. Such a machine has now been developed but there is still a need for more information about processing ramie fibres into textile products. Vary little has been processed on modern textile machinery.

A hot, rainy climate is best suited for growing ramie. The plant grows from root cuttings and attains a height of three to eight feet. The plant is harvested by cutting and after cutting new growth starts immediately. Three crops a year may be harvested.

Ramie is grown in China, Formosa, the Philippines, Honduras, Borneo, Sicily, Angola, French Equatorial Africa and Brazil. Brazil has rather large production from small farms and most of it is used in that country. Much of the rest of the raw fibre is exported to Japan, where it is spun into yarns and woven into fabrics. At the present time the Japanese are the largest ramie spinners. Germany ranks second and France is third.

5.3.1 Processing of Ramie

The ramie fibre bundles are removed from the stalk by a decorticating machine. This machine strips the stalk as it pulls them through a series of rollers which remove all of the woody portion. After decortication the fibre must be degummed. The most successful degumming process is a mild chemical bath (caustic soda) that removes all about 4% of the gum. The fibre is then washed and dried in preparation for spinning. Most of the ramie fibre bundles are reduced to single fibre cells. These are longer than any of the other fibre cells in
the bast fibre group. They range from 6 to 8 inches and are usually cut into desired staple length before spinning.

5.3.2 Properties of Ramie

Ramie is coloured light brown, yellowish or yellowish-green. When bleached, ramie turns snow-white. Ramie absorbs water better than flax. Even when soaked in water or exposed to the weather, ramie will not be come deteriorated. When treated with a strong alkali at high temperatures, fibre may get weakened with loss of lustre and transparency.

It is the strongest known natural fibre and its strength increases when it is wet. It has a silk-like lustre. Ramie has excellent resistance to rotting, mildew and other micro-organisms. Other desirable properties are high durability, stability to shrinking, rapid moisture absorption, quickness in drying and good affinity for dye.

Ramie also has some disadvantages. It is stiff and low in resiliency, hence wrinkles very easily. Ramie is also low in elasticity and this property plus low resiliency tends to make the fibre rather brittle. It breaks if folded repeatedly in the same place.

5.3.3 Uses of Ramie

Ramie fibre is used primarily in apparel. It is used in fabrics resembling linen, such as suitings, shirtings, table cloths, napkins and handkerchiefs. Most of it appears in blends with cotton, rayon, polyester, acrylic and silk. The fibre often is blended with two or more other fibres. It is most suitable for summer dresses. It is also used for ropes and anchor cables of inferior quality.

5.4 Sisal

Sisal is obtained from the leaf of the agave plant. Most of the commercial fibres come from Mexico. The fibre also is cultivated in Africa, Java and some areas of South America.

The leaves are cut when the plant is about four years old. The fibres must be removed from the fleshy part of the leaf and separated from pectins, chlorophyll and other noncellulosic substances.
5.4.1 Properties and Uses of Sisal

Both acid and direct dyes can be used to dye the fibre bright colours, but the dyes are not completely colourfast. It has good strength but not resistant in sea water. Sisal is used in cordage, handbags, floor mats and flat rugs.

5.5 Pineapple (Pina)

The fibre form the leaf of the pineapple frequently is labeled “pina”. Most of the commercial fibre comes from the Phillipines. It is between 5 and 10 cm. (2 to 4”) in length and is lustrous and strong. Fabrics range in hand from crisp to very soft. Delicately embroidered clothing and accessories are often made of pina, it is also a cordage fibre.

5.5.1 Properties and Uses of Pina

This natured fibre is white and especially soft and lustrous. In the Phillipine Islands, it is woven into pina cloth, which is soft, durable and resistant to moisture.

It is used for ship cables, power transmission cables and driving cables. Light coloured fibres are spun into coarser cloth thread, which are used for clothes and bags. Fine fibres are used for making interior fabrics. It is also used as a material for summer hats, brushes and paper making material.

5.6 Coir

The hairy fibre from the soft husk of the coconut is called coir. It is the rich brown material between the outer husk and the nut.

5.6.1 Properties and Uses of Coir

Coir is stiff but elastic, strong and resistant to abrasion. It is often used in outdoor floor mats and patio coverings. The fibre may be dyed to darker shades but is difficult to bleach, so most coir products are left their natural colour. Coir is also suitable for cordage, sailcloth, brushes, carpet and coarse mattings.

5.7 Kapok

Kapok is a seed hair from the Java kapok tree. The trees grow to a height of about 15 metres (50’) and produce a seed pod similar to the cotton boll. The dried fibres shake away from the seeds easily, so ginning and processing are not necessary.
5.7.1 Properties and Uses of Kapok

The fibre is extremely soft, light and buoyant. It is extremely difficult to spin, so most of its end uses are as filling material. For years it has been used as filling for life preservers. It is still used occasionally in upholstered furniture and stuffed pillows, but it is being replaced by foam rubber, polyurethane foam, and polyester fibre-fill. It is also used for soundproofing and for insulating.
CHAPTER 6
WOOL AND HAIR

6.1 Wool

No one knows when man started using wool as a textile fibre. Probably he first used the skins for clothing and later discovered that he could form a cloth of felt by pounding and matting for the fibres together. We do know that man knew of wool during the second Stone Age and that as early as 300 B.C. the Babylonians were expert in spinning and weaving wool cloth. In the 11th and 12th Centuries in Europe textile industries began to reappear, and there was a big demand for wool. The Merino sheep which has the finest wool and is the forerunner of breeds producing fine wool today.

At first, wool was a very coarse fibre. Its development into the soft, fleecy coat so familiar on domesticated sheep is the result of long-continued selective breeding. The breeding of the animals and the production of the wool fibre into fabric are more costly processes than the cultivation of plant fibre and its manufacture. Consequently, wool fabrics are more expensive than cotton and linen. But wool provides warmth and physical comfort that cotton and linen fabrics cannot give. These qualities, combined with its soft resiliency, make wool desirable for apparel as well as for such household uses as rugs and blankets.

In recent years, wool’s share of the market has steadily declined. Wool processing plants have been a major source of river pollution, and many plants have been forced to close. Many people now consider both wool and silk to be luxury fibres. Designers continue to use these fibres extensively in their collections and the average consumer is most likely to have a wool coat. Wool and silk products, however, are not as readily available as they once were. Most wool comes from the temperature zone of the southern Hemisphere, Australia, Argentina, New Zealand and South Africa. U.S., U.K., Spain, France and Italy are the leaders. Australia produces one-fourth of the world’s wool. U.S. is the largest consumer of wool and the largest producer of wool fabrics, both in terms of yardages and dollar value.

Hair fibres have all the qualities of wool and, in general, are even more expensive than wool. Vicuna is the world’s costliest textile product and surpasses all other wool and hair fibres in fineness and beauty. These hairs are sometimes mixed with wool, adding rather than detracting from the quality of any wool fabric in which they appear.
6.2 Manufacturing Processes
6.2.1 Preparation
6.2.1.1 Shearing

Sheep are sheared once or twice a year, depending on the locality, by traveling crews. An expert shearer can clip as many as 100 to 200 sheep a day. The fleece is kept in one piece with the skirts and breech folded in and the flesh side outside. The fleece is tied with paper twine. The fleeces are sometimes graded before packing but usually are graded in the warehouse before being sold.

Fleeces vary from 6 to 18 pounds (3-8 kg.) in weight, average about 8 pounds (3.5 kg.) each, and ultimately provide about 3 pounds (1.5 kg.) of scoured wool. Since wool is sold according to the lowest grades in the fleece, it is often trimmed of the poorer quality edges, rolled up, tied, and packed in sacks weighing about 225 to 350 pounds (100-160 kg.). In Australia, the fleece is separated at the time of shearing according to its quality. Superior wool comes from the sides and shoulders, where it grows longer, finer and softer, and is treated as one fleece; wool from the head, chest, belly, and shanks is treated as a second fleece. Domestic wool reaches the mill in loosely packaged bags, imported wool comes in tightly compressed bales. Each fleece contains different grades of wool and the raw stock must be carefully graded and segregated according to length, diagram and quality of the fibre. The raw wool or newly sheared fleece is called grease wool because it contains the natural oil of the sheep. When grease wool is washed, it loses from 20 to 80% of its original weight. The grease known as yolk, is widely used in the pharmaceutical and cosmetic industries because it can be absorbed by the human skin.

6.2.1.2 Storing and Grading

Wool sorting is done by skilled workers who are expert in distinguishing qualities by touch and sight. At many as twenty separate grades of wool may be obtained from one fleece if the sorting is especially rigid. Each grade is determined by type, length, fineness, elasticity, and strength. Fine combing wools measure 2½" or more in length. French combing wools are 1½" to 2½" long. The coarser clothing wools are around 1½". Sorting breaks up the individual fleece into various qualities. The best quality wool comes from the sides and shoulders, the poorest comes from the lower legs.
The standard for wool grading in the United States is based on the quality of wool produced by the Merino sheep because it yields the finest-quality wool in terms of diagram, scales and crimp.

6.2.1.3 Garnetting

Recycled wool fibres are obtained by separately reducing the unused and used materials to a fibrous mass by a picking and shredding process called garnetting. The fibres are then put through a dilute solution of sulphuric or hydrochloric acid, which destroys any vegetable fibres that may be contained in the raw stock. This process is known as carbonizing, and the resultant wool fibres are called extracts. The new staple ranges from $\frac{3}{4}$ to $1\frac{1}{2}''$ (6-40 mm.) lengths.

The quality and cost of recycled wool fibres depend on the original stock from which they are obtained. A good grade of recycled wool may cost 5 times as much as a poor grade of virgin wool.

6.2.1.4 Scouring

The next step in preparing raw wool for manufacturing is a thorough washing in an alkaline solution, this process is known as scouring. The scouring machines contain warm water, soap, and a mild solution of soda ash or other alkali, they are equipped with automatic rakes, which stir the wool. Rollers between the volts squeeze out the water. If the raw wool is not sufficiently clear of vegetable substance after scouring, it is put through the carbonizing bath of dilute sulphuric acid or hydrochloric acid to burn out the foreign matter.

6.2.1.5 Drying

Wool is not allowed to become absolute dry. Usually, about 12 to 16% of the moisture is left in the wool to condition it for subsequent handling.

6.2.1.6 Oiling

As wool is unmanageable after souring, the fibre is usually treated with various oils, including animal, vegetable, and mineral, or a blend of these to keep it from being brittle and to lubricate it for the spinning operation.
6.2.2 Dyeing

If the wool is to be dyed in the raw stock, it is dyed at this stage. Some wool fabrics are piece-dyed, some are yarn- or skein-dyed, and some are top-dyed.

6.2.3 Blending

Wool of different grades may be blended or mixed together at this point.

6.2.4 Carding

The carding process introduces the classifications of woolen yarns and worsted yarns. Manufacturing processes from this point on depend on whether the wool fibre is to be made into a wooden or worsted product.

6.2.5 Gilling and Combing

The carded wool, which is to be made into worsted yarn is put through gilling and combing operations. The gilling process removes the shorter staple and straightens the fibres. This process is continued in the combing operation, which removes the shorter fibres of 1 to 4” (25-100 mm.) lengths (called combing noils), places the larger fibres (called tops) are parallel as possible, and further cleans the fibres by removing any remaining loose impurities.

The short-staple noils are not necessarily of poor quality. Combing noils may well be of good quality, depending on the original source of the wool. They may be used as filler for other types of wool fabrics, however, such fibres must be classified recycled wool.

6.2.6 Drawing

Drawing is an advanced operation which doubles and redoubles slivers of wool fibres. The process draws, drafts, twists, winds the stock and making the slivers more compact. Drawing is done only to worsted yarns.

6.2.7 Roving

This is the final stage before spinning. Roving is actually a light twisting operation to hold the thin slubbers intact.
6.2.8 Spinning

In the spinning operation, the wool roving is drawn out and twisted into yarn. Woolen yarns are chiefly spun on the mule spinning machine. Worsted yarns are spun on any kind of spinning machine mule, ring, cap or flyer.

The differences between woolen and worsted yarns are as follows:

<table>
<thead>
<tr>
<th>Woolen yarn</th>
<th>Worsted yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short staple</td>
<td>Long staple</td>
</tr>
<tr>
<td>Carded only</td>
<td>Carded and combed</td>
</tr>
<tr>
<td>Slack twisted</td>
<td>Tightly twisted</td>
</tr>
<tr>
<td>Weaker</td>
<td>Stronger</td>
</tr>
<tr>
<td>Bulkier</td>
<td>Finer, smoother, even fibres</td>
</tr>
<tr>
<td>Softer</td>
<td>Harder</td>
</tr>
</tbody>
</table>

6.3 Classification for Wool

6.3.1 Classification by Sheep

There are about forty breeds of sheep. Counting the crossbreeds, there are over 200 distinct grades of sheep. Those that produce wool may be classified into four groupings according to the quality of the wool produced.

6.3.1.1 Merino Wool

Merino sheep produce the best wool. The variety originated in Spain. Some 40% of the world production is merino wool, especially Australia merino is high in wool quality. Its wool features fine size and high uniformity and can be made into high quality fine yarns for woven fabrics. The staple is relatively short, ranging from 1 to 5” (25-125 mm.), but the fibre is strong, fine, and elastic and has good working properties. Merino fibre has the greatest amount of crimp of all wool fibres and has a maximum number of scales. Merino is used in the best types of wool clothing.

6.3.1.2 Class-Two Wools

This class of sheep originated in Englands, Scotland, Ireland and Wales. While not quite as good as the Merino wool, this variety is nevertheless a very good quality wool. It is 2 to 8” (50-200 mm.) in length, has a large number of scales per inch, and has good...
crimp. The fibres are comparatively strong, fine, and elastic and have good working properties.

6.3.1.3 Class-Three Wools

This class of sheep originated in the United Kingdom. The fibres are about 4 to 18” long (100-455 mm.), are coarser, and have fewer scales, and less crimp than Merino and the class-two wools. As a result, they are smoother, and therefore have more lustre. These wools are less elastic and resilient. They are nevertheless of good enough quality to be used for clothing.

6.3.1.4 Class-Four Wools

This class is actually a group of mongrel sheep. The fibres are from 1 to 16” (25 ~ 400 mm.) long, are coarse and hair-like, have relatively few scales and little crimp, and are therefore smoother and more lustrous. This wool is less desirable, with the least elasticity and strength. It is used mainly for carpets, rugs and inexpensive low-grade clothing.

6.3.2 Classification by Fleece

Sheep are generally shorn of their fleeces in the spring, but the time of shearing varies in different parts of the world. In the U.S., shearing takes place in April or May; in Australia, in September; in Great Britain, in June or July. Texas and California sheep are shorn twice a year because of the warm climate.

Sheep are not washed before shearing. Sometimes, they are dipped into an antiseptic bath. Formerly, sheep were shorn with hand clippers; today the fleeces are removed in one piece by machine clippers, which shear closer as well as faster.

Wool shorn from young lambs differs in quality from that of older sheep. Also, fleeces differ according to whether they come from live or dead sheep, which necessitate standards for the classification of fleeces.

6.3.2.1 Lamb’s Wool

The first fleece sheared from a lamb about 6 to 8 months old is known as lamb’s wool and sometimes referred to as fleece wool or first clip. This wool is of very fine quality; the fibres are tapered because the ends have never been clipped. Such fibres produce a softness
of texture in fabrics that is characteristic only of lamb’s wool. Because of its immaturity, however, lamb’s wool is not as strong as fully developed wool of the same sheep.

6.3.2.2 Hogget Wool

Hogget (hogg or teg) wool comes from sheep 12 to 14 months old that have not been previously shorn. The fibre is fine, soft, resilient, and mature, and has tapered ends. Hogget wool is a very desirable grade of wool and, because of its strength, is used primarily for the warp yarns of fabrics.

6.3.2.3 Whether Wool

Any fleece clipped after the first shearing is called whether wool. This wool is usually taken from sheep older than 14 months, and these fleeces contain much soil and dirt.

6.3.2.4 Pulled Wool

When sheep are slaughtered for meat, their wool is pulled from the pelt by the use of line, by sweating, or by a chemical depilatory. Such wool fibre, called pulled wool, is of inferior quality for two reasons: (1) because sheep that are raised for meat generally do not have a good quality of wool, (2) because the roots of the fibres are generally damaged by the chemicals and the tension exerted in pulling.

6.3.2.5 Dead Wool

The wool fibre known as dead wool is sometimes mistaken for pulled wool. The term is correctly used for wool that has been recovered from sheep that have died on the range or have been accidentally killed. Dead wool fibre is decidedly inferior in grade, it is used in low-grade cloth.

6.3.2.6 Cotty Wool

Sheep that are exposed to serve weather conditions or lack of nourishment yield a wool that is matted or felted together and is hard and brittle. This very poor grade is known as cotty wool.
6.3.2.7 Taglocks

The torn, ragged or discolored parts of a fleece are known as taglocks. These are usually sold separately as an inferior grade of wool.

6.4 Physical and Chemical Properties of Wool
6.4.1 Strength

Wool fibres are weak but wool fabrics are very durable. The durability of wool is the result of the excellent elongation and elastic recovery of the fibres. Fibre strength is not always an indication of durability since flexibility of the fibre and its resistance to abrasion are also important. The tear strength of wool is poor. Wool is fair abrasion resistance. Flexibility of wool is excellent. They can be bent back on themselves 20,000 times without breaking.

6.4.2 Resilience

Wool is a very resilient fibre. Its resiliency is greatest when it is dry and lowest when it is wet. It a wool fabric is crushed in the hand, it tends to spring back to its original position when the hand is opened. Because wool fibre has a high degree of resilience, wool fabric wrinkles less than some others; wrinkles disappear when the garment or fabric is steamed. Good wool is very soft and resilient, poor wool is harsh. When buying a wool fabric, grasp a handful to determine its quality.

6.4.3 Heat Conductivity

As wool fibres are poor conductor of heat, they permit the body to retain its normal temperature. Wool garments are excellent for winter clothing and are protective on damp days throughout the year. The scales on the surface of a fibre and the crimp in the fibre create little pockets or air that serve as insulative barriers and give the garment greater warmth.

6.4.4 Absorbency

Initially, wool tends to be water-repellent. One can observe that droplets of water on the surface of wool fabrics are readily brushed off. Wool can absorb about 20% of its weight in water without feeling damp; consequently, wool fabrics tend to feel comfortable rather than clammy or chilly. Wool also dries slowly.
6.4.5 Cleanliness and Washability

Dirt tends to adhere to wool fabric. Consequently, wool requires frequent dry cleaning or laundering if the fabric is washable. Extreme care is required in laundering. Wool is softened by moisture and heat, and shrinking and felting occur when the fabric is washed. Since wool temporarily loses about 25% of its strength when wet wool fabrics should never be pulled while wet.

To control the possibility of shrinking or stretching when laundering a wool sweater or a similar garment, wash it in cold water with an appropriate detergent. To dry the garment, roll it in a towel, squeeze gently to remove as much moisture as possible then spread it out to its original shape on a towel or heavy cardboard.

6.4.6 Effect of Heat

Wool becomes harsh at 212°F (100°C) and begins to decompose at slightly higher temperatures. Wool has a plastic quality in that it can be expressed and shaped at steam temperature, whether in fabric as for slacks and jackets, or in felt, as for hats.

6.4.7 Effect of Light

Wool is weakened by prolonged exposure to sunlight.

6.4.8 Resistance to Mildew

Wool is not ordinarily susceptible to mildew, but if left in a damp condition, mildew develops.

6.4.9 Reaction to Alkalies

Wool is quickly damaged by strong alkalies. The alkali test can be used to identify wool and wool blends. The test is a simple one and can be done by the homemaker using lye, which can be purchased in any supermarket. Recipe for use a 5% alkali solution (solution of lye).

- heat to boiling 1 tablespoon of lye per pint of water in a glass.
- immerse a strip of fabric or yarns.
The wool reacts to the alkali by turning yellow, then becoming stick and jellylike, and finally going into solution. If the fabric is a blend, the wool in the blend will disintegrate, leaving only the other fibres. Mild alkali-in warm or cool water-can be used in scouring the raw wool fibres to remove grease.

6.4.10 Reaction to Acids

Although wool is damaged by hot sulphuric acid, it is not affected by other acids, even when heated. Acids are used in the manufacture of wool fabrics to remove cellulose impurities, such as leaves or burrs, that may still be in the fabric after weaving. This treatment is called carbonizing.

Carbonizing is an acid both treatment of wool fibre or fabric to remove burrs, leaves, and other vegetable matter. The fibre or fabric is heated to char the foreign matter and then dusted to remove the charred matter.

6.4.11 Affinity for Dyes

Because of their high affinity for dyes, wool fabrics dyes well and evenly. The use of chrome dyes assures fastness of colour. A variety of other dyes may be effectively used.

6.4.12 Resistance to Perspiration

Wool is weakened by alkali perspiration. Garments should be dry cleaned or washed with care to avoid deterioration and odor. Perspiration, generally, will cause discolouration.

6.4.13 Flammability

Wools burns very slowly and it self-extinguishing. It is normally regarded as flame-resistant. For curtains, carpets and upholstery to be used in trains, planes, ships, hotels and other public buildings, wool is often given a flame-retardant finish.

6.4.14 Press Retention

Wool also has good press retention. It takes and holds creases well. Creases are set by use of pressure, heat and moisture. During pressing the fibre molecules adjust themselves to the new position by forming new cross-linkages. Creases in wool are not permanent, however, since they can be removed by moisture.
6.5 End Uses

Overcoats, suits, dresses and underwear are commonly made from wool. Apart from being suitable for knitted fabrics and sweaters, the two big distinctive woven fabric groups are woollen and worsted.

6.6 Care

Grease and oils do not spot wool fabrics as readily as they do fabrics made of other fibres. Dry cleaning is preferable for cleaning wool. Laundering of wool fabrics should be done with care to prevent shrinkage. Mild alkali, soaps, and detergents used in home laundry cause little if any damage, if heat is kept at a minimum.

Avoid: chlorine bleach, alkali, and hot water. Machine-washable wools are available in sweaters, blankets, hand-knitting yarns, and fabrics for home sewing. Wool garments are labeled with permanently attached care instructions. Care instruction labels are available for wool fabrics on request.

6.7 Speciality Hair Fibres

Hair fibres that have qualities of wool are obtained from certain kinds of animals throughout the world. The hair of these animals has been so adapted by nature for the climate in which they live that the cloth produced from the fibre gives warmth with lightweight.

Most speciality wools are obtained from the goat, camel and rabbit families.

<table>
<thead>
<tr>
<th>Good family</th>
<th>Camel family</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angora goat – mohair</td>
<td>Camel’s hair</td>
<td>Angora rabbit - angora</td>
</tr>
<tr>
<td>Cashmere goat – cashmere</td>
<td>Llama</td>
<td>Fur fibres</td>
</tr>
<tr>
<td></td>
<td>Alpaca</td>
<td>Musk ox-qiviut</td>
</tr>
<tr>
<td></td>
<td>Vicuina</td>
<td>Guanaco</td>
</tr>
</tbody>
</table>

6.7.1 Mohair

Mohair, the fibre of the Angora goat, is produced in Turkey, South Africa and the United States. Texas is the largest producer of mohair. The goats are sheared twice a year, in the early fall and early spring.

The raw fleece from the Angora goat is quite long and is of a slightly yellowish or grayish tint, however, when the fleece is washed it comes out a lustrous white.
The fibre length is 4 to 6 inches for half a year or 8 to 12 inches for a full year. Mohair fibres have a circular cross section. It is more uniform in diameter than wool fibre. Mohair, shows almost no scales.

Mohair is the most resilient natural fibre. It has none of the crimp found in sheep's wool, giving it a smoother surface which is more resistant to dust and more lustrous than wool. Mohair is very strong and has good affinity for dyes. It does not attract or hold dirt particles.

The coarse hairs are used for interlinings for ties, suits and coats; the fine hairs are used in woolens and worsted for clothing; the medium quality fibres are used in upholstery and rugs. Mohair is blended with wool, silk, cotton and rayon are also used in combination with these fibres.

6.7.2 Cashmere

The Cashmere goat is native to the Himalaya Mountain region of Kashmir in India, Mongolia and China. The Cashmere goat is smaller than the Angora goat.

The fleece of this goat has long, straight, coarse outer hair of little value, is made into luxuriously soft woollike yarns. The fibres rang in colour from white to gray to brownish gray. The hair is combed by hand from the animal during the molting season, and care is taken to separate the coarser hair from the fine fibres. Only a small part of the fleece is the very fine fibre, probably not more than 4 oz. per goat. Because supply of the fibre is limited and demand for it is high, cashmere fibre is quite expensive.

Cashmere is more sensitive to the action of alkali than wool. Cashmere is used in high-quality apparel. Fabrics are warm, buttery in hand, and have beautiful draping characteristics. It is used for such garments as sweaters, sports jackets, suits and over coats when a luxurious, soft fabric is desired. It is often blended with wool to reduce the cost of the product.

6.7.3 Camel Hair

This textile fibre is obtained from the two-humped Bactrian camel, which is native to all parts of Asia (Mongolia and Tibet). Each animal sheds about 2.7 kg. (5 lbs.) of fibre per year. Camel hair fabrics are ideal for comfort particularly when used for overcoating, as they are especially warm but lightweight. The best quality is expensive when used alone. It is
often mixed with wool, thus raising the quality of the wool fabric by adding the fine qualities of camel hair. The price of a mixed cloth is naturally much less than that of a fabric that is 100% camel hair.

In the textile industry, camel hair is divided into three grades. Grade 1 is the soft and silky light tan underhair found close to the skin of the camel. This is short staple or noil, of from 1¾” to 3½” (30-90 mm.). Formerly, it was the only true camel hair used in the manufacture of apparel. In wool, noils represent the less valuable short-staple; in the hair fibres, the short fibres are the prized product and are only used in high-grade apparel fabrics.

Grade 2 is the intermediate growth, consisting of short hairs and partly of coarse outer hairs, ranging from 1½” to 5” (40-125 mm.) in length.

Grade 3 consists entirely of coarse outer hairs measuring up to 15” (380 mm) in length and varying in colour from brownish black to reddish brown. It is coarse, tough, stiff and wiry. It is used in artists’ brushes industrial fabric, blankets, press cloths, ropes, cordage and some lower grade apparel fabrics.

6.7.4 Alpaca

The alpaca is a domesticated animal of the South American branch of the camel family. The alpaca is a small animal about three and one-half feet high and looks like an overgrown poodle. The fleece is quite long, reaching almost to the ground. The animals are clipped every second year and yield four to eight pounds of fibres per animal.

The fibre is valued for its silky beauty as well as for its strength. The hair of the alpaca is stronger than ordinary sheep’s wool, is water-repellent, and how a high insulative quality. The staple is 6 to 11”(150-250 mm.) in length and is noted for its softness, fineness and lustre. The natural colours of alpaca are white, light fawn, light brown, dark brown, gray, black and piebald.

6.7.5 Llama

The llama is a domesticated animal native to the same geographic area as the alpaca. Fibres are shorn from the animal once a year, and they are similar in length and diameter to alpaca fibres. The fibres are both coarse and fine and are difficult to separate. Most fabrics produced from llama fibres are made by South America Indians, although some fibre is sold abroad for blending with sheep’s wool.
6.7.6 Vicuna

The vicuna is the wild animal of the South American branch of the camel family. The vicuna is a small animal about three feet high (90 cm.) and weighs 75 to 100 lbs. (35 - 45 kg.). A single animal yields only \( \frac{1}{4} \) lb. (100 gm.) of hair, thus forty animals are required to provide enough hair for the average coat. To preserve the species the vicuna is now under the protection of the Peruvian and Bolivian governments. Vicuna is the softest, finest, rarest and most expensive of all textile fibres. The fibre is short, very lustrous and a light cinnamon colour.

6.7.7 Guanaco

The guanaco, native to southern Argentina where it is both wild and domesticated, is related to the llama and alpaca. The fibre is extremely soft and silky. It is so light, resilient, and warm, and the colour is a honey beige. Because of these characteristics and its limited availability, it is expensive. It generally is blended with wool, frequently lamb’s wool, so as not to mask the fibre’s soft texture.

6.7.8 Angora

Angora is the hair from the Angora rabbit, which was raised originally in North Africa and France, United States, Italy and Japan. Each rabbit produces only a few ounces of hair, and since the rabbits are difficult to raise and produce a small yield, the total quantity of Angora is very limited and very expensive.

Angora is fairly long, fine, fluffy, soft, smooth, lustrous, slippery and resilient. It requires special processing to spin it properly. It is pure white in colour. It is used primarily for items such as sweaters, mittens, baby cloths, millinery and yarns for knitting or knitted fabrics.
CHAPTER 7
SILK

7.1 Introduction

Silk is often referred to as “the queen of the fibres”. Silk can be produced in any climate but it has only been successfully produced where there is a cheap source of labour. Silk is a continuous filament protein fibre produced by the silkworm. Cultivated silk is obtained by a carefully controlled process in which the silkworm lives a coddled and artificial life especially for the purpose of producing fibres. Wild silk production is not controlled; instead, these silkworms feed on oak leaves and spin cocoons under natural conditions.

7.2 Cultivation of Cocoons

Since the discovery, so many years ago, that the fibre, or filament, composing the cocoon of the silkworm can be unwound and constructed into a beautiful and durable fabric, silkworms have been bred for the sole purpose of producing raw silk. The production of cocoons for their filament is called sericulture.

Sericulture is the name given to the production of cultivated. The process begins with the silk moth which lays eggs on specially prepared paper. The eggs are kept in cold storage until they are needed for hatching. Hatching takes place continuously throughout the mulberry growing season, thus making it possible to keep labour and equipment at a minimum. The eggs are hatched into caterpillars which are put on special mats and fed fresh, young mulberry leaves.

When the silkworm is grown, it spins a double strand (filoain) of silk fibres surrounded by water soluble substance called sericin or silk gum. The liquid substance hardens immediately on exposure to the air. The silkworm surrounds itself with the fibre which it forms into a cocoon. The bulk of the silk moths are killed inside the cocoons by heat and only those which are needed for reproduction are allowed to emerge. The pierced cocoons are used for staple fibre.

It is possible to control the fineness, uniformity, and strength of the silk fibre by selective breeding, and better silk is resulting from research in this area.
7.3 Filature Operations

The cocoons that are raised by silk farmers are delivered to a factory, called a filature, where the silk is unwound from the cocoons and the strands are collected into skeins. Some cocoons are scientifically bred in such factories.

7.3.1 Sorting Cocoons

The cocoons are sorted according to colour, size, shape, and texture, as all these affect the final quality of the silk. Cocoons may range from white or yellow to grayish, depending on the source and the type of food consumed during the worm stage. Cocoons from China are white; Japanese cocoons are creamy white and yellow; Italian cocoons are yellow.

7.3.2 Softening the Sericin

After the cocoons have been stored, they are put through a series of hot and cold immersions, as the sericin must be softened to permit the unwinding of the filament as one continuous thread. Raw silk consists of about 80% fibroin and 20% sericin. At this time, only about 1% of the sericin is removed, because this silk gum is a needed protection during the further handling of the delicate filament.

7.3.3 Reeling the Filament

The process of unwinding the filament from the cocoon is called reeling. The care and skill used in the reeling operation prevent defects in the raw silk. As the filament of a single cocoon is too fine for commercial use, three to ten strands are usually reeled at a time to produce the desired diameter of raw silk thread. The cocoons float in water, bobbin up and down, as the filaments are drawn upward through porcelain eyelets are rapidly wound on wheels or drums while the operator watches to detect flaws. As the reeling of the filament from each cocoon nears completion, operators attach a new filament to the moving thread. The sericin aids in holding the several filaments together while they are combined to form a single thread. On old style reeling machines at high speed, an operator could handle five to seven threads, and on the newest models, twenty five threads.

The term “reeled silk” is applied to the raw silk strand that is formed by combining several filaments from separate cocoons. The diameter of the silk fibre is so fine that an estimated 3000 cocoons are required to make a yard (one metre) of silk fabric. The silk
filaments are reeled into skeins, which are packed in small bundles called books, weighing 5 to 10 lbs. (2-4.5 kg.) - (30 skeins to a book). Twenty to thirty books are put into bales, weighing about 133.33 lbs. (60 kg.). In this form, the raw silk is shipped to all parts of the world. When the silk arrives at the mill, it is opened, bunched, soaked, dried, and wound on bobbins.

7.4 Kinds of Silk

Silk refers to cultivated silk

7.4.1 Wild or Tussah Silk

The silkworms that hatch from a wild species of moth live on oak leaves instead of mulberry leaves that form the food of the cultivated species. This coarser food produces an irregular and coarse filament that is hard to bleach and hard to dye. The tannin in the oak leaves gives wild silk its tan colour. Wild silk is less lustrous than cultivated silk, as only a low percentage (about 11%) of sericin is removed in the degumming process. Wild silk fabrics are durable and have a coarse, irregular surface. They are washable and are generally less expensive than pure-dye silk.

7.4.2 Doupion Silk

Doupion silk comes from two silkworms who spin their cocoons together. The yarn is uneven, irregular, and large in diameter.

7.4.3 Raw Silk

Raw silk refers to cultivated silk-in-the-gum. Raw silk varies in colour from gray-white to canary yellow but since the colour is in the sericin, boiled-off silk is white.

7.4.4 Reeled Silk

Reeled silk is the long continuous filament, 300 to 1600 yards in length.

7.4.5 Spun Silk

Spun silk refers to yarns made from silk from pierced cocoons and waste silk.
7.4.6 Waste Silk

Waste silk is comprised of the tangled mass of silk on the outside of the cocoon and the fibre from pierced cocoons.

7.5 Physical and Chemical Properties of Silk

In spite of its high cost, silk has been one of the most popular fabrics because of its unique properties. Soft, supple, strong and lighter in weight than only other natural fibre, silk is prized for its lightness with warmth, sheerness with strength, and delicacy with resiliency.

7.5.1 Strength

Silk is the strongest natural fibre. It loses some strength when it is wet.

7.5.2 Elasticity

Silk fibre may be stretched from 1/7 to 1/5" its original length before breaking. It returns to its original size gradually and loses little of its elasticity. This characteristic means less binding and sagging, thus contributing to the wearer's comfort. It should be kept in mind that the elasticity of the yarn and the fabric is affected by the kind of yarn used (thrown or spun), the construction of the fabric, and the finish that it is given.

7.5.3 Resilience

Silk has average resiliency. Silk fabrics retain their shape and resist wrinkling rather well. Fabrics that contain a large percentage of weighting or are made from short-staple spun silk have less resilience.

7.5.4 Drapability

Silk has a pliability and suppleness that, aided by its elasticity and resilience, give it excellent drapability.

7.5.5 Heat Conductivity

Silk, like wool, is a poor conductor of heat so that silk scarves and raw silk suitings are comfortably warm. The weight of a fabric is important in heat conductivity-sheer fabrics, will be cool whereas heavy suitings fabrics will be warm.
7.5.6 Absorbency

Silk has a good absorbency with a moisture regain of 11% and like wool it is hygroscopic. This makes silk fabrics comfortable in summer in skin contact apparel. This property is also a major factor in silk’s ability to be printed and dyed easily. Silk is smooth and soft and is thus not irritation to the skin.

7.5.7 Cleanliness and Washability

Silk is a hygienic material because its smooth surface does not attract dirt. When dirt does gather, it is given up readily by washing or dry cleaning. Care should be exercised in laundering silk—always use a mild soap. Dry cleaning is preferable for weighted silks, but wild silk and spun silk fabrics may be washed.

7.5.8 Reaction to Bleaches

Strong bleaches containing sodium hypochlorite will deteriorate silk. A mild bleach of hydrogen peroxide or sodium perborate may be used with normal caution.

7.5.9 Shrinkage

Because of the straightness of the filament, smooth-surfaced silk fabrics have only a normal shrinkage, which is easily restored by ironing. Crepe effects shrink considerably in washing, but careful ironing with a moderately hot iron will restore the fabric to its original size.

7.5.10 Effect of Heat

Silk is sensitive to heat. It will begin to decompose at 330°F (165°C); therefore, it should be ironed while damp with a warm iron. High ironing temperatures cause a yellowing of the fibre.

7.5.11 Effect of Light

Continuous exposure to light weakens silk faster than cotton or wool. Raw silk is more resistant to light than degummed silk, and weighted silk has the least light resistance. Silk drapery and upholstery fabrics should be protected from direct exposure to the light.
7.5.12 Resistance to Mildew

Silk is resistant to attack by mildew and many bacteria and fungi, but it is attacked by rot-producing bacteria. Silk attracts carpet beetles but is fairly resistant to attack by moths.

7.5.13 Reaction to Alkalies

Silk is not as sensitive as wool is to alkalies, but it can be damaged if the concentration and the temperature are high enough. Use a mild soap or detergent in warm water when laundering.

7.5.14 Reaction to Acids

Concentrated mineral acids will dissolve silk faster than wool. Organic acids do not harm silk.

7.5.15 Affinity for Dyes

Silk has a very good affinity for dyes. It readily absorbs basic, acid and direct dyes. Dyed silk is colourfast under most conditions, but its resistance to light is unsatisfactory. The resistance of weighted silk is particularly poor; therefore, silk is not recommended for windows curtains.

7.5.16 Resistance to Perspiration

Silk fabrics are damaged by perspiration. The silk itself deteriorates, and the colour is affected, causing staining.

7.6 End Uses

Silk is used for luxury apparel, household textiles. It is popular in men's neckties for its hand and drape. Silk apparel fabrics are available in a wide range of weights and constructions. The fibre is used alone and in blends with other fibres.

Silk is used in fine drapery and upholstery fabrics. Some of the most expensive handmade oriental rugs are made of silk fibres. Protection from sunlight damage may be provided by careful lining of draperies and the positioning of furniture so that the silk upholstery is not a direct sunlight. Very fine silk filaments are used in eye surgery. Silk sutures still are used by some surgeons. The protein fibre is believed by some to be more compatible with human tissue than sutures of other materials.
7.7 Care

Dry cleaning is usually specified on labels as the preferred method of care for silk garments. Silk may be washed although care should be taken in handling the fabric. Use warm or cold water and a mild detergent. Pretreat stains before laundering, but avoid the use of pretreatments that may contain protein reactive enzymes. If bleach is required, use a nonchlorine bleach.

Avoid wringing the garment, and rinse it thoroughly to remove all detergent. The best method of extracting water from silk garments is to warp them in an absorbent towel and squeeze gently. Silk should not be dried in the sun, nor should it be tumble dried unless the label specifically states that such treatment is acceptable.

Iron or press silk at medium to low temperatures; steam pressing with a press cloth is recommended to avoid producing shiny spots on the fabric.
CHAPTER 8
MINERAL FIBRES

8.1 Asbestos

Asbestos is a natural fibre obtained from varieties of rocks found in Italy, South America and Canada. Other deposits are also found in Russia, Arizona and Africa. The fibre is obtaining by mining or quarrying. The fibre is carefully separated from the crushed rock and sorted according to fibre length.

Asbestos in a fibrous form of silicate of magnesium and calcium, containing iron, aluminum and other minerals. The soft, long, glossy white fibres are pressed into sheets, and the best quality can be spun into yarn.

8.1.1 Properties of Asbestos

Asbestos fibres are 3/8" to 3/4" in length and are quite small in diameter. The physical structure of the fibre makes it very difficult to spin into yarns, because it is lacking in length and cohesiveness. For textile uses, 5 to 20% cotton is blended with asbestos. Asbestos is white or grayish-white in colour. Asbestos fibres do not task dye readily. Some fire screens and draperies have been printed.

Asbestos will not burn, but it will melt at a sufficiently high temperature. It is acidproof and rustproof. Its chemical resistance is excellent, allowing it to be used in some chemical manufacturing processes. The fibre is tough and flexible enough for spinning into yarn, and has low electrical conductivity. The outstanding property of asbestos fibre is its resistance to heat. The fibre fuses at 1520°C (2770°F).

8.1.2 End Uses

Asbestos has been used in making fire fighting suits and fire resistant fabrics and in fireproof materials of many types -theatre curtains, draperies, tiles, auto brake lining, iron holders, and partitions. It is spun around copper wire and wrapped around pipes and joints of high-pressure steam engines. Inferior grades are used for soundproof. It is also used for padding for laundry presses and mangles, belting for conveying hot materials, and in clothing such as gloves, aprons, suits, etc. Dish towels have been made from blends of cotton and asbestos. The asbestos in the blend makes the towel more absorbent and polishes the dishes.
better. Given the safety hazards at asbestos fibre, its use is limited to applications where no substitute for the product is available. Its processing and use, therefore, must be carefully controlled.

8.2 Glass Fibre

\[
\text{Silica Sand} + \text{Lime Stone} + \text{Soda Ash, Borax} \\
\downarrow \\
\text{Marbles of Glass} \\
+ \\
\text{Heat} \\
\downarrow \\
\text{Glass Spinning Solution} \\
+ \\
\text{High Speed Drawing at Semi-liquid Form} \\
\downarrow \\
\text{Glass Filament}
\]

There are two major methods of producing glass fibre yarns. Both begin with accurate batch formulation of selected silica sand, limestone, soda ash, and borax in an electric furnace. From the precisely controlled furnace, the molten glass at temperature of about 2500°F flows to marble-forming machines that turn out small glass marbles about 5/8” (15 mm.) in diameter. These marbles permit visual inspection of the glass for the purpose of eliminating impurities, that would interfere with subsequent operations or lower the desired uniform quality of the fibres. The marbles are then remelted in small electric furnaces and extruded through spinnerettes. Another method eliminates thee marble operation but maintains quality control. The molten glass is extruded directly from the furnace through spinnerettes.

8.2.1 Physical and Chemical Properties of Glass Fibre

8.2.1.1 Strength

Glass fibre is the strongest of all textile fibres. Some types are stronger than equivalent diameters of stainless steel.
8.2.1.1 Elasticity

Glass fibre is virtually inelastic. Being the least elastic of all textiles has obvious disadvantages for clothing, but when used for draperies and curtains, such fabrics will not stretch or sag out of shape.

8.2.1.3 Resilience

The lack of elasticity has no effect on the flexibility and wrinkle resistance of glass fibre fabrics. With the aid of certain finishes, glass fibre fabrics have good wrinkle resistance qualities.

8.2.1.4 Drapability

The fine glass fibres have excellent flexibility and pliability and can be woven into fabrics of excellent draping quality. Consequently, they are excellent for curtains and draperies. Glass fibre fabrics can be easily sewed by hand or by machine with good quality mercerized cotton thread, using a sharp needle, a long stitch, and low tension.

8.2.1.5 Heat Conductivity

As with ordinary glass yarns made of glass fibre are good conductors of heat. Yet, when glass fibre is in staple form, the thousands of fibres form cells of trapped air. These dead air spaces act as excellent insulation and make glass fibre staple batting very effective as an interlining in jackets and coats. (The same principle is applied to insulate refrigerators and gloves)

8.2.1.6 Absorbency

Glass fibre is not absorbent. Being nonabsorbent, these fabrics are water-repellent, and, in general, unaffected by water. This quality makes glass fibre unsuitable for clothing worn next to the skin because perspiration and humidity make the fabric uncomfortable.

8.2.1.7 Cleanliness and Washability

The cleaning of these fabrics is simple and quick. They may be wiped clean with a damp cloth. If the fabrics are hung properly while wet, ironing is unnecessary.
8.2.1.8 Effect of Bleaches

Glass fibre is unaffected by bleaches.

8.2.1.9 Shrinkage

Glass fibre is dimensionally stable. It will not shrink because it is unaffected by water.

8.2.1.10 Effect of Heat

Glass fibre is highly resistant to heat and will not burn. The types available for general consumer use begin to lose strength at about 600°F (315°C) and they soften above 1350°F (732°C).

8.2.1.11 Effect of Light

Sunlight has no effect on glass fibre fabrics. This makes them useful for outdoor purposes, as well as for such decorative fabrics as curtains and draperies.

8.2.1.12 Resistance of Mildew

Glass fibre is unaffected by mildew, but the binder or resin used to finish or size such as a fabric may be attacked by mildew.

8.2.1.13 Resistance to Insects

Moths and other insects do not attack glass fibre.

8.2.1.14 Reaction to Alkalies

Glass fibre is resistant to most alkalies.

8.2.1.15 Reaction to Acids

Glass fibre is damaged only by hydrofluoric and hot phosphoric acids.

8.2.2 End Uses

Glass fibres are used primarily as industrial fibres. Everyday uses of industrial fibres in products such as window screens, insulation, reinforcement for fishing poles, skis and boat hulls are more familiar to consumers. The fibres also are found in printed circuit boards, electrical insulation, aircraft interiors, gaskets and high-temperature filtration fabrics.
Glass fibre is used in such home furnishings as draperies, curtains, lamp shades, and ironing board covers. Glass is not used in apparel because the shape ends of the fibre at the cut edges of the fabric frequently cause skin irritation.

8.2.3 Care

Fibreglass often can be wiped clean with a damp cloth. When additional cleaning is needed, laundering is the preferred method. Hand laundering is recommended because fibre residue is difficult to remove from washers and dryers.

Mild detergents are recommended, and when materials must be bleached, either oxygen bleaches or dilute chlorine bleaches may be used. Fabrics should be handled carefully to avoid breaking the fibres. They should not be washed in the same container with other types of fabrics because tiny fibre residues may be deposited on the other fabrics.

Machine drying is not recommended; instead, carefully press water from the fabrics. The fabrics dry very quickly in the air because they absorb very little moisture when immersed in water.
CHAPTER 9
RAYON

9.1 Introduction

Rayon is a manmade cellulose fibre in which the starting material, wood pulp or cotton linters, is physically changed. The first rayon data had a brilliant, harsh lustre, was rather stiff, and did not hold its shape well. Colours were not uniform or very fast. Because it lost so much strength when wet, it had poor washability. The development of rayon was a hard struggle for its manufacturers. The manufacturers had so much confidence in rayon that they spent time and money on research to find out how to make their product better. They defined rayon as “Manmade textiles fibres and filaments composed of regenerated cellulose and yarn, thread, or textile fabrics made of such fibres and filaments”. A regenerated fibre is one which has a different physical structure than the substance from which it is made, but is essentially the same chemically. Rayon is Regenerated Cellulose, i.e., a cellulose that has gone through the manufacturing process, from solid to liquid to solid, without chemical change.

The manufacturing process of regenerated fibres consists of bringing a natural high polymer substance into solution in a suitable way and extruding this solution through an nozzle (orifice), regenerating the same high polymer in the form of a solid filament.

Rayon is a general term for manmade filaments prepared from various solutions of modified cellulose. Rayon, like other manmade fibres, are used in either continuous form or in staple form. Ordinary rayons are termed “bright” because finished products of these fibres appear “glossy” to the naked eye. In “delustered” rayons, this glossiness is reduced by the presence of fine particles of titanium dioxide (TiO₂) inside the fibre which scatter the light. This compound is added as a fine powder to the spinning solution to obtain the “dull” fibre. Oil emulsions are also used.

Two types of rayon, viscose and cuprammonium, are made of regenerated cellulose, and their differences are due to the differences in the chemicals used to put the cellulose into solution.
9.2 Viscose Rayon

Figure 9.1 Viscose Flow Chart

Cellulose + NaOH
(Cotton linter, wood pulp)
↓
Alkali Cellulose + Carbon Disulphide
↓
Cellulose Xanthate + NaOH (dilute)
↓
Viscose Spinning Solution
↓ Wet Spinning in Fluid Acid Bath
Viscose Filament
↓ Drawing and Stretching
Viscose Filament for Textile Use
The starting material for viscose, usually wood pulp, is purchased as sheet of purified cellulose. These sheets are placed in presses two to each division, and steeped in caustic soda for 30 to 60 minutes (Figure 9.1). They are then squeezed by a hydraulic ram to remove excess liquid, taken from the presses and dropped into a shredding machine, which breaks up the pulp into small crumbs. These alkali cellulose crumbs are aged for one to three days. After aging, the crumbs are treated with carbon disulphide (CS₂), which causes the crumbs to change from the white to orange and to change chemically so they will dissolve readily. This process is called xanthation. The crumbs are then treated with a dilute solution of caustic soda which converts them to a liquid known as viscose solution.

The lustre of rayon is controlled at this point by the addition of a delustering agent, usually titanium dioxide. Colour can also be added to the spinning solution of this time.

The viscose solution is allowed to stand (age) for 4 to 5 days. It is filtered to remove air bubbles and insoluble particles and is then pumped through spinnerette into an acid bath. The sulphuric acid causes the cellulose xanthate to coagulate, thus forming regenerated cellulose or rayon.

The spinnerette is a small thinable like cup made of platinum or some other precious metal, containing a number of fine holes from 0.002 to 0.005 inch in diameter. Each hole in the spinnerette forms one filament or strand.

9.3 Physical and Chemical Properties of Rayon

9.3.1 Strength

The tensile strength of viscose rayon is greater than that of wool, but is only about half as great as that of silk. Viscose rayon is also weaker than cotton and linen and its strength is reduced 40 to 70% when wet. The strength is controlled by stretching, which causes a greater orientation of the molecules. Viscose is easily stretched when wet and swollen. If dried in a stretched condition, it will relax and shrink upon again becoming wet.

9.3.2 Elasticity

Viscose rayon has greater elasticity than cotton or linen but less than wool or silk.
9.3.3 Drapability

Viscose rayon possesses a marked quality of drapability because it is a relatively heavyweight fabric. The filament can be made as coarse as desired depending on the holes in the spinnerette.

9.3.4 Resilience

Viscose rayon lacks the resilience natural to wool and silk and creases readily; but it should be remembered that the resistance of a fabric to creasing depends on the kind of yarn, weave, and finishing process.

9.3.5 Heat Conductivity

Viscose rayon is a good conductor of heat and is therefore appropriate for summer clothing. Spun rayon fabrics, however, are adaptable to winter apparel because they can be napped.

9.3.6 Absorbency

Viscose rayon is a one of the most absorbent of all textiles. It is more absorbent than cotton or linen. The combination of high heat conductivity and high absorbency of rayon makes it very suitable for summer wear.

9.3.7 Cleaning and Washability

Because of its smoothness, viscose, rayon fibre helps to produce hygienic fabric that shed dirt. Some viscose rayon fabrics wash easily, and depending on the finish that may be given to them, they will not become yellow when washed or dry cleaned. Regular rayon fabrics have limited washability because of the low strength of the fibre when wet. When laundered, a mild soap or detergent and warm water should be used.

9.3.8 Shrinkage

Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Knitted fabric always shrink more than flatwoven fabrics because of the nature of the construction. When spun viscose rayon is blended with wool, the great amount of shrinkage characteristic of the wool is reduced.
9.3.9 Affect of Heat

   Since viscose rayon is a pure cellulose fibre, it will burn in much the same manner as cotton. Application of heat at 300°F (150°C) causes viscose rayon to lose strength; above 350°F (177°C), it begins to decompose.

9.3.10 Effect of Light

   Viscose rayon has generally good resistance to sunlight, though prolonged exposure of intermediate tenacity rayon results in faster deterioration and yellowing.

9.3.11 Resistance to Mildew

   Like cotton, viscose rayon has a tendency to mildew. Moths are not attracted to cellulose. Consequently, moth-proffing treatments are not necessary for viscose rayon. Resistance to other insects is also similar to that of cotton.

9.3.12 Reaction to Alkalies

   Viscose rayon is fairly resistant to alkalies and oxidizing agents but tends to be harmed to a greater extent by alkalies than are cotton or linen. A mild soap and warm water is recommended when laundering such garments.

9.3.13 Reaction to Acids

   Viscose rayon reacts to acids in a manner similar to cotton. It is harmed by acids. Being pure cellulose, the fabric is disintegrated by hot dilute and cold concentrated acids.

9.3.14 Affinity for Dyes

   Viscose rayon has good affinity for most cotton dyes. Viscose rayon fabrics absorb dyes evenly and can be dyed with a variety of dyes, such as direct, acid, chrome and disperse. Coloured viscose rayons have a high resistance to sunlight. This property makes them suitable for window curtains.

9.3.15 Resistance to Perspiration

   Viscose rayon is fairly resistant to deterioration from perspiration. The colour, however, is not usually as resistant as the fabric and will fade if not solution-dyed.
9.4 Cuprammonium Rayon

Figure 9.2 Flow Chart of Cuprammonium Rayon Production

Cellulose + Copper Oxide + Ammonia

(Cotton linter or wood pulp) ↓
Currammonium Spinning Solution
↓ Wet Spinning in Water Bath
↓ Acid Wash
↓ Water Wash
Currammonium Rayon Filament

Cotton lintes or wood plus are dissolved in copper oxide and ammonia forming spinning solution at low temperature. The solution is filtered and aged. It is then pumped through spinnerettes. In this process, a spinnerette with fairly large holes is fitted into a glass cylinder containing a long, tapering funnel. Water from the spinning bath is admitted at the bottom of the cylinder and flows up and comes out through the funnel with the rayon filaments into a slightly acid spinning bath. It is the force and flow of the water which stretches the filaments as they come through the funnel. The final coagulation occurs in the sulphuric acid bath. The finished yarn is wound on reels in skain form. The yarns are decoppered, washed, soaped, and dried. The washing removes any traces of blue colour.
9.5 Properties of Cuprammonium Rayon

Cuprammonium is stronger than viscose rayon. It has good strength, absorbency and takes dyes well. It’s strength reduces in sunlight. It swells in strong alkali and reduce in strength.

9.6 End Uses

Chiffons fabrics, sheerest fabric, underwear, woman’s fine hosiery, gloves, socks, lining materials, fine warp-knit underwear.

9.7 Acetate

![Flow Chart of Acetate Rayon Production](image)

**Figure 9.3 Flow Chart of Acetate Rayon Production**

\[
\text{Cellulose} + \text{Glacial Acetic Acid} + \text{Acetic Anhydride} + \text{Sulphuric acid} \downarrow \\
\text{(Cotton lint, wood pulp)} \downarrow \\
\text{Primary Cellulose Acetate} + \text{Water} \downarrow \\
\text{(Cellulose tri-acetate)} \downarrow \\
\text{Secondary Cellulose Acetate} + \text{Acetone} \downarrow \\
\text{Acetate Spinning Solution} \downarrow \\
\text{Dry Spinning in Warm Air} \\
\text{Acetate Filament}
\]
Cotton linters or wood chips are converted into sheets of pure cellulose. The cellulose is steeped in glacial acetic acid and aged for a period of time under a controlled temperature. After aging, it is thoroughly mixed with acetic anhydride. A small amount of sulphuric acid is then added as a catalyst to facilitate a reaction producing a thick, clear liquid solution of cellulose acetate. After further aging, water is added, and causing the cellulose acetate to precipitate as white flasks. The flasks are dried, dissolved in acetone, and filtered several times to remove impurities. The result is clear, white spinning solution of the consistency of syrup.

If delustered yarn is required, titanium dioxide, a delusterant, is added at this stage to produce the desired degree of brightness: bright, semidull, or dull. Dyestuff may be added to the spinning solution to provide superior colour-fastness. After the delusterant has been added, the spinning solution is forced through a spinnerette and into a cabinet of heated air that evaporates the acetone and solidifies the filament. The filaments are then ready for winding on spools, cones, or bobbins ready for shipping to the mills for weaving or knitting. Staple fibres are cut, crimped, lubricated, dried, and baled for shipment.

9.8 Physical and Chemical Properties of Acetate

The properties of acetate fabrics will vary to some extent depending on the type of yarn used (filament, textured, or spun), on the type of fabric construction, and on the finish.

9.8.1 Strength

Acetate is not a strong fibre. It is weaker than any rayon and is, in fact, one of the weakest textile fibres. It loses much of its strength when wet.

9.8.2 Elasticity

Acetate is more elastic than any rayon.

9.8.3 Resilience

Acetate is more wrinkle resistant than any rayon; consequently, the fabric will tend to return to its original shape much better than will rayon after it is pulled or crumpled. After washing, acetate garments should be carefully hung to permit the yarns to relax to their original shape.
9.8.4 Durability

Acetate fabrics have good body and flexibility and therefore drape very nicely.

9.8.5 Heat Conductivity

Acetate does not have as high a rate of heat conductivity as rayon and therefore is warmer. Acetate is consequently more useful for linings and warmer clothing, particularly if it is spun acetate.

9.8.6 Absorbency

Acetate is not very absorbent. It absorbs only half as much moisture as the rayons. Acetate fabric get wet mostly on the surface and will not become saturated; therefore; they dry quickly. This makes acetate very suitable for shower curtains, umbrellas, and rain coats. It is also suited for bathing suits, particularly at the seashore because salt water does not have any deteriorating effect on acetate. On the other hand, acetate is uncomfortable in warm, humid weather because of its low absorbency. Acetate garments, such as blouses and lingerie, worn next to the skin feel clammy and uncomfortable because they do not absorb atmospheric humidity.

9.8.7 Cleanliness and Washability

Acetate fibre smoothness helps to produce hygienic fabrics that shed dirt and wash easily. They will not become yellow when washed or dry cleaned.

Since acetate temporarily loses some strength when wet, such fabrics must be handled with care when washed. When laundered, a mild soap or detergent and warm water should be used. The garments should not be rubbed rigorously but should be handled gently and squeezed to remove the water. They will dry readily and should be hung so that the water will drip off. Acetate garments dry clean well.

9.8.8 Effect of Bleaches

White acetate remains white, and acetate fabrics need not be bleached. If bleaching is desired, it should be done with a very mild solution of hydrogen peroxide or a very dilute solution of sodium hypochlorite.
9.8.9 Shrinkage

Acetate fabrics will shrink less than any rayon. Sometimes they are given a shrink resistant finish.

9.8.10 Effect of Heat

Acetate fabrics need less ironing than rayon fabrics. A warm iron will easily smooth out an acetate fabric, particularly if the fabric is a little damp. If the irons is too hot, it will melt the acetate causing it to stick to the iron and make the fabric stiff.

9.8.11 Effect of Light

Acetate is more resistant to the effect of light than cotton or any rayon. Over a period of time, acetate will be weakened from exposure to light.

9.8.12 Resistance to Mildew

Acetate is highly resistant to mildew. It is ideal for fabrics exposed to moisture, such as shower curtains.

9.8.13 Reaction to Alkalies

Strong alkalies should not be used on acetate since they cause a chemical change in the fibre.

9.8.14 Reaction to Acids

Acetate is more resistant to acids than pure cellulose, but it will be decomposed by concentrated solutions of strong acids.

9.8.15 Resistance to Perspiration

Acetate fabrics are fairly resistant to deterioration by perspiration, but the colour will be affected if it has not been solution-dyed.

9.9 End Uses

Acetate is used in woman’s apparel for its hand and drape. Decorative fabrics for the home may contain acetate or blends of acetate with other fibres. Upholstery fabrics, drapery
fabrics, and drapery linings are often made of acetate. The major industrial use for acetate is in cigarette filters. The abrasion resistance of the fibre is fairly low.

9.10 Care

Reading the care instructions for acetate and rayon fabrics is especially important. Acetate is the more delicate fibre.
CHAPTER 10
NYLON (POLYAMIDE)

10.1 Methods of Manufacture

The word “nylon” is a generic term that designates a group of related chemical compounds classified as *polyamides*.

![Flow Diagram for a Process Used to Manufacture Nylon](image)

**Figure 10.1 Flow Diagram for a Process Used to Manufacture Nylon**

Carbon (coal) + Nitrogen (air) + Hydrogen (water) + Oxygen (air) +
Adipic Acid and Hexamethylene Diamine

↓

Amide (Nylon Salt)

↓

Heated in Vacuum (Loss of Water)

↓

Nylon Super Polymer

↓

Heated

Nylon Spinning Solution (Polyamide)

↓

Dry Spinning (Cool Air)

↓

Drawing and Stretching

Nylon Filament
Nylon is actually a group of related chemical compounds. It is composed of hydrogen, nitrogen, oxygen and carbon in controlled proportions and structural arrangement. Variations can result in types of nylon plastics, such as combs, brushes, and gears.

By a series of chemical steps beginning with such raw materials as coal, petroleum, or such cereal byproducts as oat hulls or corncobs, two chemicals called hexamethylene diamine and adipic acid are made. These are combined to form nylon salt. Then, since the nylon salt is to be shipped to the spinning mill, it is dissolved in water for easily handling. At the spinning mill, it is heated in large evaporators until a concentrated solution is obtained. The concentrated nylon salt solution is then transferred to an autoclave, which is like a huge pressure cooker. The heat combines the molecules of the two chemicals into giant chainlike ones, called linear superpolymers. The linear superpolymer is then allowed to flow out of a slot in the autoclave onto a slowly revolving casting wheel. As the ribbons of molten nylon resin are deposited on the wheel, they are sprayed with cold water, which hardens them to milky white opaque ribbons. The ribbons are removed from the casting wheel to a chipper, which transforms them into flakes.

Nylon flakes are blended and poured into the hopper of the spinning machine to insure uniformity in the final nylon yarn. Through a valve in the bottom of the hopper, the nylon flakes fall onto a hot grid, which melt them. The molten nylon is pumped through a send filter to the spinnerette. The spinnerette has one or more holes, depending on the purpose for which the yarn is to be made. As the filaments come out of the spinnerette and hit the air, they solidify. This filament can be changed, however, by stretching or cold drawing, the filaments from two to seven times their original length. The amount of stretching is dependent on the diameter, elasticity, and strength desired. As the filaments are stretched, they become more and more transparent. The polyamide molecules straighten out, become parallelized, and are brought very close together. Up to a point, the nylon becomes stronger, more elastic, more flexible and more pliable.

10.2 Types of Nylon Yarn

The diameter of the individual nylon filaments is determined by the rate of delivery from the pump to the spinnerette, by the number of holes in the spinnerette, and by the rate at which the yarn is drawn away from the spinnerette. The denier, or size, of the yarn before
drawing is determined by the diameter, and number of filaments in the yarn. The size of the yarn after drawing is determined by its original diameter and the amount of cold-drawing. If it is drawn three times its original length, the stretched yarn will be one-third of its original diameter. The individual filaments produced usually range from 1 to 15 denier.

10.2.1 Monofilament Yarns

Though single-filament; or monofilament, yarns are produced, or heavier yarns are more often manufactured. The monofilament yarns are used for hosiery and for industrial filters. These yarns are very fine and have little or no twist. Heavier and stronger monofilament yarns are also produced for various purposes.

10.2.2 Multifilament Yarns

Multifilament yarns are made in both standard and high-tenacity forms. The number of filaments in each yarn varies according to the purpose of the yarn. The yarns generally range in denier from 20 to 210. Multifilament yarns are stronger than monofilament yarns because of the numerous filaments. The strength can be increased by the amount of twist given to the yarns.

10.2.3 Stretch Yarns

Nylon filament can be produced to have a crimp or coiled characteristic. This gives yarns made of such nylon filament the ability to be greatly stretched and come back to shape when the tension is released. These yarns are produced under several trademarks, of which one of the better known is Helanca.

10.2.4 Textured Yarns

Nylon filaments can also be produced to have a looped characteristic. Crimp-textured nylon is sometimes referred to as BCF nylon—that is, bulk continuous filament nylon. It is given a permanent crimp by the producer. One of the best known of textured yarn is Taslan, which is used for sport shirts and similar apparel. Some textured filament yarns have a curly appearance that imparts a resilient, springy effect called left.
10.2.5 Spun Yarns

Nylon filaments may be cut about 1 to 5 inches (15-125 mm.) in staple length. The individual filaments range in denier from 1.5 to 15. The staple is usually crimped and spun on a cotton system. These yarns are fuzzy and soft. They have lower tensile strength but greater abrasion resistance. They are not so elastic as the filament yarns and take longer to dry.

10.3 Physical and Chemical Properties of Nylon

10.3.1 Strength

Nylon is produced in both regular and high tenacity strengths. Although one of the lightest textile fibre, it is also one of the strongest. The strength of nylon will not deteriorate with age. These advantages make nylon desirable for sheer hosiery, curtains, blouses, dress fabrics, upholstery and carpets. Nylon not only has great tensile strength with lightweight, it is also tough and pliable. Nylon has the highest resistance to abrasion of any fibre. Spun nylon yarn has even a higher abrasion resistance than filament nylon, which makes it desirable for socks and upholstery.

10.3.2 Elasticity

Nylon is one of the most elastic fibre that exists today, though it does not have the exceptional elastic quality of spandex fibre. After being stretched, nylon has a strong natural tendency to return to its original shape, and has its own limit to elasticity. If stretched too much, it will not completely recover its shape. In addition, the type of yarn and the construction of the fabric may contribute to the behaviour of the garment. eg., spun nylon is not so elastic as filament nylon. Knitted spun nylon fabrics, such as those used in sweaters, will sag more easily than knitted filament nylon fabrics.

10.3.3 Resilience

Nylon has excellent resilience. Nylon fabrics retain their smooth appearance, and wrinkles from the usual daily activities fall out readily. Pile fabrics, such as velvets and carpets, keep a neat uncrushed appearance.

10.3.4 Shrinkage

Nylon has good dimensional stability and retains its shape after being wet.
10.3.5 Drapability

Fabrics at nylon yarn have excellent draping qualities. Lightweight sheers may have a flowing quality, medium-weight dress fabrics can drape very nicely, and heavier weight jacquards also drape well.

10.3.6 Heat Conductivity

Nylon fabrics may or may not conduct heat well. The warmth or coolness of a nylon garment depends on the weave of the fabric and on the type of yarn used. The smoothness, roundness, and fineness of nylon filaments permit the manufacture of very smooth, very fine yarns, which can be packed very closely when weaving the fabric. If nylon fabric is woven compactly, it will not be porous. The tight construction will not permit air to circulate through the fabric, and the heat and moisture of the body will not readily pass through it but will built up between the fabric and the body; so, the wearer will feel very warm. Such fabrics are good for winter apparel, such as wind breakers, but are not suitable for summer garments.

On the other hand, these fine nylon filament yarns may be woven into extremely thin, lightweight, sheer fabrics. These materials are very porous and permit the circulation of air. Consequently, they are cool and can be used for summer blouses and curtains. Spun nylon yarn will produce warm fabrics. These yarns are compared of thousands of short, crimped fibres twisted together, which provide millions of tiny dead-air spaces that act as insulators. This insulation makes spun nylon fabrics warm.

10.3.7 Absorbency

Nylon does not absorb much moisture. Fabrics made of nylon filament yarns will not readily wet through the material-most of the water remains on the surface and runoff the smooth fabric, which therefore dries quickly. Such fabrics are useful for rain coats and shower curtains. Spun nylon fabrics, however, will not dry quickly. Nylon's low absorbency has a disadvantage in that the fabric feels clammy and uncomfortable in warm, humid weather.
10.3.8 Cleanliness and Washability

Because of nylon's smooth surface, dirt and stains often come clean merely using a damp cloth. To wash nylon garments by hand or washing machine, use lukewarm water at about 100°F (38°C) and a detergent or soap with a water softener.

White nylon fabrics should always be separated from coloured fabrics before washing because the nylon will pick up colour and develop a dingy gray appearance that is extremely difficult to remove. Nylon filament fabrics dry very quickly. They need little or no ironing because the garments are usually heatset to retain their shape, pleats or creases. Spun nylon has a tendency to pill or form balls, on the surface of the fabric. To minimize this, such fabrics should not be rubbed. They should be washed gently, preferably by hand. Brushing with a soft brush will reduce the pilling.

10.3.9 Effect of Heat

Like acetate, nylon will melt if the iron is too hot, therefore, the iron should be set at the proper heat level. It does not burn readily but melts to form glossy beads formation.

10.3.10 Effect of Light

Bright nylon is more resistant to the effects of sunlight than most other fibres. Dull nylon will deteriorate a little more quickly than bright nylon; however, even dull nylon has good resistance to light.

10.3.11 Resistance to Mildew and Insects

Mildew has absolutely no effect on nylon. Mildew may form on nylon, but it will not weaken the fabric. Moths and other insects will not attack nylon because it has no attraction for them.

10.3.12 Reaction to Alkalies

Nylon is substantially inert to alkalies. No reaction with soap, alkalis and alcohols.

10.3.13 Reaction to Acids

Nylon is decomposed by cold concentrated solutions of such mineral acids as hydrochloric, sulphuric and nitric acids. A boiling dilute 5% solution of hydrochloric will destroy nylon.
10.3.14 Affinity for Dyes

Nylon can be more easily dyed with a wider range of dyes. Nylon retains their colour and have good resistance to fading.

10.3.15 Resistance to Perspiration

Nylon fabrics are resistant to perspiration. The colour, however, may be affected.

10.4 End Uses

*Domestic Used*

Women’s hosiery, stockings, lingerie, shirts, underwear, socks, dress materials, children garments, knitting yarns, blouses, coat, pyjamas, gloves, rainwear, outer wear, carpet, table cloth, slippers, sportwear, swimming suits, night wear, laces, bed sheets, rugs, cords, ropes, cables, and fur fabrics, etc.: 

*Industrial Used*

Tyre cords, air plane tyres, conveyor belts, ropes, sail cloth, filter cloth, webbing, firehose, parachutes, tennis racket strings, electrical insulations, machine belts, fishing nets, cordage, car-seat cover, working cloths, and book cloths, etc.: 

10.5 Care

Nylon is easy to care for. The first drip-dry, no-iron clothing was made of nylon. Hot water does not harm the fibre, but wrinkles is minimized by the use of warm or cold water.

An iron that is too hot may melt the fibre, glaze the surface of (scorch) the fabric, or actually make a hole or void ironing wrinkles into it. Once heat-set wrinkles are put into a fabric, it is difficult to remove them, so care should also be taken to avoid squeezing or compressing the fabric during laundering at hot temperatures. Follow the care labels on such fabrics carefully.
CHAPTER 11
DACRON (POLYESTER FIBRE)

11.1 Methods of Manufacture

Figure 11.1 Flow Diagram for the Process Used to Manufacture Polyester

Terephthalic Acid + Ethylene Glycol

Polymerization

Polyester + Highly Heated

Polyester Spinning Solution

Melt or Dry Spinning (Cool Air)

Dacron Filament

Drawing and Stretching

Dacron Filament for Textile Use

The process of manufacture of polyester fibre is similar to that of nylon, but the chemicals used are different. The principal raw materials are ethylene glycol and terephthalic acid, in an reactor at a high temperature in a vacuum. The starting products are polymerized...
at high temperatures and then filtered to remove any impurities. The molten polymer may be spun directly or it may be extruded in cooled air and through a spinnerette.

During the extrusion step, the molten polymer is metered through a spinnerette. The filaments solidify in cooling air and are taken up on large bobbins or pins. The filaments must be drawn to orient the polymer and develop the fibre properties of the filament. The fibre may be completely drawn after extrusion, or it may be partially drawn to form a partially oriented yarn (POY). Careful control of the drawing process is required to produce the tenacity and elongation required by the customer.

11.2 Types of Polyester Yarn

The diameter of the polyester yarn is determined by (i) the rate of extrusion of the filaments from the spinnerette, (ii) the number of spinnerette holes and therefore the number of filaments, and (iii) the rate of drawing of the filaments. The yarns come in a wide range of diameters and staple lengths. The yarns are produced, basically as monofilament, multifilament and spun.

11.2.1 Filament Yarns

Filament yarns are produced of PET (polyethylene terephthalate) polyester. They are made in monofilament and multifilament forms. The direction and amount of twist are determined by the desired end use. Bright, regular tenacity polyester yarn is one popular type. It has good light resistance, as well as stretch and sag resistance. It can be used for sheer, lightweight fabrics and is very suitable for curtains. Another very popular type is the regular tenacity, semidull yarn. It is used for a wide variety of apparel, including dresses and lingerie. A duller version is used for shirts and blouses.

Polyester yarns, which are resistant to various chemicals, seawater, and microorganisms, are made of a bright, high tenacity fibre for such industrial uses as conveyor belts, ropes, netting and sails.

11.2.2 Textured Yarns

Textured polyester yarns are produced of PET multifilaments. They are given a texturizing either in conjunction with the drawing process or subsequently as part of the throwing and texturizing process in producing the finished yarns.
11.2.3 Spun Yarns

Spun yarns are made of staple or of cut, cramped two of PET polyester fibre. The staple is produced in a wide range of deniers and lengths according to the desired end uses. The staple may be bright, semidull or dull. The fibre may be polished to reduce the crimp and increase the lustre. The staple may be spun directly into yarn or blended with other staple, such as cotton, wool or yarn and then spun into yarn.

The type of fibre cut into staple depends upon the ultimate end use. Semidull, regular tenacity polyester staple may be spun on either the cotton or wool system, depending upon the ultimate yarn desired.

Finer yarns are used for summer suiting that require both unusual resiliency and dimensional stability to prevent puckering and change in shape during humid weather. Heavier yarns made of this staple may be used for outerwear and for knitted fabrics because of their exceptional shape retention and stretch resistance. Polyester staple is also produced for fibrefill, rather than yarn. It is lightweight and has excellent resilience and loft, which provides comfort and insulation since it is also non-allergenic, it is used for pillows, quilting, skiwear and sleeping bags.

11.3 Physical and Chemical Properties of Dacron

11.3.1 Strength

Polyester fibres may be characterized as relatively strong fibres. Fabrics of regular tenacity polyester filament yarns are very strong and durable. The high-tenacity polyester filament yarns used for tires and industrial purposes are extremely strong; some types are the strongest of all textiles except glass, aramid etc. The staple fibres also vary in strength depending on the type of fibre.

The abrasion resistance of polyester fibre is exceptionally good. The strength, abrasion resistance, and stability of polyester make it very suitable for sewing thread.

11.3.2 Elasticity

Polyester fibres do not have a high degree of elasticity. In general, polyester fibre is having a high degree of stretch resistance. This property makes polyester suited for knitted garments; sagging and stretching that would ordinarily occur are reduced. Fabrics of polyester fibre have good dimensional stability.
11.3.3 Resilience

Polyester fibre has a high degree of resilience. Not only does a polyester fabric resist wrinkling when dry, it also resists wrinkling when wet. And heat set polyester fibre is suitably resilient for use in carpets.

11.3.4 Drapability

Fabrics of polyester filament yarn have satisfactory draping qualities. Staple polyester can produce spun yarn that is more flexible and softer, thereby imparting the draping quality. Drapability of fabrics of blended polyester staple will depend upon the type and proportion of blend in the yarn as well as the fabric construction.

11.3.5 Heat Conductivity

Fabrics of polyester fibre are better conductors of heat. The basic polyester filament fibre is round. This results in a smoother yarn woven into fabrics with fewer air spaces and less insulation. Polyester staple fibre is crimped and this does provide greater insulation in the yarns and fabrics.

11.3.6 Absorbency

Polyester is one of the least absorbent fibres. This low absorbency has two important advantages. Polyester fabrics will dry very rapidly since almost all the moisture will lie on the surface rather than penetrate the yarns. Fabrics of polyester fibre are therefore well suited for water-repellent purposes, such as rainwear. Furthermore, this low absorbency means that polyester fabrics will not stain easily. Many substances lie on the surface and can be wiped or washed off easily.

Fabrics of low absorbency generally have the disadvantage of being clammy and uncomfortable in humid weather because they will not absorb perspiration or atmospheric moisture. As a result, an absorbent fibre such as cotton is often blended with the polyester staple.

11.3.7 Cleanliness and Washability

Since polyester fibres are smooth and have a very low absorbency, many stains lie on the surface and can easily be washed by hand or machine. Strong soaps are not needed.
However, oil stains are more stubborn and under certain circumstances cannot be entirely removed. Fabrics of polyester filament yarn dry very quickly. When ironing polyester fabrics, it is best to use low to medium heat. Excessive heat will cause polyester to melt. Actually, little ironing is needed even after long wear or after being completely wet, because garments made of polyester hold their shape and creases after being heat-set. Furthermore, the wrinkle resistance of polyester is extremely good. Fabrics of spun polyester yarn that have a tendency to pill should be washed gently and brushed with a soft brush.

11.3.8 Effect of Bleaches

Polyester fabrics may be safely bleached because polyester had good resistance to deterioration by household bleaches. If the polyester has an optical brightener, no bleaching is necessary.

11.3.9 Shrinkage

Polyester fabrics shrink as much as 20% during wet-finishing operations. Finished polyester woven and knitted fabric will not shrink. They have excellent dimensional stability.

11.3.10 Effect of Heat

Depending upon the type, polyester will get sticky at 440 to 468°F (227–242°C). Therefore, if ironing is needed, it should be done at lower temperatures. At temperature in the range of 480 to 554°F (249–290°C), polyester will melt and flame.

11.3.11 Effect of Light

Polyester has good resistance to sunlight. Fabrics of polyester are therefore well suited for outdoor use. Over a prolonged period of exposure to direct sunlight, however, there will be a gradual deterioration of the polyester fibre. When exposed to sunlight behind glass, polyester shows a considerable increase in resistance to sunlight, it has a marked superiority over most other fibres under these conditions and is very well suited for curtains.

11.3.12 Resistance to Mildew and Insects

Polyester fabrics are absolutely resistant to mildew. They will not be stained or weakened. Mildew should readily wash off the fabrics without any deterioration to it.
However, there may be some discoloration. Polyester is also unaffected by moths, carpet beetles, silverfish or other insects.

11.3.13 Reaction to Alkalies

At room temperature, polyester has good resistance to weak alkalies and fair resistance to strong alkalies. This resistance is reduced with increased temperature. At boiling temperature, it has poor resistance to weak alkalies and dissolves in strong alkalies.

11.3.14 Reaction to Acids

Depending upon the type, polyester has excellent to good resistance to mineral and organic acids. Highly concentrated solution of a mineral acid, such as sulphuric acid, at relatively high temperatures will result in degradation.

11.3.15 Affinity for Dyes

Polyester can be dyed with appropriate disperse, azoic, and developed dyes at high temperatures, producing a good range of shades that have good-to-excellent wash fastness and fair-to-good light fastness.

11.3.16 Resistance to Perspiration

Polyester has no significant loss of strength from continued contact with either acid or alkaline perspiration.

11.4 End Uses

Polyester is widely used in apparel and home furnishing fabrics. In apparel, it is used in filament form in knit and woven fabrics and in staple form in 100% polyester yarns and blends. Polyester can be blended with cotton, wool, linen, silk, rayon, acrylic and nylon. Blends for two or more fibres are used.

The fibre is used in lingerie, swimsuit, outerwear, neckties, and men’s underwear (blended with cotton). Polyester garments pack and travel well because the fibre is so wrinkle-resistant. The major reason for their use is ease of care.

Special polyester fibre-fill products are used to stuff upholstered furniture, pillows and mattress pads. Industrial uses for polyester fibre include tire cord, fire hoses, sail cloth, rope, twine, and conveyor belts.
Polyester is also used in the medical field. Artificial arteries other surgical implants materials are made of polyester fibres.

11.5 Care

Polyester usually is advertised as “the easy-care fibre”. It can be machine washed and dried. Oily stains may be a problem, but pretreating with one of the prewash sprays that contain solvents or with concentrated liquid detergent helps to remove oily stains. As with any fabric, follow care instructions for the best results.
CHAPTER 12
MINOR MANMADE FIBRES

12.1 Vinyon

Vinyon is produced by co-polymerizing polyvinyl chloride and polyvinyl acetate. The resultant vinyl resin is dissolved in acetone, filtered, and then stored in heated tanks as a viscose solution. It is extruded through a spinnerette down a hollow tube in the warm air which evaporates the acetone, producing filaments in tow form. The tow is then passed through a lubricating bath and cut into staple.

12.1.1 Properties of Vinyon

Vinyon is a relatively weak fibre, but has high extensibility. Vinyon is essentially water-repellent, since it will absorb less than 0.1% moisture. It has high resistance to acids and alkalies, and is insoluble in gasoline, alcohols, glycols, and mineral oils. It will not take dyes well special techniques are required to colour it. The effect of sunlight or age is negligible. It is not affected by perspiration and is nontoxic. Although vinyon will char to a black ash in flame, it will not support combustion.

12.1.2 Uses of Vinyon

Vinyon is primarily used as a bonding fibre in nonwovens because of its heat-reactive properties. Its widest application is in heat-sealable paper, full and needled felts, and bonded fabrics. Due to its low strength and high extensibility, vinyon staple is not suitable for spinning into yarn. Such yarns have been woven into fabrics for industrial applications.

12.2 Saran

The raw material used to produce vinylidene chloride are ethylene, which is derived by cracking natural petroleum, and chlorine, which is electrolyzed from seawater. Ethylene is treated with chloine to produce trichloroethane, which in turn is treated with lime to produce vinylidene chloride. The vinylidene chloride is then copolymerized with a small quantity of vinyl chloride to produce a powdered resin. The resin is melted and extruded through a spinnerette into a water-cooling bath.
12.2.1 Properties of Saran

Saran is of moderate strength, being weaker than any natural fibre except wool but stronger than rayon. Woven saran fabrics have excellent abrasion resistance. It has a fair degree of stretchability but its return to size is gradual. Saran is a rather stiff fibre, and, while fairly resilient, it could be permanently deformed by crushing. Like vinyon, saran is essentially nonabsorbent. Fabrics have excellent stain resistance and the surfaces can be easily cleaned by wiping with a damp cloth or washing by hand in lukewarm water.

Saran has good resistance to bleaches, excellent resistance to most alkalies and excellent resistance to acids. It cannot be dyed readily because it is nonabsorbent. Saran has good resistance to deterioration by sunlight and the affect of age is negligible. It is very resistant to perspiration and is nontoxic. It is completely resistant to mildew, bacteria, and insects. It weakens at temperatures below the boiling point of water.

12.2.2 Uses of Saran

Monofilament saran yarn is used for such purposes as car seat covers, filter fabric, outdoor furniture tape, insert screening, and grille fabrics. Multifilament yarn is used for such purposes as filter cloth, upholstery, drapery, and rope.

12.3 Alginate Fibres

Seaweed is dried and ground to a fine powder and then dissolved in a solution of sodium carbonate and caustic soda. The reaction produces a solution of sodium alginate which is allowed to stand until the undissolved components of the seaweed precipitate and are filtered. The solution is bleached with sodium hypochlorite to prevent bacterial attack. Hydrochloric acid is then added, producing alginic acid which is precipitated out of the solution, purified, and dried. The alginic acid is then neutralized with sodium carbonate to form a solution of sodium alginate. Filtered sodium alginate is extruded through a spinnerette into a bath of calcium chloride, hyprochloric acid, and a surface active agent. The streams emerging from the spinnerette coagulate into filaments of calcium alginate, which are washed, oiled, dried, and wound on spools.
12.3.1 Properties of Alginate Fibres

The alginate fibre has a dry strength comparable with that of viscose rayon. However, considerable strength is lost when wet, and the fibres could ultimately disintegrate if care is not exercised. If soap that contains an alkali is used, the fibres will dissolve in the water. However, organic solvents have no effect. Alginate fibre can be dyed with basic and direct dyes. The fibre is nonflammable but will decompose to ash when held in a flame.

12.3.2 Uses of Alginate Fibres

The sensitivity of alginate fibre to water and dilute solutions of alkali have resulted in some interesting applications. For instance, alginate yarns have been used as scaffolding to help support other yarns in the manufacture of lightweight, sheer, and lacy fabrics.

The alginate fibre has also been used in medical application for dressings. It has been found to hasten blood coagulation and to facilitate healing when placed over wound. Alginate fibre dressings have also been used by dentists as packing to stop bleeding; as healing progresses, the dressings eventually break down and disappear. The flameproof characteristic has also made the alginate fibre suitable for limited applications: it is used to some extent instead of asbestos for theater curtains.

12.4 Acrylic

The term acrylic comes from the chemical composition of the fibre; the word modacrylic comes from “modified acrylic”. Dimethylformamide or dimethylacetamide is used as a solvent. Some fibres can be spun from acetone. After the polymer is dissolved, it must be filtered to remove impurities and undissolved polymer. The solution is spun by either a wet-spinning or a dry-spinning system. Bicomponent acrylic fibres are formed at the spinnerette.

After coagulation, the fibre is drawn to produce fibre properties. Fibre crimp is also developed before the fibre is cut into staple.

12.4.1 Properties of Acrylic

The acrylic fibres are stronger than wool and acetate but weaker than most of the other fibres. Elongation and recovery of the fibres are also variable. The acrylic fibres have good resilience. They do not wrinkle easily, and any wrinkles that are formed in garments usually
disappear after the fabric relaxes. Pile, or plush, fabrics made from acrylics and modacrylics recover well from crushing.

They are more absorbent than polyester but less absorbent than nylon. The low moisture regain indicates that the fibres generate static electricity.

Acrylic fibres burn with a yellow flame. They form a hot gummy residue that drips away from the burning material. The molten drop solidifies to a hard, brittle black bead. The reaction of the original modacrylics to heat was one of the major reasons for their popularity. The fibres were difficult to ignite, and they self-extinguished. The ash was a hard black char. The fibres could be treated so that some were more sensitive to heat than others.

Weak alkalies do not affect acrylics. Concentrated alkalies degrade acrylics. Cold, concentrated nitric acid dissolves acrylic fibres, and other concentrated acids weaken them. Dilute acids do not harm the fibres. The acrylic fibres are not affected by household organic solvents.

Acrylic has excellent resistance to sunlight. Even prolonged exposure does not affect fibre strength. Most acrylic fibres are dyed with disperse dyes.

12.4.2 Uses of Acrylic

The primary markets for acrylic is in apparel and home furnishings. The fibres are usually soft and light in weight. In apparel, the fibre may be used alone or in blends with cotton, wool, rayon, and polyester. Apparel in which acrylic fibre are likely to be found include socks, knit sweaters, sportswear fabrics, and the “sweats” so loved by joggers.

Blankets, carpets, and upholstery fabrics are made from acrylic fibres and acrylic blends. The fabrics have a woollike hand but are not affected by moths. Household fabrics made from acrylic fibres are especially popular where exposure to sunlight is a problem.
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Part Two
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CHAPTER 1
INTRODUCTION

1.1 General

Microscopy plays an important and ever increasing role, both in modern textile routine testing and in research. The application of microscopy in the textile laboratory can be classified as follows:

(1) Identification of fibres and the determination of the quantities of component fibres in blends.

(2) Grading or determination of quality of fibres. Eg: the determination of the maturity of cotton.

(3) Various types of damage to fibres during processing, storage, and use can be determined quantitatively by microscopic methods.

   (Mechanical, microbiological and chemical damage)

(4) Detection of impurities, foreign matter, and adulteration.

(5) Demonstration of the various effects and treatments of fibres like mercerization, chemical treatments, and treatments with resins.

(6) Determination of defects in synthetic fibres, and control of the manufacturing processes of man-made fibres.
1.2 Classification of Textile Fibres

Fibres used for Textile Purpose

Natural Fibres

(1) Seed Fibs. (1) Wool & hair Fibs. (1) Asbestos Fibs.
(2) Woody Fibs. (2) Silk Fibs.
(3) Bast Fibs.
(4) Leaf Fibs.
(5) Fruit Fibs.

Man-made Fibres

Regenerated Natural Fibs.

Cellulose Base

Chemically modified Cellulose Fibs.
(1) Viscose Rayon
(2) Cuprammonium rayon

Animal
(1) Casein
(2) Keratin
(3) Albumin

Vegetable
(1) Soybean
(2) Peanut
(3) Metallic steel Fibs

Mineral Base

Synthetic Fibs.

Polyester
(1) Dacron (Tetron, Terylene)

Polyamide
(1) Nylon

Polyvinyl
(1) Orlon

Polyacrylics
(1) Reevon
(2) Olefin

Vinyl Chloride
(1) Vinyon
(2) Dynel

Vinylcyamide
(1) Dolon
(2) Acrilan

Vinyldene Chloride
(1) Saran
(2) Velon
CHAPTER 2
THE MICROSCOPIC AND ITS MANIPULATION

2.1 The Microscope

It is an optical instrument by which the image of a very small object can be formed on the retina of the eye.

The function of the microscope is to reveal objects and details which are too small to be distinguished by the naked eye (unaided eye).

Microscopes are divided into two classes:
(1) Simple microscope (magnifying glasses) consists of one lens or one lens unit.
(2) Compound microscope consists of two lens units, i.e. objective and eyepiece (or) ocular.

Objective → the set closer to the object
Eyepiece → the set by which the object which is formed by the objective is remagnified into the enlarged image.

The ordinary compound microscope has one objective and one eyepiece in use at a time. The binocular microscope has a double set of eyepieces and a double set of objectives.

2.2 Mechanical Parts of the Compound Microscope

![Simple Microscope Diagram](image)

Figure 2.1 Simple Microscope
The microscope consists of the following main parts:

(1) Body tube
(2) Stand
(3) Stage
(4) Focusing mechanism/apparatus
(5) Illuminating apparatus

(1) Body tube

It carries the objective and eyepiece. Tube length can be varied by raising or lowering an inner tube, the draw tube. Increase in tube length, increase in magnification. The standard tube length is 160 mm. Nosepiece is attached to the bottom of the body tube. Revolving nosepiece carries of different power. Eyepiece or ocular is carried by the upper end of the draw tube.

(2) Stand

It consists of horse shoe base or foot, vertical pillar with inclination joint and mechanical stage.

(3) Stage

A rigid flat platform on which the slide and object are placed, with a centre hole to permit illuminating the specimen from below.

(4) Focusing Mechanism

It permits adjustment of the distance between the microscope (objective) and the object. This device consists of coarse and fine adjustment.

(5) Illuminating Apparatus

Concentrating and regulating the intensity of the light on the specimen. The apparatus consists of the mirror, with flat and concave sides, which directs the light into the microscope; the diaphragm (generally an iris diaphragm), which regulates the amount of light passing into the microscope and the condenser, which concentrate the light on the specimen.
2.3 Geometric Construction of the Image

2.3.1 Ray Diagram of Image Formation in Visual Microscopy

Figure 2.2 Ray Diagram of Image Formation in Visual Microscopy

\[ \text{F}_1 = \text{Focal distance of objective} \]
\[ \text{F}_2 = \text{Focal distance of eyepiece} \]
\[ O = \text{Object} \]
\[ R_1 = \text{First real image} \]
\[ R_2 = \text{Virtual image} \]
\[ T = \text{Optical tube length} \]

The distance between the upper focal plane of the objective and the lower focal plane of the eyepiece.

Magnification of objective = \( \frac{\text{Size of image}}{\text{Size of object}} \) = \( \frac{T}{\text{F}_1} \) = \( \frac{\text{Optical tube length}}{\text{Focal distance of objective}} \)

Magnification of eyepiece = \( \frac{\text{Near point (distance close vision)}}{\text{Focal distance of eyepiece}} \) = \( \frac{25 \text{ cm (250 mm)}}{\text{F}_2} \)

Total magnification (in compound microscope) = Magnification of objective \times Magnification of eyepiece

\[ = \frac{T}{\text{F}_1} \times \frac{25 \text{ cm}}{\text{F}_2} \]

\[ \therefore M = \frac{T}{\text{F}_1} \times \frac{C}{\text{F}_2} \]

Near Point – The nearest distance of the object from the eye at which the eye lens can still sharply focus the image on the retina. For normal eye, it is 10" or 250 mm.
2.3.2 Ray Diagram of Image Formation in Photomicrography

\[ F_1 = \text{Focal distance of objective} \]
\[ F_2 = \text{Focal distance of eyepiece} \]
\[ T = \text{Optical tube length} \]
\[ C = \text{Bellow length} \]

Magnification of objective = \[ \frac{\text{Size of image}}{\text{Size of object}} = \frac{T}{F_1} \]

Magnification eyepiece = \[ \frac{\text{Bellow length}}{\text{Focal distance of eyepiece}} = \frac{C}{F_2} \]

Total Magnification (in photomicrography) = \[ \frac{T}{F_1} \times \frac{C}{F_2} \]

2.4 Correction of Lenses

2.4.1 Spherical Aberration

Rays parallel to the axis of the lens do not meet in one focal point, the border rays having a focal spot closer to the lens than the central rays. As a result an uncorrected lens
will give a distorted image. It is overcome by the use of a combination of several different lenses of right curvature acting as one unit.

The coverglass may effect on the light from the specimen. It is corrected for use with a definite coverglass thickness of 0.17 mm.

2.4.2 Chromatic Aberration

![Figure 2.6 Chromatic Aberration](image)

This correction is connected with the compound nature of the ordinary light. A lens of one kind of glass has different focal lengths for light of different wavelengths (different colours) so that no sharp image can be obtained.

When a beam of light is passed through a lens, it is dispersed and the red rays are caused to cut the base line further from the lens than the violet rays. The red rays are brought to a focus at the point $F_2$ outside of the mean focal point $F$. Also violet rays are focus at the point $F_1$ inside the mean focal point $F$. $F_1$ and $F_2$ are the limiting points of the aberration. If the image is focused at $F_1$, violet will be predominant and at $F_2$ red will be the dominant colour.

The chromatic aberration of a lens can be compensated by using a system of lenses of different types of glass of different refractive indices.

2.4.3 Effect of Coverglass on Objective

The rays from point 'O' centre the lens through the coverglass. But for the lens, these rays seem to come from the point 'X' and 'Y'. The portion of object which emitted $R_1$ appears to be at $X$ and that which emitted $R_2$ appears to be at $Y$, giving two separate foci and thus detracting from the quality of image.

The effect of coverglass on the light from the specimen is similar to the spherical aberration. It is corrected by using a definite coverglass thickness (0.17 mm).
2.5 Manipulation of the Microscope

2.5.1 Illumination of Light

2.5.1.1 Transmitted Light

Most microscopes are observed with transmitted light, which reaches the object from beneath the stage and passes through it (the object) into the objective. It may be perpendicular to the object along the axis of the microscope (axial transmitted light), or under an angle (oblique transmitted light). It is used for the study of the internal structure of an object.

2.5.1.2 Reflected Light

This reaches the object from above and is reflected by the object upward into the objective. Incident light ray may reach the object from above at an angle or straight down. In the latter case, a special type of objective is necessary, allowing the light to pass through it and being directed straight down along the axis of the microscope and on the object (vertical illuminator). It is used for the study of surface structure.

2.5.1.3 Dark Field Illumination

The light reaches the object obliquely from beneath and enters the objective only after reflection by the object. In this case, the image is formed entirely by reflection of light.

The object is illuminated only by indirect light, incident at an angle larger than the aperture of the objective. All direct light incident under an angle that would permit it to enter
the objective is closed off by a circular stop under the condenser. The indirect light that illuminates the object can enter the objective lens only after it has been reflected or refracted by the object which then appears white on a black background.

Dark field illumination can be obtained with ordinary condensers. The circular stop disk may be suspended (by three arms) on the diaphragm. The disk must be large enough to block the direct light that could enter the objective, but smaller than the fully opened diaphragm so that light can pass between the edge of the disk and the border of the diaphragm. For more nearly perfect dark field illumination, especially for high power, special dark field condensers exist.

![Figure 2.9 Dark Field Illumination](image)

2.5.1.4 Oblique Illumination

It is used to increase the contrasts in unstained preparation. This technique uses special holders which allow horizontal displacement of the diaphragm out of the axis of the microscope. Oblique illumination can be obtained in a simple way by using the mirror after it has been swung to the side after removal of the condenser, or by closing off one-half of the light cone with a card held under the diaphragm.
2.6 Focusing and Use of Fine Adjustment

The microscopic examination is always started by using a low-power objective. The objective is lowered until it almost touches the slide, while the observer watches this operation from the side of the microscope. After this, operator is looking into the microscope, the objective is moved in an upward direction by the coarse adjustment until the specimen is in focus. The final focusing is done by use of the fine adjustment.

After that, by adjusting the mirror to obtain the highest possible light intensity and most uniform illumination of the field of vision of the microscope.

2.7 Use of Diaphragm

The intensity of light is regulated by the diaphragm. This adjustment is extremely important since only at a definite light intensity, full details of the specimen will be visible.

The opening of the diaphragm controls the angular size of the cone of light illuminating the object (working aperture), and entering the objectives.

The size of the front lens of the objective and its distance from the specimen determine the angular size of the maximum cone of light that may enter the objective (angular aperture of objective).

The larger the angular aperture of the objective the higher the power of the objective to reveal fine details. Therefore, a wide open diaphragm would seem desirable. Besides, when the diaphragm is closed too far, diffraction bands are formed at the boundary of the image and false image will result.

On the other hand, when the diaphragm is wide open, undesirable glare is produced and the contrast of the image of unstained specimens is lowered.

Thus, the optimum conditions - the object is illuminated by a cone of light (working aperture) of an angle of about three-fourths of the maximum aperture of the objective.
CHAPTER 3
PREPARATION AND EXAMINATION OF THE UNSTAINED FIBRE

3.1 Preparation of the Slide
3.1.1 Slides and Coverglass

Slides or slips and coverglasses must be kept scrupulously clean. Any dirt will affect the clearness of the image and may cause confusion. The glasses must be free from fat, so that the mounting fluid will spread uniformly over the surface and not contract into droplets.

New slides and coverglasses are cleaned in 5% ammonia or 50% alcohol. They are wiped with a clean linen towel, absorbent gauze, or lens paper. The slips and coverglasses are held by edges, the fingers of the other hand being covered by the wiping cloth. Used slides are best cleaned in dichromate cleaning mixture. The cleaning of these slides may take about a week. Complete removal of fatty or only films from the slide and coverglass is achieved by putting them in an emulsion of 5 gms. of Bon Ami soap powder stirred in 100 cc. of water. The slide is dried by draining it in a vertical position on blotting paper.

3.1.2 Preparation of Fibre Before Mounting

Before mounting the fibres, it is often necessary to remove greases, waxes, and dirt present on their surface by scouring the fibres in dilute soap solution. This may be done by boiling a tuft of the fibre for a few minutes in a test tube in water to which a few drops of a soap solution have been added.

3.1.3 Mounting of Fibres

Fibres are usually mounted in a liquid or a solid medium. For ordinary work water is the most universally used, but mineral oil, glycerin, or other substances are often more suitable since they have the advantage of evaporating more slowly than water. In the case of many biological materials, mounting in water is necessary to prevent the material from drying out and dying.

3.1.4 Arrangement of Fibre in Preparation

Fibres should be mounted in parallel and separated carefully from each other to prevent overlapping. Orderly and parallel arrangement of the fibres facilitates examination.

Use of the right amount of liquid is important in making the preparation. An excess of liquid will cause the coverglass to float and the sample to move during observation.
Excess liquid can be removed with a small strip of filter paper; shortage can be remedied by adding a drop of the fluid on the side of the coverglass.

3.1.5 Air Bubbles

Another important point in the making of the preparation is the prevention of the inclusion of too many air bubbles. By gently lowering the coverglass in a slanting position over the sample, bracing it on one side of the slide, excessive air bubbles may be excluded. If air bubbles are still enclosed, they can be removed in water mounts by the addition of a drop of 96% alcohol on the side of the coverglass, using a strip of filter paper on the other side to draw the alcohol under the glass.
CHAPTER 4
COTTON

4.1 Growth and Structure of the Cotton Hair

(a) Primary Wall Formation

The cotton fibre is an epidermal hair from the seed of the cotton plant. It grows out of a single epidermal hair in the cotton seed coat.

The hair reaches its final length of more than 1000 times its cross section in from 18 to 25 days after fertilization of the ovules. It is a cylindrical hollow tube and has almost constant diameter along the entire length. Tube diameter varies in different species from 12 to 45 (usually 15 to 22) microns. (A micron or μ is 1/1000 mm). Only the tip is much narrower. Cell wall pushes rapidly out and attain the natural length of the fibre by the end of first stage. The original wall of the fibre in this stage is composed of pectins, some cellulose, and a cuticle of wax on the outside.
(b) Secondary Wall Formation

Length growth stops completely after 18 to 25 days and during the next period of from about 20 to 60 days after fertilization, secondary cellulose layers are deposited inside this primary wall. A daily periodicity has been observed in these secondary layers. It is called daily growth rings, which become visible after swelling. After 60 days, development of secondary cellulose layers are stopped and spaced inside along the fibre length. This spaced is called lumen. Width of lumen depends on cotton species. Good quality cotton has small lumen.

The secondary cell wall layers gradually fill up the original lumen of the cell until about one-third of the lumen is left over in the fully mature fibre. In fibres designated as immature, the diameter of the lumen is equal or larger than twice the thickness of the adjacent cell wall. Sometimes extremely thin-walled fibres are found which are completely flat and ribbon-like because their development is stopped at a very early stage, these are called dead fibres. Various systems of striations or fibrillation have been described in cotton hairs.

(c) Dehydration

During the drying of the fibres and the resulting shrinkage after the boll opens, the original cylindrical fibre flattens out and collapses.

The degree of collapse will depend on the thickness of the cell wall - the thinner the wall the greater the collapse or flattening. The flat ribbon of the collapsed fibre is twisted around its axis. These twists are known as convolutions.

The convoluted appearance is connected with the spiral orientation of the cellulose molecules and microcrystallities of the secondary wall, left-hand convolutions corresponding to a right-hand internal spiral. The twist reverses itself manytimes along the length of the fibre.

4.2 Microscopic Examination of Cotton

(a) Longitudinal View

![Figure 4.2 Longitudinal View of Cotton](image)
Cotton fibre is a irregular twisted and collapsed flattened tube, with a central canal or lumen throughout the length. It has twists or convolutions at irregular intervals all over its length.

(a) Cross-sectional View

![Cross-sectional View of Cotton Fibre]

**Figure 4.3 Cross-section of Cotton**

The cross-section of the collapsed cotton is generally U-shaped or elliptical with lumen.

For mature cotton - it is elliptical to circular, flat and rectangular with rounded corners.

For immature cotton - it is often U-shape.

### 4.3 Chemical Composition of Cotton

<table>
<thead>
<tr>
<th>Component</th>
<th>% By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>1.2%</td>
</tr>
<tr>
<td>Wax</td>
<td>0.6%</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.3%</td>
</tr>
<tr>
<td>Pigment</td>
<td>Trace</td>
</tr>
<tr>
<td>Others</td>
<td>1.4%</td>
</tr>
<tr>
<td><strong>Primary wall</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Secondary wall</strong></td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>94%</td>
</tr>
<tr>
<td>Protein</td>
<td>1.3%</td>
</tr>
<tr>
<td>Pectic</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

### 4.4 Microchemical Reaction

Almost 95% of the cotton fibre is cellulose; the specific reagent used to indicate cellulose is Zinc chloroiodine.
Zinc Chloroiodine (depends on fresh)  → reacts to give a blue colour ranging in shade from violet to purple
(brick red colour in dilute Zinc Chloroiodine)
(darker colour for mercerized cotton)
This reaction calls positive reaction

Sudan III → orange colour (presence of the wax cuticle)
colourless (removed wax)

Ruthenium red → stains the primary wall, the cuticle and the lumen of the fibre red

Cont: H₂SO₄, HCl, Iodine → swells the cotton and become blue

4.5 Observation in Sodium Hydroxide

1 – 5% NaOH  - swelling of the wall, the fibre straightens out almost immediately
             - resuming its original cylindrical form while convolutions disappear
             - study the maturity of cotton

9 – 11% NaOH  - swell to its full original size
18% NaOH  - occurs a very strong swelling of the fibre (mercerization process)
             - damaged in primary wall
             - maintains increased strength and lustre
             - increase in fibre diameter
             - decrease of the lumen
             - straightening out of the convolutions
             - greater dye affinity

4.6 Separation of Primary and Secondary Wall by Formation of “Balloons” in Cuprammonium Hydroxide (Balloon Test)

Figure 4.4 Balloons of Cotton in Cuprammonium Hydroxide
The wall composition of the cotton fibre can be studied by immersing in a freshly prepared ammoniacal copper oxide solution (cuprammonium solution).

The cotton fibre is boiled for one minute in a 0.3% solution of Victoria blue B and, being washed in water for one or two minutes. After that, it is also boiled in a 0.1% solution of the benzo purpurin 10B and being washed in water.

The dyed fibres are immersed in a drop of cuprammonium solution on the slide and studied as soon as possible. After initial untwisting of the fibres, a high degree of swelling occurs in the cellulose of the secondary wall. The primary wall, which has a different structure and composition, does not expand and, as a result of the pressure by the secondary wall, is ruptured in many places. The part of the primary wall between the ruptures are pushed together to form rings and spirals. Between the neighboring rings the secondary wall protrudes in the form of round balloons. In this stage, the fibre looks like a string of pearls.

In this example (sample), rings and spirals of the primary wall have a dark purplish blue colour, the swollen secondary wall has a fainter blue colour and the lumen have a clear red colour.

The formation of balloons takes place very rapidly in cuprammonium solution, and after a short period the cellulose dissolves completely.

After bleaching (the greatest part of the primary wall, especially its wax, has been removed or ruptured of primary wall), no typical balloon formation occurs, but swelling all over the length of the fibre.

4.7 Damaged Cotton

- Absence of primary wall
- Rupture of primary wall
- Weakening of primary wall

Three kinds of damaged based on rupture of primary wall.

(i) Mechanical damage

Because of the mechanical action (cutting, ginning, abrasion and bruising, etc.) some parts of primary wall are ruptured.

(ii) Chemical damage

The hole primary wall is weakened. By heating, over bleaching or acid results in a gradual breakdown of the cuticle.

(iii) Microbial or Biological damage

Primary wall is slightly weakened. Whether by mildew, bacteria or fungus.
4.7.1 Investigation of Damaged Fibres
(a) Swelling test
(b) Staining test on primary wall
(c) Staining test on secondary wall

4.7.1.1 Swelling Test
(i) Cuprammonium Test
This test causes no balloons to form in fibres of which the cuticle and primary wall
have been removed by intensive bleaching. Typical balloons formation occurs for fresh
primary wall.

<table>
<thead>
<tr>
<th>Presence of primary wall</th>
<th>balloon formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of primary wall</td>
<td>no balloon formation but uniform swelling</td>
</tr>
</tbody>
</table>

(ii) Carbon Disulfide + 15% Caustic Soda Test
Fibres are treated with a mixture of equal volumes of carbon disulfide and 15%
caustic soda. This solution reacts the cellulose.

<table>
<thead>
<tr>
<th>Presence of primary wall</th>
<th>balloon formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of primary wall</td>
<td>no balloon formation</td>
</tr>
</tbody>
</table>

(iii) Extrusion Test
Cotton fibres are cut about 0.01 inch in length with a set of parallel razor blades. The
sections are placed in 18% caustic soda and are examined after one minute. If the primary
wall is intact, it will prevent the fibre from swelling in width, and the pressure inside the fibre
will cause the secondary wall material to be extruded at the cut ends of the fibre section. The
sections become dumbbell-shaped.

If the cuticle or primary wall has been damaged, it can not resist the intensive pressure
and fibre section swells over its entire length without formation of extrusion of material at the
ends.

4.7.1.2 Staining Test on Primary Wall
(i) Sudan III Test
By staining the fibres with Sudan III or ruthenium red. These dyes stain on wax
cuticle or primary wall. If the fibres become orange colour, it will have a primary wall.

| Presence of primary wall (undamaged cotton) | orange colour |
| Absence of primary wall (damaged cotton)   | colourless   |
Mechanical damaged → gives spot  
Chemical damaged → not stained the hole fibre  
Microbial damaged → faintly stained

4.7.1.3 Staining Test on Secondary Wall

(i) Congo Red Test

These dye has great affinity for cellulose but cannot easily penetrate the primary wall, especially the wax cuticle.

Immersing the cotton samples of 0.1 gram in 25 cc 11% NaOH for five minutes (to swell the fibre to its original shape), wash quickly and place in saturated solution of Congo red for six minutes, shaking at intervals, rinse in water until no more dyestuffs comes off. After that, examine in 18% NaOH. If the fibre is damaged, red-stained will occurs.

Presence of primary wall → Faintly red color, with normal cell wall thickness obtain cylindrical cross-section
   (undamaged)
   → Faint pink with thin wall obtain convolutions
   → Red spiral with very thick cell wall

Absence of primary wall (damaged) → Irregular red stained patches

4.8 Differentiation of Various Types of Damage

9% NaOH → mechanical damage  
11% NaOH → chemical and heat damage  
18% NaOH → microbial damage (slightly weakened)
4.9 Differentiation Between Mercerized and Unmercerized Cotton

<table>
<thead>
<tr>
<th>Mercerized Cotton</th>
<th>Unmercerized Cotton</th>
</tr>
</thead>
</table>
| 1. Almost cylindrical in longitudinal view  
  No convolutions | 1. Convolutions present  
  (Besence of convolutions) |
| 2. Circular or round contour and the small,  
  round lumen in cross-section | 2. U-shaped or elliptical in cross-section |
| 3. Greater dye affinity (more intensive take-up of stain, especially iodine)  
  Lustrous | 3. Slightly stained  
  (due to wax content) |
| 4. No typical balloon formation occurs, but uniform swelling along the fibre length with cuprammonium hydroxide test  
  (Primary wall destroyed) | 4. Typical balloon formation occurs with cuprammonium hydroxide test |
| 5. Immersing the fibres for few seconds in Hubner's reagent and then wash the fibres several times in water  
  The fibre becomes black or dark blue | The fibre is only slightly stained |
CHAPTER 5
FLAX AND HEMP

5.1 Preparation and Structure of Bast Fibres

Flax or linen belongs to the group of bast fibres. Most of the best fibres are derived from that portion of the plant lying between the outer bark or epidermis and the woody central cylinder. The bast fibres are so called “soft fibres” and the principal textile fibres, which produce fine cloth namely flax, hemp, jute and ramie.

Most of the best fibre are prepared from the steam by a microbiological, or chemical, retting process. The fibre bundle is loosened from the bast cells as well as the other nonfibrous parts of the stalk.

Principle - decomposition of the pectins of the middle lamellas which cement the individual cells together so that the tissue falls apart.
Retting process - to free the fibres from the woody material and from each other. This retting operation is accomplished in two ways, namely
(1) Dew retting (in snow)
(2) Water retting (in water)

After retting process, the fibre can be easily extracted from the stem by mechanical processes, and then combing (Heckling) to separate the bundles, each bundles split into several groups to form commercial fibres. These fibres are used in the spinning operation and are spun and woven.

Technical fibres (commercial fibres) are composed of individual fibres (elementary fibres). Commercial fibres can be broken down to the elementary fibres by treatment with various chemicals (maceration).

The elementary fibre consists of cellulose or lingo-cellulose; a fine layer of pectins is often found on the outside of the fibre. Differentiated by their morphological features: diameter, length, cell wall structure, size and shape of lumen, cross-sectional shape and microchemical composition.

Common characteristic of most bast fibres is the presence of dislocations (transverse markings) of the cell wall. These are due to change in the orientation and result from mechanical influences during preparation of the fibre. The marking may be single or double (cross like mark and node). Dislocations are most conspicuous in thick-walled fibres like flax, absent in jute.
5.2 Flax

A plant with blue flowers cultivated for the fibres obtained from the stem. These fibres are made into linen.

The stem of the flax plant is about 3' high and a few millimeters in diameter. It consists of central woody section, the bast layer (fibre bundles), the cortex and the epidermis on the outer surface. The bundles of bast fibre are built up of many individual fibre cells packed in a parallel arrangement along the length.

Fibre bundles become silver gray when dew retted and yellowish-white when water retted.

5.2.1 Characteristics

- raw fibre has creamy white colour
- highly lustrous
- very strong, tensile strength 2-3 times that of cotton
- highly absorbent and good resistance to moisture and mildew
- soft and flexible
- better conductor than cotton
- cool feeling
- very light

5.2.2 Uses

- blending with other fibres
- summer suiting, dress goods, consumers fabrics, high grade cordage and string, nets, threads, furniture cover, table linens, bed sheet, etc.

5.2.3 Microscopic Examination of Elementary Flax Fibre

(a) Longitudinal View

[Diagram showing nodes, lumen, dislocation, and ends of fibres]
Figure 5.1 Longitudinal View of Flax

The elementary fibre is transparent white and has an almost constant diameter along the length; tapering to a fine point at both ends; very fine canal lumen; thick cell wall; X or V shape dislocations; before and after this dislocations or cross markings fibre axis is slightly shifted; swelling or bulge (node) at the place of dislocation.

(b) Cross-sectional View

Figure 5.2 Cross-section of Flax

Hexagonal shape with sharp corners in cross-section and has well defined lumen.

5.2.4 Examination of Technical Fibre in Clearing Agents

Figure 5.3 Technical Fibre of Flax

In air, elementary fibres lying over each other. But technical fibre is very difficult to study the many layers of elementary fibres.

For a better study of the technical fibre, some clearing agents are added. For this purpose chloral hydrate (n = 1.44) or methyl salicylate (n = 1.538) are used.

5.2.5 Examination of Components of Technical Fibre by Maceration

For studying the technical fibre is to break it down into its elementary fibre cells by a chemical treatment. Several methods are as follows:
(i) Sodium Hydroxide

A small piece of technical fibre mounted between a slide and coverglass in NaOH is heated over a small flame; the slide is removed from the flame as soon as gas bubbles develop and the solution starts to boil. Great care to prevent complete evaporation of the fluid during boiling. After three boilings, the elementary fibre separated by slightly rubbing the coverglass over the slide.

(ii) 10% Solution of Sodium Carbonate

Boiling the fibre from 30 minutes to a few hours in a 10% solution of sodium carbonate and then, rubbing the fibre between the fingers results in complete elementary fibre.

(iii) 40% Nitric acid and Potassium Chlorate

Boiling the material in a few cubic centimeters of 40% HNO₃ to which a few crystals of potassium chlorate have been added and then washed out of the fibres.

(iv) 100% Chromic Acid

By treating the samples with 100% chromic acid for a few minutes at room temperature. This is a easiest way to separate the elementary fibres.

5.2.6 Microchemical Reactions of Flax

The elementary flax fibre is composed at almost pure cellulose (98%). Therefore, reacts to give a deep blue-violet colour with zinc chloroidine solution(positive reaction). The structure of the fibres becomes much clearer by applying zinc chloroidine.

The dislocations are intensively blue at low power magnification. At high-power magnification, the central canal appears to contain yellow-coloured protoplasmic particles.

5.2.7 Reaction with Cuprammonium Hydroxide

Figure 5.4 Snake-like Formation of Flax in Cuprammonium Solution
The reaction is carried out after dyeing the fibre with ruthenium red solution in water. After adding a drop of cuprammonium solution to the fibre, fibre becomes swell laterally and contracts lengthwise at the same time. The contraction results in a compression of the protoplasm in the central canal (Snake-like formation).

After some time the whole fibre dissolves completely.

5.3 Hemp

It is a bast fibre which is closely related to flax. It originates from the stem of common hemp. 4 - 12’ in height (much taller than flax), and stem varies in diameter from $\frac{1}{2}$ - 1”. Fibres are much coarser than flax, but they are prepared by a similar retting process. This fibre is grown in Italy and other European countries and small scale in the United States.

5.3.1 Characteristics
- greenish or blue colour (low grade)
- coarser than flax in diameter
- very light coloured and quite lustrous
- stronger than flax
- 40 - 80” length in fibre strands
- light in weight

5.3.2 Uses
- various types of cordage, tarpaulin, canvas.
- stockings, fine yarns on commercial basis with resulting fabrics that are very soft and lustrous and similar in appearances to flax (Italian hemp)

5.3.3 Microscopic Examination of Elementary Hemp Fibre
(a) Longitudinal View

![Figure 5.5 Longitudinal View of Hemp](image-url)
Larger average diameter and greater variation in diameter (10 to 50 μ; average 18 to 23 μ); blunt or forked top; no sharp ends; wider lumen than flax; dislocations on wall; no typical nodes; heavy layers of cell; lumen cannot be seen obviously for numerous striations.

(b) Cross-sectional View

![Cross-section of Hemp](image)

Figure 5.6 Cross-section of Hemp

More rounded corner polygonal shape in cross-section; larger flattened lumen; thick cell wall.

5.3.4 Microchemical Reaction of Hemp

This fibre composed of 78% cellulose (less cellulose percent than flax, cotton). It is called lignified cellulose fibre.

- With zinc chloroiodine, reacts to give greenish blue colour.
- Iodine, H₂SO₄ give bluish green colouration.
- HCl, caustic potash give brown colouration.
- Ammonia produces a faint violet.

5.3.5 Reaction with Cuprammonium Hydroxide

![Swollen Mass of Cellulose](image)

Figure 5.7 Accordion-like Pleats of Hemp in Cuprammonium Solution

Fibres are dyed with ruthenium red solution and add a drop of cuprammonium solution between slide and coverglass. First, swelling is slower than in flax, the layers of the wall appear to be thicker. The fibre contracts like flax but undulated thread does not appear. The more strongly developed middle lamella shows up during the contraction of the fibre and
transformed by the contraction of the fibre into a ruffled band with accordion-like pleats. These folded middle lamella remains after the cellulose has been dissolved.

Cell ends blunt or forked and show lateral branches – never present on flax fibre.

Less transparent, interior canal is more difficult to distinguish because of numerous striations on the surface.

Cross-section different.
CHAPTER 6
RAMIE AND JUTE

6.1 Ramie

This plant was originally cultivated in China for fibre production. The fibre is prepared from the roughly cleaned bast ribbons stripped from the stalk. It is called "China grass".

The plant is also grown in the Philippines, Formosa, Java and the United States, in Florida.

Retting process is required to free the fibre from the cane and degumming process is also required to remove the gums for spinning. It is the least lignified and purest cellulose of the bast fibres. Elementary fibre length is 10 - 16" and diameter is 40 - 50(80 μ). This fibre diameter is larger than other.

6.1.1 Fibre Preparation by Retting Process

(1) Mechanical decortication process... which separates the bast ribbons from the stalk.

(2) Chemical degumming process... the pure white silklke fibre from the ribbons is removed the gum by this process. The commercial or technical fibre prepared in this process consists of the separate single elementary fibres, and not of fibre bundles.

6.1.2 Properties

- very white and does not change colour upon exposure to sunlight
- highly lustrous and resistance to the effect of bacteria and fungi including mildew and weather attack
- highly absorbent and dry quickly and take dyes readily
- easily laundered
- requiring no special care, only minor strength loss after repeated washing
- tensile strength very high, three times stronger than hemp
- breaking strength = 3 ~ 9 gm / denier
- shows satisfactory strength when knotted or looped
- resistance to sunlight, abrasion
- durable
- not change in strength depends on moisture, water
- specific gravity = 1.5 ≈ 1.55
6.1.3 Uses
- Curtains, table cloth, canvas,
- twine for fishing nets, cords
- industrial sewing threads, industrial packings, fire hose, filter cloths
- upholstery fabrics, clothing and household furnishing fabrics
- short fibre strands and processing waste used for the manufacture of paper

6.1.4 Optical Cross-Sections
In the studying the microscopic characteristics, it is necessary to make the "optical cross sections".

Optical cross sections of the fibre is the studying with great accuracy on the different planes in the specimen.

An optical cross section is the image obtained when examining transparent objects under the microscope and focussing on some plane below the surface of the specimen.

![Diagram](image)

**C** - transverse plane  
**T** - tangential plane  
**R** - radial plane  
Fibre - hollow cylinder

![Diagram](image)

**A** - plane is perpendicular to the long axis of the fibre  
**B** - perpendicular to a radius  
**C** - longitudinal plane contains the long axis parallel to the long axis

**Figure 6.1** Schematic Representation of Planes Distinguished in Cylinder Fibre
6.1.5 Microscopic Examination of Ramie Fibre

(a) Longitudinal View

(i) Tangential Section (focus on outer surface of fibre) (along the surface)

(ii) Radial Section (focus along the axis of fibre)

Figure 6.2 Longitudinal View of Ramie

Flat ribbon shape: convolutions at some places; thin cell wall; large and uneven diameter; well-defined lumen; uneven diameter of lumen sometimes narrow and broad, sometimes indistinct lumen with heavy striations along the fibre; irregularities on the surface (faint dislocations, fissures or cracks).

(b) Cross-sectional View

Figure 6.3 Cross-section of Ramie

Flat elliptical shape like cotton; diameter is much larger than cotton; elliptical lumen; lines radiating out from the lumen; granular matter in lumen.
6.1.6 Microchemical Reaction of Ramie

Almost cellulose fibre (96 – 98% cellulose)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Reaction Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Chloroidine</td>
<td>reacts to give a violet-blue colour (positive reaction)</td>
</tr>
<tr>
<td>Cuprammonium solution</td>
<td>fibre swells considerably but does not dissolve</td>
</tr>
<tr>
<td>Aniline</td>
<td>gives no colour</td>
</tr>
<tr>
<td>Chloriodide of calcium</td>
<td>rose red colour</td>
</tr>
</tbody>
</table>

6.2 Jute

It is one of the most important bast fibres and second most widely used in vegetable fibre.

The fibre originates from the best of jute plant, which is mainly cultivated in India. The bast bundles (about 2 yards in length) are prepared by a retting process. They are of a brownish colour owing to the presence of tannic substances. Jute plant height is about 5-16’ and ½ - ⅔” diameter. Jute fibre is utilized in the bast form (technical fibre) and is never separated down to the elementary fibre (i.e. - very short 2-3 mm length, 15-25 μ diameter).

6.2.1 Properties

- strong and lustrous
- 1.1% elongation; low elasticity gives jute an advantage as a bagging material
- technical fibre is long (≈ 2 yards)
- cheapest fibre
- dyed with dark colour
- no dislocations

6.2.2 Uses

- bagging and wrapping fabrics for agricultural product
- yarns for carpet backing, linoleum backing
- ropes, twines
- carpets and rugs
- binding threads
- cheap pile fabric, coarse fabric
- cordage because of its low price and variability in large quantities, acceptance and use of jute fibre and its products expanded rapidly
6.2.3 Microscopic Examination of Jute

(a) Longitudinal View

![Longitudinal View of Jute](image)

*Figure 6.4 Longitudinal View of Jute*

The elementary fibre is very short (2 to 3 mm) and measures 15 to 25 μ in diameter; no dislocations; tapered to a point at both ends; irregular width of lumen which varies from wide to very narrow, sometimes even closing up (closed lumen with opposite cell walls touching “Constriction”).

(b) Cross–Sectional View

![Cross-sectional View of Jute](image)

*Figure 6.5 Cross-section of Jute*

Similar to flax; consists of many polygonal elementary cells which stick together in groups; more rounded corners polygon shape in individual cell; lumen rounded to oval or elliptical; variation in lumen.

6.2.4 Microchemical Reaction of Jute

It is 50 ~ 65% cellulose. This fibre calls ligno cellulose fibre.

- **Zinc Chloroiodine** → gives yellowish brown (negative reaction) due to high degree of lignification
- **Aniline Sulfate** → yellow colour
- **Aniline Sulfate (after bleaching)** → colourless
- **Iodine and H₂SO₄** → yellow colour
- **Dilute Chromic Acid, HCl.** → blue colour
- **Ferric of Copper Oxide** → deep blue colour
- **Cuprammonium Solution** → to swell but does not dissolve it
CHAPTER 7
MOUNTING AND STAINING OF WHOLE FIBRES

7.1 Theory and Technique

For the study of the internal structure of whole fibres, it is necessary that the sample is sufficiently transparent. In nontransparent material the surface structure can be studied by using reflected light. Transparency is much improved by mounting fibres in fluids rather than in air. Many mounting media can be used. The choice of the suitable mountant depends largely on whether the fibre is examined in the unstained condition or after it has been stained.

The image of a stained object is mainly visible as a result of the differential absorption of light by the object and its surroundings. (colour contrast)

The image of the unstained object may be visible as a result of different absorption over the total spectrum of the light by object and surroundings and as a result of differences in refractive index between object and medium. (light-dark contrast)

7.2 Choice of Medium for Examination of Unstained Fibres

The selection of a suitable mounting medium is important in the study of the unstained fibre.

The nearer the refractive index of the medium is to the index of the object, the lower the contrast will be, but the higher the transparency and vice versa.

The refractive index of most fibres varies between $n = 1.56$ and $n = 1.47$. In air ($n = 1.00$), the refractive index of the medium is too far from the fibre; therefore the transparency of the fibre is too low and the general structure of the specimen is obscured. This can be obviated by mounting the fibre in a medium of higher refractive index than the air. When the refractive index of the medium is too close to the fibre, the contrast of the image is too low and the line of demarcation between the unstained object and the medium disappear.

Theoretically, the image will be completely invisible when the refractive indices are equal. According to Preston, the best ratio of refractive indices (of fibre + mountant) is 1.06. ($\mu_m = \mu_f / 1.06$)

Other requirements for a suitable liquid mountants are low evaporation and no influence in swelling or affecting the fibre in any way. The best mountants for unstained
fibre are: glycerol \((n = 1.473)\), paraffin oil \((n = 1.471)\), heptane \((n = 1.385)\), water \((n = 1.333)\) and alpha-monobromonaphthalene \((n = 1.66)\).

7.3 Clearing and Optical Dissolving of Fibres

In a special case, a mountant of a refractive index very close to one of an unstained material. A good clearing agent for fibres is methyl salicylate \((n = 1.538)\).

The use of a mountant of a refractive index which is exactly the same as that of the fibre results in *optical dissolving* of the fibre. In this way mixtures of two types of fibres can be separated for purposes of counting one of the fibre present.

7.4 Choice of Medium for Examination of Stained Fibres

Medium of refractive index is different from that of the fibre for obtaining the best contrast and transparency of the specimen is not necessary when the fibre is stained. The differential absorption of light by the stain makes the details of the specimen already sufficiently visible. Equality of refractive indices will be preferable to obtain the maximum transparency of the object.

The best mountants for stained fibre are: canada balsam \((n = 1.52)\), Euparal and synthetic resins.

7.5 Staining

- Colour test based on various microchemical reactions of fibres.
- Very useful in the study of the chemical composition of the fibres.
- One of the most important microchemical stains are the iodine stains (detection of damage).

In the general staining procedure the fibres are immersed in the solution of the stain in water or alcohol for a time, then rinsed in pure water or alcohol, extracting the excess colour which is known as “differentiation”.

Vegetable fibres are generally stained with a direct dye and animal fibres with an acid dye. Green or red stains are mostly used. A few examples of suitable stains for fibres are: *Saffrante* differentiates lignified cellulose from non-lignified cellulose; dark red first; pale red second. (e.g. jute and flax)

*Gelatin violet* is one of the most general microscopic stains. Fibres are overstained and the colour is differentiated with 95% alcohol; fully stain cellulose, but lignin only lightly.

*Cyanine* is one of the best stains for fibres.
Methylene blue is absorbed by oxy cellulose; differentiated with either water or alcohol; check on mercerization: deep shade with mercerized.

Congo red has special affinity to cellulose; test on damaged cotton.

Indigo carmine is useful in the study of wool damage.

Picric acid in alcohol gives an intense yellow colouring to protein fibres.

Sudan III is soluble in fats and oils; staining then orange or red detection of such materials in fibres; wax in cotton cuticle, fats in section of animal skin. (also test on cotton damage)

Various identification stains differential staining of fibres of identification purposes. The best stain is Shirlastain-Shirley Institute, Manchester, England I.C.I; Calco (American). These stains are a mixture of dyestuffs, each having different affinities for different fibres to identify the fibre by the resulting colour.

7.6 Dehydrating and Clearing

Highest possible transparency is generally mounted in a medium of a refractive index close to its own solution. Very often solidifying media are used to make the preparation into a permanent one. These mountants require the previous dehydration of the fibre, as such media are mostly not miscible with water. The dehydrating agent is replaced by a clearing agent which is miscible both with dehydrating agent and final mountant. The clearing agent has a refractive index close to the fibre.

Dehydrating is accomplished by passing the dyed fibre, after rising in water, through different alcohol solutions of increasing concentrations: graduated series of 25%, 50%, 80%, 95% and absolute alcohol is suitable for fibres. In less careful work, to pass the fibre after rinsing through 50% and 95% absolute alcohol or to dry it and pass it through absolute alcohol and xylene only before mounting. Fibre is left for a few minutes in each concentration. The dehydrating must take place gradually in increasing concentrations to avoid shrinkage (damaging the fibre structure).

Xylene or chloroform or cedarwood oil may be used for clearing. Clearing agent is miscible with dehydrating agent (alcohol) and final mountants. A few minutes immersion in the clearing agent is sufficient time.

7.7 Simplified Rapid Method

Dehydrating method may be eliminated by use of a more rapid method. Cellosolve (rapid dehydrant) liquid is suited for the preparation of fibres (e.g. ethylene glycol monoethyl ether).
After staining in a water solution, the fibre is placed in the Cellosolve liquid for a only a few minutes. Clear in xylene for a few minutes and mount.

Another dehydrating agent that clears at the same time is Dioxan (diethylene oxide). It is a most important new microtechnical chemicals but toxicity, which makes it less suitable for classroom use. It is miscible with water, alcohol, xylene, paraffin and canada balsam.

7.8 Permanent Mounting of Fibres

After dehydrating and clearing, it is ready for mounting in several mediums. The most important medium are:

(1) *Glycerin gelatin* - $n = 1.37$; aqueous mountant and does not required previous dehydration and clearing. It gives good contrast with most fibres. It is a mixture of gelatin, glycerin and water to which a few crystals of phenol are added. It is solid at room temperature therefore it must be melted to make the preparation (It is also used for stained or unstained fibres).

(2) Mountants for unstained fibres

*Perston’s colloidin* - excellant nonequeous mountant. When set, $n = 1.45$ for good contrast with most fibres.

*Technicon* (new synthetic mounting medium) - $n = 1.65$, high refractive index and its easy application make this medium highly suitable for mounting unstained fibre.

*Euparal* - $n = 1.483$, low refractive index and is suitable for mounting unstained cellulose and animal hair fibres (nearly invisible when mounted in Canada balsam).

(3) Mountants for Stained Fibres

*Canada balsam* - $n = 1.541$, is close to those of most fibres so that it is suitable for mounting stained specimen and it contributes high transparency. It is the most widely used for nonaqueous mountant.
CHAPTER 8
MICROMETRY

8.1 Micrometers

The quantitative measurement of the diameters and other dimensions of fibres is important for various purposes and many tests of fibres (identification, grading). Microscopic measurement is done with a small scale mounted in the eyepiece (eyepiece micrometer).

(i) **Simplest type of eyepiece micrometer** . . . consists of a glass disk carrying a fine ruled scale which is placed on the diaphragm in the eyepiece. The image of the specimen is formed by the objective at the plane of the diaphragm. Division of the ruler coincide with the plane of the image and since the eye lens is focused on this same plane both image and micrometer scale simultaneously in focus and similarly magnified. The micrometer scale appears superimposed on the image, so that the dimension of the image can be measured.

(ii) **Eyepiece filar micrometer** . . . is a more accurate type which is permanently attached to the eyepiece. With this type, fractions of scale divisions can be read by traveling crosshair moved by a fine screw micrometer; accurate reading obtained.

(iii) **Movable micrometer** . . . is especially recommended for fibre measurements, the entire micrometer scale is moved and ready by the micrometer screw. First, one scale line is made to coincide with one side of the image, reading the micrometer screw drum; then the scale line closet to the other edge is moved by the micrometer screw until it coincides with the other side of the feature, after which the drum read again. The difference between the micrometer readings gives the fraction of a scale unit by the second side was removed from the last scale division.

(iv) **Stage micrometer** . . . Eyepiece micrometer can be used for relative measurements of the specimen, for instance to determine the percentage diameter increase of fibres. Eyepiece micrometer can not be used for direct measurements because it measures the enlarged image of the specimen and not the specimen itself. For absolute measurements, eyepiece micrometer has to be calibrated.

Eyepiece micrometer is calibrated by comparing its divisions with the known length units of a stage micrometers. Stage micrometer is the same size as an ordinary slide and carries a series of ruled lines separated at 10µ and 100µ respectively (1µ = 0.001 mm). There is a total of twenty 100-µ divisions, two of them being subdivided into 10µ units.
8.2 Calibration of Eyepiece Micrometer

The calibration consists in counting the number of eyepiece scale division, covering a
definite number of stage micrometer divisions. The value of one division of the eyepiece can
be obtained by dividing the number of eyepiece divisions into the known value of the stage
micrometer divisions.

\[
\text{Micrometer value (or)} \quad = \quad \text{value of stage micrometer} \\
\text{Value of one division of eyepiece} \quad \text{No. of eyepiece division}
\]

Example: 30 (10μ) divisions of stage micrometer are covered by 12 divisions of eyepiece.

Therefore, the value of one eyepiece division will be:

\[
12 \text{ EPD} = 30 \text{ SMD} \\
1 \text{ EPD} = ? \\
= \frac{(30 \times 10) \mu}{12} = 25\mu
\]

This value is sometimes called the micrometer value.
CHAPTER 9
RECORDING OF OBSERVATIONS

9.1 Freehand Drawing of Microscopic Image

Its has many advantages over other methods. This method requires a high degree of
collection and sharpens the powers of observation.

Free hand drawing from the microscope is the important method. For a
drawing which represents all parts of the specimen in the right proportion it is advisable to
obtain an outline of the image by tracing a projected image or by using a drawing camera.
The detail is added in this outline by freehand drawing. This drawing must be made on as
large a scale as possible to facilitate the reproduction of the finer details.

9.2 Drawing from Projected Image; Drawing Prisms

\[ \text{D - rays from plane of drawing} \\
\text{E - eye} \\
p - prism \\
e - eyepiece \]

Figure 9.1 Passage of Light in Prism of Camera Lucida

Freehand drawing can be facilitated by the use of various techniques of tracing the
projected microscopic image by using a mirror or prisms. A mirror or prism above the
 eyepiece may be used for projected on a plane convenient for drawing.

A simpler method is the use of the drawing prisms or the camera lucida.

The light reaching the eye is made up partially of rays from the specimen and partially
of rays from drawing paper, placed beside the microscope. The prism is placed above the
eyepiece; receiving light coming from the drawing paper which it reflects to the eye; at the
same time light from the microscope reaches the eye. As a result the image of the specimen
is seen superimposed on the drawing paper. The outline of the image can be easily traced on
the papers. The box holds the prism is attached to the tube of the microscope by a clip.
Camera lucida consists of a single small prism, placed above the eye lens and reflecting the drawing paper into the eye in combination with a mirror, which is above the drawing paper, about 5 inches from the microscope, and at the same height as the eyepiece.

9.2.1 Important Points in Using the Camera Lucida

(1) The lighting conditions (light intensity) of microscope image and drawing paper are the same intensity. (image, paper and drawing pencil be equally and sufficiently visible) (by using the tinted glasses, the light from the paper may be further adjusted and regulating the diaphragm)

(2) To prevent distortion of the picture drawn with the camera lucida, the axial ray of the image on the paper must be at right angle to the paper.

(3) The drawing paper must be horizontal to prevent distortion, so it may be checked by using stage micrometer and adjusting board.
CHAPTER 10
WOOL AND OTHER ANIMAL HAIR FIBRES

10.1 Structure

The woolly, hair-like covering of the sheep constitutes one of the most important and most typical of the textile fibres that are obtained from the skin tissues of different animals. The principal members of the wool-bearing animals are sheep and goats.

It consists of a dead part (shaft) outside the skin and a living part (root) in the skin. The root is a living part situated beneath the surface of the skin. The root is fixed at the base of the shaft and when the hair is pulled out. The shaft is cylindrical and tapers to a point at its free end. This dead cell units composing the shaft from three distinct regions:

1. the thin outer covering - the epidermis or cuticle;
2. the middle region - the cortex; and
3. an inner central core - the medulla.

Figure 10.1 Schematic Cross-section of Wool Fibre

(1) Epidermis

The outside or surface of the fibre is made up of flat irregular cells or scales, which are so arranged that those on the side of the root partially overlap the ones on the side of the tip. This results in a separated outer edge of the fibre. The number of scales necessary to cover the circumferences of the fibre varies considerably depending on the diameter of the fibre. The visible scale length is an important characteristic for differentiation between wool and related hair fibres. In the fine wool, these visible scale lengths as 8 to 10 microns. In coarse wool, the scale length may increase to 18 microns. This decreases the overlapping of the scales in given the entire fibre a smoother appearance. The thickness of the epidermis varies considerably with different animal fibres whereas in wool the thickness is between 0.5 and 1 μ.
On the outside of the epidermis, it is covered by a very fine membrane which is called epicuticle. It should form a continuous sheet on the surface of the fibre and is disrupted only by damage to the fibre or during the manufacturing process. It has low permeability to dyestuffs and stains. It can be separated or destroyed from the scales by putting the fibre in chlorine water.

(2) Cortex or Cortical Layer

The cortex is formed below the protective epidermis scales (main portion of the fibre). It constitutes the principle body of the wool fibre and is made up of long slightly spindle shaped cells. The average cells range from 80 to 100μ in length, 2 to 5μ in width and 1.2 to 2.6μ in thickness. These cells lie their long axis parallel to the fibre axis. The spindle-like cortical cells consists of parallel fibrils. The outer layer of the cortex has more consistent structure and forms a continuous membrane which can be isolated in the form of a tube (middle membrane).

(3) Medulla

The medulla is built up of many superimposed cells, of various shapes, often polygonal, forming a honey-comb like structure. Various porous channels pass through the medulla cells which are normally filled with air. The shape and size of the medulla vary greatly. This central layer is not always present. In wool it occurs only in the coarser grades. This may be continuous or interrupted.

![Figure 10.2 Different Types of Medulla](image)

10.2 Two Types of Animal Hair Fibres

(1) Wool hairs ... which from a soft flexible wavy covering.

(2) Beard hairs ... longer more flexible hair which project beyond the wool and form the outside coating.

Wool hairs are using for textile purposes. In wool hair, more fine and soft wool is called worried hair.
In certain type of wool, hairs are found in which the scales have fused together to form a continuous layer around the cortex. It is called *kempy* wool. Kempy wool has a large diameter and a low affinity to dyestuffs. *Bristles* are short stiff hairs with a large medulla; they form the coating.

10.3 Differentiation of Hair Fibres

The following features are important in the differentiation of mammalian hairs.

1. Scales . . . visible length and projection of tip from the fibre outline. It is depending on different animals.
   - Long scale length $\rightarrow$ coarse wool
   - Short scale length $\rightarrow$ fine wool

2. Average diameter of fibre and standard variation from the mean and coefficient of variation.

3. Pigment . . . presence and colour.

4. Medulla . . . presence in certain percentage of fibres width and interruptions.

5. Cross-sectional shape . . . the cross-sectional shape of most hair fibres is round to oval and may vary in the same type of fibres.

10.4 Microscopic Examination of Wool Fibre

(a) Longitudinal View

![Longitudinal View of Wool](image)

*Figure 10.3 Longitudinal View of Wool*

The outline of each scale is noted by the irregular line across the fibre and the saw-tooth serrated sides of the fibre. The scales measure 28 to 30$\mu$ in length, 34 to 38$\mu$ in width and 0.5 to 1$\mu$ in thickness. The visible scale length is about 8 to 10$\mu$ but in greater in coarse wool because of a smaller overlap. Longitudinal striations are clearly visible through the epidermis.
(b) Cross-sectional View

![Cross-section of Wool](image)

Figure 10.4 Cross-section of Wool

Round or elliptical (round to oval) shape in cross-section.

10.5 Varieties of Hair Fibres

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of wool</th>
<th>Colour</th>
<th>Dia: in μ</th>
<th>Scales per 100μ</th>
<th>Medulla</th>
<th>Cross-section</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sheep wool</td>
<td>White</td>
<td>10-12</td>
<td></td>
<td>Only in coarse grades</td>
<td>Oval</td>
</tr>
<tr>
<td></td>
<td>(a) Fine wool</td>
<td></td>
<td></td>
<td></td>
<td>Absent in best qualities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Medium wool</td>
<td></td>
<td>17-23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) Coarse wool</td>
<td></td>
<td>23-33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) Carpet wool</td>
<td></td>
<td>33-42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(d) Carpet wool</td>
<td></td>
<td>20-50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Mohair (hair from the Angora goat)</td>
<td>White</td>
<td>14-90</td>
<td>5-6</td>
<td>Completely absent</td>
<td>Almost circular</td>
</tr>
<tr>
<td></td>
<td>(b) Mohair (hair from the Angora goat)</td>
<td>Reddish-brown</td>
<td>16-25</td>
<td>6.5-9</td>
<td>Absent</td>
<td>Irregular circular</td>
</tr>
<tr>
<td>3.</td>
<td>Camel hair</td>
<td>Reddish-brown</td>
<td>12-16</td>
<td>6-9</td>
<td>Absent</td>
<td>Circular</td>
</tr>
<tr>
<td>4.</td>
<td>Cashmere</td>
<td>White or fawn</td>
<td>20-35</td>
<td></td>
<td>Periodical interruptions</td>
<td>Oval</td>
</tr>
<tr>
<td></td>
<td>(b) Cashmere</td>
<td></td>
<td></td>
<td></td>
<td>dog-bone shape</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Llama</td>
<td>White brown</td>
<td>20-34</td>
<td></td>
<td>Separated in short,</td>
<td>Oval</td>
</tr>
<tr>
<td></td>
<td>(b) Llama</td>
<td></td>
<td></td>
<td></td>
<td>granular portions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Llama</td>
<td></td>
<td></td>
<td></td>
<td>arranged in one, two, or three parallel rows</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Alpaca</td>
<td>White, gray,</td>
<td>6-18</td>
<td>7-9</td>
<td>Absent</td>
<td>Circular</td>
</tr>
<tr>
<td></td>
<td>(b) Alpaca</td>
<td>brown, black-brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Vicuna</td>
<td>Reddish-brown</td>
<td></td>
<td></td>
<td>Separated in short,</td>
<td>Round</td>
</tr>
<tr>
<td></td>
<td>(b) Vicuna</td>
<td></td>
<td></td>
<td></td>
<td>granular portions</td>
<td>and oval</td>
</tr>
<tr>
<td></td>
<td>(b) Vicuna</td>
<td></td>
<td></td>
<td></td>
<td>arranged in one, two, or three parallel rows</td>
<td></td>
</tr>
</tbody>
</table>

10.6 Physical Properties of Wool

The wool fibre varies with in wide limits depending on the broad and geographic location of the sheep and the part of the fleece from which the wool is derived. Conversion of fibres into yarns and goods brings out additional physical characteristics, such as the contour, crimp, elasticity, resilience, rigidity, felting quality, specific gravity, moisture content, electric properties and warmth.
- moisture regain = 13 ~ 15%; wool is more hygroscopic than any other fibre. The amount of moisture varies considerably according to the humidity and temperature of the atmosphere.
- specific gravity = 1.32.
- poor conductor.
- lustrous; wools vary in lustre considerably. It varies with origin and brand of animal and with climate.
- 30% elongation.
- best resilience property.
- crimp is probably a direct consequence of the formation of the fibre. Equality of crimp is associated with uniformity. It is a sign of good quality. Crimps occur in the form of waves or curls.

Greater crimp/in —→ fine wool
- good felting property; this is one of the most important characteristics of wool. To make felting possible a fibre must possess a surface scale structure.
- The diameter of wool fibres varies greatly, even in the same fleece; it may range from 10 to 20 μ.
- fibre contour; the shape of the cross-section varies greatly. Some cross-sections are nearly circular. As a rule they are irregular and have a varying degree of ovality. (more circular wool spins better)
- length; the length of wool fibres varies in large limits not only in different brands but also on the same animal.

10.7 Microchemical Reaction of Wool

Wool is an animal fibre, protein base.

Zinc chloroiodine —→ gives negative reaction (colourless)
Million’s reagent —→ pink brick-red colour (positive reaction)
Boiling 5% KOH —→ dissolve the fibre completely
Conc: HNO₃ —→ reacts to give a yellow colour

10.8 Impurities in Wool

(1) Natural impurities . . . fat, grease, oil
(2) Added or Acquired impurities . . . dust, dirt
(3) Applied impurities . . . treatment againsts diseases, identifying purposes
10.9 Measurement of Fineness of Wool

For determination of fineness the diameter of 100 to 400 fibres must be measured and averaged and the standard error calculated. The diameter of wool is one of the most important characteristics for grading. Wool is classified in four groups on the basis of the fineness.

(1) Fine wool - 17 - 23 μ
(2) Medium wool - 23 - 33 μ
(3) Coarse wool - 33 - 42 μ
(4) Mixed carpet wool - 20 - 50 μ

10.10 Detailed Investigation of Scales or Study of Scale Structure in Wool

For study of the scales, it is necessary to remove the fat from the surface of the fibre. The presence of fatty substances can be shown by reacting with Sudan III, which gives a red colour with the fats. The fats and related substances can be removed by cleaning the fibre in warm water and treating with either and alcohol.

If the fibre is too (fully) transparent, the layer of scales on the lower half interferes with the observation of the scales in the upper half.

If the fibre is heavily pigmented or dyed and not transparent at all, the scales are invisible of the interception of the light.

Therefore, special techniques have been worked out for obtaining better visibility of the scales.

(1) Semi-mounting Method

A fully transparent fibre, the influence of the lower part of the fibre can be eliminated by immersing the lower half (semi-mounting) in a liquid with the same refractive index of the fibre (n = 1.54). The mountant consists of a solution of transparent rubber 1 cc dissolved in xylene 8 cc.

After the fibre has been degreased, it is fixed in a straight position on a slide by two drops of paraffin wax in such away that it is removed from the glass at a distance of three times its diameter. A drop of the solution is placed near the fibre on the slide using a fine glass rod. There upon the liquid is brought carefully in contact with the fibre and moved by capillary action between the fibre and the slide. If it is carried out correctly, the fluid will wet only the lower part of the fibre.
After the evaporation of xylene, which takes about an hour at room temperature, the fibre is attached to the glass slide by the layer of rubber, which enables the study of the upper surface without interference of the lower surface.

(2) Scotch Tape Method

This is a simplified method. It consists of cementing under light pressure a few fibres on a coverglass with a piece of scotch tape and observing the fibre from the slide opposite the scotch tape. As the tape material and wool have the same refractive index.

(3) Fibre Impression Method

The method is for pigmented or dyed opaque hair to study the surface structure. In this case, special cement is required. The following medium is used for making fibre impressions:

- Cellulose acetate - 12 gm
- Ethyl lactate - 10 cc
- Amyl acetate - 78 cc

A drop of above solution is placed on the coverglass and a degreased fibre is gently lowered on the surface of the medium. The preparation is then dried for 30 minutes in an incubator at 35°C, whereupon the fibre is removed. The impression studied under the microscope with the cast on the underside of the coverglass.

Another cement is du Noyers Lanoline cement. The substance is melted before use.

- Lanolin - 20 gm
- Colophony resin - 80 gm.

The fibres are degreased and cut into short pieces. The cement is melted and applied on the slide, and just before it cools and hardens the fibres are pressed into it, after complete cooling, the fibres are pulled out of the cement. The impression studied under the microscope.

10.11 Damage in Wool

(1) Mechanical damage . . . such as loss of scales, fibrillation, and bending of fibres. It can be recognized by direct microscopic study after mounting the fibre in water, paraffin oil or glycerin.

(2) Chemical damage . . . cannot be easily directly detected. It is appeared by scouring, bleaching, etc. After scouring process,

- more acid ➔ acid damage
- more alkali ➔ alkali damage
(3) *Microbial damage* . . . can be detected mostly by direct observation. The fibre is often more or less macerated in this damages.

(a) Allworden Reaction for Alkali Damage

The degreased fibre is mounted in water to which an equal volume of freshly prepared chlorine water (or bromine water) is added.

Undamaged fibres react to *develop bubbles* all along their surface. The reaction is connected with the presence of the epicuticle on the outside of the fibre. The reagent also increases the extensibility of the epicuticle. Damaged fibres do *not develop bubbles*.

Normal wool fibres are treated with 10% sodium carbonate at 50°C. By this treatment the epicuticle is dissolved (i.e. damaged fibre). The Allworden reaction is negative in the treated fibres and globule formation no longer takes place.

If this same wool is treated with strong acids, the epicuticle is not destroyed and the Allworden reaction remains positive. This makes it possible to differentiate between damage due to alkali and acids.

(b) Krais-Viertel Reaction for Acid Damage

This reaction is also based on the formation of bubbles on the fibre. The fibres, cut in 3 mm. lengths, are mounted in a solution of 20 gram of sodium hydroxide in 50 ml. concentrated ammonia dissolved by cooling and shaking.

The time until appearance of the first granular bubbles, which are characteristic of this reaction, is recorded with a stopwatch. A test with undamaged wool of the same quality (diameter) is always carried under the same conditions (temperature). The time recorded at normal room temperature is

1 - 2 minutes → strong acid damage
2 - 6 minutes → normal acid damage
6 - 10 minutes → no damage (acid treated material)
8 - 12 minutes → normal wool (untreated)

A *longer period* than the one in the undamaged fibre and *smaller bubbles* indicate damage by alkali, heat and light; a *shorter time and larger bubbles* damage by acid.
CHAPTER 11
HAND SECTIONING

11.1 Technique

It is necessary to prepare thin cross sections in the microscopic study of fibres.

1. Identification of many natural and synthetic fibres . . . the cross-sectional appearance is used as one of the most important microscopic characteristics.

2. Control the spinning process . . . blocking of the holes of the spinnerets can be detected in this way.

3. Determination of the fibre size, fineness . . . can be determined from the cross-sectional area.

4. Study of the dyeing process . . . cross section of fibres and yarns is an important method.

There are several techniques for the preparation of cross section. Special techniques have been designed and more proved particularly suitable for the sectioning of textile fibres.

11.2 Plastic Plate Method (or) Brass Plate Method

![Diagram of Plastic Plate Method](image)

\[ \phi 0.5 \text{ mm} \quad 0.4 \text{ mm} \]

Figure 11.1 Preparation of Cross-section of Fibres by Plate Method

This method is a simplest method for preparing cross sections of fibres. This plate has approximately the same size as a microscopical slide, and is 0.4 mm. thick; the holes in the plate have a diameter of 0.5 mm.

A bundle of fibres in an untwisted and parallel arrangement is pulled into one of the holes by using a small nylon yarn. Care must be exercised to take just enough sample to fill the hole in a way that the fibres are tightly held together without being excessively compressed or distorted. With a sharp razor blade the protruding ends are cut flush with the plate on both sides. After the fibres have been cut, the plate is placed on the stage and viewed without any further preparation.
11.3 Cork Method

![Diagram of cork method steps]

A, cork; B, cork pierced longitudinally by needle carrying thread; C, needle is removed leaving thread forming loop at top of the cork; D, a bundle of fibers is placed at the top of loop; E, and pulled into cork; F, cross sections of cork containing fibers are made; G, section; H, section of cork containing fibers stuck to coverglass by drop of glycerol; I, J, K, coverglass and section are carried by ring on the slide.

**Figure 11.2 Preparation of Cross-section of Fibres by Cork Method**

This is an another simple method. This method consists of the following operations:

1. Put a long sewing needle threaded with a nylon yarn through the center of an ordinary small cork stopper.

2. A small object (a pin) is placed through the protruding loop, the needle is withdrawn, leaving the string threaded through the cork.

3. A bundle of fibre, a paralleled is placed in the loop and pulled carefully into the cork by pulling the two loose ends of the string. Care must be taken that the amount of fibre pulled into the cork is such as to assure a slight compression to hold the fibres together without distorting them.

4. The surface of the cork is squared accurately with the direction of the fibre bundle.

5. A thin slice is cut from the cork with a sharp razor blade.

6. The slide of cork containing the fibre is attached to the coverglass with a drop of glycerin.

7. The coverglass is mounted on a slide supporting it by a ring of paraffin to keep the surface of the fibres parallel to the focal plane of the objective.

It is essential that the cork sections are cut accurately perpendicular to the axis of the fibre and that they are not too thin, $\frac{1}{2}$ mm., thickness given the best results.
11.4 Hardy Microtome Method

The hardy microtome is especially suitable for the preparing of relatively thin cross sections of fibres.

It is a metal plate which consists of two halves held in alignment by two grooved pieces around the long sides. There is a small slot parallel to the long side in one of the two halves; into which fits a tongue protruding from the centre of the other half of the device. If the two halves are put together, the tongue does not completely fill the slot, but leaves room for the fibres to be held in it. A tiny plunger which fits exactly in the open space of the slot is operated lay a fine screw; the complete plunger system can be swung a side during the preparation of the fibre bundle.

The procedure in using the instrument is as follows:

1. Parallelize the fibres by coming; it is very important that they be exactly parallel. Insert a sufficient number of them in the slot so that the device will close only with a little pressure when the two parts are put together. It is important to use the correct amount of fibres to prevent too tight or too loose a packing. This can be checked by pulling the fibre bundle up and down in the slot, which must be just possible.

2. With scissors cut the ends of the fiber tuft outside the plate as closely as possible to the plate and apply collodion solution or Neg-O-Lac or lacquer with a brush to the remaining parts of the tuft so that all fibres are embedded in it. Let the lacquer dry.

3. With a single-edge razor blade cut off the protruding parts of the tuft flush with the metal surface, cutting first the tuft on the upper side of the plate.

4. Bring the plunger system in place and propel the embedded tuft upward by use of the plunger screw. The slighter the protrusion of the tuft above the surface of the plate, the thinner the section will be.

5. Coat the protruding tuft with lacquer.

6. Slice with a single stroke, holding the blade as flat to the metal as possible and obliquely across the slot. A movement of the plate toward the blade during the sectioning is necessary and will make the cutting easier.

7. Sections are removed from the razor blade with a brush and mounted on the slide in mineral oil or some other mountant.
Figure 11.3  Schematic Representation of the Various Steps in the Preparation of a Correction with the Hardy Microtome

With the hardy microtome sections from 10 to 30 μ can be easily made and thickness as slight as 2 to 3 μ can be reached. For good sections of cotton a thickness of 5 to 8μ is required.
CHAPTER 12
RAYONS

12.1 Manufacturing Process of Rayons

The manufacturing process of regenerated fibres consists of bringing a natural high polymer substance into solution in a suitable way and extruding this solution through an orifice, regenerating the same high polymer in the form of a solid filament.

Rayon is a general term for man-made filaments prepared from various solutions of modified cellulose. Rayon, like other man-made fibres, are used in either continuous form or in staple form. Ordinary rayons are termed 'bright' because finished products of these fibres appear 'glossy' to the naked eye. In 'delustered' rayons, this glossiness is reduced by the presence of fine particles of titanium dioxide (TiO₂) inside the fibre which scatter the light. This compound is added as a fine powder to the spinning solution to obtain the 'dull' fibre. Oil emulsions are also used. Rayon and other synthetic fibres are produced in different degrees of fineness measured by units of weight (denier).

Solidifying or spinning process

1. Wet spinning process . . . in which solidification of the filaments takes place in a fluid acid bath. In this process, a solid skin is first formed, followed by the solidification of the inner portion of the filament. This results in a contraction of the fibre during the spinning process and the formation of folds or lobes on the surface.

2. Dry spinning process . . . in which solidification of the filaments is prepared by the evaporation of the solvent (acetone).

12.2 Microscopic Examination of Viscose Rayon

(a) Longitudinal View

Figure 12.1 Longitudinal View of Viscose Rayon
Even diameter with several fine striations on the surface (in 100% pure glycerin or paraffin oil). These are more visible in bright than in dull filaments.

(b) Cross-sectional View

Figure 12.2 Cross-section of Viscose Rayon

The general shape is irregularly oval; the outer edge is strongly scalloped by approximately 8 to 20 lobes or folds in cross-section (solid skin is first formed, followed by the solidification of the inner portion of the filament. This results in a contraction of the fibre during the spinning process and the formation of folds or lobes on the surface).

12.2.1 Microchemical Reaction of Viscose Rayon

Viscose rayon has 99% cellulose content. Therefore, it is a pure cellulose fibre.
Zinc chloroiridine \( \rightarrow \) gives a blue colour

12.2.2 Properties of Viscose Rayon

- specific gravity = 1.52
- smooth, straight and easy to handle
- swell in water and low tensile strength especially when wet
  (wet \( \rightarrow \) 0.7 - 1.2 gm/denier; dry \( \rightarrow \) 1.5 - 2.4 gm/denier)
- moisture content higher (13 ~ 14%) and good affinity for dyestuff but easily mildew attack
- wet yarn elongates more than dry, both elongation and elasticity are altered by change in fibre structure
- under the influence of heat as well as light, show rapid loss in strength
- weak in sunlight
- use direct dyes for dyeing

12.2.3 Measurement of Cross-sectional Area and Computation of Denier Size

The denier (D), being the weight in grams of 9000 meters of filament of yarn.

\[ D = \text{weight in grams per 9000 meters length of yarn} \]
The cross-sectional area of the filament is determined in the following way. If the
fibre is circular, the area of fibre is \( \pi/4 \ d^2 \). For the filament which has non-circular, cross-
section are calculated in the following way.

About ten images of cross sections are drawn with the camera lucida on graph paper.
The graph squares are calibrated with the stage micrometers, and the value of the squares in
square microns is computed. By counting the number of squares covered by the area of the
fibre, the cross-sectional area of the fibre is obtained. The average surface area of ten fibres
is defined and the average value is used to calculate the denier size of filament.

If the denier of the individual filaments is known, the denier of a yarn composed of
these filaments may be calculated by multiplying the filament denier by the number of
filaments in the yarn (taking into consideration the percent of contraction due to yarn twist).

\[
\begin{align*}
\text{Density} &= \frac{\text{Weight}}{\text{Volume}} \\
&= \frac{W}{V} \\
&= \frac{\text{gm}}{\text{cc}}
\end{align*}
\]

\( \therefore \) Weight = Volume \times Density

\[
\text{Density} = \text{Specific gravity} = \frac{\text{Density of rayon}}{\text{Density of water}}
\]

\[
\begin{align*}
\text{Denier} &= \frac{\text{gm}}{9000 \ \text{meter}} = \text{weight} \\
&= \text{Volume} \times \text{Density} \\
&= (\text{Length} \times \text{Area}) \times \text{Specific gravity} \\
&= (9000 \ \text{m} \times a \ \text{in} \ \mu^2) \times 1.52 \ \text{gm/cc} \\
&= (9000 \times 100) \ \text{cm} \times a \ \text{in} \ \mu^2 \times 1.52 \ \text{gm/cc} \\
&= (9000 \times 100 \ \text{cm}) \times (a \times 10^{-8}) \ \text{cm}^2 \times 1.52 \ \text{gm/cc}
\end{align*}
\]

\( \therefore \text{Denier} = \frac{9000 \times 100 \ \text{cm} \times a \ \text{in} \ \mu^2 \times 1.52 \ \text{gm/cc}}{10^8} \)

\( \therefore \text{Denier} = \frac{900,000 \ \text{x surface area in} \ \mu^2 \ \text{x} \ 1.52}{10^8} \)

where, \( a = \text{cross-sectional area in sq-cm} \)

Denier of yarn composed of a number of filaments = Denier of filament \times \text{no. of filaments}

12.2.4 Relation Between Denier and Diameter

Diameter of fibre of cylindrical yarn = \( d \) (known)

\( \therefore \) Cross-sectional area = \( \pi d^2 / 4 \)
But in this case there still is a close correlation between diameter and cross-sectional area. Therefore, between diameter and denier; the diameter will vary approximately as the square root of the denier.

\[
\text{Denier} = \frac{900,000 \times 1.52}{10^8} \times \frac{\pi d^2}{4}
\]

\[
D = K \cdot d^2
\]

\[
d^2 = \frac{D}{K} = \frac{1}{K} \cdot D
\]

\[
\therefore d = \frac{1}{K} \cdot \sqrt{D}
\]

e.g., \( D = 5 \); \( \text{Sp. gr.} = 1.12 \text{ gm/cc} \)

\[
1.52 \text{ gm} \quad \text{---} \quad 1 \text{ cc}
\]

\[
1 \text{ gm} \quad \text{---} \quad ? = \frac{1}{1.52} \text{ cm}^3
\]

\[
\therefore 5 \text{ gm} \quad \text{---} \quad ? = \frac{5}{1.52} \text{ cm}^3 (V)
\]

\[
\text{dia: } = d
\]

\[
\text{vol: } = 900,000 \times \frac{\pi d^2}{4}
\]

\[
\frac{5}{1.52} \text{ cm}^3 = 900,000 \times \frac{\pi}{4} \cdot d^2
\]

\[
d^2 = \frac{5}{1.52 \times 900,000 \times \pi/4}
\]

\[
\therefore d = \frac{\sqrt{5} \times 4}{1.52 \times 900,000 \times \pi} \text{ cm} = 22.54
\]

12.3 Microscopic Examination of Cuprammonium Rayon

(a) Longitudinal View

---

Figure 12.3 Longitudinal View of Cuprammonium

The filaments appear fine and structure less cylindrical, without striations or marking of any kind.
(b) Cross-sectional View

Figure 12.4 Cross-section of Cuprammonium

Circular or sometimes slightly oval, with a smooth contour; no folds.

12.3.1 Microchemical Reaction of Cuprammonium Rayon

Zinc chloroiodine → positive reaction, pure blue colour
Cuprammonium hydroxide → dissolve

12.3.2 Differentiation Between Viscose and Cuprammonium Rayon

Treat with Brilliant Benzo Blue 6 BA at room temperature, followed by rising in warm water.

- Cuprammonium gives blue colour
- Viscose rayon gives unstained

12.3.3 Properties of Cuprammonium Rayon

Since cuprammonium rayon is a regenerated cellulose it has properties similar to viscose rayon. The fibres are not as strong as viscose rayon. Cuprammonium yarns are made in finer deniers and with a higher number of filaments than viscose.

- specific gravity = 1.52 gm/cc
- moisture regain = 12.5%
- elongation at break = 10 - 17%
- tenacity = 1.7 - 2.3 gm/ den (dry)
  = 0.95 - 1.25 gm/den (wet)
- strength reduce in sunlight
- has good draping properties
- subjected to mildew attack due to its moisture content
- long exposure to light will weaken the fibre
- swell in strong alkali solution and reduce in strength
- weak alkali will not attack the fibre
- insoluble in acetone
- soluble in cuprammonium solution
12.4 Microscopic Examination of Acetate

(a) Longitudinal view

Figure 12.5 Longitudinal View of Acetate

The fibre surface is smooth and the lobes are visible; instead of the many striations, there are 1 to 3 prominent striations running lengthwise in the fibre. Between the striations, the presence of a central canal or lumen (false lumen). This lumen does not always lie in the centre of the fibre but sometimes on one side, sometimes two are formed in the width of one fibre.

(b) Cross-sectional View

Figure 12.6 Cross-section of Acetate

The general shape of fibre varies from circular to flat-elliptical; a few deep grooves observed in length view occur on its surface; a cloverleaf with large lobes; 3 ~ 4 lobes (max: 5 lobes).

12.4.1 Microchemical Reaction of Acetate

This fibre is not a cellulose.

Zinc chloroiodine \[\rightarrow\] gives negative reaction, yellow colouration the fibre and dissolve in it.

Acetate, ether, chloroform, acetic acid \[\rightarrow\] dissolve

Conc: \(\text{H}_2\text{SO}_4\) \[\rightarrow\] decomposed

Cuprammonium hydroxide \[\rightarrow\] undissolve
12.4.2 Properties of Acetate
- specific gravity = 1.32 gm/cc
- moisture regain = 6%
- higher strength than cuprammonium rayon but lower strength than viscose rayon
- strength weak in sunlight (exposure)
- has thermal plastic properties
- resistant to bacterial attack and fungus
- best crimp resistance
- best feeling
- has excellent electrical insulating properties
- high resilience properties
- resistant to heat
- very pale colour can be obtained, used disperse dyes
CHAPTER 13
RESOLVING POWER

13.1 Theory

Microscopes are intended to reveal fine structural details rather than to produce enlarged images of what can be seen at a lower magnification.

The ability of the objective to separate distinctly small elements or structural details in the image of an object is termed "resolving power".

The resolving power of any lens has a specific limit which is the smallest distance between two structural details that the lens will reveal separately in the image. Resolving power and magnification are two desired features of a microscope. Resolving power is the more important and may be considered as the minimum distance between two points which allows them to be distinguished when examined under a microscope fitted with the given objective.

13.2 Numerical Aperture and Resolving Power

The resolving power of a lens depends on the wavelength of the illuminating light and the numerical aperture of the lens. It is independent of the magnification by the lens.

Formerly, angular aperture $\theta$ used as the measure of resolving power, is the angle at the apex of the maximum cone of light received by the lens AB from a point P in the object.

![Diagram of numerical aperture](image)

**Figure 13.1** The Concept of Numerical Aperture

The greater the focal length, the greater must be the diameter of the front lens in order to maintain a given angular aperture. Although the angular aperture gives an indication of the resolving power it is not precise, and a more satisfactory measure is given by the Numerical Aperture (NA).

Numerical Aperture is an optical constant introduced by Abbes and which can be calculated from the expression:

\[ NA = n \sin \theta \quad \text{or} \quad NA = n \sin \frac{\theta}{2} \]
Where, \( n \) = the lowest refractive index encountered by light rays during passage from object to objective

\[ A = \text{half the angular aperture of the objective} \]

\[ \theta = \text{angular aperture} \]

The resolving power (R) or the size of the finest detail that can be shown by a microscope is given by the formula:

\[ R = \frac{KL}{NA} \]

\[ R = \frac{0.61\lambda}{NA} \]

where, \( \lambda \) = the wavelength of the illuminating light

\[ K = 0.51 \text{ (Abbe)} \text{ or } 0.61 \text{ (Rayleigh)} \]

13.3 The Relation Between the Numerical Aperture and the Diameter and Focal Length of a Lens

If the lens and P are in air, then \( n = 1 \).

So that \( NA = n \sin \theta/2 \)

\[ = 1 \times \sin \theta/2 \]

\[ NA = \frac{AC}{AP} \]

Where P lies at the focal point of the lens, PC = f, the focal length. Let, the diameter of the lens AB be D, then the above expression becomes:

\[ NA = \frac{AC}{AP} \]

\[ = \frac{D}{2} \times \frac{1}{\sqrt{(D/2)^2 + PC^2}} \]

\[ = \frac{D}{2 \sqrt{(D^2/4 + f^2)}} \]

From the expression \( NA = n \sin \theta/2 \), it follows that optimum resolution will be achieved when \( \theta = 180^\circ \) and with a dry objective, the maximum NA obtainable is theoretically 1.0. In practice, the value does not exceed 0.95 owing to mechanical limitations.

Greater NA can be obtained if the object and front lens of the objective (AB) are immersed in a medium with a refractive index greater than that of air.
When such an immersion medium is employed it should have a refractive index slightly greater than the value of NA desired, since in practice θ is less than 180°.

In practice, satisfactory results are obtained using optical glass immersion objectives with cedar wood oil. It should be noted, however, that the refractive index of cedar wood oil varies from 1.514 when fresh, to more than 1.52 in the thickened material.

The maximum NA of an objective in general use is 1.4, although lenses have been designed to give an NA of 1.6 when used with α-monomonaphthalene. For ultra-violet microscopy, glycerol and water is used as the immersion liquid.

The resolving power of the lens can be directly computed from \( R = \frac{0.61\lambda}{NA} \), when the numerical aperture of the lens and the average wavelength of the light are known.

The actual resolution which can be achieved by using an efficient microscope of NA = 1.40 in conjunction with green light of wave length 0.55 x 10\(^{-4}\) cm is given by:

\[
R = \frac{0.61\lambda}{NA}
\]

\[
= \frac{0.61 \times 0.55 \times 10^{-4} \text{ cm}}{1.40} = 0.24 \times 10^{-4} \text{ cm}
\]

For white light, an average wavelength of 5555 Å or 0.5555 μ is introduced. If the numerical aperture of an objective is, for instance, 0.60, then

\[
R = \frac{0.61\lambda}{NA}
\]

\[
= \frac{0.61 \times 0.5555 \mu}{0.60} = 0.55\mu
\]

(An angstrom = 10\(^{-8}\) cm or 10\(^{-4}\) μ, 1μ = 10\(^{4}\) Å)

\[
A = 10^{-8} \text{ cm}
\]

\[
5555 \text{ Å} = 10^{-8} \text{ cm x 5555} = 5.555 \times 10^{-5} \text{ cm}
\]

\[
R = \frac{0.61 \times 5.555 \times 10^{-5}}{0.60} = 5.5 \times 10^{-5} \text{ cm}
\]

13.4 Resolving Power Versus Magnification

In formula \( R = \frac{0.61\lambda}{NA} \) for the resolving power the magnification is not represented: the resolving power is independent of magnification, but a certain magnification of the image is necessary for the human eye to be able to distinguish the details of the image separately. This is because the human eye (lens) in turn has a limited resolving power. The smallest internal the unaided eye can distinguish is from 1 to 2 minutes of arc or about 0.1 mm at a distance of close vision.
This limitation may be understood by first considering the eye as a lens, the resolving power of which is again dependent on the wavelength of light and the aperture of the eye.

If the radius of pupil is 1.5 mm, then the sine of the aperture at the distance of close vision (250 mm) will be 1.5/250 and hence the resolving power at that distance for a wavelength of 0.65\( \mu \)m will be:

\[
\lambda = 0.65 \ \mu = 0.65 \times 10^{-3} \text{ mm} = 0.00065 \text{ mm}
\]

\[
\text{NA} = n \sin \theta/2 = 1 \times \sin \theta/2 = 1.5/250
\]

\[
R = 0.61 \lambda/\text{NA}
\]

\[
= 0.61 \times \frac{0.00065}{1.5/250} = 0.066 \text{ mm or about 1 minute of arc}
\]

Therefore, the magnification of the microscopic image at 250 mm from the eye must be such that the details in this image are at least the same minimum distance of 0.06 ~ 0.1 mm apart. The magnification at which this last condition is fulfilled is termed *useful magnification*.

There is no advantage in further increasing the magnification, above this value is termed *empty magnification*. Increased magnification without increased resolving power does not reveal more details.
CHAPTER 14
SILK

14.1 The Cycle of Silk Worm

The silk fibre is a continuous protein filament produced by a caterpillar known as the silk worm, in forming their cocoon. Silk worm eggs are of two types:

(1) Those used for reproduction, (2) Those used for cocoon production. The former are used as stock by egg producers whereas the latter are hatched by cocoon farmers for the production of silk.

The caterpillar lives on mulberry leaves and extrudes a pair of silk filaments from two silk glands. Both these filaments are extruded from a common exit in the head of the worm and on emerging are cemented together by a surrounding film of gum. Although both the gum and filaments are protein in nature, they differ in their exact chemical composition and in their physical characteristics. The filaments consist of fibroin which is strong and elastic and the gum is composed of sericin which is brittle in the dry state, easily ruptured by mechanical action and readily dissolved in boiling water.

Working from the inside each worm builds an oval casing or shell by extruding through its spinnets the viscose liquid from its silk gland. Layer after layer is added by moving so that in 24 to 72 hours, the cocoon is completed which serves as the enclosed silk worm undergoes a series of transformation to form a moth. The moth lives about 1 to 4 days during which the mother moth lays about 500 eggs which complete her life cycle.

The double silk filament as it exist in the cocoon is known as bave and the single filament is called the brin.

Figure 14.1 Silk Filament
The filament is reeled from the cocoon treated with warm water to soften the sericin. A considerable amount of gum remains and holds the pair of filaments together. Normally, silk is spun in raw state, after which the gum is completely removed by a boiling processes called degumming. The total weight loss in degumming is about 20%. As a result of the degumming, fibrils of the outside may be loosened and during operations may become entangled in small clusters.

In the reeling the outer and inner layers of the cocoon are discarded as waste. It is also obtained from pierced and inferior layer. The waste silk is degummed and carded and a short length is obtained to the staple of wool. The fineness of raw silk corresponds to 1.7 to 4.0 denier (10 to 12μ, max: 25μ). Silk is often weighed by the tin-silico-phosphate process, by which tannic oxide is precipitated in the fibre. A phosphate is added by treating the fibre with a phosphate bath; and this is followed by a silicate bath to increase in weight still further and to fix the salt.

14.1.1 Microscopic Examination of Raw Cultivated Silk

(a) Longitudinal View

![Image showing longitudinal view of silk filament]

**Figure 14.2 Longitudinal View of Cultivated Silk**

Very irregular surface structure; traverse cracks, folds, fissures and creases on outer sericin layer; some places is peeled off the fibre, uncovering the filament underneath; faint striations and band portions. The underlying filaments (degummed fibre) have smooth surface and lie closely together, structureless filament, sericin absent, separated filaments, almost constant diameter, only faint striations.

(b) Cross-sectional View

![Image showing cross-sectional view of silk filament]

**Figure 14.3 Cross-section of Cultivated Silk**
Rounded corners triangular shape; usually two filaments are observed to lie close together with their flat sides; showing the two triangular brin surrounded by sericin facing each other with the flat side of the triangle.

14.1.2 Microchemical Reaction of Raw Cultivated Silk

- Reactants on protein → gives positive reaction
- Million's reagent → positive reaction, brick-red colour
- Zinc chloroidide → negative reaction, yellow colour
- Boiling 5% KOH → quickly dissolve
- Cuprammonium solution → dissolve if weighted silk, weighting material undissolve
- Conc: HNO₃ → swell and change yellow colour, slowly dissolve
- Conc: H₂SO₄ → dissolve
- HCl → rapidly dissolve

14.1.3 Microchemical Separation of Sericin Layer and Fibroin Filaments

The sericin layer and fibroin filaments have different chemical nature so separate by:

1. Cuprammonium solution . . . fibroin → first swell in width while contracting in length, causing a bulging of the gum layers and formation of transverse cracks in the gum. The fibroin dissolve in a short time
   Sericin → remains,
2. Boiling the fibre in water . . . series layer dissolve fibroin are remained.

14.1.4 Properties of Raw Cultivated Silk

- quite hygroscopic and absorb as much as 30% of its weight of moisture and still appear dry
- distinguished by its considerable strength, breaking strength about 4gm/denier
- relatively low elasticity (20% elongation)
- poor conductor of electricity and accumulate a static change by friction
- specific gravity = 1.33
- light filament
- it can stand a high temperature without injury
- highly absorbent fibre and readily becomes impregnated or wetted by water
- dissolve in Conc: H₂SO₄ and HCl
- Conc: HNO₃ gives yellow colour
- swell and contract in 90% formic acid
- not as sensitive to dilute alkali as wool, though the lustre of fibre is somewhat diminished
- dissolve in strong hot alkali
- toward colouring matters in general, silk exhibits a greater capacity of absorption than perhaps any other fibres. It also absorbs dyestuffs at much lower temperatures than does wool.

14.2 Tussah or Tusser Silk (Wild Silk)

Tussah silk is produced by the wild silkworm. The worm lives on the leaves of oak trees in the wild state. It is much lower in quality and much coarser and stiffer than cultivated silk. Its colour is brownish. It has less reactive in general towards chemicals reagents more difficulty in bleaching and dyeing and much more severe treatment for degumming than raw cultivated silk.

14.2.1 Microscopic Examination of Tussah Silk

(a) Longitudinal View

![Longitudinal View of Tussah Silk](image)

Figure 14.4 Longitudinal View of Tussah Silk

The degummed fibre shows a ribbon-like shape with some twists; brown fibre and shows a large number of clear longitudinal striations on the surface; diameter of filament at its greatest width is between 30 to 40 μL.

(b) Cross-sectional View

![Cross-section of Tussah Silk](image)

Figure 14.5 Cross-section of Tussah Silk

The individual filament has a wedge-like shape or flattened triangular shape in cross-section.
### 14.3 Microchemical Differentiation between Cultivated and Tussah Silk

<table>
<thead>
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<th>Cultivated Silk</th>
<th>Tussah Silk</th>
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<td>(1) Longitudinal View</td>
<td>Irregular surface structure (cracks, knees)</td>
<td>Ribbon-like shape</td>
</tr>
<tr>
<td>(2) Cross-section</td>
<td>Rounded corner triangular</td>
<td>Wedge-like shape</td>
</tr>
<tr>
<td>(3) Conc: H₂SO₄</td>
<td>Dissolve</td>
<td>Undissolve, much more resistant than cultivated silk</td>
</tr>
<tr>
<td>(4) HCl</td>
<td>Rapidly dissolve</td>
<td>Only slightly affected even after one or more days</td>
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<tr>
<td>(5) Boiling KOH</td>
<td>Quickly dissolve</td>
<td>Partially dissolve</td>
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CHAPTER 15
MECHANICAL SECTIONING

15.1 Technique

Mechanical sectioning is used to prepare very thin cross sections as required for special research purposes.

(1) Standard Paraffin Wax Method
(2) Collodin or Celloidin Method
(3) Gelatin Method

Mechanical sectioning involves embedding the fibre in a mass that hardens on cooling or an evaporation of the solvent.

For obtaining perfect sections, the substance must penetrate the fibre as completely as possible by infiltration. For this purpose, the fibre is passed through a series of fluids, which are miscible with each other, the last one being a solvent for the infiltration substance.

In some cases, a rapid method in which the fibre is dipped directly into the embedding substance (not good as one above).

15.1.1 Standard Paraffin Wax Method

(i) Dehydrating
(ii) Clearing process
(iii) Infiltration process
(iv) Embedding process
(v) Blocking and Trimming process
(vi) Cutting process

Paraffin was is a non aqueous solvent.

(i) Dehydrating . . . Dehydrating is accomplished by passing the dyed fibre through different alcohol solutions of increasing concentrations; a graduated series of 25%, 50%, 80%, 95% and absolute alcohol is suitable for fibres. The fibre is left for a few minutes in each concentration. This process must take place gradually in increasing concentrations, otherwise shrinkage occurs, damaging the fibre structure.

(ii) Clearing process . . . Xylene or chloroform or cedarwood oil may be used for clearing agents. The fibre is treated in a liquid miscible with dehydrating agent and also with paraffin. Bring the fibre from absolute alcohol to a 1:1 mixture of xylene (or chloroform) and absolute alcohol and then to pure xylene for several hours.
(iii) Infiltration process . . . The clearing agent is replaced by melted paraffin and impregnated. Add small chips of paraffin gradually to the clearing agent and when dissolved, place to 60°C to evaporate gradually. Therefore, fibre is transferred to pure molten paraffin (60°C) at least 24 hours for complete infiltration. The thickness of sections depend upon the melting point of the paraffin. The melting point may vary from 55°C (thick sections) to 65°C (thinner sections). A melting point of 60°C is suitable for relatively thin sections made at 20°C room temperature.

(iv) Embedding process . . . Specimen is enclosed in a solid block of hard paraffin. The melted paraffin wax and paraffin infiltrated fibres are poured out into a small paper or tinfoil box. Arranged the fibres properly with a needle before the paraffin sets. Immersed the box in water to allow to cool and harden quickly as soon as solid film has formed on the surface.

(v) Blocking and Trimming process . . . Suitable rectangular blocks of solid paraffin containing the fibres are cut from the embedding mass and attached to the holder of the microtome. Excess paraffin is cut away.

(vi) Cutting process . . . Successive sections of the desired thickness are cut from this block on the microtome. There are two types of microtome.

- sliding microtome ➔ (knife-moved) a transverse sliding is applied during the sectioning and the sections remain separate.

- rotary type of microtome ➔ (knife- fixed) the block is moved straight down against the knife, get continuous series or ribbon-like sections.

The thickness of sections may vary from 1 to 100 μ; a thickness of 10 μ is sufficient for most fibre sections.

This method is satisfactory for sectioning soft fibres like rayon.

Many natural fibres are so hard and brittle that infiltration with other harder substances is necessary. Therefore, using the mixture of equal parts of paraffin and stearic acid for sectioning of natural fibres.

15.1.2 Collodion or Celloidin Method

(i) Staining
(ii) Dehydration
(iii) Clearing
(iv) Infiltration
(v) Chloroform
(vi) Alcohol

(vii) Double Embedding process

(viii) Blocking and Trimming process

(ix) Cutting process

Infiltration with celloidin, a high-viscosity cellulose nitrate, is more laborious than paraffin. This method is specially suitable for hard, brittle fibres (for all bast fibres).

(i) Staining . . . For microscopic observation is generally done prior to infiltration and embedding.

(ii) Dehydration . . . After staining, dehydrate the fibres in the conventional way through the series of alcohol, a graduated series of 25%, 50%, 80%, 95% and absolute alcohol is suitable for fibres. The fibre is left for a few minutes in each concentration. This process must take place gradually in increasing concentrations, otherwise shrinkage occurs, damaging the fibre structure.

(iii) Clearing process . . . From absolute alcohol, they are transferred to a mixture of ether and alcohol (equal parts) and then for several hours.

(iv) Infiltration . . . Chips of dried celloidin are added to the bath at intervals of from 6 to 24 hours after celloidin has been dissolved. Celloidin is added until the solution has become a jelly (6 times).

(v) Chloroform . . . The celloidin infiltrated fibres are transferred to chloroform for two days, in which liquid the celloidin coagulates.

(vi) Alcohol . . . If the fibres cannot be sectioned immediately, they are transferred to 92 – 95% alcohol, in which they remain until the sectioning.

(vii) Double Embedding process . . . The sectioning of the infiltrated fibres is done after embedding in celloidin or in molten paraffin wax. The malted celloidin or paraffin are poured into a small box. Arranged the fibres properly with a needle before the celloidin or paraffin sets. Immersed the box in water to allow to cool and harden quickly as soon as solid film has formed on the surface.

(viii) Blocking and Trimming process . . . Suitable rectangle block of solid containing the fibres are cut from the embedded mass and attached to the holder of the microtome.

(ix) Cutting process . . . Successive sections of the desired thickness are cut from this block on the microtome. 

sliding type (knife-moved) → a transverse sliding is applied during the sectioning and the sections remain separate.
rotary type (knife-fixed) → block is moved straight down against the knife, get continuous series or ribbon like sections.

The thickness of section depends on the type of fibres. 10 μ is sufficient for most fibre sections.

15.1.3 Gelatin Method

This method is used for rapid sectioning of fibres, especially cotton. Gelatin is an aqueous material therefore this method does not require dehydration and clearing of the materials.

(i) Immersed in water
(ii) Infiltration
(iii) Formaldehyde and ethyl alcohol
(iv) Absolute alcohol
(v) Embedding process
(vi) Blocking and Trimming process
(vii) Cutting process

(i) Immersed in water ... First, the fibre are immersed in water.

(ii) Infiltration ... Transferred the fibres into a concentrated solution of gelatin which is kept fluid on the water bath for 3 hours.

(iii) Formaldehyde and ethyl alcohol ... The infiltrated fibres are immersed in a mixture of 5 cc formaldehyde (40%) and 95 cc ethyl alcohol to coagulate the gelatin for several hours.

(iv) Absolute alcohol ... Harden the gelatin by immersion in absolute alcohol for a few minutes.

(v) Embedding process ... Embed the infiltrated fibres in paraffin.

(vi) Blocking and Trimming process ... Suitable rectangular block of solid paraffin containing the fibres are cut from the embedded mass and attached to the holder of microtome.

(vii) Cutting process ... Successive sections of the desired thickness are cut from block on the microtome. In sliding type, knife-moved and transverse sliding is applied during the sectioning and remains the separate sections. In rotary type, knife-fixed and block is moved straight down against the knife, remains the continuous or ribbon like sections.
15.1.4 Direct Embedding Method

In previous method, complete infiltration of fibres before embedding is necessary. In this method, the fibre is directly embedded in melted paraffin and it is used for rapid sectioning and obtained satisfactory results.

(1) The fibre is mounted horizontally by fixing the ends of the bundle in two slits located in opposite sides of a small metal box. The melted paraffin is poured into the box and hardens around the fibre bundle. After the paraffin has hardened, the sides of the box are removed and the wax block is taken out.

(2) Another method is performed by dipping a small bundle of fibres in melted paraffin. After the paraffin has solidified, the process is repeated several times until a sufficiently large volume of wax surrounds the fibre bundle (candle).

15.2 Staining and Mounting of Section

The general procedure for handling paraffin sections is to cement the paraffin ribbons to a slide, dissolve the wax, thereby leaving the cut fibres cemented to the slide and allowing to be easily stained. The sections are floated on a little water on a slide which has been smeared with some albumen adhesive. By gently warming the slide the paraffin ribbon will flatten out. By removal of the water and heating the ribbon will be attached to the slide by the coagulating albumen. After the sections have been fixed, the paraffin may be dissolved away by immersing the slide in xylene.

For staining the sections, the slide is passed through the series of liquids (alcohol and xylene mixtures and decreasing concentrations of alcohol in water) or through cellosolve to be stained in a solution of alcohol or water.

After staining, the sections are passed in reverse order through the same series of liquids and are mounted in one of the nonaqueous mountants.

Celloidin sections are generally directly mounted without removal of the celloidine.
CHAPTER 16
SYNTHETIC FIBRES

16.1 Chemical Nature

Synthetic fibres are prepared from pure synthetic polymers. The fibres of this group are spun by either a melt or dry spinning processes, usually followed by a stretching (cold drawing) operation. Synthetic fibres have been classified in various ways. They are:

(1) Polyamide (2) Polyvinyls (3) Polycrylics (4) Polyethylene (5) Polyester
- Nylon - Vinylon
  - Saran
  - Velon
  - Pece
  - Dynel
- Orlon - Reevon - Dacaron
- Vinyon
- Acrilan
- X-51

16.2 Polyamide (Nylon)

16.2.1 Microscopic Examination of Nylon

(a) Longitudinal View

![Figure 16.1 Longitudinal View of Nylon]

The fibre has prefect cylindrical shape; diameter of the filament is near constant; no surface structure; smooth and lustrous; air pockets.

(b) Cross-sectional View

![Figure 16.2 Cross-section of Nylon]

Regular and usually circular shape in cross-section, almost uniform diameter (extremely uniform diameter).
16.2.2 Microchemical Reaction of Nylon

Iodine $\rightarrow$ the outer layer of the fibre stains light violet and dissolve slowly off the central past.

Million's reagent $\rightarrow$ negative reaction

16.2.3 Solubility Tests

Nylon is specifically differentiated from all other synthetic fibres. Soluble in 1:1 ratio of HCL and water at room temperature. The fibre dissolves quickly.

The acid solution containing the dissolved nylon is poured in excess water a white precipitate (ppt.) is formed.

The fibre also dissolves in hot glacial acetic acid, m-cresol, phenol, or dichloroethylene.

It is insoluble in acetone, cuprammonium hydroxide, and methylene chloride.

16.2.4 Burning Test

An important method of identification of nylon is the burning test. When a bundle of nylon filaments is brought towards a small flame, it melt and fuse into a glossy bead of extraordinary hardness with a characteristic amide odor.

16.2.5 Physical and Chemical Properties of Nylon

- specific gravity = 1.14
- moisture regain = 4%
- high tensile strength with high degree of true elasticity
- has definite recovery of stretch, when the stretched nylon yarn is released, it instantly recovers up to 50% of the stretch and gradually creeps back to original length
- excellent abrasion resistance
- naturally tough and pliable and can take immerse amount of rubbing, bending and twisting without breakage
- resistant to heat, moth and mildew
- long wear and durability
- quick drying and no ironing
- melting point = 480 - 500°F (215 - 220°C)
- no reaction with soap, alkali and alcohols
- dissolve in conc: formic acid, phenol, conc: H₂SO₄, conc: HNO₃ and phosphoric acid (H₃PO₄)
- become brittle in boiling 5% HCl and completely disintegrated
- does not burn readily but melt to forms glossy beads
- degraded on prolong-exposure to sunlight
- dyed with disperse and acid dyes
- soften at 180°C

16.2.6 Uses of Nylon

**Domestic used**

Women’s hosiery, tricot knitted, stockings, shirts, underwear, socks, dress materials, children’s garments, knitting yarns, blouses, coat, pyjamas, gloves, rainwear, outer wear, carpet, table cloth, slippers, sport wear, summer suits, swimming suits, night wear, laces, bed sheets, rugs, upholstery, fur fabrics, etc.

**Industrial used**

Tyre cords, airplane tyres, road tyres, conveyor belts, ropes, sail cloth, filter cloth, webbing, fire hose, parachutes, tennis racket strings, electrical insulations, machine belts, fishing nets, cordage, car-seat cover, working cloths, book cloths, etc.

16.3 Polyester (Dacron, Terylene, Tetoron, Japanese Rayon)

16.3.1 Microscopic Examination of Dacron

(a) Longitudinal View

![Figure 16.3 Longitudinal View of Dacron](image)

Transparent fibre, fine air pockets, cylindrical shape with very even diameter, a distinct pitted surface.

(b) Cross-sectional View

![Figure 16.4 Cross-section of Dacron](image)

Circular shape with even diameter.
16.3.2 Solubility Tests
The fibre is soluble in boiling m-cresol and boiling 40% NaOH when boiled for 45 minutes, but does not dissolve in most other customary solvents.

16.3.3 Colour Tests
The fibre is not stained by Shirlastain and other water soluble dyes, but is dyed by some acetate type dyes.

16.3.4 Burning Test
Burns slowly with melting and smoking, self-extinguishing.

16.3.5 Physical and Chemical Properties of Dacron
- specific gravity = 1.38
- moisture regain = 0.4%
- high resistance to stretch
- good resistance to heat, wrinkling and recovery from wrinkling
- quickly drying (out standing property)
- essentially permanent creases can be pressed into fabrics at ordinary ironing temperature
- good sunlight resistance in general
- excellent electrical insulating properties
- freedom from damage by insects or micro organisms
- good abrasion resistance
- washable, cleanable by ordinary day clearing fluids
- less absorbent than nylon
- dispersed acetate dyes can be successfully applied
- high tensile strength
- smooth and lustrous
- good resistance to chemicals and common solvents such as acetone, benzene
- very high resistance to acid
- sticking temperature is 460°F and melts 480°F
- soften at 232 - 240°C
- resistant to most weak acid at boiling state
- resistant to strong acid at room temperature
- resistant to weak alkali at room temperature
- dissolve in strong alkali on boiling (45 ~ 50% NaOH for 45 minutes)
- dissolve in boiling meta-cresol, o-chlorophenol
- insoluble in formic acid

16.3.6 Uses of Dacron

Domestic used

Used in various blends where it may improve and add desired quantities to fabrics. Used in all kinds of dresses and since it is insensitive to moisture, it is suitable for clothings to be worn in high humidity conditions. Mostly used as suitings, possible to heat set, thus very useful for fabrics or garments. Subjected to creasing such as ties, blouses, skirts, etc. Used as stockings and other materials where rubbing is likely to occur, due to its abrasion resistance. Used for curtains and screens (behind the glasses) for good resistant to sunlight. Not suitable for sewing thread as less stretching properly.

Industrial used

Fire hoses, tyres, V-belts, nets, tarpaulins, ropes, twine, sail cloths, etc:

16.4 Polyacrylic
16.4.1 Orlon (Pure polymer)
16.4.1.1 Microscopic Examination of Orlon

(a) Longitudinal View

![FALSE LUMEN](image)

SURFACE IRREGULARLY STRIATED TO VARYING DEGREE

Figure 16.5 Longitudinal View of Orlon

A clear internal fibrillation, false lumen.

(b) Cross-sectional View

![Y](image) ![Bone](image)

Figure 16.6 Cross-section of Orlon

Dog bone or dumb-bell shape with some Y or T shape.
16.4.1.2 Solubility

The fibre dissolves in a 70% solution of ammonium thiocyanate at the boil (10 minutes). Orlon 41 is soluble in dimethyl formamide at 160°F, Orlon 81 in the same solvent at 210°F. Resistant to most mineral acids, dyestuffs and stains. Insoluble in most common solvents. Insoluble but less resistant to alkali (boiling in 10% NaOH).

16.4.1.3 Physical & Chemical Properties of Orlon

- specific gravity = 1.17
- moisture regain = 1.2%
- excellent tenacity = 2 gm/denier (staple)
  
  $3 \sim 5$ gm/denier (filament)

- % elongation at break = 35% (staple) (outstanding property)
  
  17% (filament)

- good resistant to heat, highly resistance to sunlight and outdoor exposure
- resistance to moth and mildew
- good abrasion resistance
- high covering power or bulking power (outstanding property)
- gives feel and appearance of heavier cloth containing other fibres
- excellent draping characteristics and flexibility
- hard wearing and comfortable
- resistant to industrial fumes
- no effect and no dimensional changes with chemical fumes
- good recovery from stretching
- good resistance to chemical solvents (common) such as acetone, ammonia, chloroform, hydrogen peroxide and methyl alcohol
- resistant to most mineral acids, dyestuffs and stains
- excellent resistance to common solvents, oils, greases
- less resistant to alkali.

16.4.1.4 Uses of Orlon

Filter cloth, work cloth, sails, curtains, swim suits, rain coats, garments, trousers, skirts, dresses, knitwear, over coats, industrial fabrics, chemical resistant filter cloths, pressed felts, sewing threads, twines of various types, chemical worker's uniforms and clothing, fishing nets, water proof, light coats, light sweaters and hats, etc:
16.4.2 Dynel (Copolymer)

Dyed is prepared from vinyl chloride 60% + acrylonitrile 40% by wet spinning process with stretching.

16.4.2.1 Microscopic Examination of Dynel

(a) Longitudinal View

![Figure 16.7 Longitudinal View of Dynel](image)

Ribbon-like shape and sometimes twisted or folded double in length direction; clear lengthwise striations and fibrillation; less transparent; a clear, often broad, transparent skin on the side of the ribbon.

(b) Cross-sectional View

![Figure 16.8 Cross-section of Dynel](image)

Irregular slender knuckle bone shape and sometimes forked (Y or T shape) or bent.

16.4.2.2 Properties of Dynel

- specific gravity = 1.31
- moisture regain = less than 1%
- fabrics feel warm to the skin
- natural colour of the fibre is a light/pale cream but near white can be made by bleaching
- resist burning, burns slowly while directly exposed to a flame, but stops burning quickly when the flame is removed, does not melt; will not support combustion.
- highly resistance to water and sunlight
- not attacked by mildew (bacteria), moth, insects and fungus
- poor dye affinity for most conventional dyestuffs and stains
- highly resistance to acids and alkali at room temperature
- soluble in acetone, dimethyl formamide (100°F)
- insoluble in G-acetate acid
- unaffected by conc: HCl, conc: phosphoric acid and conc: aqueous solution of NaOH

16.4.2.3 Uses of Dynel

Mixed with other fibres.

Apparel (dress, clothing) —→ socks, work clothing, suiting blends, knitted jerseys, knit underwears, rain wear, pile fabrics, dress

Home Furnishings —→ blankets, carpets, draperies, upholstery, rugs, filling for pillows

Industrial —→ fitter fabrics, chemical resistant clothing, bags, dye and laundry nets, valve and flange covers, paint roller covers, felts and nonwoven fabrics.

16.4.3 Acrilan (Acrilic Fibre)

16.4.3.1 Microscopic Examination of Acrilan

(a) Longitudinal View

![Figure 16.9 Longitudinal View of Acrilan](image)

One single groove or striation, which appears as a distinct dark line giving rise to a false lumen.

(b) Cross-sectional View

![Figure 16.10 Cross-section of Acrilan](image)

Round to kidney - bean shape.

16.4.3.2 Properties of Acrilan

- specific gravity = 1.135
- moisture regain = 1.5 ~ 2%
- not effected by moth and mildew
- wrinkle resistance when heat set
- retain a semi-permanent crease
- warm to touch and easily dyed
- creamy white smooth-surfaced fibre
- highly resistant to sunlight
- turns yellow to orange to brown under heating
- good resistant to mineral acids
- turns red-orange colour with 10 ~ 50% NaOH
- acids have no effect on this fibre, except conc. H₂SO₄
- dissolve in HNO₃ and room temperature and 35% HNO₃ at 100°C and dimethyl
  formamide at 130°F
- resistant to weak alkali and generally very resistant to all other chemicals

16.4.3.3 Uses of Acrilan

Woven and knitted fabric, men and women wear, children wear, sport wear, blend
with other fibres, sweaters, jersey, carpets, rugs, blankets, work cloth, industrial uniform.

16.4.4 X-51

X-51 fibre is presently produced in two forms, staple of 3 and 1.5 D, and continuous
filament yarn. The colour of staple is almost white, the filament almost white with a
yellowish. Both can be easily bleached.

16.4.4.1 Microscopic Examination of X-51

(a) Longitudinal View

![Figure 16.11 Longitudinal View of X-51](image)

Cylindrical shape, faint, smooth, longitudinal or diagonal folds or creases on the
surface.
(b) Cross-sectional View

Round and pronounced ring structure.

16.4.4.2 Properties of X-51
- specific gravity = 1.17
- good wrinkle recovery
- easily dyed and quick drying
- retain crease
- thermoplastic
- excellent resistance to outdoor exposure
- resistant to moth and mildew
- do not dissolve or soften by the usual solvents
- resistant to alkali but good tendency to turn yellow
- excellent resistance to acids and most solvents

16.4.4.3 Uses of X-51
The spun yarns made from staple are used in blankets, sweaters, knitted jerseys (brushed and pile type), draperies, filter fabrics, hand knitting yarns, bathing suits.

16.4.5 Vinyon
Two types if vinyon fibre:
- Vinyon HH (unstretched staple fibre)
- Vinyon CF (stretched continuous filament)
16.4.5.1 Microscopic Examination of Vinyon HH

(a) Longitudinal View

Figure 16.13 Longitudinal View of Vinyon HH
Cylindrical shape; smooth surface (appearance are depending on the manufacturing process and on the degree of stretching after spinning).

(b) Cross-sectional View

Figure 16.14 Cross-section of Vinyon HH
Circular or round shape.

16.4.5.2 Microscopic Examination of Vinyon CF

(a) Longitudinal View

Figure 16.15 Longitudinal View of Vinyon CF
Stretched continuous filament, cylindrical shape with false lumen.

(b) Cross-sectional View

Figure 16.16 Cross-section of Vinyon CF
Dog-bone shape in cross-section with the absence of Y or T shape.

16.4.5.3 Properties of Vinyon
- specific gravity = 1.37
- moisture content and regain is less than 0.5%
- resistant to sunlight and water (water proof)
- non-conducting material
- does not swell in water
- thermoplastic
- not attacked by bacteria and fungi
- readily dyed with acetate type dyestuff
- resistant to alkali
- dissolve in acetone, chloroform, boiling ethylene diamine
- insoluble in 80% H₂SO₄, 98% cold formic acid and G-acetate acid
- low heat resistance
- melts and develop acid vapors on burning
- softening and contraction in boiling water

16.4.5.4 Uses of Vinyon

Mixed with other fibres, felts and bonded fabrics, industrial fabrics such as chemical resistant filter cloths, pressed felts, sewing threads, twines of various types, chemical worker's uniform and clothing, dental floss, fishing nets, etc.

16.5 Polyvinyls

Polyvinyl alcohol fibre - vinyon
Polyvinyl chloride and Polyvinylidene chloride - saran, velon, pece

Raw material for these fibres are petroleum and brine (salt water). Saran and velon are plastic polymer and produced by melt spinning in acid bath.

16.5.1 Vinylon

Vinylon is a derivative of polyvinyl alcohol from which an important textile fibre is produced in Japan. It is similar to orlon and dynel.

16.5.1.1 Microscopic Examination of Vinylon

(a) Longitudinal View

![Figure 16.17 Longitudinal View of Vinylon](image)

Smooth surface; heavy fibrillation.
16.5.1.2 Properties of Vynylon
- specific gravity = 1.26 ~ 1.3
- moisture regain = 4.5 ~ 5%
- softens at 220 ~ 230°C
- burns slowly with softening and shrinking
- light, warm and comfortable handle
- good resistant to sunlight, fungi, mildew and insect attack
- good dyeing properties
- strong and resistant to abrasion
- insoluble in acetone, alcohol, ether, benzol, phenol and cresol
- swells or dissolves in conc: H₂SO₄, HCL, HNO₃, formic acid

16.5.1.3 Uses of Vynylon
Socks, suitings, underwear, rugs, ropes, fishing nets, industrial applications dress materials, overcoats, gloves, hats, blankets, knitting yarns, sewing threads, carpets, pyjama, filter cloth, laces, brocades, twill, tyre cord, hose.

16.5.2 Pece
Before World War II, Pece was developed in Germany. Pece is made from polyvinyl chloride, which is after chlorinated to produce a polymer soluble in acetone. An acetone solution of chlorinated polyvinyl chloride is wet spun into a coagulating bath containing water. The acetone dissolves in the water, leaving filaments of chlorinated polyvinyl chloride which are stretched and dried.

16.5.2.1 Properties of Pece
- specific gravity = 1.39
- good resistant to most common chemicals
- not attacked by insects, mildew or bacteria
16.5.2.2 Uses of Pece

Filter cloths, ropes, swim - wears.

16.5.3 Saran

Saran is produced in monofilament or multifilament forms and staple form, usually in two types: curve staple and straight staple.

Cross-section is circular or round shape and cylindrical shape in longitudinal view. Saran filament yarns vary from 10-15 filament denier.

16.5.3.1 Properties of Saran

- specific gravity = 1.68 ~ 1.75
- moisture regain = less than 0.1%
- smooth surface
- faint golden-yellow or straw colour
- melting point = 180° ~ 200°C
- unaffected by aging but slightly affected by sunlight
- high abrasion resistance
- thermoplastic
- highly resistant to acids and alkali but NaOH
- resistant to moth and mildew

16.5.3.2 Uses of Saran

Insect screens, drapery fabrics, filter cloths, narrow webbings, upholstery fabrics for cars and public transport vehicals, carpet.

16.5.4 Velon

Velon is produced in monofilaments containing pigments colouring the fibre gold or straw colour. It has glossy surface, transparent and lustrous. It is stiff or flexible or stretchable depending on the polymer.

Cylindrical in longitudinal view and circular and uniform in cross-section with a smooth outer surface.

16.5.4.1 Properties of Velon

- specific gravity = 1.70
- moisture regain = less than 0.1%
16.5.4.2 Uses of Velon

Car-seat cover, screens, tapes, outdoor fabric, carpet and belting.

16.6 Polyethylene

16.6.1 Reevon

Pure plastic fibre produced by wet-spinning in water bath. Cylindrical shape in longitudinal view and circular shape in cross-section.

16.6.1.1 Properties of Reevon

- specific gravity = 0.92
- moisture regain = Nail
- lustrous
- burn very slowly
- not affected by mildew
- good resistance to sunlight, abrasion and aging
- resistant to most chemicals, acids and alkalis
- softens above 90°C
- melts between 110° ~ 120°C

16.6.1.2 Uses of Reevon

Clothing (applying special finish), shower curtains, water proof, upholstery fabrics, matting, ribbons, good insulator for high voltage industrial motors.
CHAPTER 17
MINERAL FIBRES

17.1 Glass Fibre

Glass fibre is prepared by a melt-spinning process. The fibre has amorphous structure. The fibre is more brittle than any other fibre and cannot be dyed. Various finishes are applied to it. Coloured resins may be used to give a colour to the fibrous product, but the resins are present only on the outer surface of the fibre. It can be folded or knotted without breaking.

17.1.1 Microscopic Examination of Glass Fibre
(a) Longitudinal View

Figure 17.1 Longitudinal View of Glass Fibre

Perfectly smooth with no visible structure on the surface; edges are perfectly parallel without any irregularities; structureless cylindrical.

(b) Cross-sectional View

Figure 17.2 Cross-section of Glass Fibre

Typical circular shape in cross-section.

17.1.2 Properties of Glass Fibre
- specific gravity = 2.54 (highest in textile fibre)
- low moisture absorption
- 100% elastic recovery and no stretching properly
- resistant to rot, mildew, moisture and stretch
- amorphous nature and brittle
- good resistant to heat
- incombustible
- resistant to fungus or micro-organisms, light and aging
- easily and quickly laundered
- no wrinkle and need no ironing after washing
- electrical resistance of glass is very high
- unaffected by most conc: acids except by hydrofluoric acid, hot phosphoric acid
- resistant to alkalis and most chemical solvents
- insoluble in all solvents

17.1.3 Uses of Glass Fibre
- The practical utility of glass fibre as an electrical insulation material and the used for fabrics that are fire proof
- From the beginning of World War II, it is used in military, naval and aircraft materials
- glass cloths and tapes; wrapping over pipe insulation in hot location; curtains on board ship and for similar application requiring fire proof fabrics; as a facing material for thermal blankets used in aircraft and naval ships
- outer coating in boiler room; boiler insulation; steam pipe covering; aircraft parts; high voltage insulator used in space
- used as shower curtains and kitchen curtains; printed and piece-dyed materials; combined with plastic resins to make lamp shades
- it can only be dyed with synthetic resin

17.2 Asbestos

Asbestos fibres are fibrous forms of natural mineral substance. The mineral is obtained by mining, and the fibre is prepared from the rock by a hand dressing process and a mechanical treatment which involve a milling process. It is produced from Canada, South Africa, Cyprus, and Russia.

There are two types of asbestos fibre:
(1) hard-type (needle like)
(2) soft-type (wavy form)

- long staple \( \frac{3}{8} '' \) - textile used
- medium staple \( < \frac{3}{8} '' \) - paper industry
- short staple \( < \frac{1}{16} '' \) - industrial purpose
17.2.1 Microscopic Examination of Asbestos

(a) Longitudinal View

![Figure 17.3 Longitudinal View of Asbestos](image)

Needle shape, extremely fine (less than 0.5 μ) and stick close together in bundle of numerous fine splinter-like fibres which can be separated into even finer fibres. The surface edge of the finer fibres is smooth.

(b) Cross-sectional View

![Figure 17.4 Cross-section of Asbestos](image)

Circular shape and uneven diameter.

17.2.2 Burning Tests

Asbestos fibre does not burn. Attention must be paid to the fact that in yarns the fibre is often blended with cotton whose component is combustible.

17.2.3 Properties and Uses of Asbestos

- incombustible
- usually blended with 5 ~ 20% cotton for yarn manufacturing
- resistant to heat, fire, acid and durable used as clothing only for fire and acid protection and fire fighting. Also used as curtains and upholstery fabric at fire stops in public places (especially in ships)
- durable under serve conditions
  used as belt conveyor for hot materials. Basically made into yarn and then into cloth, tape, brake lining, gasket cloth, industrial packing, twines, threads, covering for electric fixtures or cable covering
- non-conducting materials, good insulator under high temperature
used as conveyor belting surface, bags and diaphragms in oxygen producing machine. Also used as theatre curtains

- Asbestos clothings are especially useful for rescue work at building fire and airplane crashes. Airports and broadcasting stations are equipped with asbestos materials. Used in vehicle parts as insulator against shock or vibration. It is especially used for War use

- highly resistant to abrasion, high temperature, corrosive and strong
- durable to weathering characteristics and easily blended with other fibres
- useful for winding coils, underground cables and filter cloths of various types
- specific gravity = 2.2
CHAPTER 18

FIBRE IDENTIFICATION

The identification of fibre is based on their morphological, their chemical and their physical properties.

18.1 Preparation of Samples

Some preparation is generally necessary before a material may be investigated for purposes of identifications. For example, separation of the material into individual fibres and removal of nonfibrous materials, such as dyestuffs and finishing agents, etc.

In a fabric, there are the following possible combinations of different fibre types:

(1) different warp or filling (different yarn adjacent to each other).
(2) each warp or filling composed of a number of plies each of a different fibre type.
(3) each type of warp or filling yarn composed of a blend of different fibre types.
(4) any combination of the above situations.

Fabric (1) warp yarns  (2) weft yarns
   (a) one fibre type in a single yarn. same type as warp or different as classification a, b, c, d in warp.
   (b) two more types in single yarn.
   (c) one different fibre type in each ply of two or more ply yarn.
   (d) two or more types of fibres in each ply of a yarn.

18.1.1 Chemical Removal of Dyestuff from Dyed Material

Microchemical reactions and microphysical tests. It is necessary partially or completely to remove the dyestuff by various chemical treatments.

Dyestuffs can be removed by a treatment in warm soda, hot diluted (0.1% ammonia, sp. gr. 0.880), alkaline solution, hydrogen peroxide (to which 1% ammonia is added). If the removal of the dye by these agents is not sufficient, one of the following ‘stripping’ agent is used to obtain a more intensive action:

- 5% sodium hydrosulfite with 1% NaOH
- an acid hydrosulfite solution
- sodium sulfoxylate-formaldehyde (formosul)
- sodium hypochlorite solution
- boiling 20-60% aqueous pyridine or cellosolve
- boiling 5% acetic acid
- boiling 1% ammonia (sp. gr. 0.880)
- 95% alcohol plus 10% acetone
- sodium chlorite 5% in dilute acetic acid

18.1.2 Removal of Sizes

Starch size is removed by treating the material for 1 hour in a 3% enzyme solution at 140°F; gelatin or oil size can be removed by scouring with a 0.5% soap solution.

Finishing agents can be removed by boiling in water which contains a detergent (eg: 20 min: in carbon tetrachloride), followed by rinsing and drying.

18.2 Fibre Properties and Tests on Which Identification is Based

The identification of textile fibres may be based on various characteristics and properties of the fibre, of purely morphological or chemical or physical nature.

Identification of natural fibres can be based almost solely on the morphological features. The chemical properties of the natural fibres are secondary importance in the identification.

Identification of man-made fibres can be based on the chemical and physical properties (relatively more important). The morphological features are relatively less important than in the natural fibres.

18.2.1 Microscopic - Morphological Characteristics

Morphological features of fibres requires the use of the microscope and permits the most reliable identification of natural fibres and very important in the identification of man-made fibres. Mixture of different fibres is present and the most important and widely used method of identification.

The most valuable microscopic features of fibres are longitudinal and cross-sectional shapes and dimensions, the presence and shape of the lumen, the internal and surface structures.

(1) Fibres with surface scales ——— Wool or hair fibres
(2) Fibres with cross markings (dislocations) ——— Flax (typical node), Hemp (large uneven lumen), Ramie (wide lumen, cracks)
(3) Fibres with length wise striations → Jute (constrictions), Silk (knee), Viscose, acetate (false lumen)
Orlon, dyneil, acrilan, vinylon, vinyon CF

(4) Fibres with twist → Cotton (lumen, convolution)
Wild silk (without lumen, ribbon-like)

(5) Fibres without markings (structureless) → Nylon, Dacron, Cuprammonium rayon,
Glass, Vinyon HH, X-51, Mercerized Cotton

18.2.2 Chemical Characteristics

The chemical characteristics of fibres may be studied by macro-methods without the use of the microscope or by microchemical methods with the microscope.

Microchemical methods comprise:
(1) microchemical tests
(2) microsolubility tests
(3) microcolouring tests
(4) use of selective stains under the microscope.

Microchemical tests comprise:
(1) burning tests
(2) macrosolubility tests
(3) use of identification stains without the microscope
(4) determination of density
(5) identification of decomposition products of fibre.

18.2.2.1 Microchemical Tests

Microchemical reactions are chemical reactions and observed under the microscope.

A few examples of microchemical reactions widely used in fibre microscopy are:
- Zinc chloroiodine reaction on cellulose
- Million’s reagent on protein fibres
- Aniline sulphate on lignocellulose
- Sudan III on fats
- Diphenylamine on nitrocellulose rayon
18.2.2.2 Microsolubility Tests

This is carried out by placing the fibres on a dry slide and covering them the edge of the cover and its effect is observed under the microscope. Short heat-treatments are carried out by intermittently bringing the slide for short periods over a small flame.

The most generally used specific solubility tests are:

- **5% KOH at boiling point for 10 minutes**
  - all animal fibres and natural silk - soluble
  - vicara and tussah silk - partly soluble
  - cellulose and synthetic fibres - insoluble

- **Conc: HCL at room temperature**
  - cellulose → viscose rayon - dissolve
  - natural fibre - undissolve
  - protein → cultivated silk - dissolve
  - tussah silk - slowly dissolve
  - wool and reg: protein - insoluble
  - casein fibre - violet colour
  - nylon and acetate - dissolve

- **Cuprammonium hydroxide**
  - cellulose fibres → dissolve (not wax in cotton)

- **70% H2SO4 at 30°C for 15 minutes**
  - cellulose fibres → dissolve

- **Sodium hypochlorite solution (3.3% chlorine)**
  - wool and other animal hair fibres → dissolve

- **Acetone (80 – 100%)**
  - acetate rayon → dissolve
  - vinyon HH and CF → dissolve (100% acetone)
  - vinyon N, pece, dynel → slowly dissolve (100% acetone)
  - other fibres → insoluble

- **Chloroform**
  - vinyon HH → dissolve
  - acetate rayon → insoluble

- **Methylene dichloride**
  - vinyon → dissolve
acetate rayon $\rightarrow$ insoluble

- **Glacial acetic acid**
  
  acetate rayon $\rightarrow$ dissolve
  
  vinyon, dynele $\rightarrow$ insoluble

- **HCl (1.19 sp. gr, 37 ½ %) is diluted with an equal value of water and is cooled to room temperature**
  
  only nylon $\rightarrow$ dissolve
  
  other fibres $\rightarrow$ insoluble

- **Phenol (90%)**
  
  nylon $\rightarrow$ dissolve
  
  dynele, acetate, vinyon, terylene, polyvinyl chloride $\rightarrow$ dissolve (boiling)

- **Formic acid (85%)**
  
  nylon $\rightarrow$ dissolve (100°F)

- **Dimethyl formamide**
  
  acrylic fibre $\rightarrow$ dissolve
  
  dynele $\rightarrow$ dissolve (100°F)
  
  acrilan $\rightarrow$ dissolve (130°F)
  
  orlon 41 $\rightarrow$ dissolve (160°F)
  
  orlon 81 $\rightarrow$ dissolve (210°F)

- **Conc: HNO₃**
  
  acrilan, acetate, nylon $\rightarrow$ dissolve

- **40% NaOH at boiling temperature for 45 minutes**
  
  dacron $\rightarrow$ dissolve

- **Calcium Thiocynate**
  
  viscose, cuprammonium $\rightarrow$ dissolve

18.2.2.3 Microcolouring Tests

The fibre is treated with one single special dyestuff which stains a particular fibre type in a characteristic manner (one dyestuff to different types of fibres).

18.2.2.4 Use of Selective Staining

Use the mixture of dyestuffs from which each fibre type absorb a particular one, therefore exhibiting a characteristic colour.
The selective staining method can be carried out as a microscopic method if one fibre type is present, but must be carried out under the microscope if there is a mixture of fibres. For many purposes the microscopic method is to be preferred and may be more convenient.

There are several dyestuff mixtures commercially available which will identify the more common fibres by the distinctive colour absorption of the various fibre types. The original dyestuff mixture was superseded by Shirlastain.

The degreased fibre is mounted in water and immersed in the Sgirlastain. A solution or 1 minute at room temperature. It is thoroughly rinsed in water, squeezed out, and examined. The following colours result with the fibres indicated.

<table>
<thead>
<tr>
<th>Cotton</th>
<th>pale dusty purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton (mercerized)</td>
<td>mauve</td>
</tr>
<tr>
<td>Indian kapok</td>
<td>yellow</td>
</tr>
<tr>
<td>Flax</td>
<td>brownish purple</td>
</tr>
<tr>
<td>Ramie</td>
<td>lavender</td>
</tr>
<tr>
<td>Sisal and Jute</td>
<td>golden brown</td>
</tr>
<tr>
<td>Silk (raw)</td>
<td>very dark brown</td>
</tr>
<tr>
<td>Silk (degummed)</td>
<td>brownish orange</td>
</tr>
<tr>
<td>Tussah silk</td>
<td>pale chestnut brown</td>
</tr>
<tr>
<td>Weighted silk</td>
<td>orange-red to bluish-red</td>
</tr>
<tr>
<td>Wool</td>
<td>bright yellow</td>
</tr>
<tr>
<td>Chlorinated wool</td>
<td>golden yellow to orange</td>
</tr>
<tr>
<td>Regenerated protein fibre</td>
<td>yellow-orange</td>
</tr>
<tr>
<td>Casein</td>
<td>orange to yellow</td>
</tr>
<tr>
<td>Alginate</td>
<td>salmon pink</td>
</tr>
<tr>
<td>Viscose</td>
<td>bright pink</td>
</tr>
<tr>
<td>Cuprammonium</td>
<td>bright blue</td>
</tr>
<tr>
<td>Acetate</td>
<td>bright greenish yellow</td>
</tr>
<tr>
<td>Nylon</td>
<td>cream to yellow</td>
</tr>
<tr>
<td>Cellulose triacetate</td>
<td>off-white</td>
</tr>
<tr>
<td>Orlon, Dacron, Dynel,</td>
<td>unstained</td>
</tr>
<tr>
<td>Vinyon N, Vinyon, Saran,</td>
<td></td>
</tr>
<tr>
<td>Glass fibre, Asbestos</td>
<td></td>
</tr>
</tbody>
</table>
18.2.2.5 Burning Tests

They are carried out without the use of the microscope. A burning test is carried out by advancing a bundle of fibres slowly through a small flame and observing the burning, melting or formation of a bead and the odor developed.

(1) Fibre that burns quickly without melting, leaving very little ash skeleton in the form of the fibre and have a smell of burning paper - . . . 

*all cellulose fibres, natural and regenerated cellulose*

(2) Fibre that burns slowly, without ash and have the odor of burning hair and leaves a knob at the end - . . .

*protein fibre*

Ash skeleton is left and same odor is produced - . . .

*weighted silk*

(3) Fibre that burns slowly, melting and formation of a bead or knob and do not have the odor of burning hair - . . .

*acetate* (hard knob – black bead – with odor of acetic acid)

*nylon* (glassy bead with amidelike odor)

*orlon, dynel, vinyon* (acid odor with an irregular knob)

*dacron, saran* (irregular knob with aromatic odor)

(4) Fibre that does not burn at all but melt or glow - . . .

*glass, asbestos*

18.2.3 Physical Properties

They are important in identification and can be studied microscopically are refractive index and birefringence.

Microphysical tests which are important for fibre identification are:

(1) Determination of density and

(2) Determination of temperature contraction.

18.2.3.1 Determination of Fibre Density by Density Gradient Tube

Density is a physical property very useful for identification. The density of a fibre can be determined by finding a liquid of known density in which it neither floats nor sinks. A modification of this floatation test is the use of a density gradient tube.

The fibres are tied in a small knot which is boiled for a few minutes in xylene and then immediately dropped into the density gradient tube. After 30 minutes the fibres will
have generally sunk to the final depth. The depth to which different fibres sink in this liquid gives a measure for the density.

Some densities of fibres are:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>2.56</td>
<td>Orlon staple</td>
<td>1.39</td>
</tr>
<tr>
<td>Asbestos</td>
<td>2.40</td>
<td>Vinyon</td>
<td>1.37</td>
</tr>
<tr>
<td>Alginate</td>
<td>1.75</td>
<td>Dacron</td>
<td>1.38</td>
</tr>
<tr>
<td>Saran</td>
<td>1.71</td>
<td>Acetate rayon</td>
<td>1.33</td>
</tr>
<tr>
<td>Viscose rayon</td>
<td>1.53</td>
<td>Wool</td>
<td>1.32</td>
</tr>
<tr>
<td>Cuprammonium</td>
<td>1.52</td>
<td>Soybean</td>
<td>1.31</td>
</tr>
<tr>
<td>Cotton</td>
<td>1.50</td>
<td>Zein</td>
<td>1.31</td>
</tr>
<tr>
<td>Casein</td>
<td>1.29</td>
<td>X-51</td>
<td>1.17</td>
</tr>
<tr>
<td>Dynel</td>
<td>1.28</td>
<td>Nylon</td>
<td>1.14</td>
</tr>
<tr>
<td>Vicara</td>
<td>1.25</td>
<td>Acrilan</td>
<td>1.13</td>
</tr>
<tr>
<td>Silk, boiled off</td>
<td>1.25</td>
<td>Polythene</td>
<td>0.92</td>
</tr>
<tr>
<td>Orlon filament</td>
<td>1.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18.2.3.2 Determination of Temperature Contraction and Melting Point of Synthetic Fibres

Many of the new synthetic fibres contract when heated to a certain temperature. The temperature has been suggested as a useful index in the fibre identification. The temperature of contraction and melting can be conveniently measured by using a copper block which is heated at one end and contains the fibre in a slot at the other end.

18.3 Scheme for Identification of Principal Fibres

Based on the tests mentioned above, the following scheme has been prepared for the identification of the principal textile fibres. The first step is to identify the broad group (vegetable, animal or man-made fibres) to which the material belongs; this is determined on the basis of the result of the morphological examination and burning test. Subsequent steps are then followed to identify the individual types of fibres in each group, as explained in the scheme.
18.3.1 Qualitative Analytical Scheme for the Identification of Some Principal Textile Fibres

**Step 1**

1.1 Fibres single or aggregate, irregular in dimensions, with cell wall and lumen or surface scales (except silk, where filaments are long), fine or coarse; burning test: smell like that of burning paper or hair. Presence of vegetable or animal fibre indicated ... Follow *step 2.*

1.2 Fibres uniform in diameter; regular features all along the length. Presence of man-made fibres indicated ... Follow *step 6.*

**Step 2**

2.1 Cellulose and/or lignin reaction positive (reagents: zinc chloroiodine); protein reaction negative (Million’s reagent). Presence of vegetable fibres indicated ... Follow *step 3.*

2.2 Protein reaction positive; cellulose reaction negative; burns steadily emanating burnt hair smell. Presence of animal fibres indicated ... Follow *step 5.*

**Step 3**

3.1 Single cells, cell-wall thick, lumen narrow ... Follow *step 4.*

3.2 Single cells, cell-wall very thin; lumen very broad with large air bubbles; cross-section round, very thin wall; stains yellow with Shirlastain A; insoluble in cuprammonium hydroxide ... KAPOK present.

3.3 Aggregate cells forming strands, cross-section polygonal with defined angles; stains golden-yellow with Shirlastain A ... JUTE present.

**Step 4**

4.1 Fibres convoluted, so dislocations; cross-section bean or kidney shaped; stains pale purple with Shirlastain A; dissolves in 75% H$_2$SO$_4$; insoluble in conc. HCl or boiling 5% NaOH; ballooning in cuprammonium hydroxide and then dissolving slowly; zinc chloroiodine reagent stains reddish purple ... COTTON present.

4.2 Fibres rod-like, smooth, with few convolutions, lumen fine; cross-section round to elliptical; swells and readily dissolves in cuprammonium hydroxide without ballooning; stains mauve with Shirlastain A ... Mercerized COTTON present.

**Step 5**

5.1 Fibres having pronounced protruding overlapping scales, cross-section round to oval; bright yellow with Shirlastain A; insoluble in 75% H$_2$SO$_4$ or conc. HCl; dissolves in boiling 5% NaOH ... WOOL present.
5.2 Filaments fine uniform without visible internal structure; cross-section approximating equilateral triangle with round; dissolves in 75% H₂SO₄ or boiling NaOH; Shirlastain A stains golden-brown ... Degummed Cultivated SILK present.

5.3 Filament coarse to feel and brownish in colour; cross-section approximately long triangle; resembles cultivated silk in all chemical properties but more resistant to solvents; Shirlastain A stains pale chestnut brown ... TUSSAH SILK present.

**Step 6**

6.1 Cellulose reaction negative ... Follow step 7.

6.2 Cellulose reaction positive; fibre surface with longitudinal striations; cross-section irregularly round or elongated with serrated edges; stains pink to lavender with Shirlastain A ... VISCOSE RAYON present.

6.3 Cellulose reaction positive; surface without striations; cross-section nearly round with smooth edge; stains bright blue with Shirlastain A ... CUPRAMMONIUM RAYON present.

**Step 7**

7.1 No internal fibrillation; cross-section circular; fibre insoluble in acetone or glacial acetic acid ... Follow step 8.

7.2 Prominent longitudinal surface striations; cross-section of various shapes and lobes; dissolve in acetone, G-acetic acid, 85% formic acid or 90% phenol; stains greenish yellow with Shirlastain A ... ACETATE RAYON present.

**Step 8**

8.1 Fibres dissolve in con: HCl, 75% H₂SO₄, 85% formic acid; 90% phenol and in boiling G-acetic acid; stains cream to yellow with Shirlastain A ... NYLON present.

8.2 Fibres insoluble in conc: HCl, HNO₃, but soluble in H₂SO₄, m-cresol at boil and in hot nitrobenzene; does not stain with Shirlastain A ... TERYLENE present.

18.4 Quantitative Analysis of Fibre Mixtures

Microscopic methods can be used for quantitative analysis only for determination of the percentage of different fibre types by number.

After the fibres present in a textile product have been identified, another important step in evaluation of such products is the quantitative determination of fibres present.

For determining the percentage by weight numerous methods exist which use the chemical and physical properties of each fibre type and of the blend, such as solubilities,
densities, and special chemical reactions. The most universally used methods for quantitative fibre determination are based on chemical analysis by specific solubility.

The methods used for quantitative analysis like those used for fibre identification, can be grouped into three classes, namely:

1. Physical fibre separation
2. Chemical separation
3. Microscopic determination.

18.4.1 Physical Fibre Separation

(a) Separation by hand (mechanical separation by reveling or sorting)

Separation fibres in separation yarn can be separated and sorted into groups each containing one fibre only. Oven dried and weighed the groups and find the percentage of fibres content obtained (rayon W: Cotton F).

(b) Separation by floatation (mechanical separation by floatation)

(wool 1.32 and Casein 1.29)

As the specific gravity of the fibres are known, the sample, the clean yarns, cut into small sections (1 mm) are immersed into a cylinder containing separating liquid whose specific gravity is between those of the fibres, at room temperature - (eg: 1.31). After shaking and standing for a while, the fibre having a higher sp.gr. will sink to the bottom of vessel and while those of a lower sp.gr. will remain floating on the surface. Recovered separately the sinker and floating fibres, wash, dried and weighed and the percentage calculated (under the same condition).

18.4.2 Chemical Separation of Fibre Blends

The principal of all these methods is the dissolving of each fibre type one after the other by selective solvents and weighing the remaining fibres after each extraction. The solvent must be fully selective, which is generally not realized as the undissolved fibres are always affected to some extent.

Weigh the sample under standard condition and immersed in suitable solvent that would dissolve one type of fibre but not to the other. Wash and dry the residue and weigh and find the percentage. Solvents are acetone, G-acetic acid, H₂SO₄, NaOH and HCl.

18.4.3 Microscopic Determination

The essential parts of the method are the separation of the sample into its individual fibres and the counting of these fibres under the microscope at low power.
The method has been improved by using short cut fibre sections instead of whole fibres (by cutting a yarn into short lengths) and mounting these sections in glycerin gelatin, and counting them, using a squared eyepiece micrometer.

Count the different types of fibres under the microscope. 3/16 square-inch sections are cut from the fabric and yarns are separated. Mount the yarns (2 yarns/slide) in glycerol and carefully separated and parallel the individual fibres. By starting on one side of the cover glass, the slide is moved slowly across the field of vision, counting each fibre type present. Number of fibres should be more than 1000 fibres or 2000 fibres in each direction of the fabric.

Find the percentage of each type of fibres: . . . with the use of eyepiece micrometer, find the diameter of the each type of fibre. For accuracy, find the average diameter form longitudinal and cross-sectional diameters.

\[ \therefore \text{Denier} = \frac{W}{V} \times \text{Density} \]
\[ = \text{Area} \times \text{length} \times \text{specific gravity} \]
\[ = \frac{\pi}{4} d^2 \times 9000 \text{ m x sp. gr.} \]

For fibre A, \[ \therefore \text{Denier} = D_A \]
No. of fibres = \( N_A \)
1 fibre = \( D_A \)
\[ N_A = ? \]
\[ = N_A D_A \text{ (weight)} \]

For fibre B, \[ \therefore \text{Denier} = D_B \]
No. of fibres = \( N_B \)
1 fibre = \( D_B \)
\[ N_B = ? \]
\[ = N_B D_B \text{ (weight)} \]

\[ \therefore \frac{N_A D_A + N_B D_B}{100} \]
\[ = \frac{N_A D_A}{N_A D_A + N_B D_B} \times 100\% \text{ (of } W_A) \]
\[ = \frac{N_B D_B}{N_A D_A + N_B D_B} \times 100\% \text{ (of } W_B) \]