

# Cotton Fiber Structure and its Properties

COTTON FIBERS  
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# Cotton

## Introduction:

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Cotton is the undisputed “*king of fibers*” in textile world. Cotton is a soft and fluffy staple fiber that grows in a capsule around the seeds of cotton plant belonging to the family “*Gossypium*”. Cotton is a natural fiber whose source of origin is cotton plant. Cotton is further classified as vegetable fiber as it is obtained from cotton plant. There are various types of vegetable fibers depending upon the location where fibers are produced naturally. As fibers of cotton are produced in a capsule situated around cotton seeds, it is classified under “*Seed Fibers*” category. Cotton fiber is made up of countless cellulose molecules making it almost pure cellulose. Out of all the natural fibers produced in the world, more than 90% are of vegetable origin and out of this amount; more than 80% fibers having a vegetable origin are cotton. Cotton is the most used and most famous fiber in the world. Fabric made from this fiber, cotton fabric, is immensely popular for its property of “*breathability*” which is due to its high air permeability. It is best suited to every season except extreme winter as it can't entrap air in its structure to keep body warm. Due to its suitability to every season, it is called “*All-Season fabric*”. In fact, cotton is the backbone of the world's textile trade and industry.

## Structure:

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Each cotton fiber is composed of concentric layers.

**Longitudinal structure** of cotton consists of base, body and tip.

**Base:** Short fragile, coned type portion which remains constant in the epidermal of seed during growth of fiber.

**Body:** Main portion of cotton fiber and about 75% of total length.

**Tip:** Straight narrow portion at the end of fibers and about 25% of total length.

**Cross-sectional structure** of cotton consists of cuticle, primary wall, winding layer, secondary wall, Lumen wall and lumen.

**Cuticle:** Outermost layer on the fiber which itself is separable from the fiber and consists of wax and pectin materials.

**Primary wall:** The most peripheral layer of the fiber which is composed of cellulosic crystalline fibrils.

**Secondary wall:** Secondary wall of the fiber consists of three distinct layers. All three layers include closely packed parallel fibrils with spiral winding and represent the majority of cellulose within the fiber.

**Lumen wall:** Boundary wall of cavity portion inside the fiber.

**Lumen:** The innermost part of cotton fiber, the lumen, is composed of the remains of the cell contents. Before boll opening, the lumen is filled with liquid containing the cell nucleus and protoplasm.

### Chemical Composition:

Chemical composition of cotton fiber is as follows;

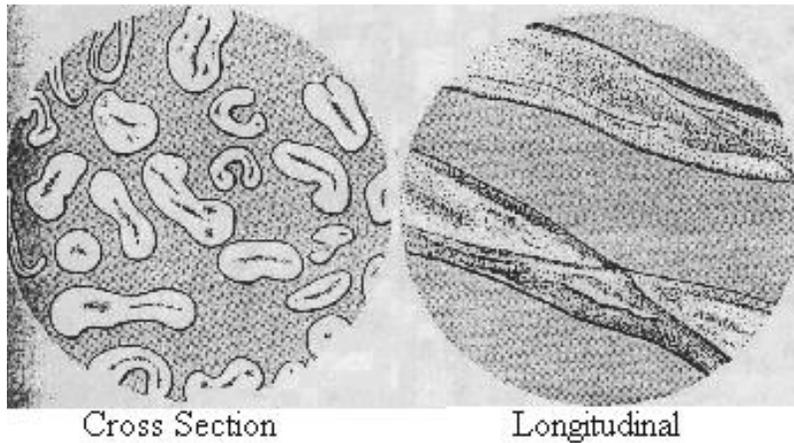
<b><i>Composition</i></b>	<b><i>%age</i></b>
Cellulose	91– 94
Water	6 – 8
Waxes and fats	0.5 – 1

Proteins	1 – 1.5
Protoplasm and pectin's	0.5 – 1
Mineral Salts	0.2 – 1

### Microscopic Appearance:

Different kind of fibers can be identified by their microscopic appearance better, than their physical appearance. When cotton is viewed under microscopic lens;

- ✘ In longitudinal view, it appears as a flat tube with spiral twists or a twisted ribbon.
- ✘ Under cross section view, it is bean shaped.



Cross Section

Longitudinal

### Physical Properties:

 According to Physical Structure:

1) Color

Color of cotton fiber is instrumental in fiber identification. The usual color of cotton fiber ranges from white to creamy white. The color of fiber depends upon the conditions under which cotton is produced e.g., time of picking, soil of growth, exposure of plant to sunlight, climatic conditions, impact of insects and fungi etc. The cotton produced normally has a cream-white color. If fiber is not picked at the right time, its color may vary. If fiber is left for an extended period of time in the boll, it may turn bluish-white. There are five recognized groups of color: white, gray, spotted, tinged, and yellow stained. As the color of cotton deteriorates the process ability of the fibers decreases.

## 2) Fiber Strength

Fiber strength is measured in *grams per denier (gm/den)*. Cotton is a moderately strong fiber. It has a tenacity of *3.0 - 4.9 gm/den*. The strength of cotton fiber is directly affected with the moisture regain and higher length. Wet cotton fiber is *20%* stronger than dry cotton fiber. Similarly, long cotton fibers are stronger than short fibers.

## 3) Elastic Property

Elasticity of cotton fiber is very low. Recovery from deformation of cotton fiber from applied load is very low as cotton fiber is a rigid fiber and inelastic. At 2% extension, it has elastic recovery (ER) of 74%. At 5% extension, it has elastic recovery (ER) of 45%. Elastic property can be achieved by;

- ✘ Chemical treatments for the purpose of improvement in crease recovery but fibers become harsher due to chemical treatment.
- ✘ Blending or mixing of cotton with elastic fiber, e.g. polyester.

## 4) Length

Physically the individual cotton fibers consist of a single long tubular cell. Its length is about 1200-1500 times than its breadth. Length of cotton fiber varies from 16mm to 52 mm or ½ to 2½ inches depending upon the type of cotton. The width varies between 12 to 20 microns, e.g.

- ✘ Indian cotton- 16-25 mm
- ✘ American cotton- 20-30 mm
- ✘ Sea Island- 38-52 mm
- ✘ Egyptian cotton- 30-38 mm

### 5) Fineness

Fineness of the fiber depends upon the length of fiber. As cotton fibers are longer in length, they have high fineness. Fineness is expressed in terms of decitex and it varies from 1.1 - 2.3 decitex in cotton fibers. Shorter cotton fibers have low fineness.

### 6) Length Uniformity

Length uniformity or uniformity ratio is determined as “*a ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage*”. Typical length uniformity of cotton fibers is shown as below;

Length Uniformity	Uniformity Index [%]
<i>Very High</i>	>85
<i>High</i>	83-85
<i>Intermediate</i>	80-82
<i>Low</i>	77-79
<i>Very Low</i>	<77

Low uniformity index shows that there might be a high content of short fibers, which lowers the quality of the future textile product. Hence, fibers with high length uniformity produce good quality products.

### 7) Crimp

Cotton fiber is more or less twisted on its longitudinal axis which can't be seen from outside. This is called fiber crimp. The twist in the fiber doesn't tend to be continuous in one direction i.e. if at first direction of fiber is right, and then direction of fiber is left. This property of cotton fiber helps in spinning.

### 8) Specific gravity

Specific gravity of cotton fiber is 1.54.

### 9) Effect of Sun-light

When cotton is exposed to sunlight, there is a gradual but consistent loss of strength of cotton fibers and they turned yellowish due to sunlight. When heat is promoted and brought to cotton fibers by sunlight, degradation of cotton is done by oxidation. From sunlight, much of the damage is caused by ultraviolet light.

### 10) Effect of Heat

Cotton is very resistant to degradation by heat. It begins to turn yellow after being burnt at 120°C for several hours. Decomposition of cotton fiber occurs at 150°C due to the process of oxidation. Cotton is severely damaged after few minutes after at 240°C. Cotton burns readily in air.

### 11) Luster

Cotton fiber has a very low luster naturally just like low elasticity.

## 12) Effect of Moisture

Tensile strength of cotton fiber is increased with the absorption of moisture. Under normally humidity condition, cotton takes up about 6 – 8% moisture. Cotton fiber has a moisture regain of 8.5%. Wet cotton fiber is 20 – 25 % stronger than dry cotton fiber as hydrogen bonding is produced between molecules of water and cellulose present in cotton. Hydrogen bonding becomes the cause of strength in wet cotton fiber.

## 13) Effect of Age

Small loss of strength is showed by cotton when stored carefully. After 50 years of storage, cotton may differ only a little from new fibers.

## 14) Smell

Cotton fiber burns rapidly in the air. Cotton burns instantaneously when it comes in contact with flame. Cotton burns quickly and readily with a smell of burning paper.

## 15) Conductor

Cotton is a very good conductor of heat and air. Cotton is a good conductor of electricity.

## *According to Usage*

### 1) Comfortable:

Cotton fiber has large amorphous portion and this is why the air can be in and out through cotton fiber. So, the fabric made by cotton fiber is quite comfortable to use.

### 2) Soft Handle:

Cotton fiber, if properly ginned, gives the best soft handle feeling among all other fibers. This property is instrumental in fiber identification.

### 3) Absorbent:

Cotton fiber has high absorbency power and this is why this fiber can be dyed properly and without any problem or difficulty. It absorbs perspiration quickly which is its highly esteemed property. As the body perspires, cotton fibers absorb the moisture and release it on the surface of the fabric, so it evaporates.

### 4) Printing:

Printing efficiency of cotton fiber is good. If the printing is applied on cotton fiber, it seems it doesn't spread the color outside the design.

### 5) Good Color Retention:

Cotton fibers have very good color retention. Fabrics made by it can retain their color in harsh conditions and in washing.

### 6) Machine Washable & Dry Cleanable:

Cotton fiber has a very good fineness and is easily washable. It is seen that some fibers can't be dried or washed due to their sensitivity to water and weak fastness properties. You can easily wash the cotton made fabric by machines and even you will be able to dry this fiber by using electronic drier. Cotton fabric is very easy to launder.

### 7) Good Strength:

Cotton fiber is a moderately strong fiber. Its strength along its other properties makes it ideal for wear. Cotton fiber is also very durable.

### 8) Draping:

The drape-ability of cotton fiber is quite good. You can use the cotton fiber made fabric in any kind of wear which needs more flexibility and drapes.

### 9) Sewing & Handling Is Easy:

The sewing efficiency on Cotton made fabric is easier and comfortable than other fiber. Cotton is very easy in handling.

### 10) Breathability:

Fabric made from cotton fiber has very high air permeability which makes it highly breathable fabric. It has a distinctive feature that it adjusts easily with climatic requirements. That is why it is called all-Season fabric. In summer season, cotton fabric keeps the body cool and absorbs the sweat easily. As the body perspires, cotton fibers absorb the moisture and release it on the surface of the fabric, so it evaporates.

## *Chemical Properties:*

### 1) Effect of Acids:

Cotton is damaged by dilute acids and cold concentrated acids which causes disintegration.

### 2) Effect of Alkalis:

Cotton has an excellent resistance to alkalis. It swells in caustic alkalis like NaOH but it doesn't damaged by alkali. It can be washed repeatedly in soap solution without any problem.

### 3) Effect of Organic Solvent:

Cotton has a high resistance to normal cleaning solvents. Cotton is dissolved by copper complexes such as cuprammonium hydroxide etc.

#### 4) Effect of Insects:

Cotton is not attacked or damaged by moths or beetles.

#### 5) Effect of Micro-Organism:

Cotton is attacked by fungi and bacteria. Mildews feed on cotton fiber, rotting and weakening the material. Mildews and bacteria will flourish on cotton under hot and humid conditions.

### Uses of Cotton Fiber:

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- ✘ Cotton fiber can be woven or knitted into fabrics such as velvet, corduroy, chambray, velour, jersey and flannel.
- ✘ It is used to make breathable textile products like underwear, socks and t-shirts.
- ✘ Cotton is also used in fishnets, coffee filters, book binding and archival paper.
- ✘ Linters are the very short fibers that remain on the cottonseed after ginning. They are used to produce goods such as bandages, swabs, bank notes, cotton buds and x-rays.
- ✘ Bed sheets are usually made of cotton because of its soft feel.
- ✘ Cotton fiber is also used to create tents and cotton paper. Cotton paper is used to create banknotes and high quality art paper.
- ✘ Cotton is used in apparel; blouses, skirts, pants, shirts, children wear,
- ✘ active wear etc.
- ✘ Cotton is used in home upholstery; draperies, curtains, bed sheets, towels, table clothes, table mats, napkins.

✘ Cotton is used to make medical textile like bandages and wound plasters.

In short, cotton fiber is a versatile fiber which has wide variety of uses.

Fiber properties through table:

Property	Evaluation
Shape	Fairly uniform in width, 12–20 micrometers; length varies from 1 cm to 6 cm ( $\frac{1}{2}$ to $2\frac{1}{2}$ inches); typical length is 2.2 cm to 3.3 cm ( $\frac{7}{8}$ to $1\frac{1}{4}$ inches).
Elasticity	Relatively Low
Specific Gravity	1.54
<b><u>Tenacity (strength)</u></b>	
Dry	3.0–5.0 g/d
Wet	3.3–6.0 g/d
Resiliency	Low
Density	1.54–1.56 g/cm <sup>3</sup>
<b><u>Moisture Absorption</u></b>	
<u>Raw</u> Conditioned	
Saturated	8.5%
<u>Mercerized</u>	15–25%
Conditioned	8.5–
Saturated	10.3%
	15–27%+
Dimensional stability	Good
<b><u>Resistant To</u></b>	
Acids	Damage, weaken fibers
Alkali	Resistant; no harmful effects
Organic Solvents	High resistance to most
Sunlight	Prolonged exposure weakens fibers.
Microorganisms	Mildew and rot-producing bacteria damage
Insects	fibers.
	Silverfish damage fibers.

<b><u>Thermal Reactions To</u></b>	
Heat	Decomposes after prolonged exposure to temperatures of 150°C or over.
Flame	Burns readily.

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