

Textile Science

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Weave Descriptors

Figure 26.1 shows a small section of a woven fabric in a weave diagram. A surface view is presented along with two cross-sectional views, one lengthwise and one crosswise. The cross-sectional views represent how the yarn positions appear when the fabric is viewed at its cut edge. They are not necessary when the fabric has a simple structure, but they become useful as the number of sets of yarns increases. The weave diagram in Figure 26.1 is labeled with many of the terms discussed in this section.

The terms *warp*, *filling*, and *bias* specify direction. The crosswise direction of woven fabrics is called the *filling* direction, and the lengthwise direction is called the *warp* direction. The yarns that transverse crosswise are filling yarns and those in the lengthwise direction are warp yarns. Other terms used for filling are weft, woof, and picks. Warp yarns may be referred to as ends. In this textbook, the warp yarns are depicted in black and the filling yarns in white. The *bias* direction is any direction other than lengthwise and crosswise. A bias is either a true bias, meaning a direction at a 45° angle to the lengthwise edge, or a garment bias, meaning a direction at any angle other than 45° to the lengthwise edge.

Usually, the lengthwise edge of a woven fabric has a *selvage* to ensure that the fabric edge will not tear when it is subjected to the stresses of the finishing and dyeing processes. It is usually $\frac{1}{4}$ to $\frac{1}{2}$ inches wide, is more closely woven (denser), and exists on both lengthwise edges of the fabric.

Woven fabrics have a *face* and *back*. The side called the face usually has the more attractive appearance and is the side viewed during use or wear, as with the outer surface

of a garment. Some fabrics, such as plain-woven and leno, are structurally identical on the face and the back due to the interlacing pattern used. Others, such as warp-faced twills and satin, differ in appearance on the face and the back.

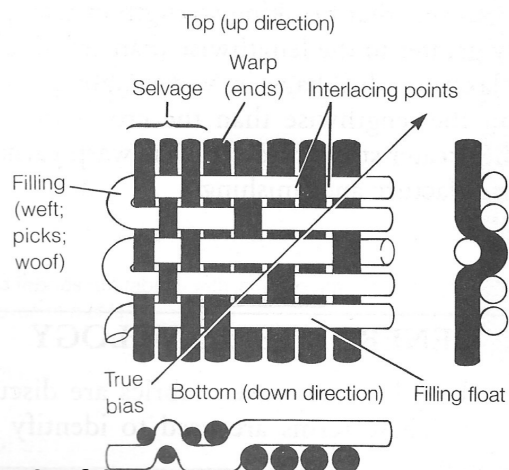
All fabrics have a *top* and a *bottom*. Usually these dimensions are not important because fabric appearance is the same regardless of which end is viewed. In other words, when a fabric is rotated 180°, its appearance is the same. However, pile woven fabrics—such as velvet, velveteen, and corduroy—exhibit different depths of color shade depending on the position in which they are viewed. This variation in appearance must be taken into account when fabricated products are made.

An *interlacing pattern* is a description of the *movement* of either the warp or the filling yarns from the surface to the back of the fabric and vice versa and of the manner in which adjacent yarns complete the movement relative to one another. The latter is called the *move number* or the *progression of interlacing* and is defined as “the number of filling yarns by which the interlacing of a warp yarn in a weave moves upwards relative to the warp yarn on its immediate left.”

The weave diagram in Figure 26.1 is just sufficient to show one pattern or *weave repeat*, the smallest number of warp and filling yarns on which an interlacing pattern can be represented. In this case, five warp and five filling yarns are just sufficient (the three warp yarns in the selvage are excluded). The movement of each filling yarn is over four warp yarns and under one warp yarn. This pattern is best observed with the filling yarn at the bottom of the diagram. The movement of each warp yarn is under four filling yarns and over one filling yarn. This movement is most easily observed by viewing the first warp yarn at the left-hand edge of the body of the fabric. The progression of interlacing in the weave diagram is 2. To obtain this result, we first determine that the far right-hand warp yarn passes over the third filling yarn from the bottom. We then determine that the second warp yarn from the right passes over the fifth filling yarn from the bottom. Therefore, it is necessary to move up two filling yarns before reaching an identical interlacing point.

A *float* is “a length of yarn on the surface of a fabric between adjacent intersections. This corresponds to the number of yarns over or under which the intersecting yarn passes in a woven structure.” In the weave diagram in Figure 26.1, the filling yarns form floats on the fabric face and the warp yarns form floats on the fabric back. The length of the floats is four. Floats can make a fabric surface flat and inelastic. The length of the floats is four. Floats can make a fabric surface flat and inelastic.

FIGURE 26.1 Structural elements of woven fabrics.



to achieve design in fabrics such as dobby and jacquard. Snagging is a problem when the float is relatively long because the float yarn can be caught on broken finger-nails or other rough surfaces. Floats weaken the fabric by reducing the frequency with which yarns pass from one side of the fabric to the other. They enable yarns to slide under each other in the fabric and are used to make fabrics with high fabric counts (many yarns per square inch).

Interlacing patterns determine the number of *interlacing points* in each square inch of fabric and the spacing of the interlacing points. The interlacing pattern has a significant influence on appearance and performance. Fabrics with fewer interlacings per unit area and more space between yarns usually are softer (and more supple) and drape better than fabrics with more interlacing and less space between yarns. When a fabric having a high number of interlacing points per unit area is pulled or torn, the warp and filling yarns dig into one another at their points of interlacing and the yarns are weakened. However, at these same points, stresses are transferred from warp to filling and vice versa, helping the fabric to maintain integrity. When the points of interlacings are too widely spaced, the transfer of stresses is reduced, so the yarns break under stress.

The terms *on-grain* and *off-grain* denote whether or not the yarns in the woven fabric are at right angles to each other at the time the fabric is to be made into an end-use item. Off-grain alignment of the yarns yields a defective fabric. Fabrics may be pulled off-grain during dyeing, printing, and finishing operations. Usually, it is the filling yarns that are distorted. Failure to straighten the fabric—to return it to its on-grain position—results in poor drape in the end-use product.

Fabric Count

Fabric count is “the number of warp and filling yarns per inch of fabric.”² It may be written as the number of the warp and the number of the filling ($W \times F$) or as the sum of the warp and filling counts. For example, the fabric count of a fabric with 80 warp yarns per inch and 80 filling yarns per inch can be given as either 80×80 , 160, or 80 square. The fabric count of a fabric with 180 warp yarns per inch and 90 filling yarns per inch can be stated as 180×90 or as 270. Usually, the count is that of the fabric when removed from the loom, or the greige fabric. This count may change in subsequent processing.

In the consumer marketplace, *fabric count* is usually given on sheets and pillowcases. A common count is 80×80 , or 160. In finer sheets, the fabric count is between 200 and 310. The more useful information is provided from the reporting of warp and filling separately because then one knows whether the fabric is balanced or unbalanced in its construction (discussed in a later section of this chapter). In mail-order catalogs, the fabric count may be printed to assist the consumer in knowing the construction of the fabric being sold.

Various adjectives are often used instead of precise counts to indicate the relative closeness of yarns in woven fabrics. These adjectives include: tight (tightly woven), close (closely woven), and dense (densely woven), as well as loose and open.

Fabric count is an important determinant of the quality of fabric. It is accepted that the higher the fabric count, the better the technological quality of the fabric. High fabric counts require the use of the finest of yarns. High fabric count is also facilitated by a low number of interlacings per square inch of fabric. If two fabrics are woven with yarns of the same size, the fabric with the fewer interlacings per inch is the higher-count fabric because yarns can be packed more closely together. High-fabric-count fabrics, although containing fine yarns, have close or dense structures that permit little yarn movement. On the other hand, yarns in low-fabric-count fabrics have some freedom of movement, enabling the fabric to better withstand the stresses of crushing and bending. Performance properties significantly affected by the fabric count appear in each of the five performance attribute categories.

Breaking strength increases as fabric count increases because more yarns are available to share the pulling force on the fabric. Tearing strength, however, decreases as fabric count increases. A tightly woven fabric allows only one yarn at a time to break as a tear propagates, but a loosely woven fabric allows more yarns to carry the load at any one time. Thus, a loosely woven fabric has a higher tear strength than a tightly woven one made of the same yarn.

Comfort is altered as fabric count increases; air permeability decreases, water resistance increases, and weight increases. The amount of fabric shrinkage decreases as the fabric count increases. Flammability is lowered as fabric count increases because less air remains within the fabric. Fabric aesthetics altered include cover, resilience, body, hand, and drape. Cover increases as fabric count increases; resiliency decreases. In a fabricated product, the higher the fabric count, the less traveling there is at the seams.

²The outdated term for fabric count is thread count. Fabric or thread count should not be confused with yarn number. Yarn number specifies the size (diameter) of spun yarns (Chapter 24).

Balance

Balanced woven fabrics are fabrics that have the same number of warp yarns and filling yarns per inch and contain yarns of equal size and character. The term *unbalanced* is not defined but is commonly used to indicate that the ratio of the number of warp to filling yarns (or filling to warp yarns) in a fabric is two or greater. For example, cotton broadcloth with a fabric count of 144×76 and nylon satin with a count of 210×80 are unbalanced, with ratios of 2:1 and 3:1, respectively.

Balance is helpful in determining the warp direction of fabrics, which usually have more warp yarns than filling yarns. Some fabrics contain two or three times as many warp as filling yarns, but some contain twice as many filling as warp yarns. Balance is also helpful in determining the name of some specific fabrics that differ mainly in the balance of yarns, such as percale and broadcloth.

Raveling a fabric on two adjacent edges and looking at the density of the fringe provides a quick means of determining whether or not a woven fabric is balanced. The comparison of a balanced plain-woven fabric with two unbalanced plain-woven fabrics in Figure 26.2 is a case in point. When there is a distinct visual difference in the density of the fringe, the fabric is unbalanced. A count of the yarns is the more accurate method of determining whether or not the fabric is balanced.

Balanced fabrics are usually more durable than unbalanced ones. The yarns in a balanced fabric share the stresses placed on the fabric; hence the fabric wears more evenly. Unbalanced fabrics differ significantly in certain aspects of performance in warp and filling directions. For example, unbalanced fabrics have far greater shrinkage in the warp direction than in the filling direction. In a balanced fabric, the amount of shrinkage will differ between warp and filling directions, but the difference is smaller.

Width

Woven fabrics vary substantially in width. Hand-woven fabrics are usually 27–36 inches (69–91 centimeters) wide, a distance that represents the width through which a weaver can insert a filling yarn while sitting at the loom. Wool fabrics are traditionally 54–60 inches (137–152 centimeters) wide. Before the 1950s, cotton fabrics were limited by loom technology to a maximum width of 36 inches. Wider fabrics are more economical to cut and weave, however, so new technology was developed. Most cotton and cotton blend fabrics are now 45 inches (114 centimeters) wide. Silk and silk-like fabrics are also

40–45 inches (101–114 centimeters) wide. Some 156-inch (396-centimeter) fabrics are available.

Narrow fabrics are defined as fabrics up to 12 inches (30 centimeters) wide. These include ribbons, elastics, zipper tapes, venetian-blind tapes, couturiers' labels, hook and loop tapes such as Velcro® (a trademark of Velcro Incorporated), piping, carpet-edge tapes, trims, safety belts, and harnesses. Webbing is a particularly important group of narrow fabrics.³

Weight

Woven fabrics differ in weight. In the apparel trade, the terms *top weight* and *bottom weight* are frequently used. *Top-weight* fabrics are those suitable for fabrication into shirts, blouses, and dresses. *Bottom-weight* fabrics are those suitable for fabrication into pants, slacks, and skirts. Weight might also be conveyed as *very light* (less than one ounce per yard²), *light* (2–3 ounces per yard²), *medium* (5–7 ounces per yard²), *heavy* (more than 7 ounces per yard²), or *very heavy*.

When fabric weight is given in ounces per yard², the area of fabric is a constant, making it convenient to compare the weights of fabrics that differ in width. Fabric weight may also be given in ounces per linear yard. The comparison of the weight of fabrics with different widths therefore requires that weight/linear yard be converted to weight/yard².

The heavier a fabric is, the more load that is placed on the human body wearing or carrying it. In certain end uses, such as tents for backpacking, consideration of fabric weight is paramount. The weight of a fabric influences its body; usually, the greater the weight, the greater the body. Weight is not a determinant of thermal insulation: heavy fabrics are not necessarily warmer fabrics than lighter fabrics. Thermal insulation is determined primarily by the amount of dead air space incorporated into the fabric structure.

BASIC STRUCTURES

The simplest woven fabrics are plain, twill, and satin. Each structure contains one set of filling yarns and one set of warp yarns. The repeat pattern of these fabrics is determined with as few as two yarns and with rarely more than eight yarns. The surface can appear flat (featureless), as a series of crosswise ribs, as a series of diagonal ribs, or smooth and lustrous. For each structure, a weave diagram is provided together with a photograph

³Narrow fabrics may also have knit or braid structures.

of the face and back of a typical fabric. The fabric face is always on the left-hand side of the photograph and the fabric back on the right-hand side.

Plain-Woven Fabrics

In plain-woven fabrics “the odd warp yarns operate over one and under one filling yarn throughout the fabric

with the even warp yarns reversing this order to under one, over one, throughout.” All three weave diagrams in Figure 26.2 show the 1/1 pattern, or interlacing with a progression of one. Any two adjacent filling or warp yarns establish the pattern repeat.

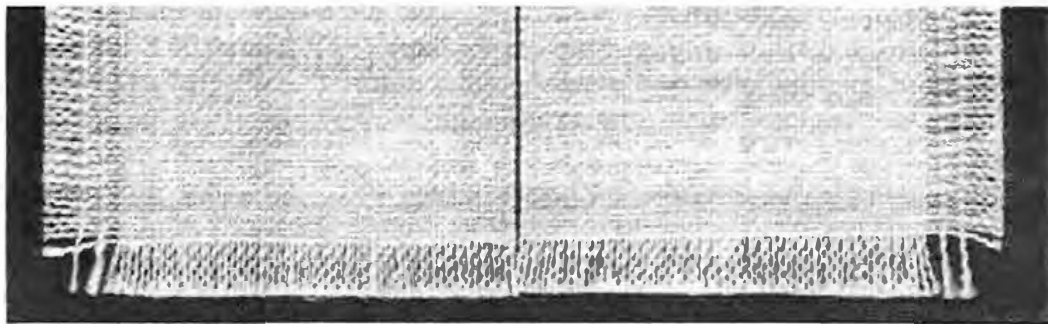
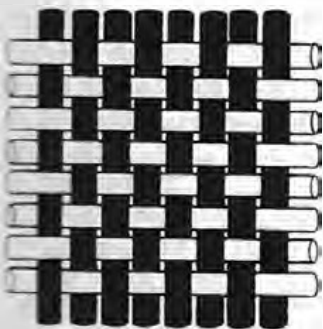
The appearance of the face and back of plain-woven fabrics is always identical, due to weave interlacing. The face and back of each of the fabrics shown in Figure 26.2

FIGURE 26.2 Plain-woven fabrics.

Plain-woven fabrics are fabrics in which “the odd warp yarns operate over one and under one filling yarn throughout the fabric with the even warp yarns reversing this order to under one, over one, throughout.”

BALANCED

Those plain-woven fabrics that contain the same number of warp and filling yarns per inch, with all the yarns about the same size.

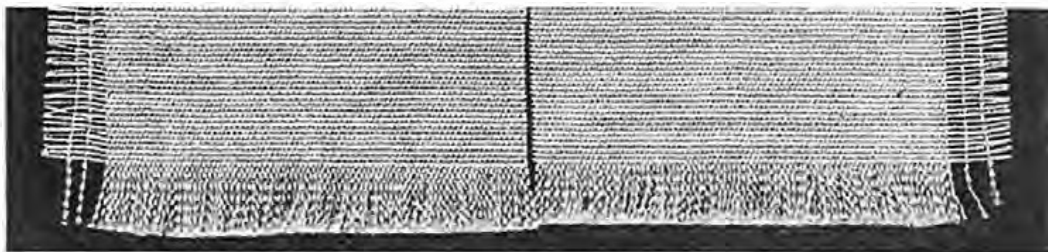
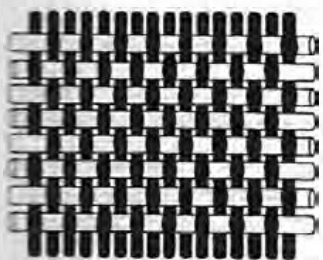


UNBALANCED (RIB)

Those plain-woven fabrics in which the ratio of the number of warp yarns to filling yarns is two or greater.

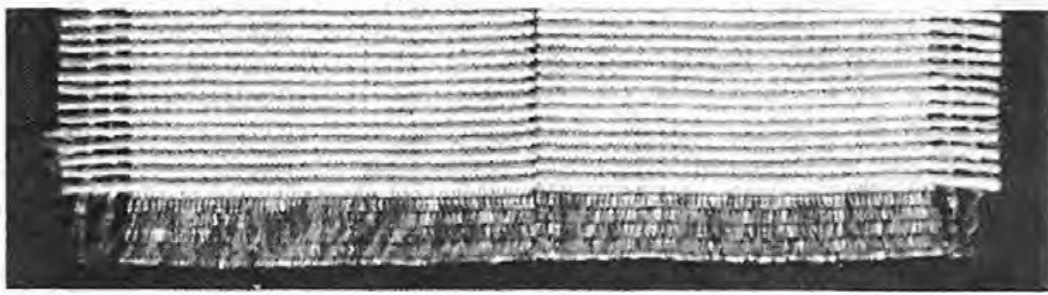
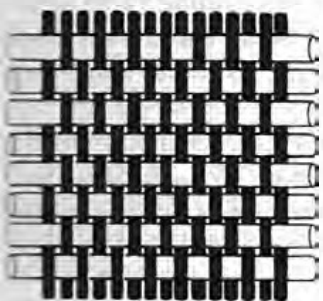
Regular

The size of warp and filling yarns is about the same.



Prominent

The filling yarns are larger than the warp yarns.



are therefore identical. Many of the plain-woven fabrics have a plain or flat surface, as shown in the top photograph in Figure 26.2. This surface serves well for printing designs, embossing, glazing, napping, and other surface finishes. Other plain-woven fabrics have crosswise ribs, as shown in the middle and bottom photographs in Figure 26.2. Color patterning of the warp and/or filling results in color-and-weave effects. Use of fancy and textured yarns as well as varying the twist and size of spun and filament yarns adds interest to the fabric.

More yardage of plain-woven fabric is available than all other types of woven fabric. Plain-woven fabrics can be found in almost any end use.

Performance. The high number of interlacings per square inch in plain-woven fabrics significantly influences their performance in comparison to the performance of twill and satin woven fabrics with identical types of yarns and fabric counts. Plain-woven fabrics wrinkle more, and the wrinkles are more visible, ravel less, have lower tearing strength, and are less absorbent.

Balanced Plain-Woven Fabrics. The largest group of plain-woven fabrics are balanced. In these fabrics, fabric count is essentially equal in the warp and filling directions, and the sizes of the yarns are approximately identical. When fringed on adjacent edges, the fringes appear to be about the same density. The fabric photographed in Figure 26.2, a typical sheeting fabric called percale, illustrates these features.

Balanced plain-woven fabrics vary in weight from very light to very heavy. They may be open or dense, depending on the fabric count, and they may contain any type of yarn. Yarns of different fiber compositions may be used in the warp direction than in the filling direction, resulting in mixture or union fabrics (Figure 24.8). When colored yarns comprise the fabric, checks and plaids may result. Fabrics are given specific names depending on weight, yarn structure, color-and-weave effect, and finishes. Names include batiste, buckram, calico, cambric, canvas, challis, chambray, cheesecloth, crash, crepe de chine, cretonne, crinoline, duck, flannel, gauze, georgette, gingham, lawn, muslin, organdy, percale, plissé, seersucker, sheeting, and voile.

Unbalanced Plain-Woven Fabrics. Unbalanced plain-woven fabrics, often called rib fabrics, are characterized by the presence of ribs (ridges) running crosswise on both the face and back of the fabric (Figure 26.2 middle and bottom). The ribs, equally prominent on face and

back, are due to the use of at least twice as many warp yarns as filling yarns interlacing in the over-one-and-under-one pattern of all plain-woven fabrics. A warp surface is created on both the face and back of the fabric. When the warp and filling yarns are different colors, the only color that shows is that of the warp yarns.

There are two types of these rib fabrics, regular and prominent. In *regular rib fabrics*, the warp and filling yarns are the same size, or nearly so, and are usually small; consequently, the crosswise ribs they form are almost indistinct. The photograph of broadcloth fabric in Figure 26.2 (middle) illustrates this characteristic. Note the difference in the density of the fringe at the two adjacent edges. *Prominent rib fabrics* are those unbalanced plain-woven fabrics in which the filling yarns are larger than the warp yarns. The greater the difference in the size of the warp and filling yarns, the larger and more prominent the ribs. The photograph of a fabric called faille in Figure 26.2 (bottom) illustrates a prominent rib fabric.

The prominence of the crosswise rib influences the ability of the unbalanced fabric to withstand abrasion. The larger the rib, the lower the abrasion resistance of the fabric because the yarn at the top of the ribs must absorb all of the abrasive force. In many rib fabrics, the warp yarns tend to be small. The warp yarns are damaged first, creating splits in the fabric. The filling yarns, covered by the warp, are protected from wear.

Slippage is a problem in unbalanced plain-woven fabrics made with filament yarns, especially in fabrics with low fabric counts. In garments, yarn slippage in the fabric occurs where abrasion and tension are greatest; for example, at seams and buttonholes. Unbalanced plain-woven fabrics with fine ribs are softer and more drapable than comparable balanced plain-woven fabrics. Those with large ribs have more body and less drape. Names of specific unbalanced plain-woven fabrics, given according to increasing prominence of the crosswise rib, are broadcloth, poplin, taffeta, faille, repp, grosgrain, bengaline, and ottoman.

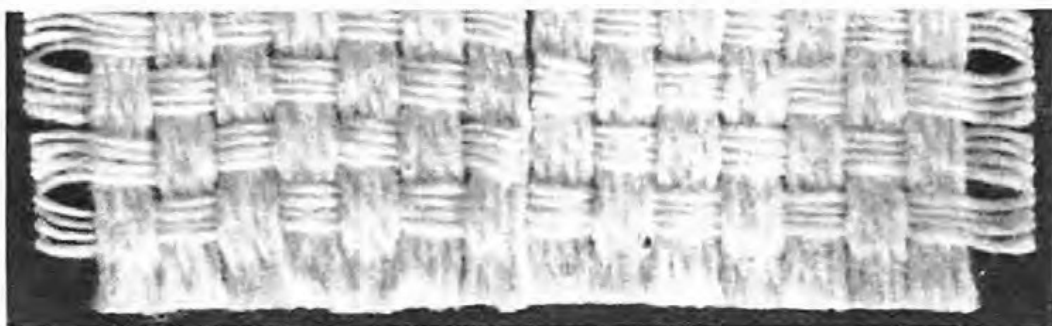
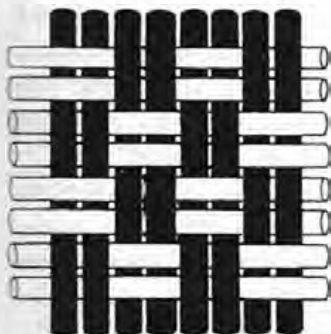
Basket Fabrics. *Basket fabrics* are those in which two warp yarns interlace with one or more filling yarns (Figure 26.3). The most common basket fabrics have two warp yarns floating over two filling yarns, as shown in the diagram at the top of Figure 26.3, or four warp yarns floating over four filling yarns as shown in the fabric photographed at the top of Figure 26.3. *Half-basket fabrics* are those in which two warp yarns float over one filling yarn, as shown in the diagram and oxford cloth at the bottom of Figure 26.3.

FIGURE 26.3 Plain-weave variations.

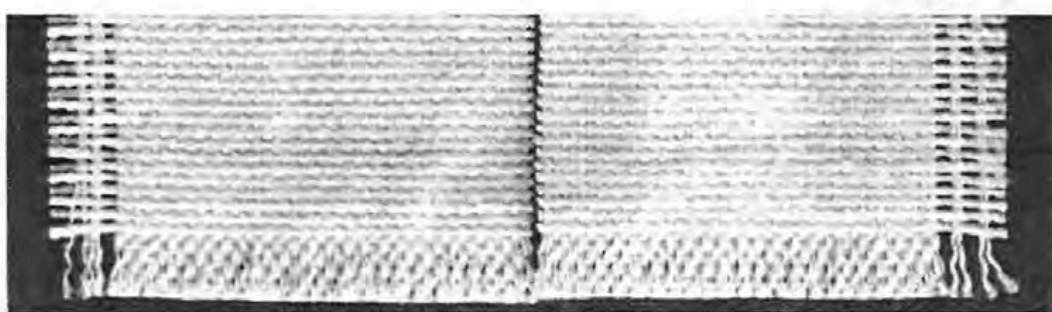
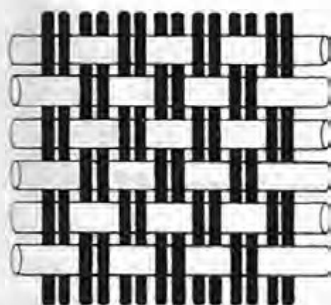
Plain-weave variations include those fabrics in which two warp yarns interlace with one or more filling yarns.

BASKET FABRICS

Those plain-woven fabrics in which two or more yarns interlace "as one," usually in a 2/2 or 4/4 interlacing pattern.

**HALF-BASKET FABRICS**

Those plain-woven fabrics in which two or more yarns interlace "as one," usually in a 2/1 or 3/1 interlacing pattern.



Although strictly speaking, basket fabrics and half-basket fabrics do not have an interlacing of over one yarn and under one yarn, they can be said to have this pattern if pairs of yarns are considered as one unit. The interlacing then progresses by one. Further, basket fabrics have the "flat" surface of plain-woven fabrics.

Basket fabrics have better wrinkle resistance than the balanced and unbalanced plain-woven fabrics because they have fewer interlacings per inch. For the same reason, they are more flexible. The floats, which are rather long because large spun yarns are widely used, cause basket fabrics to snag more easily and to be less durable than other plain-woven fabrics. The floats, however, do increase adsorbency. Due to the traditional low fabric counts, shrinkage is high.

In apparel, many basket fabrics are used for suits (hopsacking), sportswear (sailcloth), and shirts (oxford cloth and oxford chambray). Slipcovers for furniture, house awnings, and boat covers are often basket fabrics

that are sold under the names canvas and duck. Monk's cloth is also used in home furnishings.

Twill Fabrics

Twill fabrics are fabrics in which the "weave repeats on three or more warp and filling yarns and diagonal lines are produced on the face of the fabric." Therefore, the interlacing pattern is over more than one yarn and then under one or more yarns. The progression of interlacing is by one, thereby producing the diagonal line (Figure 26.4).

All twill fabrics have a series of diagonal lines, or twill lines, on at least one side of the fabric due to the interlacing of the yarns. When the twill lines appear more prominently on one side, that side is the face. When the lines are equally prominent, a convention related to the direction of twill line is used to establish the face side. The diagonal lines on the face of twill fabrics may run

plished by hand. Yet, the weaving process was considerably faster than the process of making yarn. For example, 3 days of labor were needed to weave 10 yards of the finest muslin fabric, whereas two months of toil spinning superfine cotton preceded the weaving operation.

The mechanization of the hand loom in the 18th century and subsequent improvements to it have increased production rates, so that today a yard of fine fabric can be produced in a matter of minutes. Still, even though production rates have increased dramatically, the basic technological principles of weaving have not been significantly altered.

Weaving Principles

A basic loom consists of a *warp beam*, a *cloth beam*, *heddles*, at least two *harnesses*, a *reed*, and a *shuttle* (Figure 26.15). The purpose of the warp and cloth beams is to hold the warp yarns tautly during the weaving operation. The warp beam serves as the supply of warp yarns and the cloth beam as storage for the fabric as it is formed. The heddle and harness arrangement provides a means to separate the warp yarns into a configuration called a *shed*. To accomplish this, each warp yarn passes through a hole in the wire heddle and the heddles are held in a harness frame. The harnesses are capable of moving up, and as they do so, they raise those warp yarns passing through the heddles. The reed, a set of flat wires in a frame, moves forward and backward and pushes an inserted filling yarn to the edge of previously

formed fabric. The shuttle carries the filling yarn contained on its bobbin (technically a *pirn*) across the warp yarns through the shed.

The motions of weaving are: (a) *shedding*, the raising of one or more harnesses to separate the warp yarns to form a shed; (b) *picking*, the passing of a filling yarn through the shed; (c) *beating up*, pushing a filling yarn into place with the reed; and (d) *letting off* and *taking up*, unwinding additional warp yarns from the warp beam and winding finished fabric onto the cloth beam. These four motions are synchronized and are repeated over and over to weave a fabric.

Prior to weaving, a warp beam is prepared. Packages of warp yarn, each containing thousands of yards of yarn, are mounted on a creel (a frame) and carefully wound onto an initial warp beam. The warp yarns on the beam must lie side by side without entanglement. These warp yarns usually need to be strengthened temporarily so they can withstand the stresses of weaving. In a process called *sizing* or *slashing*, water-soluble starch, resins, or gums are added to the yarns to provide the strength and abrasion resistance required. The unsized yarns on the initial warp beam are run through a size bath and carefully rewound onto a final warp beam.

The final warp beam is then mounted on the loom and each warp yarn is threaded through its own drop wire, heddle eye, and reed dent. (The drop wire is a device that will stop the loom if a warp yarn should break.) Drawing in the warp yarns is time-consuming when done by hand. Machines have been developed for accomplishing this delicate task.

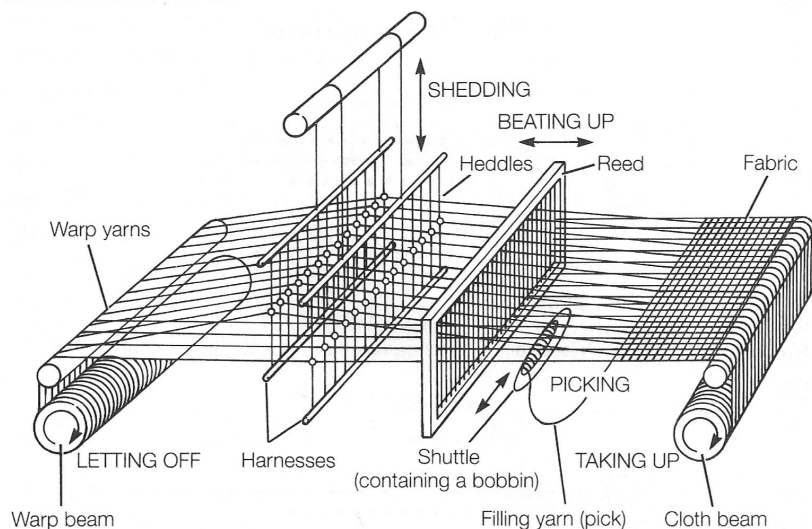


FIGURE 26.15 Essential loom parts and the formation of a plain woven fabric by the four basic loom motions.