 Functional or performance finishes enhance fabric performance.
  - Functional finishes are especially important for enhancing the performance of natural fibers; their properties cannot be enhanced during fiber production.
  - For manufactured fibers, performance is enhanced during fiber production (see the fibers section) and to a lesser extent by application of finishes to fabrics.

 Functional finishes are generally chemical finishes which enhance performance with varying degrees of permanence.
  - Majority of the functional finishes are applied by:
    - Dipping fabric in a chemical bath and squeezing between rollers.
    - Spraying a liquid or foam onto the fabric.
The recent push for environmentally friendly processes for products with enhanced performance/appearance has drastically changed the textile industry.

- Environmental considerations are routinely factored into the development of newer chemistries/technologies.
- New application methods are being developed that require less energy.

Technology enables the application of multiple/multifunctional finishes to improve fabric performance.

- For example, Solar Shield Protection®, a patented semi-durable outdoor/indoor product, is a multifunctional finish that protects fabric from fading, stain, spills, and water damage.
In Nanotechnology, molecules of the finishes are attached or associated with fibers at the molecular level and in a systematically ordered manner. 1 nm = (10^{-9} \text{ m})

- Proprietary technology is used in a wide variety of finishes ranging from antimicrobial to stain repellent finishes.
- Examples: Nanotex®, Nanodry®, SmartSilver®

Microencapsulation is a more recent mechanism to impart desirable properties that are often difficult to apply using other finishing methods. It enables the slow release of ingredients onto skin that is in contact with the fabric.

- For example, Skintex® microcapsules, filled with ingredients such as fragrance, insect repellent, or cooling materials, are anchored within the fabrics to which the finish is applied.
Micrograph of Cotton with Skintex® Microcapsules
Micrograph of Nylon with Skintex® Microcapsules

Courtesy Cognis
**Wrinkle Resistance**

- **Wrinkle resistance** is “that property of a fabric that enables it to resist the formation of wrinkles when subjected to a folding deformation...”*

- Wrinkle resistance is affected by cross linking between molecules in a fiber.
  - Cross linking agents improve the wrinkle resistance of cotton and other cellulosic fibers with weak bonds.
  - To improve wrinkle resistance, cotton and other cellulosic fibers are also blended with fibers that have strong molecular bonds.

*Source - *Dictionary of Fiber & Textile Technology*
Wrinkle Resistance

- Wrinkle recovery tests measure a fabric’s ability to recover after wrinkles are created; durable press performance is measured after washing/drying in accordance with test standards.
Evaluation of a Men’s Shirt using AATCC Durable Press Rating Replicas

Note: The shirt is hung in an area with lighting in accordance with the AATCC requirements. The replicas, placed on either side of the garment, are used to assign the durable press rating after the shirt has been washed and dried according to specifications.
Wrinkle Resistance

- Durable press, permanent press, easy care, wrinkle free, and wrinkle resistant labels are used interchangeably by garment manufacturers to highlight performance characteristics appealing to the consumer. It is difficult to differentiate between durable press and wrinkle resistant finishes based on the label.
Shrinkage Control

- Fabrics susceptible to shrinkage are “preshrunk” to avoid fabric puckering and problems with fit. The method used to control shrinkage depends on fiber content and fabric construction:
  - **Controlled compressive shrinkage** is used for cotton/cotton blends.
    - Examples: Sanforized® and Sanfor® (wovens) and Sanfor-Knit® (knits).
  - Tubular and open-width cotton and cotton blend knits are preshrunk on Micrex®/Open Width Compactors and other machines that compact fabrics.
Shrinkage Control

- Thermoplastic yarns and knit fabrics are heat set.

- Wools shrink as a result of **felting shrinkage**. Scales on the fiber surface are altered chemically or coated with polymer to create washable wool (e.g., Superwash®).
Repellent Fabrics

- **Water repellent** is “a term applied to fabrics that can shed water but are permeable to air and comfortable to wear. These fabrics are produced by treating the material with a resin, wax or plastic finish that is not completely permanent” (Source - *Dictionary of Fiber & Textile Technology*).
  - Water repellency is provided by **tightly woven** synthetic fabrics and **water repellent finishes**; these fabrics are used for all-weather coats, umbrellas, rain gear, outdoor sportswear, and outdoor furniture.
  - Silicones and fluorochemical-based finishes are water repellent; fluorochemical finishes are also oil repellent.
  - Durable water repellent (DWR) is the term for fabrics with a water repellent finish.

- Textile materials are coated, laminated, or bonded to a layer impermeable to water to produce waterproof fabrics.
  - Waterproof fabrics are used for rain jackets/slickers, rain boots, and covers for outdoor furniture, grills, etc.
Durable Water Repellent Finish - 100% recycled polyester fabric used for sportswear

Note: ECOCIRCLE FIBERS is a recycled polyester product made by Teijin Fibers Limited. The latest technology allows conversion of used polyester garments, bottles, and other polyester products to be reduced to raw material at the molecular level. With this technology, polyester can be recycled without compromising quality. This technology was used to produce the recycled polyester filament yarns in this woven fabric. ECOCIRCLE™ is a trademark of Teijin Fibers Limited. Sample courtesy Teijin Fibers Limited.
STORM DENIM™ - A technology used to apply water repellent finish to denim garments after they have been manufactured.
Repellent Fabrics

- **Stain/Soil repellent** finishes are fluorochemical finishes that prevent water-, dirt-, and oil-based stains from being absorbed.
  - Liquid stains bead on the fabric surface; the beaded liquid rolls off or can be blotted.
  - All stain/soil release finishes are water repellent as several stains are water-based. Not all water repellent finishes are soil repellent.

- Some repellent fabrics treated with fluorochemical formulations require drying/ironing to maintain the desired repellency. Newer finishes are more durable and may not require heat to maintain repellency.

- Performance of fluorochemical finishes is often affected if the garment is not rinsed well to remove the laundry detergent.

- **Teflon® HT, NanoSphere®, and Nano-Tex Resists Spills™** are examples of stain repellent fabrics.
Stain Repellent Finish – 100% cotton shirting fabric

cotton fabric without finish  cotton fabric with finish
60% Cotton/40% Polyester Shirt with Teflon® Finish

Note: Milk is used to demonstrate how the liquid beads up instead of getting absorbed by the fabric. The shirt used for this slide has been worn and laundered at home at least five times.
NanoSphere® - A nanotechnology-based self-cleaning finish

fabric after it was rinsed and dried

mustard
ketchup
food coloring
cranberry juice

turmeric

Note: The finish is promoted as a self-cleaning finish that allows stain-causing liquids to roll off from the fabric surface and other stain-causing substances to be easily rinsed off. Stain-causing food items were applied, rubbed into the fabric and then rinsed.
Stain Release

- **Stain/Soil release** is “a finish for textiles that makes it easier to remove stain and soil in laundering.”*

- Stain release finishes do not prevent stain-causing liquids from being absorbed by the fabric; they just enhance the removal of the stain.

- Stain release finishes are often used for table napkins as they allow fabrics to remain absorbent; the quality is important for table napkins (e.g., Visa® finished polyester for table linen).

- Nano-Tex Releases Stains® and Visa® Plus and Scotchgard™ Protector Stain Release are fabrics with a soil release finish.

* Source - *Dictionary of Fiber & Textile Technology.*
Dual Action Finishes

- Dual action fabrics are treated with a **combination** of stain repellent and soil release finishes.

- The stain repellent prevents staining liquids from penetrating the fabric, and the soil release assists in the removal of ground-in stains.

- StainSmart®, Scotchgard™ Protector Repel and Release, and NanoTex Resists Spills and Releases Stains are dual action finishes.

- Fabrics with these finishes have several applications, including work wear, scrubs for healthcare professionals, uniforms, children’s clothing, bedspreads and other interior textiles such as wall coverings.
Beading of Soft Drink Spilled on a 65% Polyester/35% Cotton Poplin with StainSmart™ Finish Used for Uniforms
Moisture Management

- **Moisture management** finishes provide comfort by transporting moisture (perspiration) away from the skin.
  - Effectiveness depends on temperature and relative humidity.

- In cotton and other hydrophilic fabrics the challenge is to transport the moisture away from the skin and keep it dry. Because these fabrics readily absorb sweat or moisture, they dry slowly. Proprietary technology is used to allow the side in contact with the skin to wick (instead of absorb) the moisture and allow fabrics to dry fast.
  - Examples: TransDRY™, WICKING WINDOWS™, Nano-Tex® Dry Inside, and Scotchgard™ Protector Moisture Management

- In synthetic fabrics, finish can be applied to repel moisture from the outside and transport sweat away from the body.
  - Examples: XDRY® and StainSmart®3.
Moisture Management – Fabric with a finish to repel moisture from the surface and another finish to transport sweat away from the body.

Note: A drop of water with food coloring formed a bead on the fabric surface. The bead was blotted and another drop was applied to fabric back. The finish applied to the back enabled the drop on fabric back to spread immediately.
Wicking Windows™ - A moisture management technology for cotton fabrics that transfers moisture away from the body and enables the fabric to dry faster.

Note: A drop of water with food coloring applied to fabric back spread immediately.
Sample courtesy Cotton Incorporated
Temperature Regulation

- Temperature regulation technology is designed to provide comfort by regulating the temperature next to the skin, based on environmental conditions.

- Temperature regulation is achieved by:
  - Phase change technology.
  - Use of silver-based finishes such as SmartSilver®.
  - Use of other techniques such as cooling gels (not a finish).

- The thermal comfort provided by the material depends on the temperature range for which the material is effective, as well as the duration of use.
Temperature Regulation

- Phase change technology is based on a cyclical process in which latent heat is absorbed, stored, and released by the encapsulated particles as they change from solid to liquid phase or vice versa to maintain stable body temperature.
  - During hot weather, the material absorbs heat and changes from a solid to a liquid, thus providing a cooling effect.
  - In cold weather, the finish releases heat and changes from liquid to solid, thus warming the body.

- Different methods, including embedding encapsulated particles within fibers or coating the fibers with these particles, are used to produce phase change textile materials.
Infrared Images to Demonstrate Thermal Regulation With Outlast® Material

The above images are from a test conducted by Outlast Europe to illustrate the effectiveness of Outlast® products in regulating temperature. Infrared images were taken of a normal tempered hand prior to the test and of the hand after the glove (with and without Outlast® material) was worn and the hand placed on a block of ice for 5 minutes.

Courtesy Outlast Technologies

The information and images are copyright materials of Outlast Europe.
Phase Change Materials - Micrograph of a fabric with Outlast® finish

 Thermocules™ phase change material

Courtesy Outlast Technologies
Flame Resistance

- Flame retardant treatments are applied to cotton and other fibers to improve flame resistance. Special care may be required for treated fabrics; certain laundry aids may reduce the effectiveness of the finish.

- Additives can be added to manufactured fibers (polyester, viscose rayon) prior to extrusion to make them flame resistant.

- Some high-performance fibers (aramid, PBI) are inherently flame resistant and do not require a finish.

- Flame resistant fabrics (except FR polyester) are used for protective apparel. FR polyester is used for drapes and room dividers in hospitals and other buildings. Inherently flameproof, high-performance fibers (aramid, PBI) are used for specialized end uses.
Flame Resistant Cotton Denim Fabric with a Flame Retardant Finish

Note: Applying a flame retardant finish is one method of producing flame resistant fabric.
INDURA® Ultra Soft® - 80% cotton/20% nylon fabric with a flame retardant finish

Note: High tenacity nylon is added to increase durability by enhancing abrasion resistance.

Sample courtesy Westex™
Amtex™ - Cotton fabric with flame retardant and precured durable press finishes

Note: In addition to the flame retardant finish, this fabric was treated with a precured durable press and a softener.

Sample courtesy Mount Vernon Mills
Antimicrobial

- Microbes (bacteria, viruses, mold, fungi) multiply and increase in numbers when moisture and warm temperatures are conducive to growth. Antimicrobial finishes are chemical compounds that kill or inhibit microbe (microorganism) growth and prevent cross contamination, odor, and degradation.

- Antimicrobial finishes range from non-durable finishes (e.g., bleach) to environmentally friendly dyes to biocides used for reducing risks from biological warfare agents.
  - Silver, used as an antimicrobial finish, has gained popularity because of its low toxicity.
  - Nanoparticles are permanently embedded in fabric, enhancing the durability of the finish.
  - Bleach, a non-durable finish, can be added to the wash cycle.

- Antimicrobial finishes are applied to fabrics and textile products. Chemicals can be added to the solution prior to fiber extrusion.
Antimicrobials

- In the U.S., pesticides (including antimicrobials) are regulated by the U.S. Environmental Protection Agency (EPA).
- Most antimicrobial textiles are exempt from compliance with EPA requirements for pesticides; they are designed to retard or inhibit the growth of microbes in fabric.
  - Agion® Antimicrobial, Microban® antimicrobial products, and Nanocide™ are finishes not regulated by the EPA. These products are not designed to protect consumers from infection and do not claim to in their product marketing.
- Duraban® is an example of an EPA registered antimicrobial product used to protect individuals from microbes.
Evaluation of Antimicrobial Polymer

- Cellulose filters were impregnated with polymer and tested against several Gram positive and Gram negative bacteria such as E. coli, P. stutzeri, M. luteus, B. thuringienis and MRSA at 37°C for 24 h.
- The results for M. luteus are shown in the photo.
- #1 is the blank or control sample.
- The surface of corona, the killing zone around the impregnated filters, was calculated and taken as a measurement for the antimicrobial effect. Similar effects were obtained for the other bacteria.

Courtesy Dr. D.P.W. Alkema, TNO, Netherlands.