THE WOOLMARK COMPANY

WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM

FACILITATOR GUIDE
INTRODUCTION TO WOOL PROCESSING

CONTENTS

THE WOOLMARK COMPANY | AUSTRALIAN WOOL INNOVATION

The Woolmark Company (TWC) is a subsidiary of Australian Wool Innovation (AWI) and is the global authority on Merino wool. With a network that spans the entire global wool supply chain, The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry. More than 60,000 Australian woolgrowers co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

The Woolmark Company supports and connects global supply chain participants through initiatives such as The Wool Lab and Wool Lab Sport. These internationally renowned wool-sourcing tools provide designers, retailers and brands with the latest trends in wool yarns, fabrics and technologies, while promoting Australian Merino wool as the ultimate fibre of choice for apparel.

Marketing activities focus on education and awareness raising to ensure consumers, manufacturers and designers are aware of Australian wool's benefits and qualities, can capitalise on wool's inherent properties, and can successfully integrate wool into their product lines.

THE WOOL SCIENCE, TECHNOLOGY AND DESIGN EDUCATION PROGRAM OVERVIEW

The Wool Science, Technology and Design Education Program combines a series of introductory and advanced courses of study developed to meet the needs of tertiary-level participants studying within the fields of: textile science and engineering, fashion and textile design and/or textile manufacturing. Individual courses within the series may also be of interest to participants studying sheep and wool science, and those working in the wool production, raw wool processing, textile manufacturing and textile sales and marketing industries.

Introductory level courses are suitable for participants studying at first or second-year tertiary levels, while the advanced courses are aimed at participants in their more senior years of study. The extension courses can be used for specific course requirements.

INTRODUCTORY COURSES

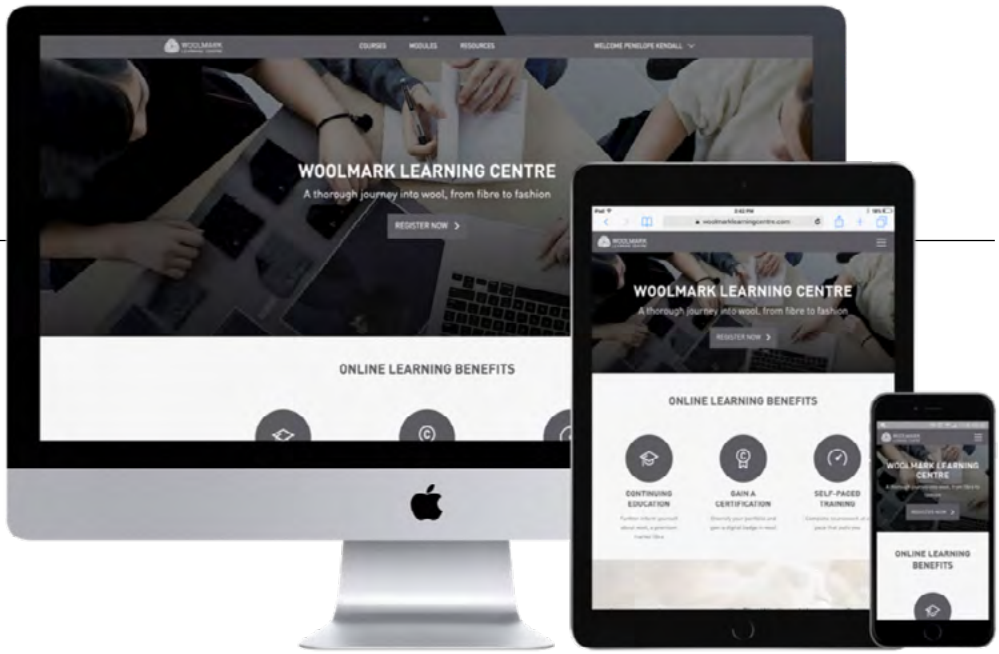
- Wool fibre science
- **Introduction to wool processing**

ADVANCED COURSES

- Raw wool scouring
- Worsted top-making
- Worsted and woollen spinning
- The dyeing of wool
- Wool fabric finishing

EXTENSION COURSES (IN DEVELOPMENT)

- Finishing of wool knitwear
- Wastewater management
- Wool product quality
- Methods of wool fabric formation



THE WOOLMARK LEARNING CENTRE

The *Woolmark Learning Centre* is a freely accessible, online learning platform, which supports The Woolmark Company's commitment to education and awareness raising with regard to wool, wool processing and product innovation.

Make sure you have completed the *Wool Appreciation Course* online before delivering any courses of the *Wool Science, Technology and Design Education Program* to familiarise yourself with The Woolmark Company's approach and core messages about wool production and the wool supply chain.

It is also important to encourage all participants to explore the online *Woolmark Learning Centre* to reinforce and build on the knowledge they have gained by attending this advanced level course.

The W*oolmark Learning Centre* can be accessed at: https://www.woolmarklearningcentre.com/

INTRODUCTION TO THIS FACILITATOR GUIDE

This Facilitator Guide covers the Introduction to wool processing course of the *Wool Science, Technology and Design Education Program*.

The information in this Guide will support you to:

- deliver the technical content across a series of face-to-face lectures in an engaging and easy-to-follow way
- carry out a range of practical demonstrations and interactive discussions to support participant learning.

This Facilitator Guide provides:

- an overview of the *Wool Science, Technology and Design Education Program* courses
- the target audience for the Introduction to wool processing course
- the pre-requisites for the course
- an overview and learning objectives for *Introduction to wool processing*
- a suggested agenda for delivering *Introduction to wool processing*
- an overview and the learning objectives for each module within Introduction to wool processing
- course materials and resources required to deliver *Introduction to wool processing*
- administrative requirements and institutional responsibilities when delivering *Introduction to wool processing*
- guidelines and processes regarding participant recognition upon completing *Introduction to wool processing*
- links to participant and facilitator feedback and evaluation questionnaires
- a facilitator checklist to enable successful planning and preparation leading up to, during and following delivery
- recommended room layout for small venues or groups
- a guideline for the effective and engaging delivery of the course content.

INTRODUCTION TO THIS COURSE

Introduction to wool processing is an introductory-level course that provides participants with a foundational understanding of the wool fibre, what it is and where it comes from, how it is assessed for quality and how it is processed and made into a wide range of products. Some recent innovations in wool products will also be introduced in this course.

Combined with the study of *Wool fibre science*, this course will underpin the more detailed content covered in subsequent courses of the program.

TARGET AUDIENCE

The *Introduction to wool processing course* is primarily aimed at tertiary-level participants studying within the fields of: textile science and engineering, fashion and textile design, textile manufacturing. It may also be of interest to participants studying sheep and wool science, and those working in the wool production, raw wool processing, textile manufacturing and textile sales and marketing industries.

The course is designed to be delivered face to face, in groups of 6 – 50 people, although the ideal number of participants who can attend course lectures depends on the resources available to support the delivery.

COURSE PREREQUISITES

As an introductory course, Introduction to wool processing is suitable for participants with little or no former knowledge of wool or the wool industry.

If this is the first *Wool Science, Technology and Design Education Program* being delivered to these participants, start the initial lecture with an Introduction to The Woolmark Company.

This presentation is included in the *Introduction to wool processing* facilitator slides as an optional introductory module.

COURSE LEARNING OBJECTIVES

By the end of the *Introduction to wool processing* course, participants are expected to be able to:

- explain briefly how wool is manufactured from a greasy raw fibre into worsted and woollen yarn
- identify the different ways yarn can be woven or knitted and how this affects the end product
- briefly describe the processes used to dye and finish wool and the environmentally-responsible options associated with each process
- explain the garment faults that can occur during processing and how to best prevent them
- recognise the quality assurance behind the Woolmark brand
- identify different Merino innovations and how these can be used to enhance products made from wool.

COURSE AGENDA

Introduction to wool processing consists of six lectures of approximately one hour each, supported by a set of PowerPoint slides and recommended demonstrations, as outlined in the table below.

NOTE: Indicated slide numbers for Module 1 take account of the introductory Woolmark Company slides as outlined in the following facilitator notes.

MODULE | SLIDE NUMBER	VIDEOS AND PRACTICAL DEMONSTRATIONS
Module 1: From farm to factory | 29 slides	Slide 10: This is wool (video) Slide 13: Australian wool property (video) Slide 15: Raw wool (handout) Slide 16: Wool products (handout) Slide 17: Shearing (video) Slide 18: Fleece components (handout) Slide 19: Wool bale material (handout) Slide 26: From farm to processor (video)
Module 2: Raw wool measurement | 42 slides	Slide 4: Staple length, strength, crimp and diameter (demonstration) Slide 5: Core sampling (demonstration and video) Slide 12: Vegetable matter analysis (video) Slide 18: Fabric comparison (handout) Slide 19: Crimp comparison (handout) Slide 28: High and low frequency crimp (handout) Slide 32: Grab sampling (video) Slide 34: Sub-sampling (video) Slide 35: Testing staple strength (video)

MODULE | SLIDE NUMBER	VIDEOS AND PRACTICAL DEMONSTRATIONS
Module 3: Manufacturing wool yarns | 35 slides	Slide 3: Wool processing (video) Slide 4: Worsted and woollen yarns (handout) Slide 8: Greasy (raw) and scoured wool (handout) Slide 8: Wool wax (handout) Slide 8: Raw wool scouring (video) Slide 12: Worsted carding (video and handout) Slide 13: Gilling (video and handout) Slide 14: Combing (video and handout Slide 15: Roving (video and handout) Slide 16: Twist insertion (demonstration) Slide 16: Spinning (video) Slide 16: Impact of friction during spinning (demonstration) Slide 17: Z twist vs S twist (demonstration) Slide 17: Snarl (demonstration) Slide 19: Carbonisation (handout) Slide 20: Woollen carding (video) Slide 21: False twist (demonstration) Slide 22: Woollen spinning (video) Slide 22: Woollen vs worsted yarn (handout) Slide 24: Winding and clearing (video) Slide 25: Twisting (demonstration) Slide 28: Fabric blends (handout) Slide 32: Low-twist vs high-twist fabric (handout)
Module 4: Manufacturing wool products | 35 slides	Slide 4: Worsted vs woollen fabric (handout) Slide 9: Knitting (video) Slide 13: Wool fabric comparison (handout) Slide 14: Weaving (rapier looms) (video) Slide 20: Wool dyed at various stages of processing (handout) Slide 23: Finished and unfinished woven fabric (handout) Slide 25: Wool processing (video) Slide 23: Finished and unfinished woven garment (handout) Slide 25: From farm to fashion (video) Slide 26: Finished garments (handout)
Module 5: The quality of wool products | 24 slides	Slide 5: Fabric handle (handout) Slide 8: Pilling (handout) Slide 19: Woolmark testing standards (video)
Module 6: Innovations in wool products | 36 slides	Slide 2: The innovator (video)

MODULE OVERVIEW AND LEARNING OBJECTIVES

Module 1 — Farm to factory starts off this six-module course by reviewing where wool comes from and how it is harvested, the impact of sheep breed on wool type and its key quality characteristics and their implication on end-product applications. Participants will also be provided with a brief overview of the farm to factory pipeline, including wool valuing and the wool auction system.

By the end of this module participants are expected to be able to:

- describe where wool comes from and how it is harvested
- outline the key categories of wool
- list the characteristics of wool that determine its value
- describe how wool is sold
- outline the stages involved in bringing wool from farm to factory.

Module 2 — Raw wool measurement introduces participants to the methods used to objectively measure the properties of raw wool. These measurements determine, in large part, the value of the wool and reflect the price paid for wool at auction.

By the end of this module participants are expected to be able to:

- the source of regulations surrounding the sampling and testing of raw wool
- the methods used to sample raw wool:
  - core sampling
  - grab sampling
- the methods used to measure the key properties of raw wool:
  - yield
  - fibre diameter distribution
  - fibre crimp
  - colour
  - residual pesticides
  - staple length and strength
- the source of calibration standards for test instruments.

Module 3 — Manufacturing wool yarns provides a brief overview of the yarn manufacturing process. The individual processes are covered in detail in subsequent courses of the Woolmark Wool Education Course.

At the end of this module participants are expected to be able to describe briefly:

- each of the major operations in the production of worsted yarns
- each of the major operations in the production of woollen yarns
- the difference in the properties of woollen and worsted yarn
- the quality attributes of yarn
- the criteria used to select yarn.

Module 4 — Manufacturing wool products explores the processes used to manufacture wool products (fabric and garments) from worsted and woollen yarns). The individual processes are covered in detail in subsequent courses of the Woolmark Wool Education Course.

At the end of this course participants are expected to be able to:

- describe three methods of wool fabric manufacture (worsted, woollen and non-woven)
- indicate the type of products manufactured using each method
- outline the mechanism of knitting in knitting machines
- describe five types of knitting machine
- indicate the key stitches used to pattern knitted fabric and give two examples
- describe the action of a weaving machine
- nominate four methods of weft transport and the suitability of each for wool
- outline how patterns are woven into fabric
- describe four methods used to manufacture non-woven fabrics.

Module 5 — The quality of wool products familiarises participants with some of the characteristics of wool products associated with its quality, how these characteristics are assessed in quality assurance (QA) programs and how faults in wool fabrics and garments can be avoided. Quality control issues and systems associated with individual wool processing and production stages are covered in detail within subsequent courses of the Woolmark Wool Education Course.

At the end of this module, participants are expected to be able to:

- describe the key features of knitted and woven products that determine quality
- outline the approach adopted by The Woolmark Company to test and ensure quality in branded products.

Module 6 — Innovations in wool products is the final module in the course. The versatility of wool lies at the core of a range of cutting-edge product innovations. Product developers continue to explore the potential of this adaptable natural fibre.

The Woolmark Company and its partners are continually pushing the boundaries to develop new, innovative wool products to meet consumers' needs.

This module will describe some of the recent innovations in wool products, which capitalise on the fibre's inherent properties and new processing technology.

At the end of this module participants are expected to be able to:

- list the inherent features of wool that support product innovation
- describe some of the innovations being used to create new wool products
- outline some of the methods used to create the wool innovations covered in this module.

COURSE MATERIALS AND RESOURCES

To deliver the *Introduction to wool processing* series of lectures, you will need the following materials:

Provided in each course Facilitator Pack

- Facilitator Guide (PDF provided via DropBox link)
- Facilitator slides (PowerPoint files for each module provided via DropBox link)
- participant sign-on sheet (Word template provided via DropBox link)
- Participant Guide (PDF provided via DropBox link)
- Demonstration kit (see details below)
- Certificates of Participation (supplied by the regional Woolmark Company office on confirmation of student numbers).

To be sourced by facilitators

- speakers (for listening to the videos)
- laptop, data projector and overhead screen
- participant name tags (e.g. sticky labels or equivalent and a black marker to write participant names)
- flipchart and paper or access to a whiteboard
- markers for the flipchart or whiteboard where available

NOTE: The WST&DEP materials are designed to be delivered on a Microsoft 365 platform, on a 64bit hard drive. Please contact the regional Woolmark office if you do not have access to adequate technology.

INTRODUCTION TO WOOL PROCESSING DEMONSTRATION KIT

A range of practical demonstrations, group activities, handouts and samples is recommended to be used throughout this course to support participant learning and complement the content delivered in the lectures.

Recommended resources for each module are listed at the start of each module in *Introduction to wool processing* Facilitator Guide.

The following samples and resources for demonstrations are provided in the *Introduction to wool processing* Demonstration kit (resources not supplied in the kit will need to be supplied by the facilitator):

Module 1:
- fine wool sample
- broad wool sample
- samples of fleece components (fleece, belly wool, crutchings, pieces and locks)
- nylon wool bale material

Module 2:
- Greasy wool sample
- Next-to-skin wool fabric (low micron)
- Heavyweight wool fabric (high micron)
- High-frequency crimp greasy wool
- Low-frequency crimp greasy wool

Module 3:
- Worsted yarn
- Woollen yarn
- Greasy wool sample
- Scoured wool sample
- Scoured and carbonised wool sample
- Unrefined wool wax
- Refined wool wax
- Carded sliver
- Gilled sliver
- Combed sliver (wool top)
- Worsted roving
- Wool/polyester blend fabric
- Wool/cotton blend fabric
- Knitted fabric (high-twist yarn)
- Knitted fabric (low-twist yarn)

Module 4 :
- Worsted-spun fabric sample
- Woollen-spun fabric sample
- Samples of wool dyed as:
  - loose wool
  - yarn
  - fabric
- Finished wool fabric sample
- Unfinished wool fabric sample

Module 5:
- Nil supplied

Module 6:
- TWC innovations pack

ADMINISTRATIVE DETAILS

ORGANISATIONAL RESPONSIBILITIES

Institutions delivering the Wool Science, Technology and Design Education Program *Introduction to wool processing* will be responsible for:

- ensuring all facilitators have completed the online Wool Appreciation Course prior to delivering their first course
- providing the venue and equipment required to support the program (i.e. lecture theatre, data projector, data screen, flip chart, whiteboard and markers)
- enrolling the participants in the course
- administrative paperwork (i.e. participant sign-in sheets, name tags etc.)
- providing administrative support for communication between the facilitator and the participants
- ensuring both the participants and the facilitator have the required access to external sites required to support participant learning
- providing supporting services, as required (e.g. interpreter, transport to or from external sites)
- providing The Woolmark Company with participants numbers, and participants and facilitator feedback and course evaluation post delivery.

The Woolmark Company will be responsible for providing:

- Facilitator Guide (PDF provided via DropBox link)
- Facilitator slides (PowerPoint files for each module provided via DropBox link)
- Participant sign-on sheet (Word template provided via DropBox link)
- Participant Guide (PDF provided via DropBox link)
- Demonstration kit
- Certificates of Participation (printed copies will be provided by the local TWC office upon request).

NOTE: Course materials are provided in English. If translation to the local language is required, this is the responsibility of the delivering institution.

PARTICIPANT RECOGNITION

At the conclusion of the seven *Introduction to wool processing* lectures, each participant who has attended all lectures is eligible to receive a Woolmark Company-endorsed Certificate of Participation.

PROGRAM EVALUATION

Feedback from those attending the *Introduction to wool processing* course must be collected by way of an online survey link. This feedback will be used to adapt the course on an annual basis, if and where necessary, to ensure it achieves the desired objectives in the most effective way.

Feedback from those delivering the *Introduction to wool processing* course also must be submitted at the completion of the course.

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

FACILITATOR CHECKLIST

The following list outlines the actions required before, during and after delivery the I*ntroduction to wool processing* course.

One month before:

- ☐ Fully familiarise yourself with the course materials.
- ☐ Check you have all the materials required to deliver the course (including the facilitator materials and the demonstration kit).
- ☐ If you are an external facilitator, obtain contact details for your key point of contact at the host institution. Make contact, introduce yourself and arrange regular meetings leading up to the delivery dates.
- ☐ Confirm the number of participants attending, along with the year level and any previous studies relevant to the course.
- ☐ Confirm any specific needs for the target audience in consultation with the institution.
- ☐ Familiarise yourself with the venue and facilities that will be available for the lectures including room size and potential room layout options (see following notes regarding room layout). This may be via site maps or discussions with your key contact.
- ☐ Confirm equipment available at the venue (e.g. data projector, screen, speakers, laboratory equipment).
- ☐ Adapt the program (if required) to meet the needs of the participants and venue facilities.
- ☐ Check the availability of participant materials in sufficient quantity.
- ☐ Ensure you have reviewed the delivery material and have checked any videos for the upcoming lectures work on the available equipment.

One week before:

- ☐ Confirm shipping details of the course materials and equipment (if required)
- ☐ Confirm transport between the institution and any external site visits. (if required).
- ☐ Confirm names of the participants attending the course.
- ☐ Ensure you have ordered a sufficient number of the 'Certificate of Participation' to be distributed to the appropriate participants following the completion of the final lecture.
- ☐ Ensure your wardrobe contains various wool garments. In order to demonstrate the benefits and versatility of wool and wool products, facilitators are encouraged to wear as much wool as possible, across a range of garment types. For example:
  - wool trousers or skirt
  - wool t-shirt or undershirt, long-sleeved shirt, sweater or jacket
  - wool socks.

One day before:

- ☐ Arrange to meet your key institution contacts face to face and any key contacts at external sites (if required).
- ☐ Familiarise yourself with the venue's emergency procedures.
- ☐ Tour the facility. Visit the rooms you will be using.
- ☐ Check the equipment you need is available in working order and you know how to use it (including lighting, heating and cooling).
- ☐ Ensure you have reviewed the delivery material and have checked any videos for the upcoming lectures will work on the available equipment (e.g. speakers).
- ☐ Familiarise yourself with the rest rooms available at the venue.
- ☐ Take note of any challenges associated with each room (e.g. noise, heat, lighting). Identify strategies to minimise these challenges.
- ☐ Prepare the student materials you will need to distribute at the first lecture (e.g. participant name tags and sign-in sheets).
- ☐ Check you have all the materials you need to deliver the course (including the Participant Guides).
- ☐ Distribute the PDF (soft copy) of the Participant Guide to participants prior to the first lecture if possible, to allow them to become familiar with the course materials and content.

Prior to each lecture:

- ☐ Ensure you are wearing a variety of wool garments that reflect the benefits and versatility of wool and wool products.
- ☐ Arrive 30 minutes before each lecture to check the equipment is available and working.

At commencement of the first lecture:

- ☐ Distribute the hard copy of the Participant Guide to each participant.
- ☐ Distribute name tags to each participant.
- ☐ Record those who are present.

After each lecture:

- ☐ Stay to answer any questions the participants may have about the course content.

Prior to the final lecture:

- ☐ Ensure you have received a sufficient number of the 'Certificates of Participation' to be distributed to the appropriate students following the completion of the final lecture.

At the completion of the course:

- ☐ Provide participants with the online feedback and evaluation survey link.
- ☐ Complete and submit your own online evaluation survey.
- ☐ Provide feedback to the institution regarding the successful completion of the course.
- ☐ Explore future delivery opportunities and liaise with The Woolmark Company regional office.

Post-course survey links:

Facilitator survey:
www.woolmarklearningcentre.com/wstd-surveyfacilitator

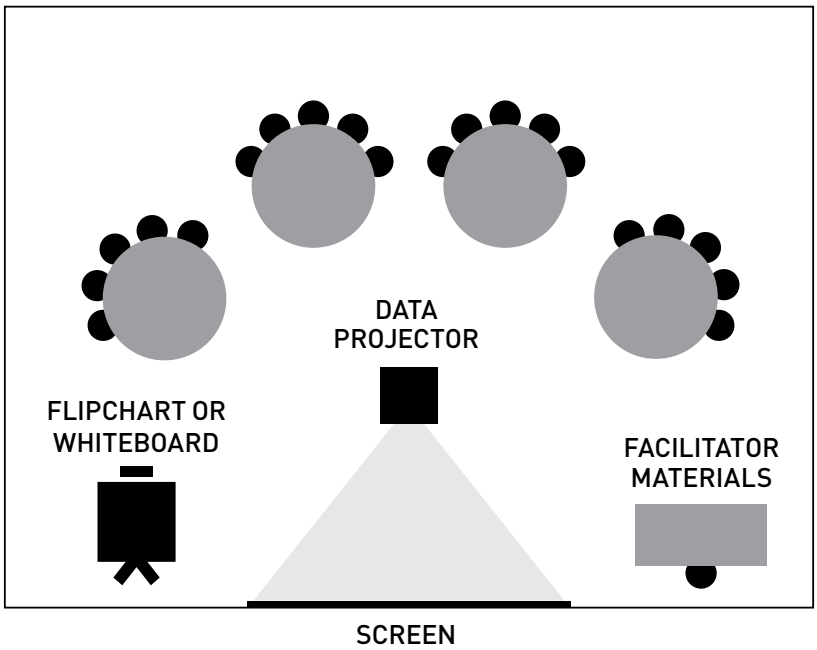
Participant survey:
www.woolmarklearningcentre.com/wstd-surveyparticipant

ROOM LAYOUT

The *Introduction to wool processing* course is designed to be delivered face-to-face, in groups of 6 – 50 people. In many cases this will mean delivery occurs in a large lecture theatre and there will not be an opportunity to influence the physical learning environment.

In smaller groups and settings where the learning environment can be influenced:

- arrange tables in a cabaret style (see diagram below) facing a flipchart or whiteboard and a data projector/screen
- allow for small group discussion in groups of three or four.



A GUIDELINE FOR THE EFFECTIVE AND ENGAGING DELIVERY OF THE COURSE CONTENT.

The course materials are designed to achieve a Gunning Fog Index of 8–10, with the exclusion of technical terms specific to the course.

The Gunning Fog Index formula implies short sentences written in plain English achieve a better score than long sentences written in complicated language.

Materials with a Gunning Fog Index of 8 have a readability equivalent to a Grade 8 reading level for English speaking students. It is considered the ideal score for readability. Anything above 12 is too hard for most people to read[1].

Information is provided in Appendix A for facilitators who wish to enhance their skills in facilitation by acknowledging the different learning styles of participants.

Research has shown each person has a preferred way of learning[2]. As adults, we tend to adopt the learning style with which we are most comfortable and ignore learning styles with which we are unfamiliar or uncomfortable. This means learning is most effective when a student can process information and solve problems in a way that is meets their preferred learning style.

When you know a person's learning style, you can present information to them so they can grasp it quickly and easily. If information is presented in a way that is at odds with their preferred learning style, the student will find it more difficult to learn. Sometimes this means, as a facilitator, you may have to present information to a student in a way that will engage them, although that may not be your preferred method. If you do not accommodate the student's preferred learning style, you make it harder to get the message across, which may lead to frustration on your part, as well as a lack of commitment from the student.

Honey & Mumford have developed a questionnaire, included in Appendix A, which helps you identify your students' preferred learning styles.

1 http://www.usingenglish.com/glossary/fog-index.html, http://juicystudio.com/services/readability.php
2 Kolb D. A. (1984). Experiential Learning experience as a source of learning and development, New Jersey: Prentice Hall.

APPENDIX A: LEARNING STYLES QUESTIONNAIRE

NAME: _____

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning "habits" that help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning preferences so that you are in a better position to select learning experiences that suit your style and having a greater understanding of those that suit the style of others.

This is an internationally proven tool designed by Peter Honey and Alan Mumford.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers.

If you agree more than you disagree with a statement put a tick by it.

If you disagree more than you agree put a cross by it.

Be sure to mark each item with either a tick or cross.

□ 1. I have strong beliefs about what is right and wrong, good and bad

□ 2. I often act without considering the possible consequences

□ 3. I tend to solve problems using a step-by-step approach

□ 4. I believe that formal procedures and policies restrict people

□ 5. I have a reputation for saying what I think, simply and directly

□ 6. I often find that actions based on feelings are as sound as those based on careful thought and analysis

□ 7. I like the sort of work where I have time for thorough preparation and implementation

□ 8. I regularly question people about their basic assumptions

□ 9. What matters most is whether something works in practice

□ 10. I actively seek out new experiences

□ 11. When I hear about a new idea or approach I immediately start working out how to apply it in practice

□ 12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc

□ 13. I take pride in doing a thorough job

□ 14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people

□ 15. I take care over the interpretation of data available to me and avoid jumping to conclusions

□ 16. I like to reach a decision carefully after weighing up many alternatives

□ 17. I'm attracted more to novel, unusual ideas than to practical ones

□ 18. I don't like disorganised things and prefer to fit things into a coherent pattern

□ 19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done

□ 20. I like to relate my actions to a general principle

□ 21. In discussions I like to get straight to the point

□ 22. I tend to have distant, rather formal relationships with people at work

□ 23. I thrive on the challenge of tackling something new and different

□ 24. I enjoy fun-loving, spontaneous people

□ 25. I pay meticulous attention to detail before coming to a conclusion

□ 26. I find it difficult to produce ideas on impulse

□ 27. I believe in coming to the point immediately

□ 28. I am careful not to jump to conclusions too quickly

□ 29. I prefer to have as many resources of information as possible – the more data to think over the better

□ 30. Flippant people who don't take things seriously enough usually irritate me

□ 31. I listen to other people's points of view before putting my own forward

□ 32. I tend to be open about how I'm feeling

□ 33. In discussions I enjoy watching the manoeuvrings of the other participants

□ 34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance

- ☐ 35. I tend to be attracted to techniques such as network analysis, flow charts, branching programs, contingency planning, etc
- ☐ 36. It worries me if I have to rush out a piece of work to meet a tight deadline
- ☐ 37. I tend to judge people's ideas on their practical merits
- ☐ 38. Quiet, thoughtful people tend to make me feel uneasy
- ☐ 39. I often get irritated by people who want to rush things
- ☐ 40. It is more important to enjoy the present moment than to think about the past or future
- ☐ 41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition
- ☐ 42. I tend to be a perfectionist
- ☐ 43. In discussions I usually produce lots of spontaneous ideas
- ☐ 44. In meetings I put forward practical realistic ideas
- ☐ 45. More often than not, rules are there to be broken
- ☐ 46. I prefer to stand back from a situation
- ☐ 47. I can often see inconsistencies and weaknesses in other people's arguments
- ☐ 48. On balance I talk more than I listen
- ☐ 49. I can often see better, more practical ways to get things done
- ☐ 50. I think written reports should be short and to the point
- ☐ 51. I believe that rational, logical thinking should win the day
- ☐ 52. I tend to discuss specific things with people rather than engaging in social discussion
- ☐ 53. I like people who approach things realistically rather than theoretically
- ☐ 54. In discussions I get impatient with irrelevancies and digressions
- ☐ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version
- ☐ 56. I am keen to try things out to see if they work in practice
- ☐ 57. I am keen to reach answers via a logical approach
- ☐ 58. I enjoy being the one that talks a lot
- ☐ 59. In discussions I often find I am the realist, keeping people to the point and avoiding wild speculations
- ☐ 60. I like to ponder many alternatives before making up my mind
- ☐ 61. In discussions with people I often find I am the most dispassionate and objective
- ☐ 62. In discussions I'm more likely to adopt a "low profile" than to take the lead and do most of the talking
- ☐ 63. I like to be able to relate current actions to a longer term bigger picture
- ☐ 64. When things go wrong I am happy to shrug it off and "put it down to experience"
- ☐ 65. I tend to reject wild, spontaneous ideas as being impractical
- ☐ 66. It's best to think carefully before taking action
- ☐ 67. On balance I do the listening rather than the talking
- ☐ 68. I tend to be tough on people who find it difficult to adopt a logical approach
- ☐ 69. Most times I believe the end justifies the means
- ☐ 70. I don't mind hurting people's feelings so long as the job gets done
- ☐ 71. I find the formality of having specific objectives and plans stifling
- ☐ 72. I'm usually one of the people who puts life into a party
- ☐ 73. I do whatever is expedient to get the job done
- ☐ 74. I quickly get bored with methodical, detailed work
- ☐ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events
- ☐ 76. I'm always interested to find out what people think
- ☐ 77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.
- ☐ 78. I steer clear of subjective or ambiguous topics
- ☐ 79. I enjoy the drama and excitement of a crisis situation
- ☐ 80. People often find me insensitive to their feelings

SCORING AND INTERPRETING THE LEARNING STYLES QUESTIONNAIRE

The Questionnaire is scored by awarding one point for each ticked item. There are no points for crossed items. Simply indicate on the lists below which items were ticked by circling the appropriate question number.

2	7	1	5
4	13	3	9
6	15	8	11
10	16	12	19
17	25	14	21
23	28	18	27
24	29	20	35
32	31	22	37
34	33	26	44
38	36	30	49
40	39	42	50
43	41	47	53
45	46	51	54
48	52	57	56
58	55	61	59
64	60	63	65
71	62	68	69
72	66	75	70
74	67	77	73
79	76	78	80
TOTALS	_____	_____	_____	_____
	Activist	**Reflector**	**Theorist**	**Pragmatist**

LEARNING STYLES QUESTIONNAIRE PROFILE BASED ON GENERAL NORMS FOR 1302 PEOPLE

ACTIVIST	REFLECTOR	THEORIST	PRAGMATIST	
20	20	20	20	Very strong preference
19				
18		19	19	
17				
16		18		
15		17	18	
14				
13	18	16	17	
12	17	15	16	Strong preference
	16			
11	15	14	15	
10	14	13	14	Moderate
9	13	12	13	
8				
7	12	11	12	
6	11	10	11	Low preference
5	10	9	10	
4	9	8	9	
3	8	7	8	Very low preference
	7	6	7	
	6	5	6	
2	5	4	4	
	4	3	3	
	3			
1	2	2	2	
	1	1	1	
0	0	0	0	

LEARNING STYLES – GENERAL DESCRIPTIONS

Activists

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-minded, not sceptical, and this tends to make them enthusiastic about anything new. Their philosophy is: "I'll try anything once". They tend to act first and consider the consequences afterwards. Their days are filled with activity. They tackle problems by brainstorming. As soon as the excitement from one activity has died down they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer-term consolidation. They are gregarious people constantly involving themselves with others but in doing so they seek to centre all activities on themselves.

Reflectors

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, both first hand and from others, and prefer to think about it thoroughly before coming to any conclusion. The thorough collection and analysis of data about experiences and events is what counts so they tend to postpone reaching definitive conclusions for as long as possible. Their philosophy is to be cautious. They are thoughtful people who like to consider all possible angles and implications before making a move. They prefer to take a back seat in meetings and discussions. They enjoy observing other people in action. They listen to others and get the drift of the discussion before making their own points. They tend to adopt a low profile and have a slightly distant, tolerant unruffled air about them. When they act it is part of a wide picture which includes the past as well as the present and others' observations as well as their own.

Theorists

Theorists adapt and integrate observations into complex but logically sound theories. They think problems through in a vertical, step-by-step logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into a rational scheme. They like to analyse and synthesise. They are keen on basic assumptions, principles, theories models and systems thinking. Their philosophy prizes rationality and logic. "If it's logical it's good". Questions they frequently ask are: "Does it make sense?" "How does this fit with that?" "What are the basic assumptions?" They tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous. Their approach to problems is consistently logical. This is their "mental set" and they rigidly reject anything that doesn't fit with it. They prefer to maximise certainty and feel uncomfortable with subjective judgments, lateral thinking and anything flippant.

Pragmatists

Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sorts of people who return from management courses brimming with new ideas that they want to try out in practice. They like to get on with things and act quickly and confidently on ideas that attract them. They tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down to earth people who like making practical decisions and solving problems. They respond to problems and opportunities "as a challenge". Their philosophy is: "There is always a better way" and "if it works it's good".

In descending order of likelihood, the most common combinations are:

1st	Reflector/Theorist
2nd	Theorist/Pragmatist
3rd	Reflector/Pragmatist
4th	Activist/Pragmatist

LEARNING STYLES – A FURTHER PERSPECTIVE

ACTIVISTS:

Activists *learn best from activities where:*

- There are new experiences/problems/opportunities from which to learn.
- They can engross themselves in short "here and now" activities such as business games, competitive teamwork tasks, role-playing exercises.
- There is excitement/drama/crisis and things chop and change with a range of diverse activities to tackle
- They have a lot of the limelight/high visibility, i.e. they can "chair" meetings, lead discussions, and give presentations.
- They are allowed to generate ideas without constraints of policy or structure or feasibility.
- They are thrown in at the deep end with a task they think is difficult, i.e. when set a challenge with inadequate resources and adverse conditions.
- They are involved with other people, i.e. bouncing ideas off them, solving problems as part of a team.
- It is appropriate to "have a go".

Activists *learn least from, and may react against, activities where:*

- Learning involves a passive role, i.e. listening to lectures, monologues, explanations, statements of how things should be done, reading, watching.
- They are asked to stand back and not be involved.
- They are required to assimilate, analyse and interpret lots of "messy" data.
- They are required to engage in solitary work, i.e. reading, writing, thinking on their own.
- They are asked to assess beforehand what they will learn, and to appraise afterwards what they have learned.
- They are offered statements they see as "theoretical", i.e. explanation of cause or background
- They are asked to repeat essentially the same activity over and over again, i.e. when practicing.
- They have precise instructions to follow with little room for manoeuvre.
- They are asked to do a thorough job, i.e. attend to detail, tie up loose ends, dot the i's, cross t's.

Summary of strengths

- Flexible and open minded.
- Happy to have a go.
- Happy to be exposed to new situations.
- Optimistic about anything new and therefore unlikely to resist change.

Summary of weaknesses:

- Tendency to take the immediately obvious action without thinking.
- Often take unnecessary risks.
- Tendency to do too much themselves and hog the limelight.
- Rush into action without sufficient preparation.
- Get bored with implementation/consolidation.
- Key questions for activists:
- Shall I learn something new, i.e. that I didn't know/ couldn't do before?
- Will there be a wide variety of different activities? (I don't want to sit and listen for more than an hour at a stretch!)
- Will it be OK to have a go/let my hair down/make mistakes/have fun?
- Shall I encounter some tough problems and challenges?
- Will there be other like-minded people to mix with?

REFLECTORS:

Reflectors *learn best from activities where:*

- They are allowed or encouraged to watch/think/chew over activities.
- They are able to stand back from events and listen/ observe, i.e. observing a group at work, taking a back seat in a meeting, watching a film or video.
- They are allowed to think before acting, to assimilate before commencing, i.e. time to prepare, a chance to read in advance a brief giving background data.
- They can carry out some painstaking research, i.e. investigate, assemble information, and probe to get to the bottom of things.
- They have the opportunity to review what has happened, what they have learned.
- They are asked to produce carefully considered analyses and reports.

- They are helped to exchange views with other people without danger, i.e. by prior agreement, within a structured learning experience.
- They can reach a decision in their own time without pressure and tight deadlines.

Reflectors *learn least from, and may react against, activities where:*

- They are "forced" into the limelight, i.e. to act as leader/chairman, to role-play in front of on-lookers.
- They are involved in situations which require action without planning.
- They are pitched into doing something without warning, i.e. to produce an instant reaction, to produce an off-the-top-of-the-head idea.
- They are given insufficient data on which to base a conclusion.
- They are given cut and dried instructions of how things should be done.
- They are worried by time pressures or rushed from one activity to another.
- In the interests of expediency they have to make short cuts or do a superficial job.

Summary of strengths:

- Careful.
- Thorough and methodical
- Thoughtful
- Good at listening to others and assimilating information.
- Rarely jump to conclusions.

Summary of weaknesses:

- Tendency to hold back from direct participation.
- Slow to make up their minds and reach a decision.
- Tendency to be too cautious and not take enough risks.
- Not assertive - they aren't particularly forthcoming and have no "small talk".

Key questions for reflectors:

- Shall I be given adequate time to consider, assimilate and prepare?
- Will there be opportunities/facilities to assemble relevant information?
- Will there be opportunities to listen to other people's points of view – preferably a wide cross section of people with a variety of views?
- Shall I be under pressure to be slapdash or to extemporise?

THEORISTS:

Theorists *learn best from activities where:*

- What is being offered is part of a system, model, concept, or theory.
- The have time to explore methodically the associations and inter-relationships between ideas, events and situations.
- They have the chance to question and probe the basic methodology, assumptions or logic behind something, i.e. by taking part in a question and answer session, by checking a paper for inconsistencies.
- They are intellectually stretched, i.e. by analysing a complex situation, being tested in a tutorial session, by teaching high calibre people who ask searching questions.
- They are in structured situations with a clear purpose.
- They can listen to or read about ideas and concepts that emphasise rationality or logic and are well argued/elegant/watertight.
- They can analyse and then generalise the reasons for success or failure.
- They are offered interesting ideas and concepts even though they are not immediately relevant.
- They are required to understand and participate in complex situations.

Theorists *learn least from, and may react against, activities where:*

- They are pitch-forked into doing something without a context or apparent purpose.
- They have to participate in situations emphasising emotions and feelings.
- They are involved in unstructured activities where ambiguity and uncertainty are high, i.e. with open¬ended problems, on sensitivity training.
- They are asked to act or decide without a basis in policy, principle or concept.
- They are faced with a hotchpotch of alternative/ contradictory techniques/methods without exploring any in depth, i.e. as on a "once over lightly" course.
- They find the subject matter platitudinous, shallow or gimmicky.
- They feel themselves out of tune with other participants, i.e. when with lots of Activists or people of lower intellectual calibre.

Summary of strengths:

- Logical "vertical" thinkers.
- Rational and objective.
- Good at asking probing questions.
- Disciplined approach.

Summary of weaknesses:

- Restricted in lateral thinking.
- low tolerance for uncertainty, disorder and ambiguity
- Intolerant of anything subjective or intuitive.
- Full of "shoulds, oughts and musts".

Key questions for theorists:

- Will there be lots of opportunities to question?
- Do the objectives and program of events indicate a clear structure and purpose?
- Shall I encounter complex ideas and concepts that are likely to stretch me?
- Are the approaches to be used and concepts to be explored "respectable", i.e. sound and valid?
- Shall I be with people of similar calibre to myself?

PRAGMATIST:

Pragmatists *learn best from activities where:*

- There is an obvious link between the subject matter and a problem or opportunity on the job.
- They are shown techniques for doing things with obvious practical advantages, i.e. how to save time, how to make a good first impression, how to deal with awkward people.
- They have the chance to try out and practice techniques with coaching/feedback from a credible expert, i.e. someone who is successful and can do the techniques themselves.
- They are exposed to a model they can emulate, i.e. a respected boss, a demonstration from someone with a proven track record, lots of examples/anecdotes, and a film showing how it's done.
- They are given techniques currently applicable to their own job.
- They are given immediate opportunities to implement what they have learned.
- There is a high face validity in the learning activity, i.e. a good simulation, "real" problems.
- They can concentrate on practical issues, i.e. drawing up action plans with an obvious end product, suggesting short cuts, giving tips.

Pragmatists *learn least from, and may react against, activities where:*

- The learning is not related to an immediate need they recognise/they cannot see, an immediate relevance/ practical benefit.
- Organisers of the learning, or the event itself, seems distant from reality, i.e. "ivory towered", all theory and general principles, pure "chalk and talk".
- There is no practice or clear guidelines on how to do it.
- They feel that people are going round in circles and not getting anywhere fast enough.
- There are political, managerial or personal obstacles to implementation.
- There is no apparent reward from the learning activity, i.e. more sales, shorter meetings, higher bonus, promotion.

Summary of strengths:

- Keen to test things out in practice.
- Practical, down to earth, realistic.
- Businesslike – gets straight to the point.
- Technique oriented.

Summary of weaknesses:

- Tendency to reject anything without an obvious application.
- Not very interested in theory or basic principles.
- Tendency to seize on the first expedient solution to a problem.
- Impatient with waffle.
- On balance, task oriented not people oriented.

Key questions for pragmatists:

- Will there be ample opportunities to practice and experiment?
- Will there be lots of practical tips and techniques?
- Shall we be addressing real problems and will it result in action plans to tackle some of my current problems?
- Shall we be exposed to experts who know how to/can do it themselves?

GLOSSARY

ACRONYMS, ABBREVIATIONS AND UNITS OF MEASUREMENT

ASTM	American Society for Testing and Materials
ATLAS	Automatic Tester of Length and Strength
AWEX	Australian Wool Exchange
AWTA	Australian Wool Testing Authority
CEN	European Standardisation Organisation
CIE	International Commission on Illumination
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CVD	co-efficient of variation of fibre diameter
GB	Chinese national standards issued by the Standardisation Administration of China
IGR	insect growth regulators
ISO	International Organisation for Standardisation
IWTO	International Wool Textile Organisation
MFD	mean fibre diameter
N/dtex	Newtons per decitex
NATA	National Association of Testing Authorities (Australia)
Ne	Cotton count for cotton yarn(indirect), hanks of 840 yds/lb
NIR	near infra-red
Nm	Metric count for yarn (indirect), hanks of 1000m/kg
Nw	Worsted count for yarn (indirect), hanks of 560 yds/lb
NZWTA	New Zealand Wool Testing Authority
OBAs	optical brightening agents
OC	organochlorines
OFDA	Optical Fibre Diameter Analyser

OP	organophosphates
POB	position of break
QA	quality assurance
SP	synthetic pyrethroids
Tex	Yarn count measure (direct), g/1000m
VM	vegetable matter
WTAE	Wool Testing Authority Europe
WTBSA	Wool Testing Bureau South Africa
micron	A millionth of a metre, micrometre (µm)

GLOSSARY

Term	Definition
3-D Merino	An innovation for wool knitwear created by limiting milling or felting to specific areas of a fabric or garment to produce a three- dimensional pattern. The felted and non-felted areas vary in thickness giving a three-dimensional appearance; uses a similar process to Merino Devoré.
air-jet loom	A high-speed weaving machine in which the weft yarn is carried across the warp by use of a jet of compressed air rather than using a rapier or projectile; has limited use in weaving wool fabric.
boiled wool	A term used to describe knitwear that has been pre-shrunk using a wet process and very hot water.
carbonising	The process used to remove vegetable matter from scoured wool using sulphuric acid; normally in woollen processing.
carding	The process where locks and clumps of wool are untangled, vegetable matter removed, fibres are individualised and partially aligned and then formed into a sliver.
circular economy	A production model that aims at recovering resources from end-of-life products and encouraging consumers to think twice before throwing away their used clothing and instead donating it for reuse or recycling.
circular knitting machine	A knitting machine in which the needles are arranged in a circular bed. Instead of one yarn guide there are multiple guides, up to 200 on large machines, simultaneously feeding yarn as the needle bed rotates.
clearing	The checking of newly spun yarn for faults as it is wound onto cones.
closed -oop system	A recycling process approach in which garments are 'pulled' back into raw fibre state and re-used as a raw material to make yarn again.
coarse edge	The amount of fibre at the broad end (normally > 30um) of the diameter distribution profile
cockling	Unsightly distortion in the appearance of a knitted garment due to 'uncontrolled relaxation' of the yarns
combination bleaching	A bleaching process in which the wool is first bleached with an oxidising agent and then with a reducing agent. This combination process gives the best whiteness and is widely used
combing	The process where nep, noil and vegetable matter is removed from sliver.
comfort factor	The number of fibres <30µm within the test sample expressed as a percentage.

Term	Definition
conditioning	The process used to ensure moisture levels of wool fibres are in equilibrium with a standardised environment before testing.
core sampling	The sampling method in which wool samples are taken from a bale using a series of tubes.
cots	Heavily tangled regions of the wool fleece.
cover factor	A measure of the density of woven fabrics related to the thread count (threads per metre) and yarn count.
crimp	Wave pattern found in wool fibres, important in processing and final product characteristics.
cross breeding	The mating of sheep of one breed with one from another breed, used to produce a dual-purpose animal.
crutching	The removal of the wool from the sheep's rear end and back legs by the shearer.
decatising	A dry process used in finishing where woven fabric is flattened and set in that state using steam.
dimensional change	The change in the dimensions of fabric in response to a change in conditions (wetting, garment cleaning etc). It can be caused by relaxation processes, felting or change in moisture content.
drafting	The process of extending the sliver or top
dry finishing	A term used for a finishing procedure carried out on wool fabric that is not wet .
dumping	A process designed to further compress wool bales into a smaller size to fit into shipping containers for transport.
ends	warp yarns
facing up	A fault in the appearance of a knitted garment observed as a fuzzy surface appearance.
finishing	The processes used to improve the dimensional stability of fabrics or garments, remove processing additives and improve the handle and appearance of the final product.
flock	A group of sheep on a single property.
folding	A process to combine singles yarn into a folded yarn by twisting the yarns together; also known as plying or twisting.

Term	Definition
gauge	A term describing number of needles per inch (npi) in a knitting machine and the subsequent fineness of a knitted fabric.
gilling	The process in which wool sliver or top is drafted and doubled to align the fibres, make the sliver more even and where processing aids can be added to the fibre.
grab samples	The sampling method in which wool samples are taken from a bale using a claw, which avoids breaking the fibres.
handle	Relates to the touch or feel of the wool garment.
hydrophilic	'water-loving', wets easily
hydrophobic	'water-hating', does not wet easily
INTERWOOLLABS	The official supplier of calibration standards (as top) for IWTO test methods for fibre diameter and length.
knitting	The process of forming fabric by creating a loop with a needle, and threading that loop through the next loop formed ion the needle, repeating the process until a row of loops is formed, locked into the row below it.
lead time	The time that normally elapses between the decision on the processing of a lot of wool and its appearance as a product on the shelves of a retailer
locks	Short wool pieces created by shears cutting twice over the same area.
mercerisation	A process for treating top that improves the lustre and handle of the wool to produce softer and more lustrous garments with a cashmere-like feel; involves degrading the scale structure from the surface of the wool fibre to create a smoother fibre surface; also known as 'soft lustre'.
Merino Devoré	An innovation created by felt-resist treating fabric in selected areas using polymer-printing processes and then milling the garment.
micron	Also called micrometres, used to measure fibre diameter (fineness).
milling	The process of controlled felting of the fabric or garment .
mob	A group of sheep in a single paddock (field).
Mottled Merino	An innovation created by treating parts of the yarn with a felt-resist finish and leaving other parts untreated, and then milling the subsequent fabrics. It results in an innovative, textured surface appearance.

Term	Definition
mungo	A term used to describe fibre recovered from unused garments and the process of fibre recovery; also called 'shoddy'.
nep	A small knot of entangled fibre.
noil	Short wool fibres removed from sliver in combing.
non-woven fabrics	Fabrics formed from a web of fibres rather than by forming yarns then knitting or weaving; can be formed by needle punching (felting), stitch bonding, traditional felting or thermally bonding the fibres together.
open loop system	A recycling process approach where the recovered wool fibres becomes the raw material for industrial products such as insulation or mattress padding.
opening	The process where wool removed from bales is broken up into smaller clumps of wool to aid scouring, removing some dirt and enhancing the blending of wool lots.
oxidative bleaching	Bleaching using an oxidising agent (normally hydrogen peroxide).
picks	weft yarns
pills	Fibrous balls on the surface of the wool fabric, formed by loosely held fibres ,which are teased out of the fabric and subjected to rubbing action during wear.
projectile weaving machine	A weaving machine in which the weft yarn is inserted across the warp with a small metal projectile, which grips one end of the weft yarn and is 'fired' across the warp.
Pure New Wool	A Woolmark trademark consisting of the original Woolmark logo indicating the product is composed of 100% pure new wool — wool that has never been used in products before.
raising	A dry process used in finishing where fibres are pulled to the surface to increase the fabric bulkiness.
rapier weaving machine	A weaving machine in which the weft yarn is carried across the warp by a thin metal rod or rapier. In some machine designs, at the midway point the yarn is 'handed over' to another rapier, which has entered the space between the warp yarns from the other side. This second rapier carries the yarn the full distance across the warp. The yarn is then released and cut.
reductive bleaching	Bleaching using a reducing agent (e.g. sodium dithionite).
rollers	The working parts of the card which compete for and separate the wool fibres. There are five types: swift, worker, doffer, stripper and licker-in.

Term	Definition
roving	A fine sliver of fibres (and the process to produce it by drafting a sliver); raw material for yarn spinning.
S twist	The anti-clockwise insertion of twist during spinning.
selvedge	The edge of woven fabric (~10mm).
sett	The number of threads per metre of woven fabric.
shearing	A dry process used in finishing where fibres standing off on the surface of the fabric are removed by cutting, resulting in a smoother, cleaner finish.
shuttle weaving machine	A weaving machine that uses a large wooden shuttle containing a small cone of yarn, to carry the weft across the warp. The weft unravels from the cone in the shuttle as the shuttle passes across the warp.
sizing	The gluing together of fibres in warp yarns prior to weaving.
skirting	The process where lower quality edges of the fleece are removed by the wool handler following shearing.
sliver	An untwisted, rope-like strand of fibre.
slubbings	Narrow strips of wool ready for spinning produced when the web produced by a woollen card is split .
snarl	When yarn twists on itself, caused by residual torque which occurs when the twisted fibres remain under some tension in the spun yarn.
solvent finishing	Describes the finishing procedure where garments are washed in an organic solvent in a dry-cleaning machine.
spinning	The process where the sliver, roving or slubbing is extended and twisted into a continuous strand (called yarn); twist is inserted to bind the fibres together and impart strength.
spirality	A fault in the appearance of a knitted garment in which the wales are not at right angles to the direction of the courses.
staple	A coherent bundle of raw wool fibres.
stocking rate	The number of sheep per hectare.

Term	Definition
straight-bar fully fashioned knitting machine	A knitting machine in which the needles are arranged on a bar of steel in a straight line and all the yarn loops form at the same time before being interlocked into the previous row of loops to build up the fabric. This knitting machine can produce shape panels in single jersey, with little or no yarn wastage.
suint	Sweat from the sheep found in wool.
V-bed knitting machine	A knitting machine with two needle beds, arranged in a V-shape; the two lines of needles are inclined towards each other to form a V-shape in cross-section with the needle hooks at the apex. The needles sequentially rise to catch the yarn being laid down by a yarn guide (feeder), which travels backwards and forwards along the beds. This versatile machine can make single and double structures as well as shaped panels.
vegetable matter	Plant material found in raw wool.
warp yarn	The yarns held on the frame of a weaving machine which are separated in changing sequences to allow the weft yarns to be inserted between them across the width of the fabric.
weaving	The process of interlacing warp and weft yarns in a weaving machine (or loom).
weft yarn	The yarns interlaced between the warp yarns across the width of the fabric during the weaving process.
wet finishing	The term used to describe knitwear or fabric finishing procedures where fabrics or garments are treated in water.
wigging	The removal of wool from the sheep's head by the shearer.
winding	The part of the processing route where spun yarn is wound onto cones and checked for faults.
Wool Blend Performance	A Woolmark trademark which indicates the product contains between 30% and 49% new wool.
wool classer	A person responsible for assessing the characteristics of the shorn fibre and the overall condition of the fleece.
Wool Rich Blend	A Woolmark trademark which indicates the product contains more than, or equal to, 50% new wool but is not pure wool.
yield	The amount of clean wool fibre in a bale.
Z twist	The clockwise insertion of twist during spinning.

COURSE
INTRODUCTION

THE WOOLMARK COMPANY

INTRODUCTION TO WOOL PROCESSING

WELCOME participants as they arrive, ensuring they collect their pre-prepared name tags or ask them to write their name on a tag as they arrive.

ENSURE each participant takes a copy of the Participant Guide and records their attendance.

INTRODUCE yourself and provide a brief (maximum three-minute) overview of your role, experience and broad objectives in delivering this series of lectures.

After introducing yourself, if you have a group of 20 participants or less, ask each participant to provide a brief introduction (name, role and organisation, or area of study) and share three things they wish to achieve by attending this series of lectures.

NOTE: If you have 20 participants and they each take about 30 seconds to introduce themselves and their objectives, this exercise will require 10 minutes.

Keep it brief. You may need to modify your approach, based on the number of participants in the room. For example, in a large group (20+ participants) select a small sample of participants to introduce themselves and share their expectations.

RECORD and group participants' responses regarding their own learning objectives on the flipchart or whiteboard.

This introduction will expand upon your understanding of each participant's needs and attitude towards their participation in the program and will give them the opportunity to build rapport with you as the facilitator and other participants in the group.

EXPLAIN that you will revisit these objectives throughout the course to ensure each objective has been covered or students are directed to additional resources that will help them meet their own learning objectives.

Endeavour to draw on these participant objectives as you progress through the course.

SPEND a few moments exploring participants current understanding of wool. Establishing how much individuals, or the group as a whole, already knows about wool will allow you to acknowledge and leverage the experience of those in the room and tailor the content and delivery of the course appropriately to either dispel misperceptions or build on current understanding.

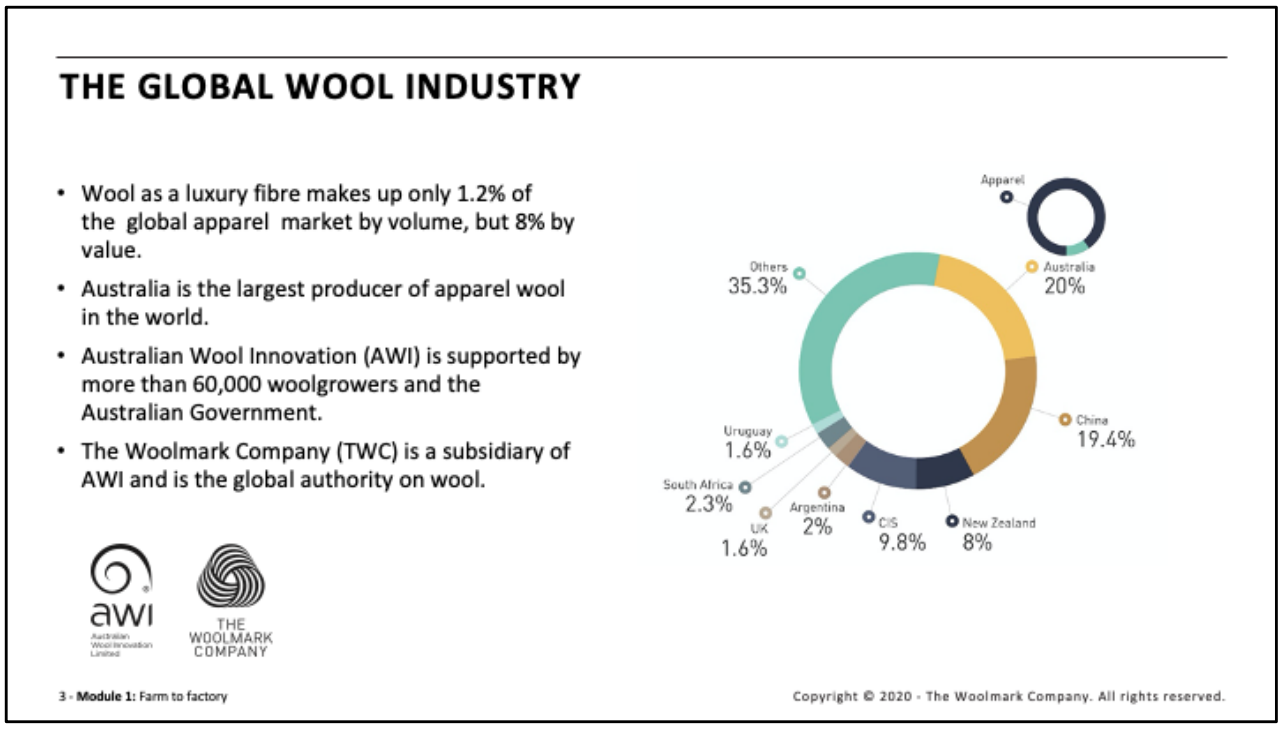
ALLOW about 5–10 minutes for a group discussion prompted by a questioning approach outlined below.

ASK participants to share what they already know about wool.

Examples of questions you might ask to encourage participation include:
- Where does wool come from?
- Is wool a natural or synthetic fibre?
- Do you own any wool garments or furnishings?
- What are some key characteristics of wool garments?

RECORD responses to the above questions on a flipchart or whiteboard and explain that you will re-visit the responses at the end of this module and the course to reflect upon what participants may have learnt during the course.

NOTE TO FACILITATOR: *If participants have not already been introduced to Australian Wool Innovation (AWI) and The Woolmark Company (TWC) run through the following three slides, before continuing to the course overview. If participants are familiar with Australian Wool Innovation (AWI) and The Woolmark Company (TWC) you may wish to hide these slides and proceed directly to the course overview.*



REFER TO the slide as you indicate that Australian woolgrowers produce 90% of the world's fine apparel wool as part of Australia's $2.5 billion wool export industry*.

**Source ABARES Agricultural Commodities, March 2020 quarter.*

EXPLAIN THAT Australian Wool Innovation (AWI) is the research, development and marketing body for the Australian wool industry, supported by more than 60,000 Australian woolgrowers, who co-invest with the Australian government to support the activities carried out by AWI and TWC along the global wool supply chain.

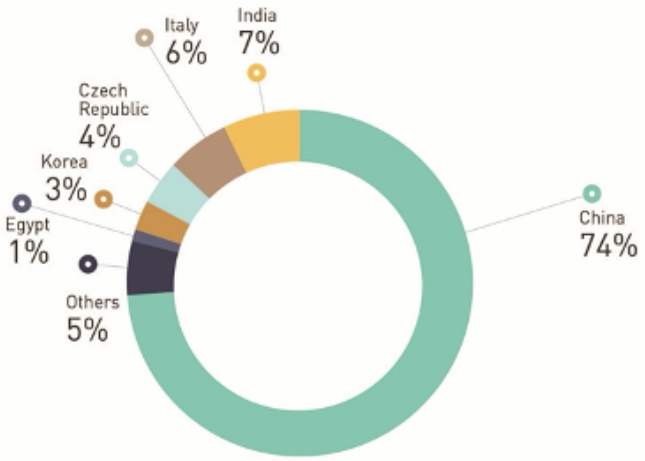
EXPLAIN THAT The Woolmark Company is a subsidiary of Australian Wool Innovation and is a global authority on Merino wool. With a network that spans the entire global wool supply chain The Woolmark Company builds awareness and promotes the unique traits of nature's finest fibre.

REINFORCE THAT The Woolmark Company collaborates with global experts on all aspects of wool science, technology and design to develop and deliver educational materials, such as the course you are about to deliver.

NOTE THAT you will provide a brief overview of the Australian wool industry and global supply chain, and elaborate on the role of The Woolmark Company in the global context before commencing the technical components of the course

THE AUSTRALIAN WOOL INDUSTRY

- 68 million sheep
- More than 60,000 woolgrowers
- 300 million kilograms of greasy wool produced in 2018/19
- 98 per cent of Australian wool is exported
- 1.6 million bales of wool sold in 2018/19

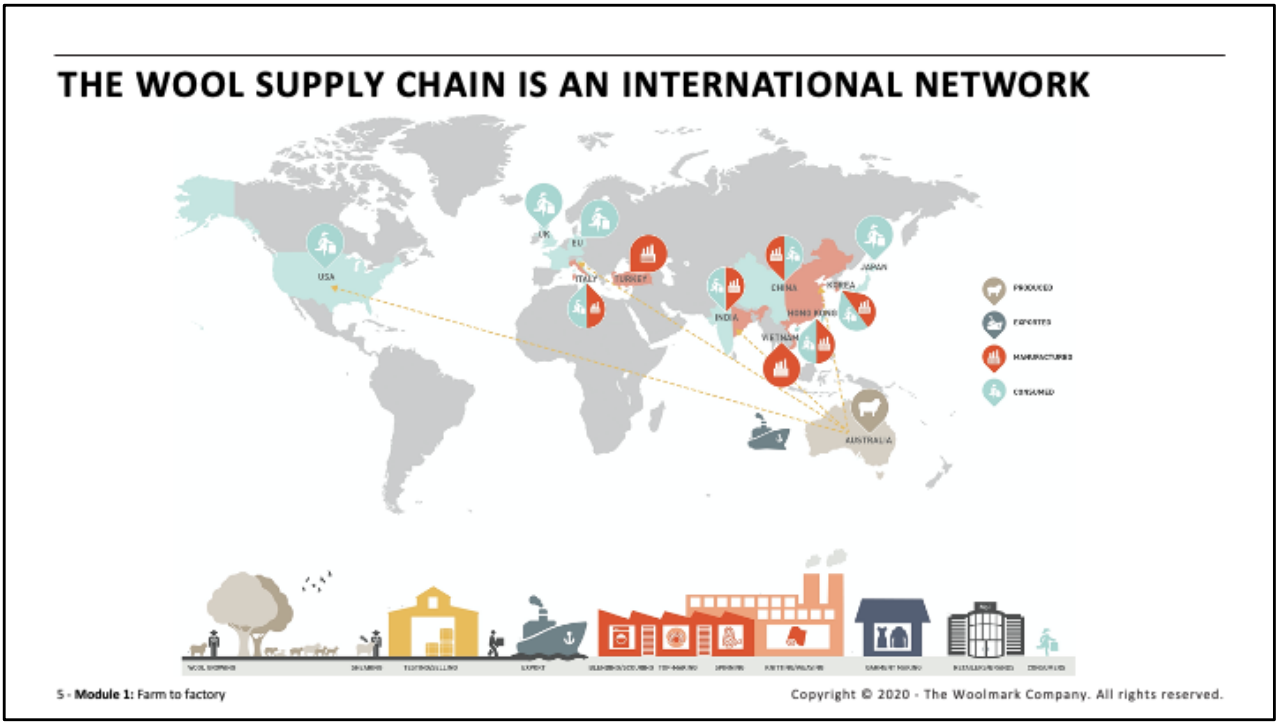


GLOBAL EXPORT DESTINATIONS FOR AUSTRALIAN GREASY WOOL

EXPLAIN THAT there are more than 68 million sheep in Australia, carefully managed by more than 60,000 woolgrowers.

INDICATE THAT in 2018/19 Australia's woolgrowers produced 300 million kilograms of greasy wool and sold 1.6 million bales of wool.

POINT OUT that 98 per cent of Australia's wool is exported to other countries for further processing into a diverse range of products.



REFER TO the slide as you explain that it offers a snapshot of the global dynamics of the Australian wool industry, illustrating where the key export markets are for Australian wool, where most wool is processed from its raw state into yarn and fabrics and where the fashion and trend influencers and wool consumers are located.

NOTE THAT countries such as China, India and Italy are major manufacturers and consumers of wool products.

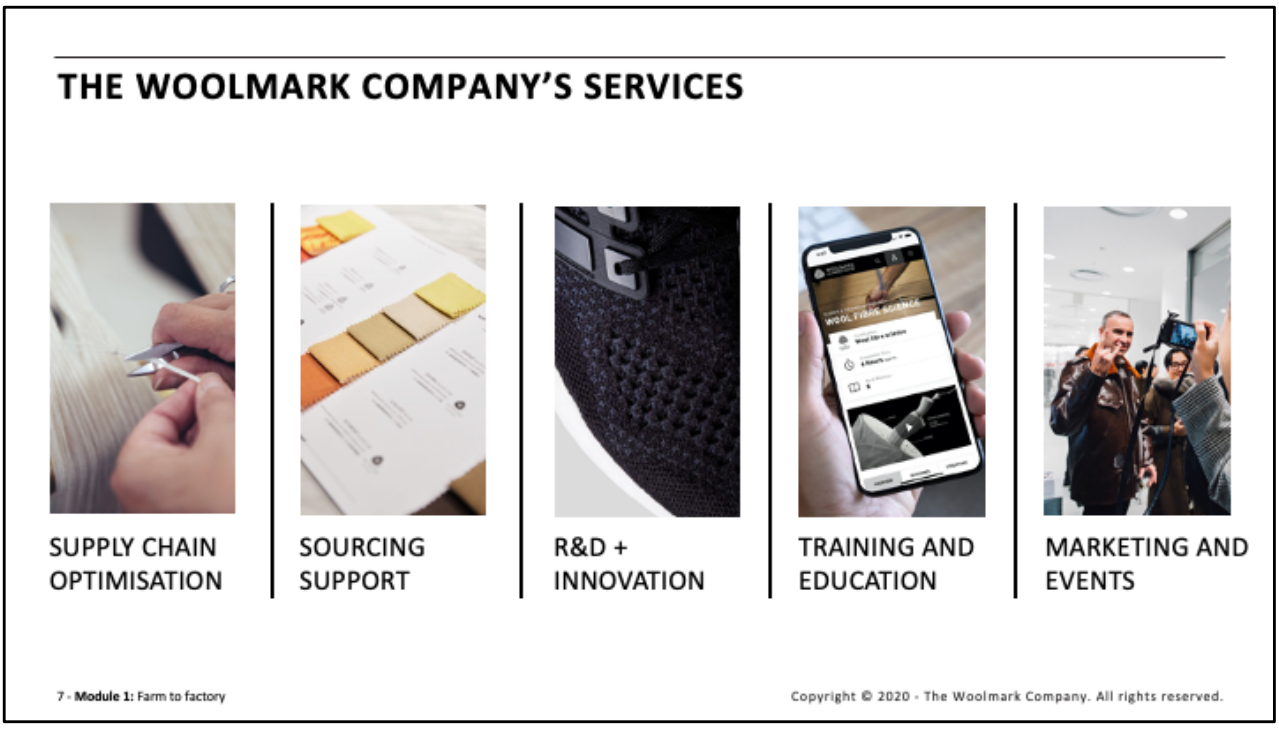
EXPLAIN THAT in line with these global dynamics, The Woolmark Company head office in Sydney, Australia is supported by a growing number of regional offices globally. Through this support The Woolmark Company invests in innovation along the global wool supply chain.

REINFORCE THAT The Woolmark Company works on behalf of Australia's 60,000+ woolgrowers, who are responsible for producing 90 per cent of the world's fine apparel wool.

EXPLAIN THAT The Woolmark Company's parent body — Australian Wool Innovation — invests in on-farm research and development to deliver new knowledge to woolgrowers to increase the profitability and sustainability of the growing wool business.

NOTE THAT The Woolmark Company strives to deliver tangible solutions across the global wool textile industry through process and product research and development.

EXPLAIN THAT the Woolmark Company builds industry confidence through communication, collaboration and a range of educational programs across the industry.



EXPLAIN THAT The Woolmark Company partners with designers, brands and retailers worldwide, offering support with quality assurance, product innovation and supply chain assistance.

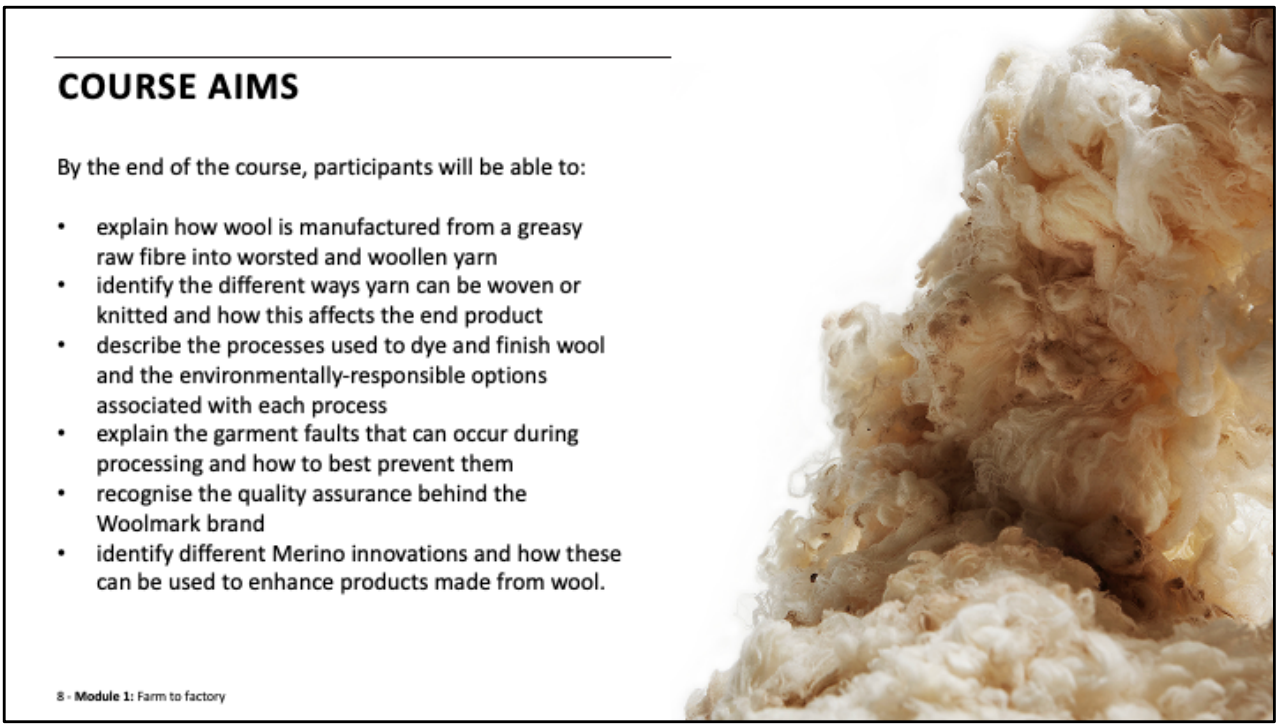
INDICATE THAT The Woolmark Company provides sourcing support through direct access to the global wool manufacturing industry through The Wool Lab. A seasonal guide to the latest innovations in wool, fabrics are sourced from the world's best spinners and weavers in the global supply network.

REINFORCE THAT The Woolmark Company takes secures funding and delivers research to improve wool production and processing through fibre science, traceability and fibre advocacy.

EXPLAIN THAT The Woolmark Company offers a range of online and face-to-face training programs to educate the industry. During 2019, The Woolmark Company launched the Woolmark Learning Centre, an online educational hub for industry professionals.

POINT OUT that The Woolmark Company markets the performance and environmental benefits of the fibre to ensure industry and consumers are informed and inspired to make better purchasing choices.

ASK PARTICIPANTS if they have any questions about the Woolmark Company before you proceed with the course aims.

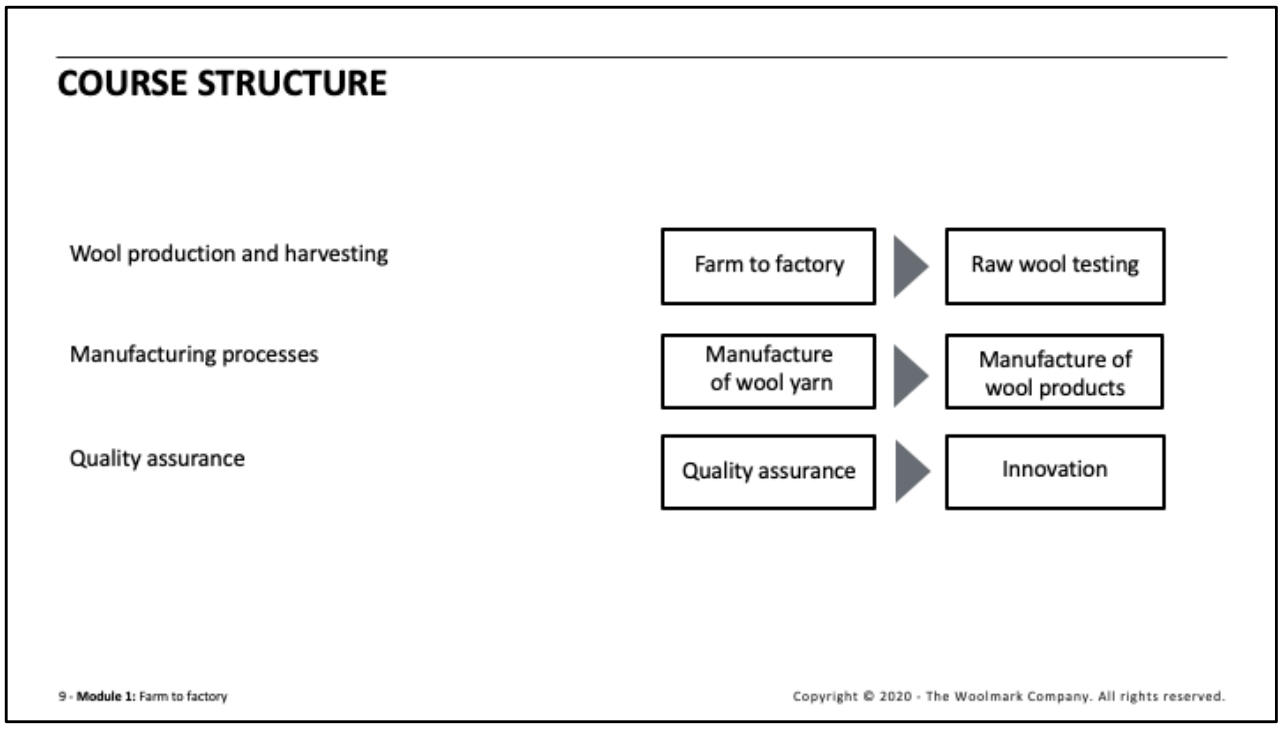


EXPLAIN THAT this course is designed to introduce participants to wool, wool processing and to wool products.

INSTRUCT participants to read the course aims for the course on the slide and remind them these aims are included in their Participant Guide.

INDICATE THAT at the end of this course the participants will be able to:

- explain briefly how wool is manufactured from a greasy raw fibre into worsted and woollen yarn
- identify the different ways yarn can be woven or knitted and how this affects the end product
- briefly describe the processes used to dye and finish wool and the environmentally-responsible options associated with each process
- explain the garment faults that can occur during processing and how to best prevent them
- recognise the quality assurance behind the Woolmark brand
- identify different Merino innovations and how these can be used to enhance products made from wool.



EXPLAIN TO participants that the sequence of the following information may differ from the actual presentation to allow for differences in venue and participant prior knowledge and experience.

DIRECT participants to the relevant slide in the Participant Guide and run through the course structure as outlined on the slide and below.

EXPLAIN THAT this course provides an introductory overview to the journey of wool from farm to fashion. Subsequent courses in the Wool Education Course explore this journey in greater depth.

EXPLAIN THAT this course explores:

- the source of wool (sheep)
- the process of harvesting wool (shearing, classing, baling and transport)
- the testing procedures carried out on raw wool to determine its value
- the sale of raw wool
- the manufacture of wool yarn through:
    - woollen processing
    - worsted processing
- the manufacture of wool textiles and products:
    - knitted
    - woven
- quality assurance processes for wool products
- innovations with wool.

INTRODUCE participants to the *THIS IS WOOL* video by explaining you are going to share with them a short, one-and-a-half-minute video that provides a brief overview of wool, where it comes from, how it grows and some of its applications.

***ASK** participants to list three features of wool mentioned in the video on the associated page of their Participant Guide.*

***PLAY** video (1:20)*

***ASK** a few participants to share some of the features they listed in their notes during the video.*

***ACKNOWLEDGE** responses*

***NOTE:** Suitable responses might include:*

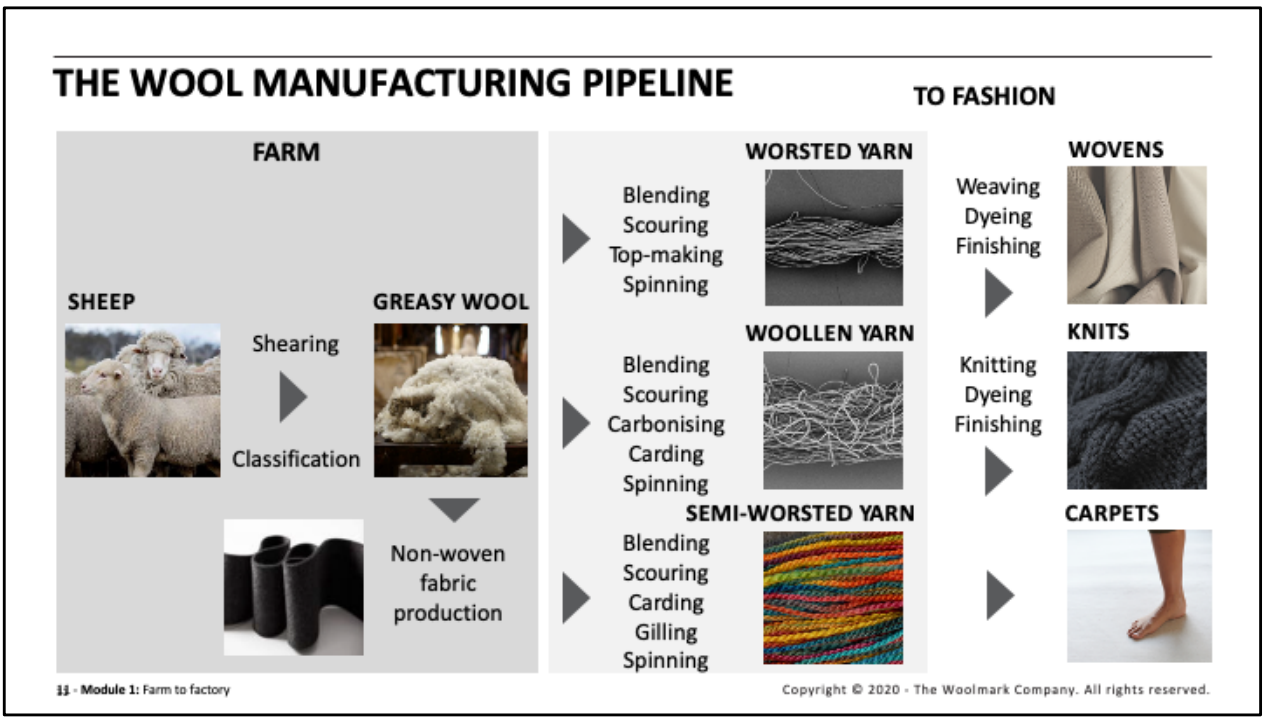
- *Wool is natural*
- *Wool grows on sheep*
- *Wool is biodegradable*
- *Wool is renewable*
- *Wool is used in clothing, interior textiles and other products.*
- *Wool can be used as a pure fibre or blended with other natural fibres or synthetics.*

EXPLAIN THAT the production and manufacture of wool is a long and complex process, involving many different processes and people.

***ASK** participants to estimate how long they think it takes for wool to make the journey from the farm to the retail shelf as a wool product ready for consumers to buy.*

***ACKNOWLEDGE** participants' responses and proceed to the next slide.*

Opinions expressed in this video do not necessarily reflect the opinions of The Woolmark Company Pty Ltd or its affiliates. To the extent permitted by law, we exclude all liability (however arising) for any loss or damage arising from or in connection with the use of, or reliance on, the opinions and information in this video.



EXPLAIN THAT it can take 12–18 months from the time the wool is harvested from the sheep (during shearing) to the point at which it is sold to the consumer as a wool (or wool blend) garment or other wool textile product (e.g. carpet, homewares etc).

REFER PARTICIPANTS to the schematic on the slide as you explain that the manufacturing pipeline for wool products can be divided into four key stages:

- Farm to factory, which involves:
    - shearing
    - classification
    - raw wool measurement (testing)
- Manufacturing of yarn, which involves:
    - raw wool scouring
    - top-making
    - spinning
    - twisting
- Manufacture of fabric, knitted garments, carpet etc. which involves:
    - weaving and knitting
    - dyeing (can occur at several points in the process)
    - finishing
- Manufacture of garments or other products (this stage is not shown on this slide or covered in this course).

NOTE THAT an additional process, is carried out to produce non-woven fabrics, such as felts. This process will be discussed separately to weaving and knitting.

INDICATE THAT at each stage of the pipeline, the semi-processed products are tested for quality assurance purposes.

EXPLAIN THAT the quality assurance process will be covered in this course.

MODULE 1

THE WOOLMARK COMPANY

FARM TO FACTORY

RESOURCES — MODULE 1: FARM TO FACTORY

Contained in the *Introduction to wool processing* Demonstration kit you will find the following resources for use as you deliver **Module 1: From farm to factory**:

- fine wool sample
- broad wool sample
- samples of fleece components (fleece, belly wool, crutchings, pieces and locks)
- nylon wool bale material

Additional resources to be sourced by the facilitator include:

- samples of various wool products, such as:
- wool carpet
- wool upholstery fabric
- next-to-skin wool fabric or product (e.g. T-shirt)
- hand knitting woollen-spun yarn

EXPLAIN THAT this module is designed as a brief introduction to the wool fibre, what it is and where it comes from.

INDICATE THAT the properties of wool fibres are covered in depth in the *Wool Science Technology and Design Education Program, Wool fibre science course*.

INDICATE THAT the production of wool products is covered in depth in subsequent *Wool Science Technology and Design Education Program, Wool fibre science courses*.

EXPLAIN THAT at the end of this module, participants will be able to:

- describe where wool comes from and how it is harvested
- outline the key categories of wool
- list the characteristics of wool that determine its value
- describe how wool is sold
- outline the stages involved in bringing wool from farm to factory.

NOTE TO FACILITATOR

If the participants have already studied the *Wool Science, Technology and Design Education Program Wool Fibre Science* course, then a small number of topics in this module can be omitted, mentioned briefly, or used for revision. Common topics are noted at the top of the relevant page throughout this course

RESOURCES REQUIRED FOR THIS MODULE:

- *samples of fine greasy wool*
- *samples of broad greasy wool*
- *samples of various wool products, such as:*
    - *wool carpet (facilitator to provide)*
    - *wool upholstery fabric (facilitator to provide)*
    - *next-to-skin wool fabric or product (e.g. T-shirt) (facilitator to provide)*
    - *hand knitting woollen-spun yarn (facilitator to provide)*
- *sample of fleece wool (i.e. body wool)*
- *sample of belly wool*
- *sample of crutchings*
- *sample of pieces*
- *sample of locks*
- *sample of nylon bale material*

INTRODUCE participants to the video by explaining you are going to share with them a short, one-minute video taken on an Australian sheep property (farm) using a drone.

***PLAY** video (1:07)*

***ASK** participants if they know the term used in Australia to describe a large group of sheep, like that shown in the video.*

***ACKNOWLEDGE** responses before proceeding.*

EXPLAIN THAT the English word for describing a group of sheep is 'flock'. In Australia the word 'flock' is used to describe all the sheep on a single property, while a group of sheep in a single paddock (field) is often called a 'mob'.

EXPLAIN THAT sheep properties in Australia can vary widely in size depending on the location and rainfall. In Australia sheep are grown in high and low rainfall (semi-desert) regions.

***ASK** participants if they think the video has been shot in a low-rainfall or a high-rainfall region (ANSWER: high rainfall — indicated by improved pasture species and other vegetation).*

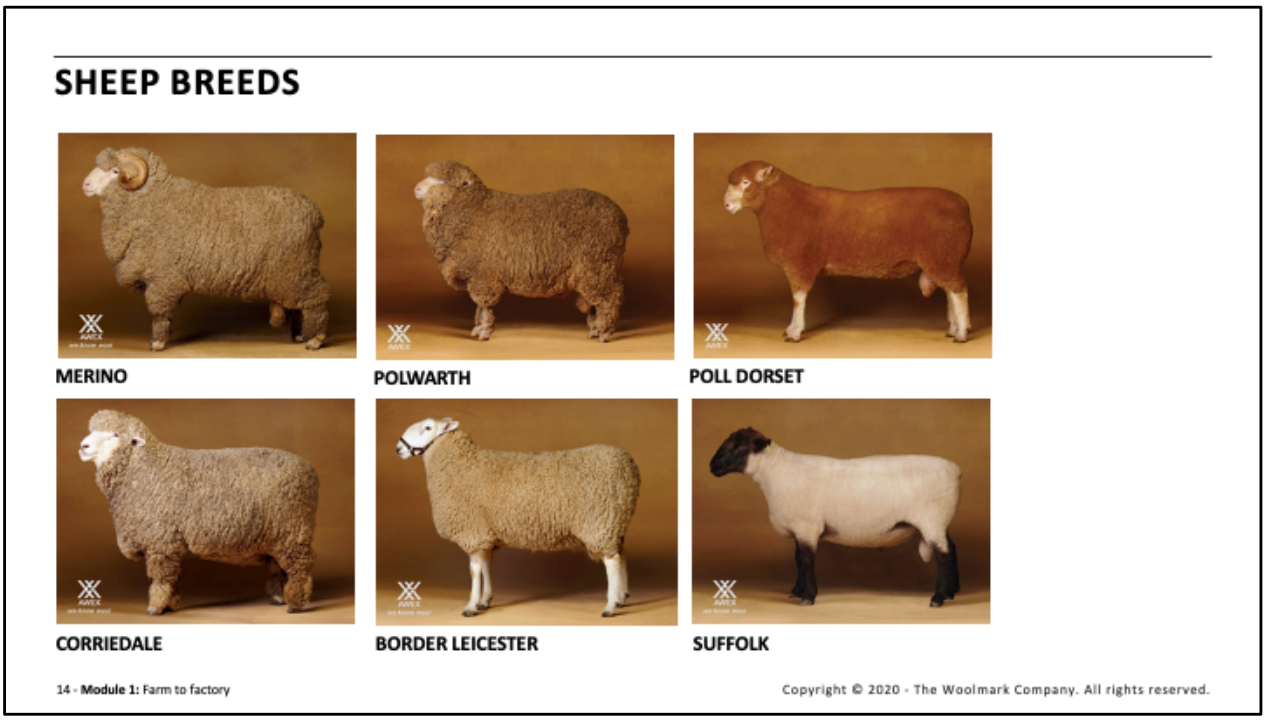
***ACKNOWLEDGE** responses before proceeding.*

INDICATE THAT the stocking rates (number of sheep per hectare) also vary widely depending on the type of farming, which is mostly driven by rainfall and the availability of feed (edible plant material, such as grass and legumes, such as clover).

***ASK** participants if they can identify what breed of sheep are shown in the video (**ANSWER:** Merino).*

***ACKNOWLEDGE** responses before proceeding.*

***ASK** participants if they can list any other sheep breeds they may be familiar with before proceeding to the next slide.*



NOTE TO FACILITATOR
This content is also covered in the *Wool Science, Technology and Design Education Program, Wool Fibre Science* course.

EXPLAIN THAT not all wool is the same. There are more than 1000 breeds of sheep around the world, which produce different types of wool, used for various purposes. This slide only shows a few of these breeds.

EXPLAIN THAT the wool from different breeds of sheep varies across a range of characteristics including fineness (fibre diameter), length of the fibre, amount of crimp and colour.

***ASK** participants if they are familiar with any other sheep products (in addition to wool).*

***ACKNOWLEDGE** responses before proceeding.*

REINFORCE THAT some sheep are primarily bred for meat and others primarily for wool. Some sheep are also used to produce milk.

- Sheep primarily bred for meat (e.g. Poll Dorset and Polwarth) usually produce a broader wool, which can be used in carpets, rugs, blankets and upholstery.
- Sheep primarily bred for their wool (e.g. Merino) usually produce a finer, (thinner) wool, which is softer and generally more expensive. Fine wool is usually used to make garments such as suits, jumpers, skirts and scarves.

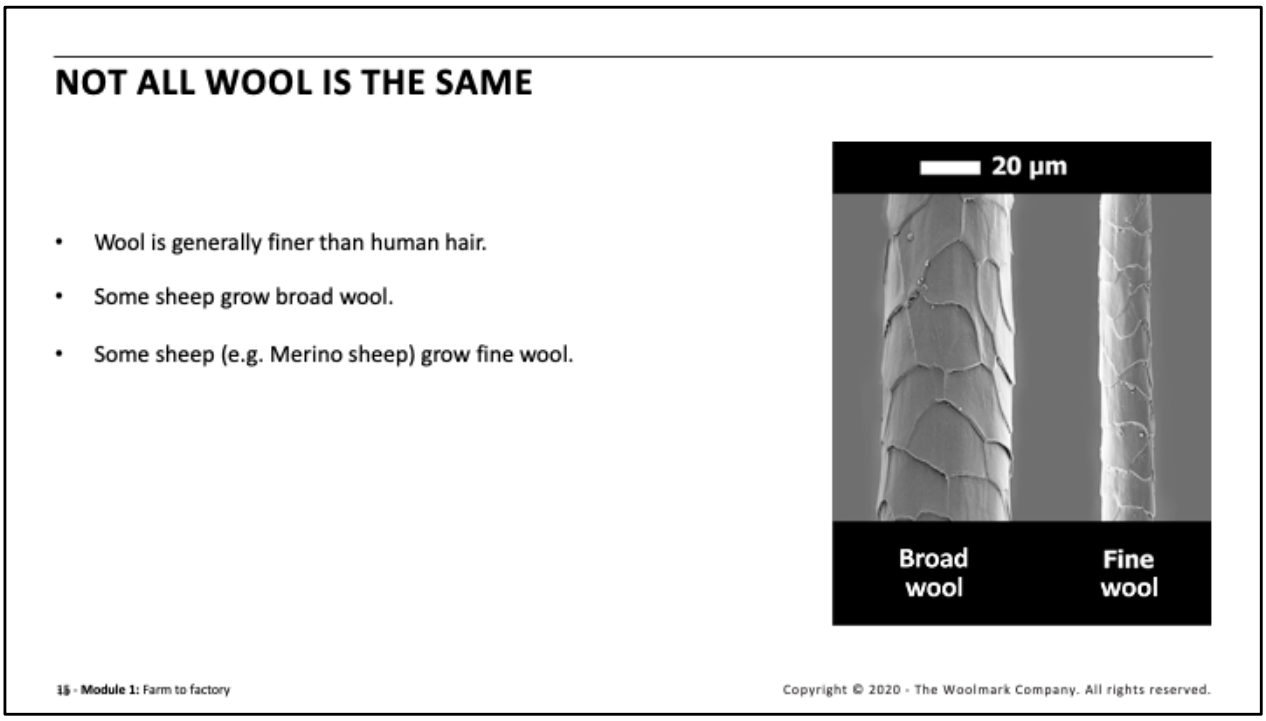
EXPLAIN THAT in addition to the many pure breeds, the crossbreeding of sheep (mating a sheep of one breed to a sheep of another breed) is popular to produce a dual-purpose animal, which can be used to produce both wool and meat.

***ASK** participants if they have any experience with any of the breeds shown on the slide).*

***ACKNOWLEDGE** responses before proceeding.*

ADVISE PARTICIPANTS that they can explore in greater detail the different sheep breeds, their origins, purpose and the characteristics of their wool, by downloading the Sheep Breed Compendium App by AWEX:
Android:
https://play.google.com/store/apps/details?id=digibale.com.sheepbreed&hl=en

Apple: https://itunes.apple.com/au/app/sheep-breed-compendium-by/id1092317391?mt=8



EXPLAIN THAT wool is generally categorised by its 'fineness'. This is measured by the thickness of the fibre (i.e. fibre diameter), with the standard course of measurement being micrometres (millionths of a metre; µm). The term 'micron' is also widely used.

INDICATE THAT wool can be divided into categories, or grades based on the average or mean fibre diameter.

Broad (>29µm)
Breeds such as the Romney produce broad, long, medium-lustre wool, which is particularly useful for carpets and furnishings because of its strength and durability.

Medium (23-29µm)
Breeds such as the Corriedale and Texel produce medium wools used in a variety of woven apparel cloths, knitting yarns and furnishings.
A wide range of medium wools also have been produced by crossing one breed of sheep with another.

Fine (<23µm)
Although some non-Merino breeds produce wool in the range of 23µm, wool with the finest micron comes from Merino sheep.

EXPLAIN THAT within the industry, the terms broad, medium and fine can be used 'loosely'.

INDICATE THAT there are some differences in the application of these terms with different sheep breeds and crossbreeds. However, the ranges shown here represent a loose consensus within the global wool-growing industry.

Merino wool
EXPLAIN THAT for Merino wool the following categories are used:

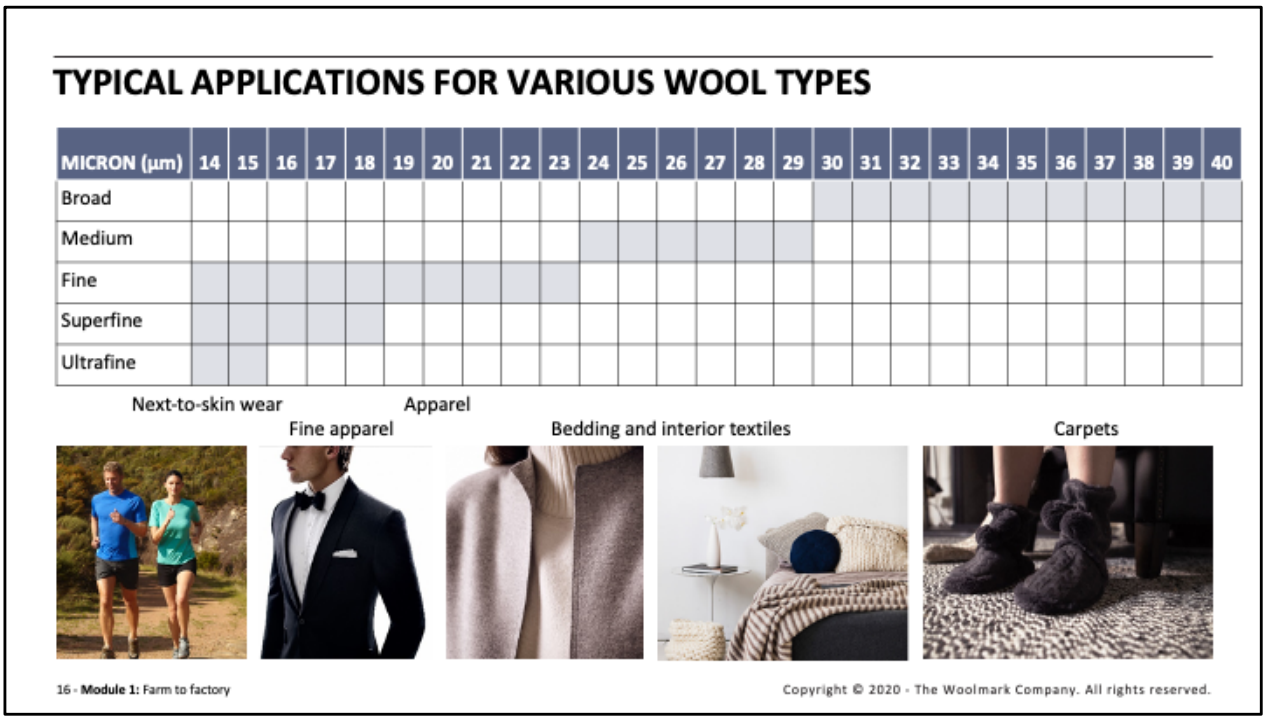
- Broad (or strong) Merino (22.6 – 24.5µm)
- Medium Merino (20.6 – 22.5µm)
- Fine Merino (18.6 – 20.5µm)
- Superfine Merino (16.6 – 18.5µm)
- Ultrafine Merino (14.6 – 16.5µm)
- Extrafine Merino (<14.5µm).

EXPLAIN THAT Merino wool is used for high-quality, soft-handling fabrics and knitted garments.

HAND OUT *samples of:*

- *fine wool*
- *broad wool*

While participants are exploring the fibre samples, ask them to describe the differences between the samples. Encourage them to observe how each sample feels and the differences in appearance; paying particular attention to the difference in fibre crimp (i.e. waviness) between the samples.



EXPLAIN THAT this slide provides some indication of the relationship between fibre diameter and end use.

HAND OUT *samples of:*

- *wool carpet*
- *wool upholstery fabric*
- *wool t-shirt or next-to-skin wool fabric*
- *hand knitting wool yarn.*

REFER TO *the chart on the slide and select participants to estimate, from the chart, the micron range of the samples.*

ACKNOWLEDGE *responses and encourage participants to observe the difference in softness between the samples and reinforce the relationship between fibre diameter, softness and end product.*

EXPLAIN THAT broad wool (i.e. >29µm) is widely used for interior textiles and carpets because of its strength, durability and the ability of the fibre to resist crushing (or other deformation) in pile structures. Carpets are made from the higher diameter broad wools. Broad wool with lower diameter is used in some furnishing fabrics (e.g. curtains and drapes).

Medium wools (23–29µm) are used in a wide variety of applications including:

- furnishing fabrics
- woven apparel cloths, particularly for heavy outerwear (jackets)
- knitting yarns for heavier ‘chunky’ knitwear.

Fine wool (<23µm) is used for high-quality, soft-handling fabrics and lighter-weight knitting yarns. Superfine, ultrafine and extrafine wools are highly valued by the world’s leading fashion houses.

EXPLAIN THAT you are now going to play a short video demonstrating how wool is harvested from sheep during the process of shearing.

_____

PLAY *video (1:20 minutes)*

AFTER PLAYING *the video through, re-play the video, encouraging participant to note the following features:*

- *The fleece is thrown onto a table (34:00 seconds).*
- *The fleeces is skirted (the dirty edges are removed) (40:00 seconds)*
- *The wool classer assesses the quality of the wool (46:00 seconds).*
- *Fleeces of similar quality are packed together in a bale (52:00 seconds).*
- *The bales are marked to identify the wool and the farm and sent off to the wool receival warehouse (57:00).*

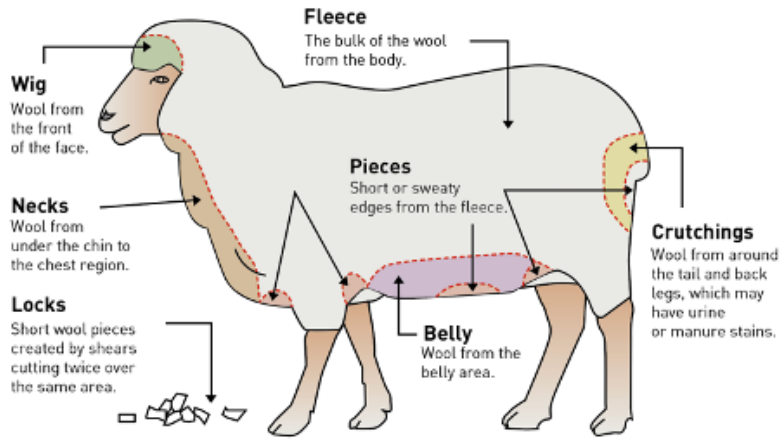
_____

REINFORCE THAT wool is harvested from sheep by shearing as shown on the video. Shearing is carried out by specialist shearing teams who remove the wool skilfully and carefully, without harming the sheep.

NOTE THAT shearing is usually carried out once a year, allowing the wool to grow back between each shearing (much like our hair grows between haircuts).

EXPLAIN THAT depending on the number of sheep, a shearing team can include two or more shearers, one or two woolhandlers and a wool classer, who grades the wool into categories ready for transport and sale.

CLASSING THE WOOL



Source: Adapted from The Story of Wool, Kondinin Group

18 - **Module 1:** Farm to factory

EXPLAIN THAT even on a single sheep the wool characteristics can vary depending on:

- where on the sheep the fibre grows
- seasonal conditions during the growing period.

EXPLAIN THAT as soon as the fleece has been shorn, the woolhandler gathers up the fleece and throws it across a large table where fleece is 'skirted'. Skirting removes the lower-quality edges of the fleece, which are kept separate from the main fleece wool. This can include necks and pieces, as well as soiled wool. The remaining fleece is rolled and given to the wool classer.

***HAND OUT** samples of:*

- *fleece wool*
- *belly wool*
- *crutchings*
- *pieces*
- *locks.*

INDICATE THAT preparation of the skirted fleece wool for classing is done in accordance with the Regulations (Code of Practice) imposed by the local authority (e.g. Australian Wool Exchange — AWEX). Fleeces are also sorted into lines (groups) according to their micron.

EXPLAIN THAT classing is a skilled job requiring accurate subjective assessment of the characteristics of the fibre in the fleece and the overall condition of the fleece. Wool classers are registered with the industry authority (e.g. AWEX).

REFER TO the slide as you explain that the wool classer sorts the wool into five main categories — fleeces, necks, pieces, bellies and locks.

EXPLAIN THAT in addition to the main annual shearing, woolgrowers will often 'crutch' and 'wig' sheep during the year.

Crutching is a process in which shearers use the electric handpiece to remove wool from around the sheep's rear end.

Crutching usually takes place well before shearing and is carried out to reduce the amount of wet manure and urine that sticks to the wool around sheep's rear end. This wetness can attract blow flies, which lay their eggs, leading to flystrike.

EXPLAIN THAT removal of wool from the sheep's face is called wigging. Wigging is done at the same time as crutching and removes any wool around the face that could stop the sheep from being able to see.

As with necks, pieces, bellies and locks, the wool from crutching and wigging is lower quality than the fleece wool and is stored and sold separately.

BALING

- Classed fleeces are placed in nylon bags and compressed into bales.
- Pieces, dags and bellies are baled separately.
- Each bale is marked to identify the source of the wool and its classification.
- Bales are transported to a receival warehouse where they are tested before sale — usually by auction.

19 - **Module 1:** Farm to factory

EXPLAIN THAT the classed wool is placed in nylon bags and compressed in a mechanical wool press to make bales as shown on the slide. All the bales are sealed and marked with brand that identifies the woolgrower, the classer and the type (breed and category) and quality of wool inside.

HAND OUT *a sample of nylon bale material.*

ASK *participants if they can explain why nylon is used to wrap wool bales instead of a less expensive product such as polypropylene. (ANSWER: Nylon dyes like wool, so any contamination of the wool by the bale material will be invisible.)*
Polypropylene does not dye and would appear as a visible contaminant in wool yarns and fabric)

ACKNOWLEDGE *responses.*

INDICATE THAT bales containing the same wool type are assembled into 'Classed Grower Lots'. These should meet the clip preparation guidelines specified by the local organisations (e.g. Australian Wool Exchange) or the national committee of IWTO. These lots can be as small as three bales from small farms to large lots from large properties.
The wool bales are transported on large trucks and taken to a wool receival warehouse.

EXPLAIN THAT at the warehouse, the wool bales from a single property may be grouped with other grower lots of similar quality (interlots).

Samples are taken from all the bales in the sale lot and tested for important fibre characteristics, which can affect subsequent processing. This testing process is covered in detail later.

A pre-sale certificate is issued that lists all the results from the testing and stays with the sale lot right through to processing.

VALUING WOOL FOR SALE

Subjective appraisal
- Visual and tactile methods.

Sale by sample
- System based on the use of objective measurement augmented by the visual (subjective) appraisal of a sample of the sale lots.

Sale by description
- Based on objective measurements.
- Not yet implemented.

http://newenglandhistory.blogspot.com/2014/06/history-revisited-nenco-newcastle-wool.html

20 - **Module 1:** Farm to factory

EXPLAIN THAT traditionally, the characteristics of wool that determined the price were appraised 'subjectively' by 'experts' who decided the price their company was prepared to pay for wool at auction.

INDICATE THAT prior to the auction, the experts would inspect and appraise the wool (visually and by touch). These experts would then bid for the wool (or set the bidding limits for their company) in the auction.

EXPLAIN THAT the need for more accurate appraisals of the properties that determine the value of raw wool in a global industry drove the development of more objective methods of measurement and appraisal.

INDICATE THAT measurement of fibre diameter, using microscopy, has been used to value wool since the 1930s. Testing of raw wool samples taken from each bale was developed in the 1950s.

'Sale by sample' — a selling system based on the use of objective measurements augmented by the visual (subjective) appraisal of a sample —was introduced in Australia in 1972–73. This method of appraisal has become the dominant approach to the valuation and subsequent sale of raw wool worldwide.

EXPLAIN THAT buyers have resisted the selling of wool without a subjective appraisal of a sample of the wool and as such, selling based exclusively on objective measurements (sale by description) has not been widely adopted.

SAMPLING AND TESTING RAW WOOL

INTERNATIONAL WOOL TEXTILE ORGANISATION IWTO

Image Courtesy of IWTO

21 - **Module 1:** Farm to factory

EXPLAIN THAT appropriate sampling and testing of raw wool is a key component of critical importance in the system to sell wool by sample and description. Regulations and test methods have been set up by the International Wool Textile Organisation (IWTO) for the international trading of wool.

INDICATE THAT in Australia, the Australian Wool Testing Authority (AWTA) is authorised to undertake the sampling and testing of the Australian wool clip. It certifies the results obtained, which are then used in the valuing and sale of wool.

EXPLAIN THAT in other countries there are similar organisations. Examples include:

- Wool Testing Bureau South Africa
- New Zealand Wool Testing Authority
- Wool Testing Authority (Europe) Ltd.

VALUING RAW WOOL

- Type (fleece or pieces)
- Fibre diameter (micron)
- Yield (clean wool content)
- Vegetable matter:
  - type
  - quantity
- Staple length (mm)
- Staple strength:
  - breaking load (N/tex)
  - position of break
- Clean colour
- Pesticide residues
- Style of the wool

22 - **Module 1:** Farm to factory

NOTE TO FACILITATOR
This content is also covered in the *Wool Science, Technology and Design Education Program, Wool Fibre Science* course.

EXPLAIN THAT the value of wool is based on its suitability for specific end uses, as well as the fundamentals of the world wool market.

INDICATE THAT the price of wool can vary enormously (from AU$1.00 a kilo to AU$500.00 a kilo). The value of wool depends on the criteria listed on the slide in combination with global supply and demand factors:

- **Type (fleece or pieces)** — The fleece is the wool from the main body of the sheep, which is skirted to remove any dirty pieces of wool around the legs and belly. Fleece wool has a higher value than pieces of wool.
- **Fibre diameter** — The lower the diameter, the higher the value/price.
- **Yield (clean wool content)** — The higher the yield, the higher the value.
- **Vegetable matter** — Vegetable matter (plant material) in wool is a disadvantage, as its removal during processing can be costly.
  - Fibre diameter is the main determinant of the price of wool.
  - Type — some types of vegetable matter (e.g. burrs) are harder to remove than others
  - Quantity — the more vegetable matter, the lower the value of wool.
- **Staple length (mm)** — Both short wools and overly long wool are discounted.
- **Staple strength**:
  - Breaking load (N/tex) — The stronger the staple, the higher the value.
  - Position of break — Staples can break in the base, middle or tip region. Staple with a low mid-break are higher in value, as they give a longer average length in the top.
- **Clean colour** — Brighter wools have a wider range of uses and often receive a higher price.
- **Pesticide residues** — The presence of excessive levels of pesticide residues can reduce the value. Woolgrowers manage pesticides carefully to ensure residual levels are environmentally acceptable.

EXPLAIN THAT the 'style' of wool is also important in determining it value, but cannot be measured objectively and is subjectively assessed by the buyer.

THE AUCTION

- The Australian Wool Exchange estimates that 85% of Australian wool is sold at 'open-cry' auctions.
- Australian wool auctions are held in Sydney, Melbourne and Fremantle.
- Other parts of the 'clip' are sold directly under contract and through electronic sales.
- In other countries (e.g. South Africa, New Zealand) both auctions and direct contracts are also used.

Images courtesy of the Australian Wool Exchange

23 - **Module 1:** Farm to factory

EXPLAIN THAT most Australian woolgrowers (about 85%) sell their wool through the open-cry (live) auction system. Other less popular selling methods include private and electronic sales.

EXPLAIN THAT the wool is put up for auction on a regular basis and processors or their agents bid against other processors for the wool lot. The bid made depends on the buyer's analysis of the value of the wool based on objective measurements and subjective assessment of the sample provided.

POINT OUT Australian wool auctions are held in Sydney, Melbourne and Fremantle.

INDICATE THAT other parts of the 'clip' are sold directly under contract and through electronic sales.

EXPLAIN THAT in other wool-growing countries (e.g. South Africa, New Zealand) both auctions and direct contracts are also used.

DUMPING AND TRANSPORTATION

- Bales may be compressed or 'dumped' to reduce their size.
- Two or three bales may be compressed into a single package.
- Fine wool may be sent 'undumped' to avoid damaging the fibre.
- Bales (dumped and not dumped) are loaded into containers and shipped to various parts of the world.

http://wool.net.au/supply-chain-costs/fleece-lot/dumping---what-is-that/index.html

Image courtesy of Australian Wool Handlers

24 - **Module 1:** Farm to factory

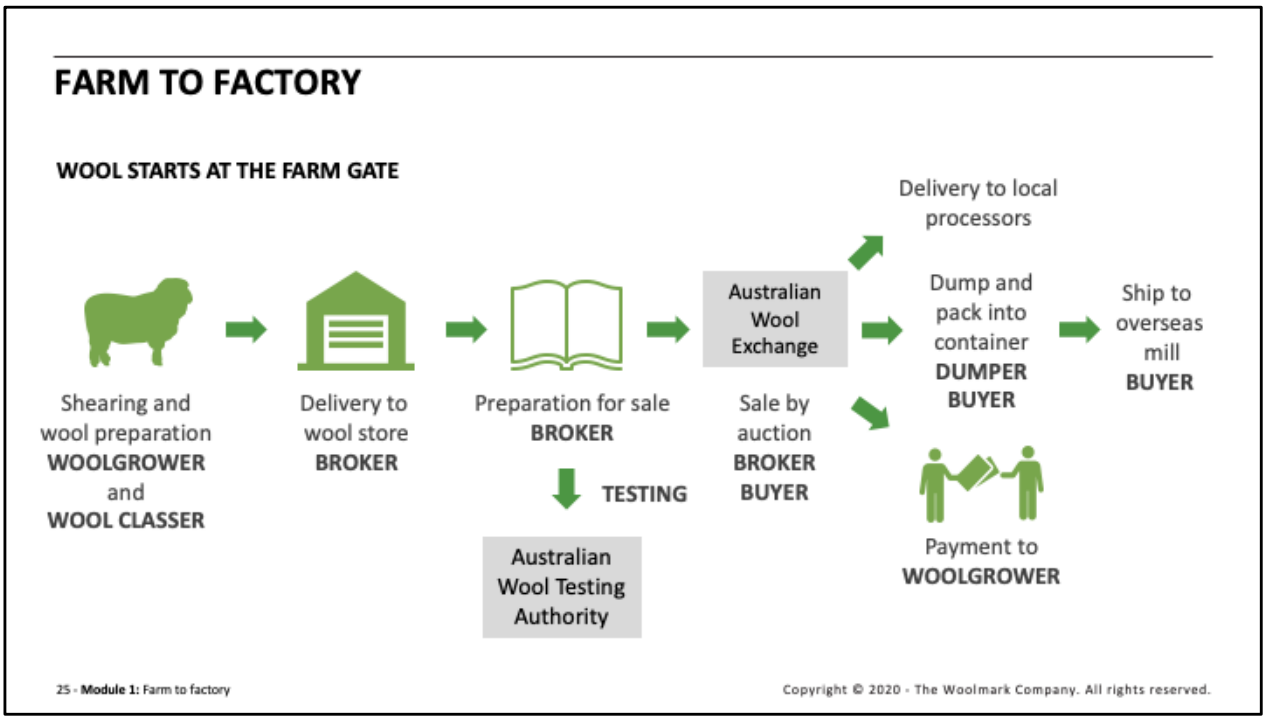
EXPLAIN THAT the last part of the progress from farm to factory is shipping — usually to China, India or Europe.

INDICATE THAT before shipping the bales may be 'dumped' — a process designed to further compress the wool bales into a smaller size so more bales can fit into a shipping container.

EXPLAIN THAT dumped lots may contain single bales, two or three bales bound together (often called a tri-pack). The cost of dumping must be offset against the increased number of bales that can be sent in a single container.

Depending on customer requirements, some wool is shipped uncompressed (not dumped). Often fine wools are sent as uncompressed bales to avoid damaging the fibre. Bales can also be sent uncompressed to avoid mixing wool types in a single dumped package.

The bales (dumped and not dumped) are loaded into containers for shipping by road and sea.



EXPLAIN THAT this slide illustrates the route from farm to factory. The first stages take place in the grower country and involve collection, testing and certification before being sent overseas as greasy wool ready for processing.

REINFORCE THAT greasy wool has to go though many processes to be converted into the final product.

EXPLAIN THAT the Woolmark Company video you are about to play provides an insight into the journey from farm to processor, outlining key features of the wool selling and buying process.

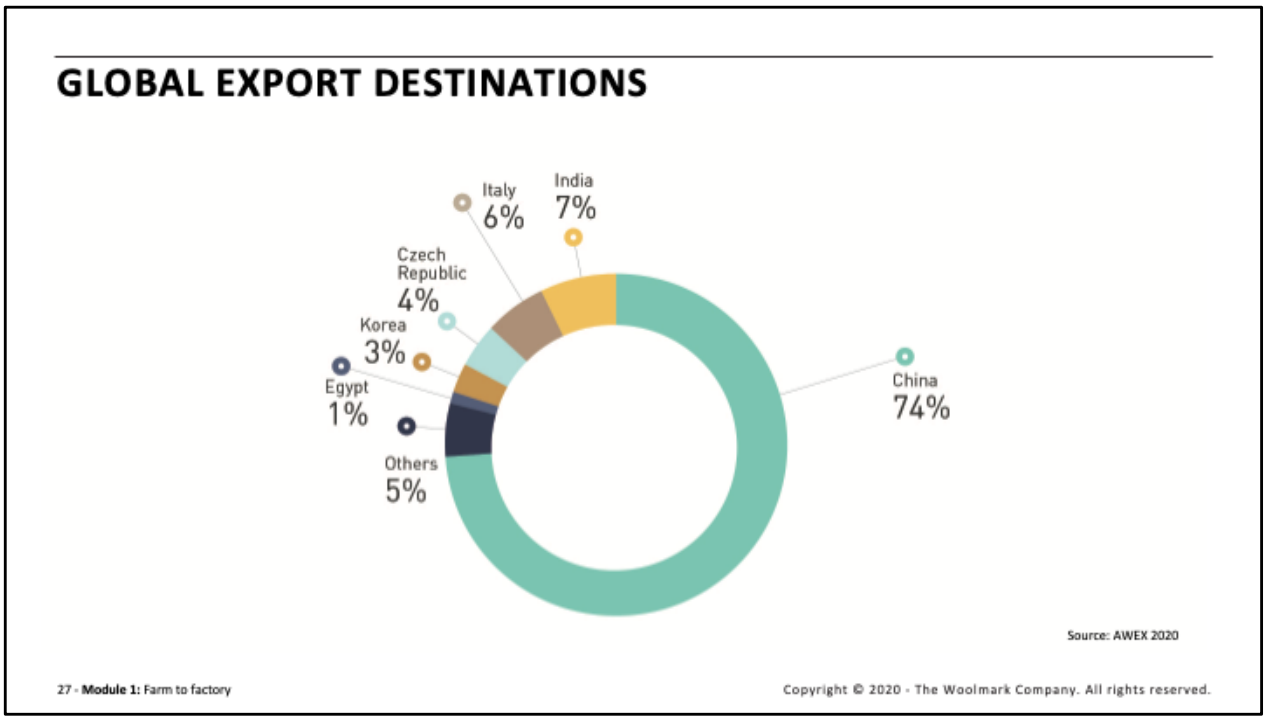
_____

PLAY *video (4:40)*

ASK PARTICIPANTS *to share something new they learned from watching the video.*

PROMPT RESPONSES *if required by asking:*

- *Why did the woolgrower flick the wool staple at the start of the video (15 seconds)? ANSWER: To test for any weakness in the staple.*
- *Why is it important for the woolgrower to receive the results of the testing carried out before sale? ANSWER: To allow the woolgrower to make future management decisions pertaining to wool quality.*
- *What is the name of the industry body that carries out the testing on wool samples? ANSWER: The Australian Wool Testing Authority (AWTA)*
- *What is the name of the industry body that works with wool classers to implement a code of practice? ANSWER: The Australian Wool Exchange (AWEX)*
- *What factors affect a buyer's decision to purchase a wool lot? ANSWER: A combination of test results and visual inspection.*
- *List two factors that are important to wool processors: ANSWER: Appropriate staple length and adequate staple strength.*



CONCLUDE THE module by indicating that in 2018/19 about 75 per cent of Australia's greasy wool was exported to China for processing.

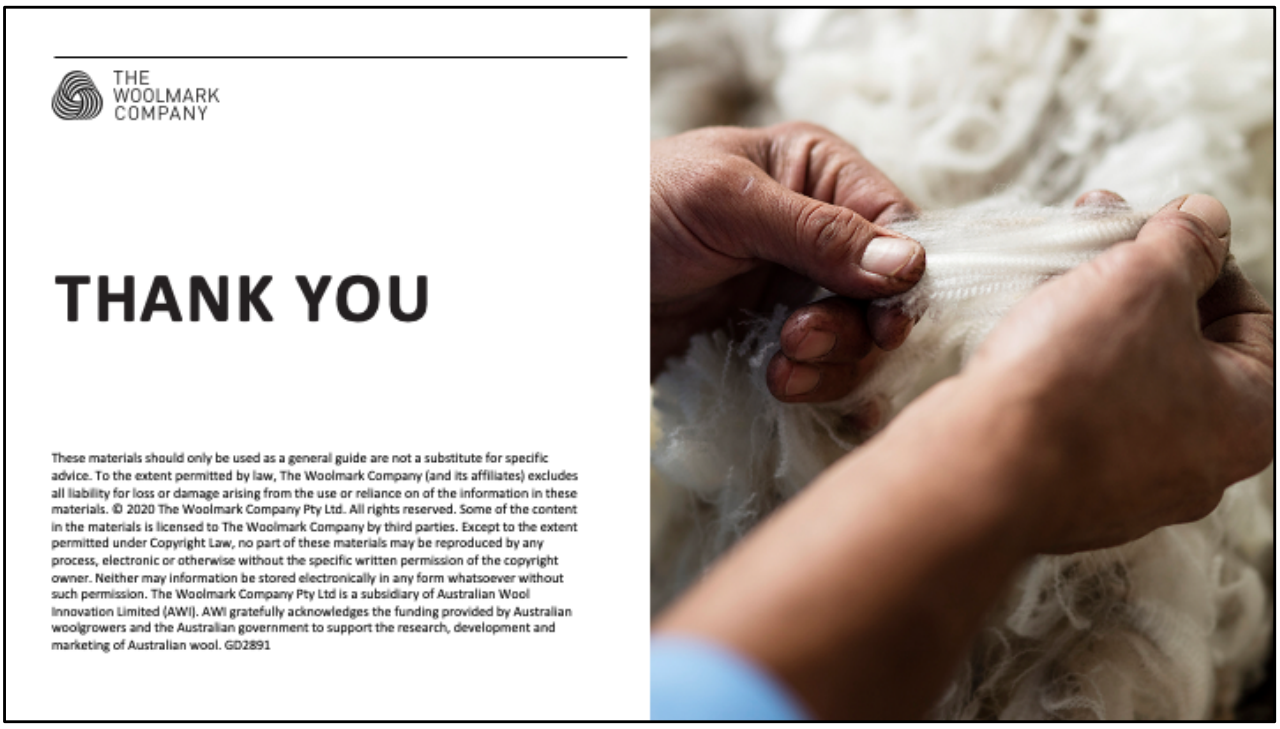
SUMMARY — MODULE 1

- Wool is a natural fibre produced by sheep.
- Different breeds of sheep produce different types of wool.
- Merino sheep produce the finest and softest wool used mainly in fine apparel.
- Wool is graded according its mean fibre diameter and other characteristics.
- From farm to factory, wool is:
  - grown and harvested (by shearing)
  - classified and baled
  - tested and sold
  - dumped and transported.

28 - **Module 1:** Farm to factory

SUMMARISE BY reinforcing:

- Wool is a natural fibre produced by sheep.
- Different breeds of sheep produce different types of wool.
- Merino sheep produce the finest and softest wool used mainly in fine apparel.
- Wool is graded according its mean fibre diameter and other characteristics.
- Fibre diameter is the key determinant of the price paid for wool.
- From farm to factory, wool is:
  - grown and harvested (by shearing)
  - classified and baled
  - tested and sold
  - dumped and transported.



INFORM participants of the time and location for the next lecture — *Module 2: Raw wool measurement*— and ensure they read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 2

THE WOOLMARK COMPANY

RAW WOOL MEASUREMENT

RESOURCES — MODULE 2: RAW WOOL MEASUREMENT

Contained in the *Introduction to wool processing* Demonstration kit you will find the following resources for use as you deliver **Module 2: Raw wool measurement**:

- sample of greasy wool
- sample of low-micron (next-to-skin) wool fabric
- sample of high-micron (heavyweight) wool fabric
- sample of high-frequency crimp wool
- sample of low-frequency crimp wool

Additional resources to be sourced by the facilitator include:

- apple corer
- apple

WELCOME participants to Module 2 of *Introduction to wool processing — Raw wool measurement*.

***ASK** participants if they can recall the reasons for sampling testing raw wool before sale.*

***ALLOW** participants sufficient time to respond.*

***IF NECESSARY** reiterate the following reasons:*

- *to provide objective data on the type and quality of the wool before sale*
- *to complement the subjective appraisal made by the potential buyers*
- *to help buyers determine a price they are prepared to pay.*

EXPLAIN THAT this module covers the methods used to objectively measure the properties of raw wool.

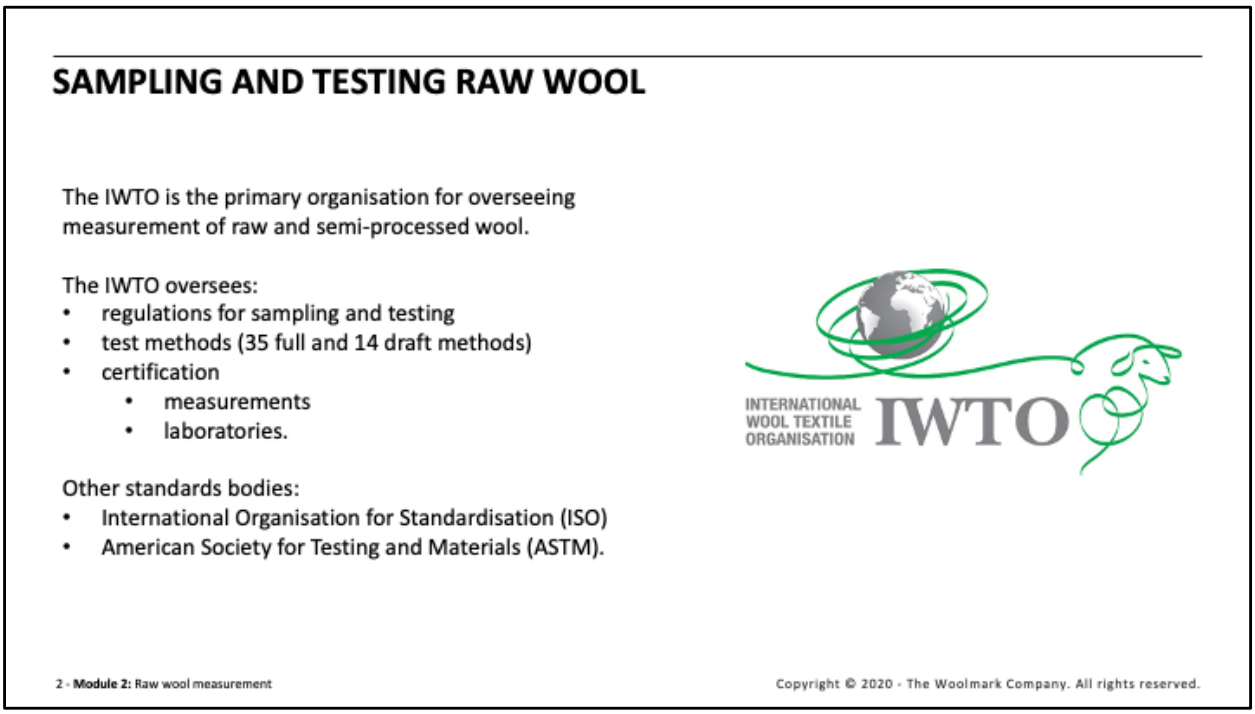
REINFORCE THAT these measurements determine, in large part, the value of the wool and reflect the price paid for wool at auction.

INFORM participants that by the end of this module they will be able to:

- the source of regulations surrounding the sampling and testing of raw wool
- the methods used to sample raw wool:
    - core sampling
    - grab sampling
- the methods used to measure the key properties of raw wool:
    - yield
    - fibre diameter distribution
    - fibre crimp
    - colour
    - residual pesticides
    - staple length and strength
- the source of calibration standards for test instruments.

RESOURCES REQUIRED FOR THIS MODULE

- *Apple (facilitator to supply)*
- *Hand-held apple corer (facilitator to supply)*
- *Sample of greasy wool*
- *Sample of low-micron (next-to-skin) wool fabric*
- *Sample of high-micron (heavyweight) wool fabric*
- *Sample of high-frequency crimp wool*
- *Sample of low-frequency crimp wool*



EXPLAIN THAT sampling is a critical component of any testing and measurement system for raw wool.

INDICATE THAT regulations and test methods developed by the International Wool Textile Organisation (IWTO) are the most widely used for sampling and testing in the international trading of wool.

The IWTO has established regulations for:

- core sampling and testing – samples are taken from the bale using a sampling tube
- grab samples and testing – samples are taken from the bale using a claw, avoiding cutting of the fibres
- staple sampling and testing
- conditioning of raw wool for testing.

EXPLAIN THAT these regulations and test methods form the basis for IWTO certification of:

- specific raw wool measurements
- laboratories that can conduct the measurements.

INDICATE THAT as part of IWTO certification, all methods for which IWTO certificates can be issued are governed by regulations that cover check tests, re-tests, and maximum re-test ranges. There are well-defined methods for dispute resolution.

EXPLAIN THAT the IWTO also oversees agreements used in wool trading and carries out arbitration to resolve any disputes.

NOTE THAT several other national and international organisations have established regulations for sampling and test methods:

- International Organisation for Standardisation (ISO)
- American Society for Testing and Materials (ASTM).

CERTIFICATION OF RESULTS

- Oven-dry mass of wool consignments
- Wool base and vegetable matter (VM) base
- Mean fibre diameter (MFD)
- Fibre diameter distribution
- Staple length and strength
- Colour

Image Courtesy of AWTA

3 - **Module 2:** Raw wool measurement

EXPLAIN THAT the use of IWTO certificates in the trading of raw wool is now widespread in the wool trade.

Results may only be certified for tests with full regulations for sampling, check testing and re-testing:

- oven-dry mass of raw wool, scoured, or carbonised wool consignments
- wool base and vegetable matter (VM) base of raw wool
- mean fibre diameter (MFD) using airflow, OFDA or Laserscan
- fibre diameter distribution of diameter by OFDA or Laserscan
- staple length and strength of raw wool
- the base and 'as-is' colour of raw wool.

EXPLAIN THAT other measurements commonly made as part of the testing procedure can only be 'reported' - not 'certified', these include:

- mean fibre curvature
- comfort factor (% fibres =<30µm)
- variation in staple strength
- fibre length distribution in sliver.

'Reported' results can only be included in contracts where parties have agreed to their use.

MEASURABLE FIBRE PROPERTIES

RAW WOOL PROPERTY	IMPORTANCE	PROCESSING	PRODUCT	IMPACT
Yield	4			Amount of wool
Fibre diameter	4	X	X	Product weight and handle
Vegetable matter	4	X		Waste
Staple length	4	X		Affects worsted or woollen processing
Staple strength	4	X		Waste
Colour	4		X	Colour of final product
Coloured fibre	4		X	Seen as fault
Diameter variation	2	X	X	Affects yarn production
Length variation	2	X		Affects yarn production
Cots	2	X		Tangled wool
Crimp	2	X	X	Affects bulk of yarn
Tip characteristics	1	X	X	Affects dyeing

4 - **Module 2:** Raw wool measurement

EXPLAIN THAT wool buyers use the raw wool properties outlined on the slide to predict:

- the amount of clean wool fibre in a bale (i.e. yield)
- the potential performance of the wool during processing,
- the quality characteristics of the final products.

INDICATE THAT these characteristics are important in determining the value of the wool in the following ways:

- Yield is a measure of the amount of 'clean' wool fibre in the sample of raw wool, distinguishing the fibre from the impurities in the raw material, such as wool wax, dirt and vegetable matter.
- Fibre diameter is the most important fibre property affecting price paid. Fibre diameter affects processing characteristics and spinning limits as well as the weight, appearance, handle and performance of the final product.
- The amount and type of vegetable matter also affects processing and processing yield.
- Staple length affects processing characteristics, spinning performance and performance of the final product.
- Staple strength and position of break (POB) affect processing performance and the amount of waste created — particularly during worsted processing.
- Colour, due to yellowing or the presence of dark fibre, affects the appearance of the wool and the range of colours that can be used in the final products (e.g. yellow wools cannot be dyed pastel shades).

EXPLAIN THAT less important, but still measured, are:

- the variability of the fibre diameter, which can affect spinning limits and product handle
- cots (heavily tangled regions of the wool), which affect processing and processing yield
- staple length variability, which affects spinning performance
- fibre crimp, which affects processing performance as well as the bulkiness and performance of the final product — particularly knitted products
- damage to the staple tips, which can affect processing and dyeing characteristics of the fibre.

DEMONSTRATION: STAPLE LENGTH, STRENGTH, CRIMP AND DIAMETER

Resources required:

- *Sample of greasy (raw) wool*

***ASK** a volunteer to hold the sample so the group can clearly see a staple. Encourage the volunteer to describe the:*

- *length*
- *crimp (waviness)*
- *fibre diameter*

***NOTE** that diameter is difficult assess by eye and requires considerable experience or computer-generated assessment.*

***ASK** the volunteer to stretch the staple under force.*
***REINFORCE** that staple strength is critical to waste reduction during processing.*

EXPLAIN THAT core samples are taken from wool bales using a rotating tube, or series of tubes each with a cutting edge. The tubes are driven into the bale cutting 'cores' of wool.

DEMONSTRATION: CORE SAMPLING

Resources required:

- *apple*
- *hand-held apple corer*

***REMOVE** the apple core using the hand-held corer while explaining the process of taking a wool sample from a bale is, in principle, the same.*

POINT OUT that the coring method for wool sampling may be manually operated or power driven. Most commercial test laboratories use automated equipment for core sampling.

***PLAY** the two-minute video as you explain the footage shows core sampling being undertaken with bales of raw (greasy) wool.*

***WHILE PLAYING** the video note:*

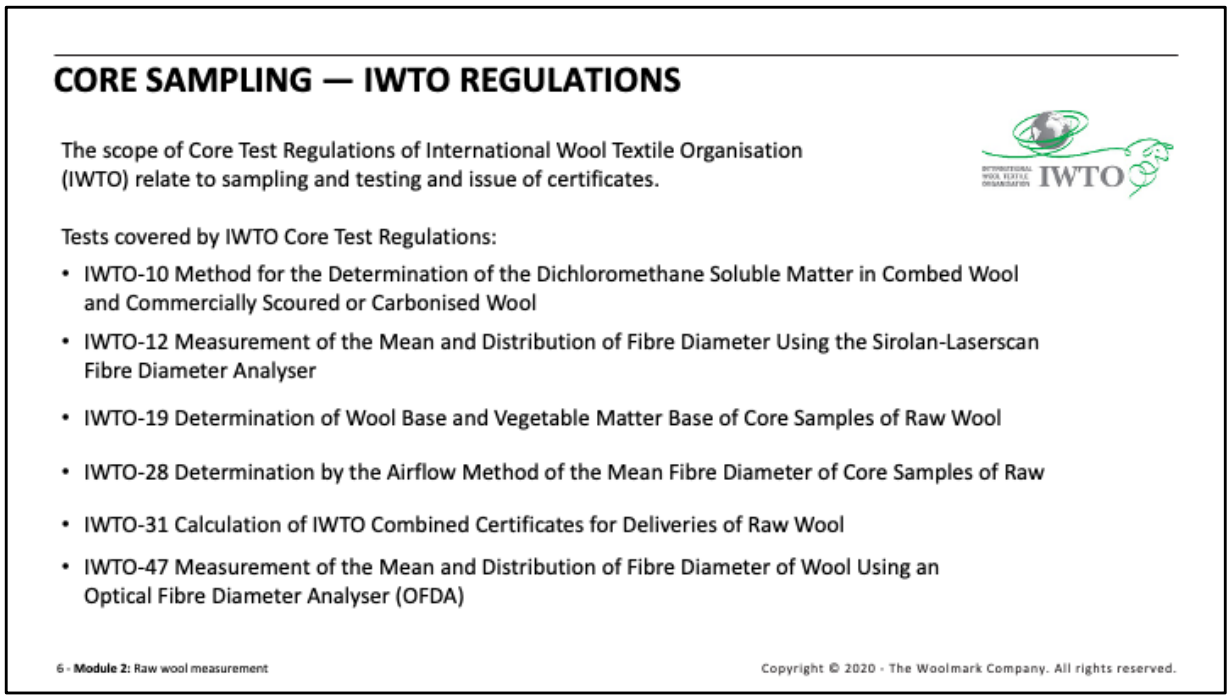
- *the bale is loaded into the frame with the bottom of the bale is facing upwards (~0:16 seconds)*
- *the bale being penetrated by the coring tubes, which take the sample (~ 0:22 –0:26 seconds)*
- *the lowering and removal of the bale (~0:30 – 0:32 seconds), noting that the activity is computer controlled and the sample of each bale is recorded*
- *the bale is weighed and the weight recorded (~1:21 seconds)*
- *the sequence is repeated — make note of the number of coring tubes (~1:39 seconds).*

EXPLAIN THAT on withdrawal of the tube, the cores are extracted into a sample container, without loss of material and without undue exposure to the atmosphere. The sample container should not allow a significant change in the moisture content of the sample during storage before weighing.

NOTE THAT core sampling of wool bales was first accepted during the 1950s as the appropriate method for commercial sampling of wool bales to test the yield of clean wool from raw wool lots.

Video courtesy of AWTA

Opinions expressed in this video do not necessarily reflect the opinions of The Woolmark Company Pty Ltd or its affiliates. To the extent permitted by law, we exclude all liability (however arising) for any loss or damage arising from or in connection with the use of, or reliance on, the opinions and information in this video.



EXPLAIN THAT the IWTO regulations surrounding the commercial core testing of wool was first adopted during 1968. A number of modifications to the regulations have been adopted over the intervening years.

The IWTO Core Test Regulations define the manner and frequency of core sampling of wool lots. For manual pressure coring, or power-driven rotary coring equipment, the coring tube must be 47% of the length of the bales and penetrate between 47–50% of the bale. When automated power-operated pressure coring machines are used, a core from 93% or more of the length of a bale is taken.

The mass of cores taken is not less than 150g for greasy wool for each 12,000kg, or part thereof, of greasy wool. For one, two or three bale lots only, the mass of cores needs to be sufficient to provide only two such sub-samples.

EXPLAIN THAT every bale in the test lot is core sampled.

The minimum number of cores (K) to be taken per bale to produce a sample having the required precision is estimated from the following formula:

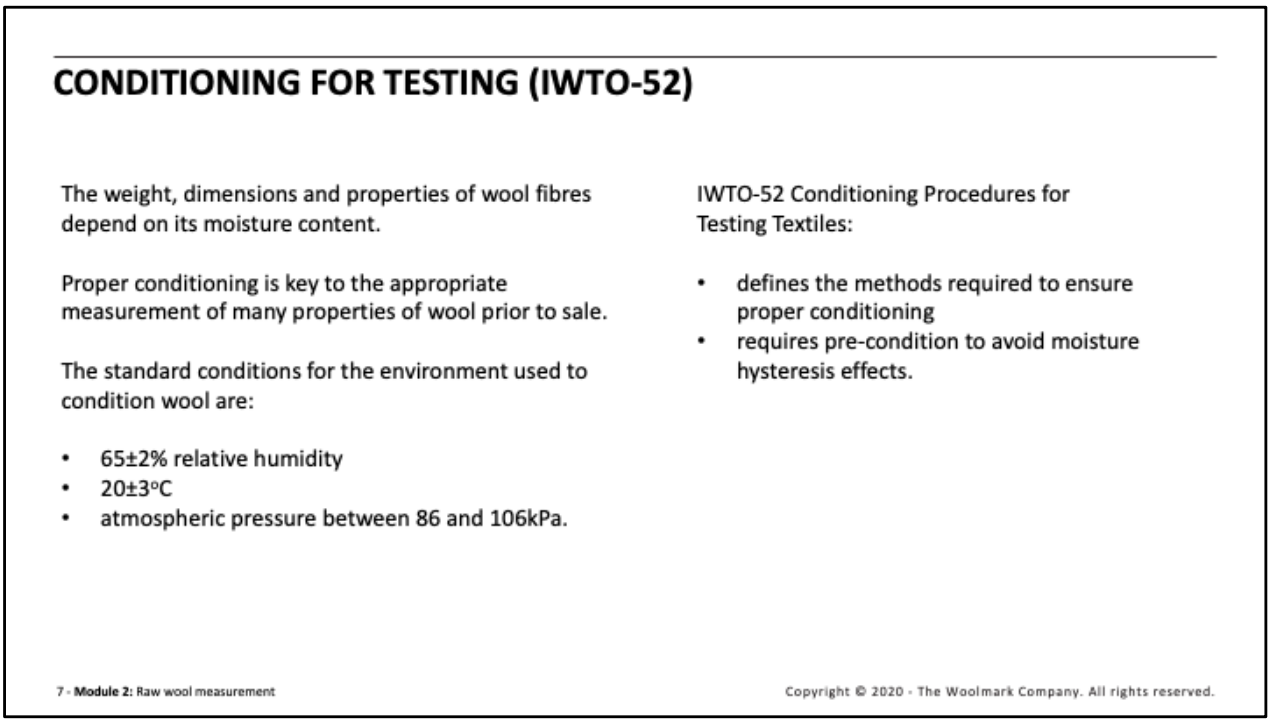
$$K = (1.96 * SD)^2 / N$$

Where,

- N = number of bales in the lot.
- SD = standard deviation of clean wool content of cores within bales. For machine coring SD ~ 2 and for manual coring SD ~ 3. For some specialty superfine wools SD ~ 1.3.

NOTE THAT these regulations are used in conjunction with the IWTO test methods listed on the slide.

The notes on the slide are derived from IWTO Core Test Regulations and reproduced with permission of the IWTO.



REMIND PARTICIPANTS that wool fibres adsorb and desorb moisture to remain in equilibrium with the surrounding air. Wool can absorb (and desorb) more moisture than most other major apparel fibres.

REINFORCE THAT the weight, dimensions and properties of wool fibres depend on its moisture content.

EXPLAIN THAT prior to testing it is necessary to control the moisture content of the test samples so accurate, reproducible results can be obtained.

This is done by ensuring the fibres are in equilibrium with a standardised environment. This process is called 'conditioning' the sample. Proper conditioning is key to the appropriate measurement of many properties of wool prior to sale.

EXPLAIN THAT the standard conditions for the environment used to condition wool are:

- 65±2% relative humidity (RH)
- 20±3°C
- atmospheric pressure between 86 and 106kPa.

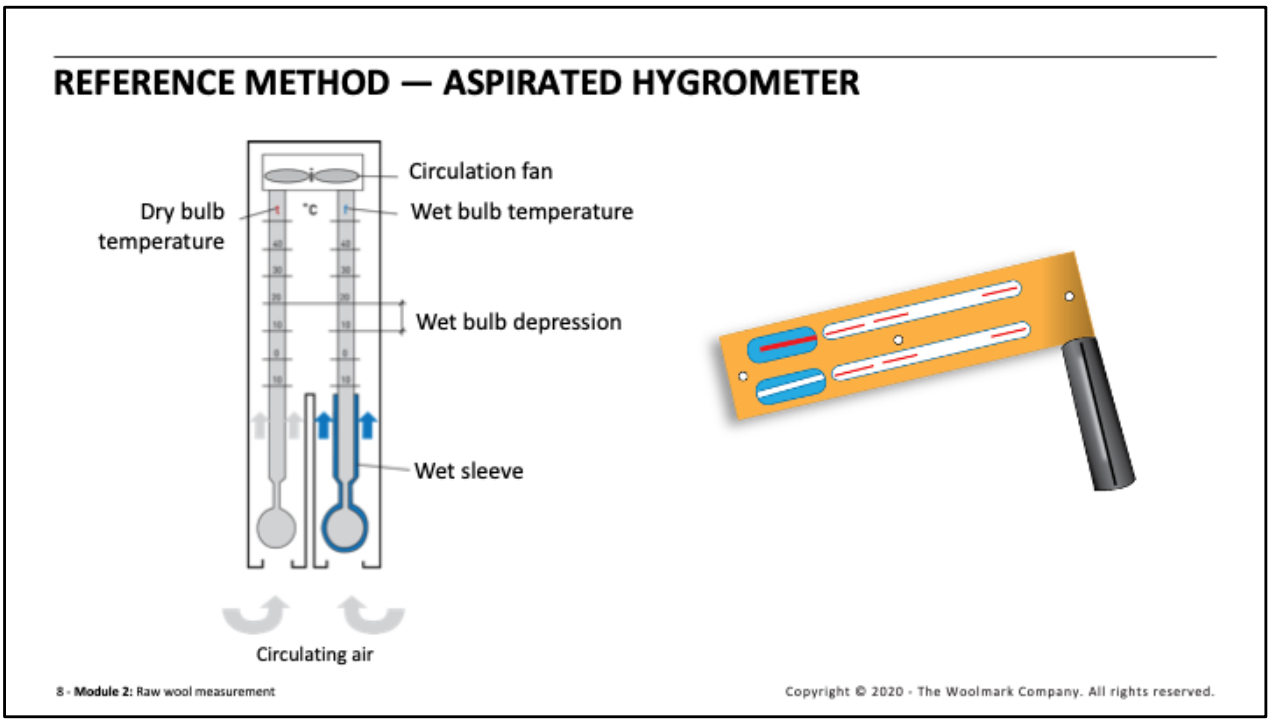
INDICATE THAT as prescribed by IWTO-52, moisture equilibrium is established following:

- two successive weighings
- an interval of 15 minutes
- a change in mass of <0.1% of the last mass recorded.

EXPLAIN THAT because the adsorption of moisture by wool has a hysteresis (i.e. different values between adsorption and desorption), samples are normally conditioned from the dry side. To ensure this, samples are normally dried to about 5% moisture content prior to conditioning in the standard environment.

EXPLAIN THAT samples must be left to condition for a time consistent with, or greater than, the time required to reach equilibrium before they are tested.

INDICATE THAT fibre should be conditioned as a layer of uniform density <20kg/m^2 spread in layers on open wire shelves.



EXPLAIN THAT IWTO-52 also prescribes the requirements of conditioning spaces and for test laboratories.

Many laboratories use automated air-conditioning systems, based on the readings from calibrated hygrometers. These must be re-calibrated annually.

EXPLAIN THAT aspirated hygrometers (as shown on the slide) may also be used to ensure the conditions of testing are met.

INDICATE THAT laboratories must also continuously measure the testing atmosphere with a suitably calibrated recording device.

EXPLAIN THAT the IWTO prescribes four conditioning routines:

- the standard method, which must be used for disputes
- the method for relatively dry materials
- a method for high-volume testing
- a method for rapid conditioning.

INDICATE THAT the standard method requires a pre-conditioning step in which the sample is first dried in a heated atmosphere of less than 15% relative humidity (achieved at >50^{o}C in an oven).

MEASUREMENTS MADE ON CORE SAMPLES

FIBRE CHARACTERISTICS	IWTO METHOD	EQUIPMENT USED
Wool base	19	
Vegetable matter base	19	
Mean fibre diameter	8	Projection microscope
	12	Laserscan
	28	Airflow
	47	OFDA
Fibre diameter distribution	8	Projection microscope
	12	Laserscan
	47	OFDA
Mean fibre curvature	12	Laserscan
	47	OFDA
Colour	56	
Residual pesticides	DTM-59	

As sampled

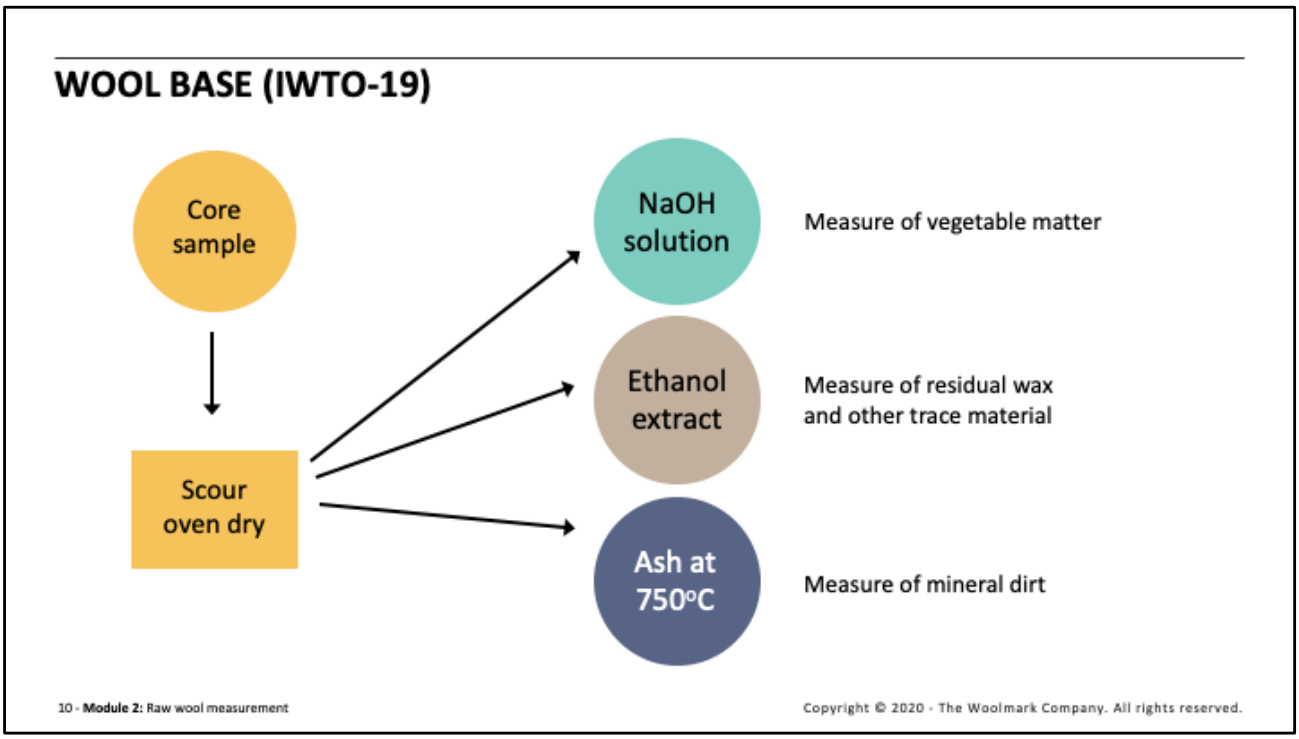
Randomised

9 - **Module 2:** Raw wool measurement

EXPLAIN THAT after core samples are collected, they are placed in a large container and randomised mechanically, or using strong air currents, so all the cores are broken up and the wool is suitably blended.

INDICATE THAT the following IWTO-prescribed tests are normally carried out on the raw wool core sample:

- Wool base (yield) and vegetable matter content (IWTO-19)
- Mean fibre diameter (IWTO-28 air flow method)
- Mean fibre diameter and distribution:
    - IWTO-08 Projection microscope
    - IWTO-12 (Laserscan)
    - IWTO-47 (OFDA)
- Mean fibre curvature
    - IWTO-12 (Laserscan)
    - IWTO-47 (OFDA)
- Colour (IWTO-56)
- Residual pesticides (IWTO draft test method DTM-59)



EXPLAIN THAT wool base is the contaminant-free dry mass of wool expressed as a percentage of the mass of the sample.

It is defined as the 'oven dry' mass of wool, which is determined using IWTO-19.

INDICATE THAT representative subsamples of the cores are weighed, scoured under specified conditions (unless scoured wool is being tested), dried and re-weighed.

EXPLAIN THE process as outlined below

Scouring

- A solution containing 0.15–0.3% of Na_2CO_3 and 0.05–0.1% of soap is used at 25°C.
- Addition of a lime-sequestering polyphosphate-type 'water conditioner' is recommended.
- A 75 micrometre sieve is used to prevent loss of wool fibre or vegetable matter (apart from that which passes through with the liquors) during scouring and rinsing.
- The scoured product should contain no more than 5% matter extractable with ethyl alcohol.

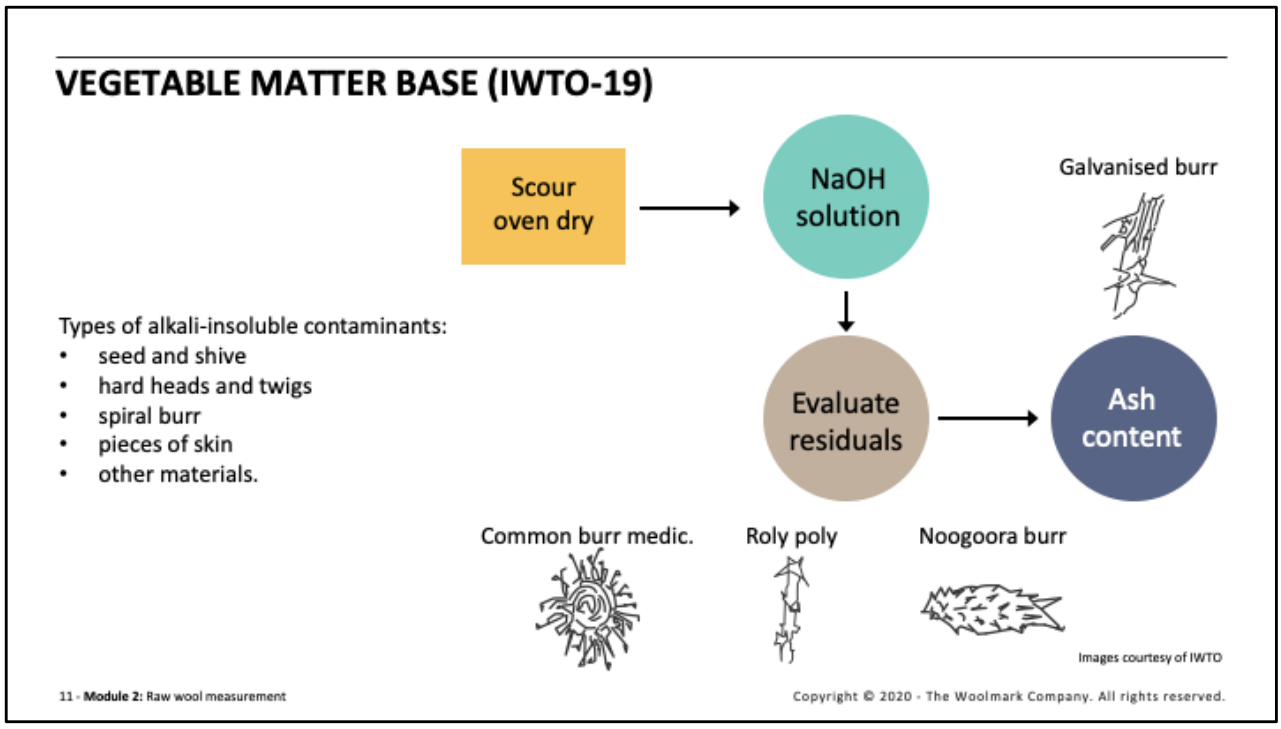
Oven drying

Test specimens are then taken from each scoured subsample for the separate determination of:

- vegetable matter (which is normally expressed as Vegetable Matter Base) using a solution of NaOH (caustic soda)
- ethyl alcohol extractives
- ash.

EXPLAIN THAT the amounts of non-wool constituents are used to determine the oven dry mass of wool fibres free from all impurities.

Text Derived from IWTO-19 with permission of IWTO



INDICATE THAT vegetable matter base is also determined using IWTO-19.

EXPLAIN THAT the wool is dissolved using boiling 10% sodium hydroxide (NaOH — caustic soda) solution for three minutes. The alkali-insoluble residue is then rinsed in a sieve by spraying with clean water for at least three minutes.

The residue is dried at 110 ± 2°C.

The total oven-dry alkali-insoluble residue is weighed to 0.001g.

NOTE THAT the types of alkali-insoluble residues include:

- seed and shive
- hard heads and twigs
- spiral burr
- pieces of skin
- other materials.

EXPLAIN THAT the determination of wool and vegetable matter base is a labour-intensive process requiring several operations and measurements.

POINT OUT that during the 1970s a device called a 'Vegemat' was developed in Australia to automate the determination of the vegetable matter base. The use of this method is allowed in IWTO-19.

EXPLAIN THAT after the vegetable matter has been separated by dissolution of the wool in a sodium hydroxide solution, it is weighed.

Where the total insoluble residue exceeds 0.5g, all the different types of residue present must be separated and weighed.

***PLAY** the 16 second video as you explain that the footage shows a technician weighing samples of vegetable matter.*

EXPLAIN THAT the hard heads and twigs are normally determined separately, as hard heads and twig base.

QUOTE FROM IWTO-19:

- *'Hard Heads' are*
    - *Ring burrs (Sida platycalyx),*
    - *Noogoora burrs (Xanthium chinense)*
    - *Bathurst burrs (Xanthium spinosum)*
    - *Similar burrs of a bean-like or woody character covered in readily removable spines.*
- *'Twigs' are small pieces of stick, woody leaf stalks and similar woody material*.

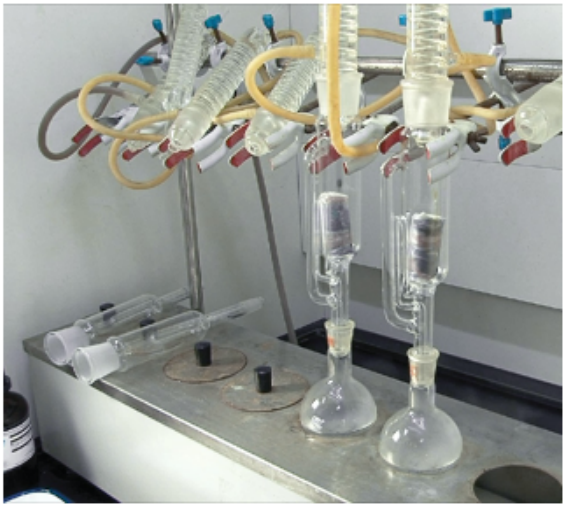
EXPLAIN THAT hard heads and twigs do not contribute to a loss of wool during processing.

ETHANOL EXTRACTABLE MATERIAL (IWTO-19)

Uses test specimen from the laboratory scoured sample.

The testing method is as follows:

- Insert test specimen in a thimble.
- Extract over 20 siphonings.
- Evaporate alcohol in round bottom flask.
- Determine weights of extractable materials.



13 - **Module 2:** Raw wool measurement

EXPLAIN THAT the ethanol-extractable material is also measured using IWTO-19, with a Soxhlet extraction technique.

OUTLINE THE process as follows:

- A test specimen of laboratory-scoured wool is:
    - inserted into a thimble
    - extracted with ethanol over 20 siphonings.
- The alcohol used in extraction is evaporated from the bottom flask.
- The weight of extractable materials is determined by the difference in weight of the flask before and after extraction.

EXPLAIN THAT near infrared (NIR) instruments have been proposed for the replacement of Soxhlet extraction of residual alcohol-extractables. This method forms Appendix K of IWTO-19. The method is indirect and must be calibrated against Soxhlet extraction. The NIR method is most widely used in Australia.

DETERMINATION OF ASH CONTENT (IWTO-19)

- The test specimens are taken from the laboratory scoured sample.
- The oven dry mass is measured.
- The specimen is charred and ashed in a ventilated furnace.
- The mass of residual material is determined.

Images courtesy of AWTA

Specimens prior to entry in Ashing Oven

Ashing Oven showing specimens

14 - **Module 2:** Raw wool measurement

EXPLAIN THAT the determination of ash content is also carried out using IWTO-19, as follows:

- The test specimens are taken from the laboratory-scoured sample.
- The oven dry mass of the specimen is determined.
- The specimen is then charred and ashed in a ventilated furnace at 750ºC (700-800ºC).
- The mass of residual material is determined.

NOTE THAT near infrared (NIR) is also used widely to measure residual ash. The method is described in Appendix K of IWTO-19. The method is calibrated against the oven-ashing method described above.

CALCULATION OF WOOL BASE AND VEGETABLE MATTER BASE

The wool base (B) of a single sub-sample is:

$$B_i = \frac{P_i\,(100 - E_i - A_i - T_i)}{W_i}\ \%$$

The vegetable matter base (V) of a single sub-sample is:

$$V_i = \frac{100}{M_i} \sum_{j=1}^{3} f_j\ m_j \cdot \left(1 - \frac{A_T}{m}\right)$$

The results from single sub-sample are combined as follows:

$$B = \frac{W_B}{W} \cdot \frac{\sum B_i W_i}{\sum W_i}\ \%$$

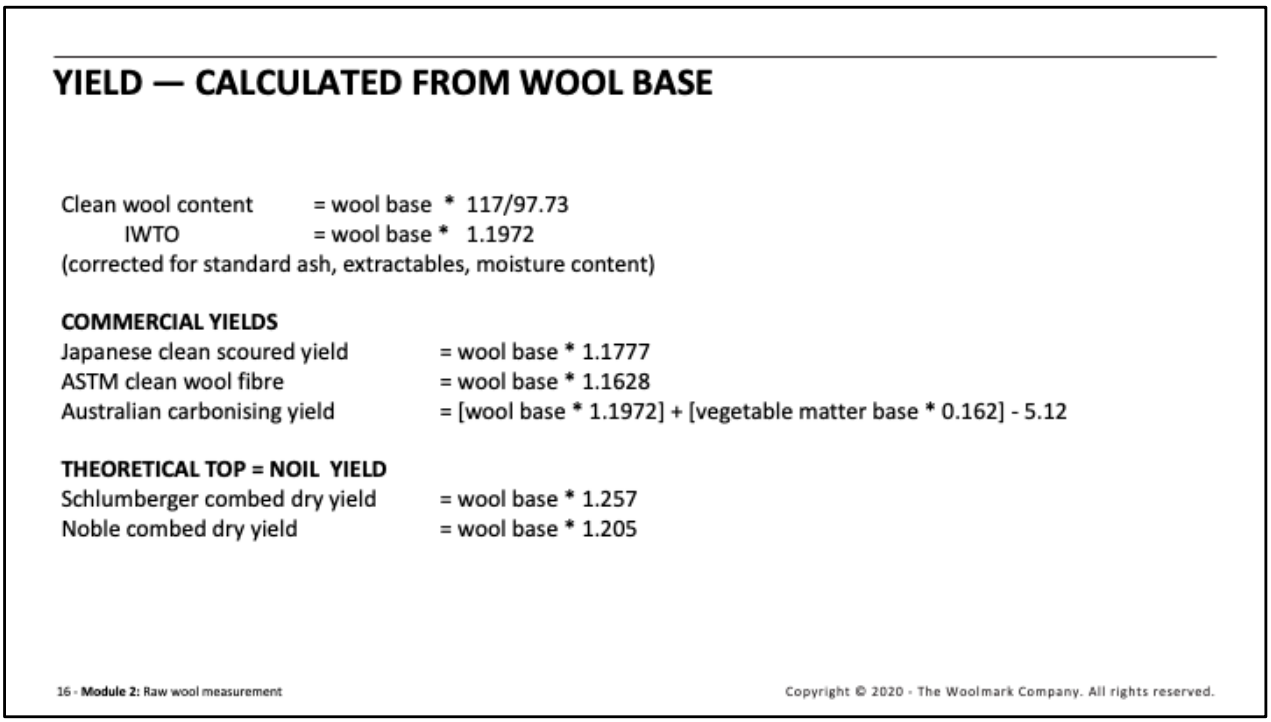
$$V = \frac{W_B}{W} \cdot \frac{\sum P_i V_i}{\sum W_i}\ \%$$

Where:
W = mass of sub-sample
P = oven-dried mass of scoured sub-sample
E = ethyl alcohol extractable material (as %)
A = ash (as %)
T = alkali insoluble impurities (as %)
M = oven-dry alkali-insoluble material
m = mass of different types of vegetable matter
f = correction factors

15 - **Module 2:** Raw wool measurement

EXPLAIN THAT the equations used to determine certified values for the wool base and vegetable matter base are shown on the slide.

NOTE THAT these equations are integral to all wool buying and top-making operations.



EXPLAIN THAT as stated earlier, yield is an important determinant of the value of greasy wool. Wool with a high yield attracts a higher price than wool with a low yield (all else being equal).

NOTE THAT for historical reasons, yield is calculated from the wool base and vegetable matter base in different ways in different countries. This reflects the differences in the types of wool used and the processing conditions in different countries in former times. Many of these differences have been reduced as the extent of globalisation of the wool industry has grown.

INDICATE THAT common yield measures include:

- Japanese clean scoured yield
- ASTM clean wool fibre yield
- Australian carbonising yield
- Schlumberger combed dry yield
- Noble combed dry yield. .

FIBRE DIAMETER TESTING

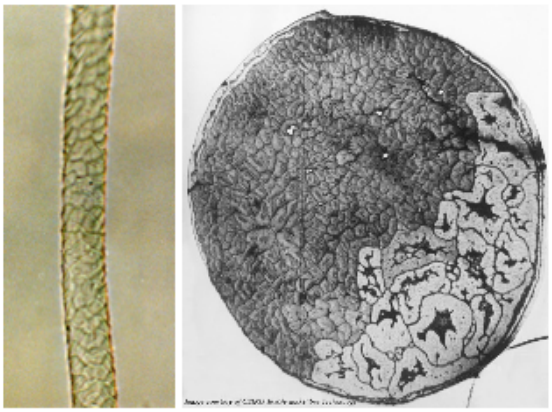
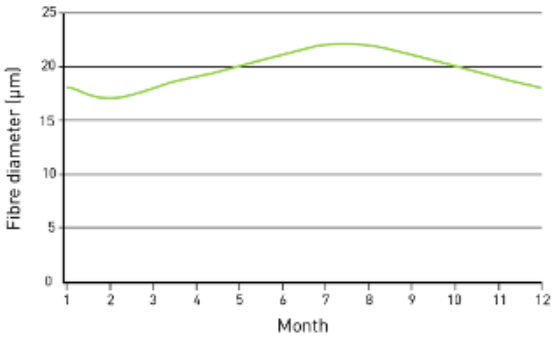


Image courtesy of DPIRDT



17 - **Module 2:** Raw wool measurement

EXPLAIN THAT as mentioned, fibre diameter is the key raw wool parameter determining its value. Statistical analysis of sale lots has determined that, for fine wools, fibre diameter determines more than 50% of the sale price of raw wool.

INIDCATE THAT the IWTO describes a number of methods for measuring the mean fibre diameter (MFD) of raw wool (IWTO-08, -12, -28 and -47) and you will discuss each method in the following slides.

NOTE: fibre diameter is measured in micro-metres (µm) or 'micron'.

EXPLAIN THAT as illustrated on the slide (from left to right) there are challenges when measuring the diameter of wool fibres:

- The scales along the wool fibre create local variations in diameter.
- The cross-section of the fibre is not circular, nor is the fibre cylindrical.
- The diameter also varies along the length of the fibre according to growing conditions.

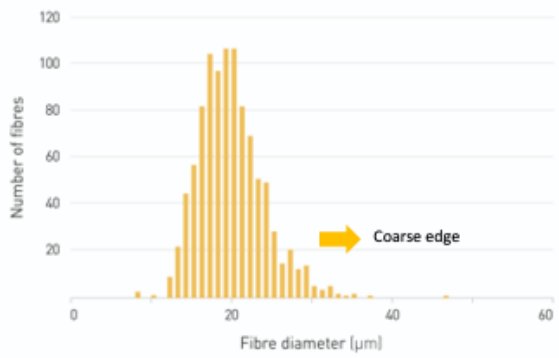
FIBRE DIAMETER DISTRIBUTION

Expressed as:

- variance
- standard deviation (SD)
- coefficient of variation (CVD)

$$CVD = \frac{100 * SD}{MFD}$$

- coarse edge
- comfort factor



Wool fibre diameter distribution

18 - **Module 2:** Raw wool measurement

EXPLAIN THAT in reality the diameter of wool fibres, even from a single sheep, is not constant nor does it follow a normal distribution. The distribution is skewed to the right (e.g. broader fibres — as shown in the slide). Nevertheless, the statistics for a normal distribution are applied (variance etc.).

EXPLAIN THAT when the wool of many sheep and different farms is combined, the distribution of the fibre diameters normally increases. The variance of sale lots is normally greater than for individual sheep.

In general terms, and all else being equal, the lower the coefficient of variation of fibre diameter (CVD) of the wool lots:

- the easier the wool is to process
- the finer or stronger the yarn that can be produced
- the more valuable the wool.

EXPLAIN THAT the term 'coarse edge' is used to describe the amount of fibre at the broad end of the diameter distribution profile.

***NOTE**: The number of fibres <30µm within the test sample (expressed as a percentage) is called the 'comfort factor'.*

EXPLAIN THAT comfort factor is related to the 'prickle sensation' associated with products made from broad wool types is associated with fibres >30µm (>28um for woven products), which can activate pain receptors in the skin. In fine wools, normally used in products worn next to the skin, for a given mean fibre diameter, the number of fibres <30µm is lower in wool with a low CVD than in wool with a higher CVD.

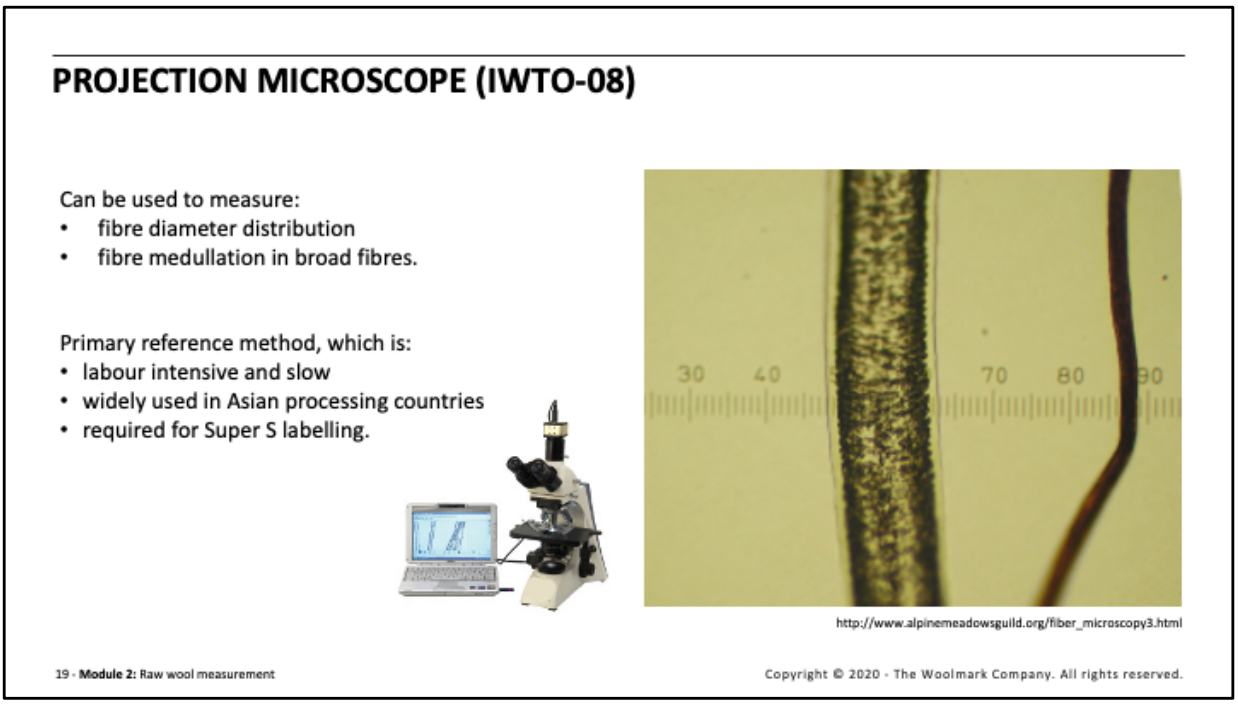
***ASK** participants if they can recall wearing a wool product they might describe as 'itchy'?*

ACKNOWLEDGE RESPONSES

***HAND OUT** the samples of the next-to-skin wool fabric and the fabric made from broad wool.*

***EXPLAIN THAT** the two samples come from two different breeds of sheep.*

As participants explore the samples, reinforce that many breeds of sheep around the world produce different types of wool used for various purposes.



EXPLAIN THAT projection microscopy (IWTO-08) has been used extensively to measure fibre diameter since the 1930s.

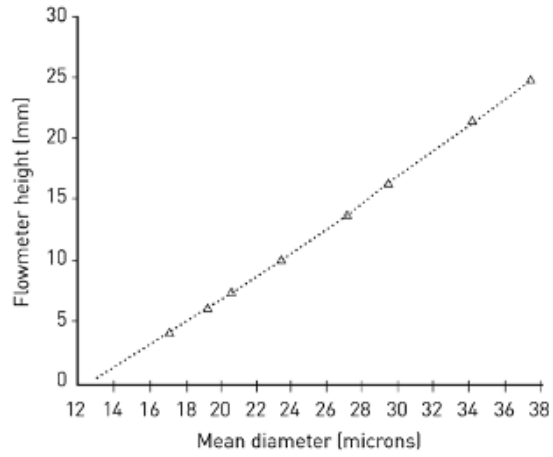
OUTLINE THAT the method:

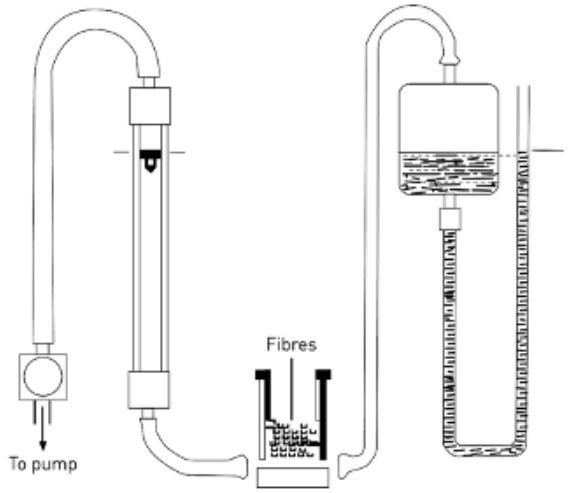
- measures fibre diameter distribution
- can be used to determine the extent of fibre medullation. Medullation describes hollow cortical cells within the wool fibre and is described in the course of the Woolmark Wool Education course called *Wool fibre science*
- is a direct measurement, so is a primary reference method
- is labour intensive and slow (300 measurements per hour)
- is still widely used, particularly in Asian processing countries.

EXPLAIN THAT the use of video cameras and image analysis software has reduced the labour involved in measuring individual fibres

EXPLAIN THAT the 'Super S' labelling scheme for final products, adopted by IWTO, prescribes the use of microscopic techniques for measuring mean fibre diameter (MFD).

AIRFLOW (IWTO-28)





The Shirley analyser draws air through the test specimen

Images courtesy of IWTO

EXPLAIN THAT the airflow test method (IWTO-28) also can be used to measure fibre diameter.

EXPLAIN THAT when air is forced through a mass of fibres packed in a chamber, the airflow is determined by:

- the pressure of the air
- the total surface area of the fibres. (Kozeny 1931).

INDICATE THAT the surface area of circular fibres is determined by the diameter. Wool fibres are not circular in cross-section and have scales. However, to a first approximation, the airflow through of a mass of fibres is inversely proportional to the mean fibre diameter.

EXPLAIN THAT the airflow method was developed during the 1940s and is simple and rapid.

EXPLAIN THAT the method is as follows:

- A subsample is taken from the scoured core sample.
- The subsample is randomised using the Shirley analyser.
- The apparatus draws air through the test specimen of known mass taken from of the randomised scoured subsample of wool.

EXPLAIN THAT there are two designs for airflow instruments:

- those that operate at constant pressure
- those that measure the pressure to achieve constant airflow.

INDICATE THAT the airflow at a specific pressure is normally measured.

EXPLAIN THAT with either instrument the apparatus must first be calibrated, using fibres of known mean diameter. The instruments are normally calibrated against wool tested by projection microscope.

EXPLAIN THAT the IWTO requires the use of the following quadratic equation to determine calibration:

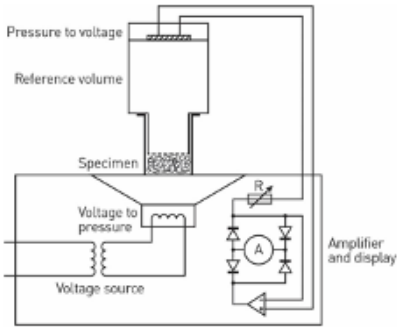
- Flow = $k1 + k2*d + k3*d^2$

d= fibre diameter
k = constant

POINT OUT that airflow does not measure diameter distribution characteristics — only mean fibre diameter.

SONIC FIBRE FINENESS TEST

- Measures mean fibre diameter (not fibre diameter distribution).
- Principle analogous to airflow (uses oscillating pressure wave).
- Reduction in amplitude of sound (pressure) wave is a measure of mean fibre diameter.



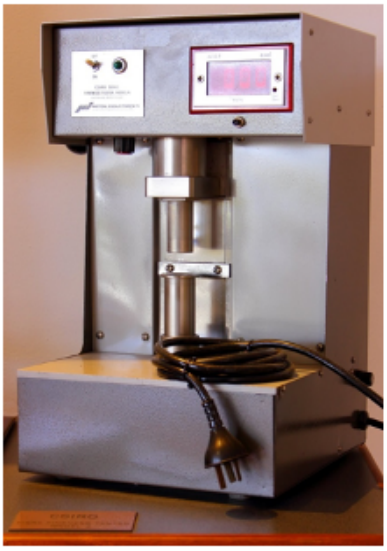


Image courtesy of AWTA Ltd

21 - **Module 2:** Raw wool measurement

EXPLAIN THAT a variation on the concept of airflow is used in the sonic fibre fineness test instrument. The mean fibre diameter is measured from the adsorption of sound or pressure waves in air by the test specimen.

The instrument uses an oscillating pressure wave of air through the specimen. The principle of the mechanism is analogous to that of the airflow instrument.

EXPLAIN THAT the airflow instrument uses a unidirectional flow of air, whereas the sonic instrument uses an oscillating airflow caused by an oscillating pressure wave.

The reduction in the amplitude of the oscillating pressure wave as it passes though the wool is analogous to the pressure drop in the airflow machine.

EXPLAIN THAT an instrument based on this principle was developed by CSIRO (Australia) during the late 1960s to measure fibre diameter.

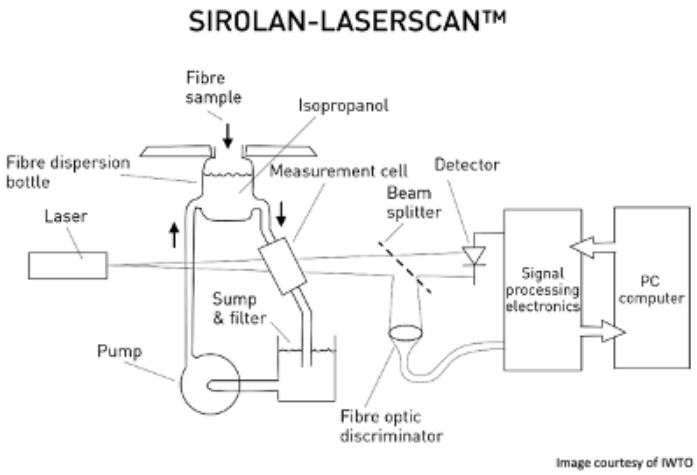
- A low frequency audio signal is passed though a pre-opened wool specimen of fixed weight.
- The wool specimen adsorbs the pressure to an extent dependent on the diameter of the fibres.
- The transmitted signal is converted to a DC voltage which is a measure of the mean fibre diameter.

The instrument was shown to correlate well with airflow measurements.

NOTE THAT a standard method exists in Australia and New Zealand for the use of the sonic fibre fineness instrument. The method uses specimens derived from core samples.

LASERSCAN (IWTO-12)

- Snippets dispersed in the solvent.
- Solvent carries individual snippets through the measurement cell.
- Analysis of change of intensity of laser beam used to measure fibre diameter of fibres in field of view.
- 2000–4000 fibres measured.
- Software calculates:
  - mean fibre diameter
  - diameter distribution
  - comfort factor
  - mean fibre curvature.



22 - **Module 2:** Raw wool measurement

EXPLAIN THAT the Laserscan instrument was developed by CSIRO (Australia) to rapidly measure the diameter of individual fibres and from this data to assess the mean fibre diameter and fibre diameter distribution of a test sample.

QUOTE THE method, from the IWTO test method, as follows:

- *Snippets are cut from pre-scoured samples of raw wool and dispersed as a dilute suspension in a liquid.*
  - *Isopropanol or water (containing surfactant) may be used.*
  - *Both systems are currently in commercial use.*
- *The suspension of snippets is transported through a measuring cell that is positioned in a beam of laser light.*
- *The diameter of fibres is measured automatically by a photoelectric system based on laser illumination.*
- *The diameter of the individual fibre is determined from the reduction in intensity of the laser beam sensed by the detector.*
- *In common with projection microscope measurements IWTO-08, fibre diameter analysers provide a count of readings grouped into diameter classes.*
- *Software determines the required mean and distribution parameters of fibre diameter*

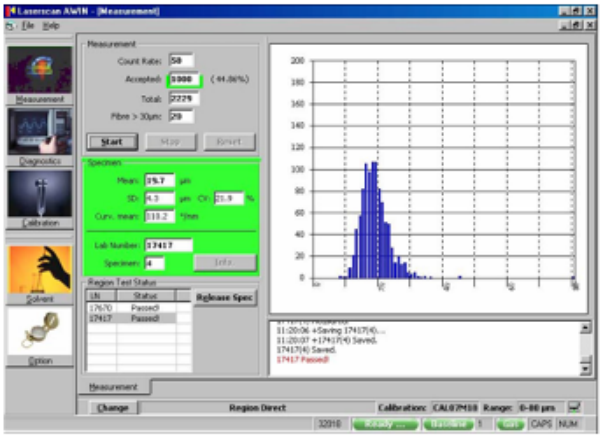
Text derived from IWTO-12 with permission

EXPLAIN THAT the use of two or more instruments is mandatory when certifying measurements of mean fibre diameter using Laserscan.

NOTE THAT additional measurements made by the instrument include:

- comfort factor
- mean fibre curvature.

LASERSCAN®



23 - **Module 2:** Raw wool measurement

INDICATE THAT the image on the slide shows some of the Laserscans used at AWTA in Melbourne, Australia.

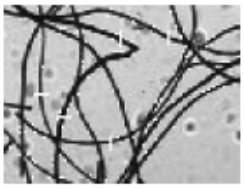
NOTE THAT the distribution of fibre diameter in a typical test specimen measured using Laserscan is also shown on the slide.

NOTE THE:

- wide distribution of fibre diameters (from around 10µm to 35µm)
- coarse edge of the distribution (fibres >30µm).

OFDA (IWTO-47)

- Snippets placed on a microscope slide.
- Image analysis to measure fibre diameter of fibres in field of view.
- Slide moved under computer control.
- Calculates:
  - mean fibre diameter
  - diameter distribution
  - comfort factor
  - mean fibre curvature.



Images courtesy of Hornik Fibretech

24 - **Module 2:** Raw wool measurement

EXPLAIN THAT the optical fibre diameter analyser (OFDA) automatically measures fibre snippets by an optical and image processing system.

NOTE THAT the IWTO - 47 prescribes that:

- *Snippets (~2mm) are cut from the scoured conditioned sub-samples of raw wool using a guillotine or mini-coring device.*
- *The snippets are spread uniformly over the surface of a microscope slide.*
- *A cover slide is placed over the specimen and the slide placed on a microscope stage, which is moved under computer control.*
- *The slide is stepped through the field of view of a low power objective.*
- *At each step, the video system captures and analyses each frame.*
- *In common with projection microscope measurements, the OFDA system provides a count of diameter readings grouped into diameter classes.*
- *At the completion of the slide, the class contents are statistically analysed to produce the mean and standard deviation of the fibre* diameter for the specimen.

Text derived from IWTO-47 with permission.

EXPLAIN THAT the use of two or more instruments (OFDA100 or OFDA2000) is mandatory when certifying measurements of mean fibre diameter using OFDA measurements.

POINT OUT that the OFDA2000 was developed to measure the mean fibre diameter and other characteristics of wool fibre staples. The use of this instrument is also covered by IWTO-47 where it must be used in the 'OFDA100 mode'.

CALIBRATION OF FIBRE DIAMETER — INTERWOOLLABS

STANDARD VALUES				
	AIRFLOW FOR AIRFLOW CALIBRATIONS	PROJECTION MICROSCOPE FOR OFDA AND LASERSCAN CALIBRATIONS		
Standard No.	Mean fibre diameter (µm)	Mean fibre diameter (µm)	Distribution of fibre diameter (CV %)	Fibre curvature (deg/mm)
1 PM	Not applicable	15.71	20.00	79
1 AF	16:46	Not applicable	Not applicable	Not applicable
2	18.61	18.47	20.89	69
3	20.74	20.66	20.29	66
4	24.31	24.29	22.43	62
5	26.79	26.57	23.29	58
6	31.47	31.65	22.18	48
7	32.59	32.60	25.57	47
8	35.43	35.37	25.07	46

Table courtesy of INTERWOOLLABS

INTERWOOLLABS
International Association of Wool Textile Laboratories

25 - **Module 2:** Raw wool measurement

EXPLAIN THAT Airflow, Laserscan and OFDA measurement apparatus for fibre diameter are 'indirect methods' of measuring fibre diameter, which require calibration standards.

INDICATE THAT INTERWOOLLABS is the official supplier of calibration standards (as top) for IWTO test methods for fibre diameter and length. Examples of these standards are shown on the slide. These calibration standards are supplied in the form of tops. The first series was established in 1972 and are updated regularly.

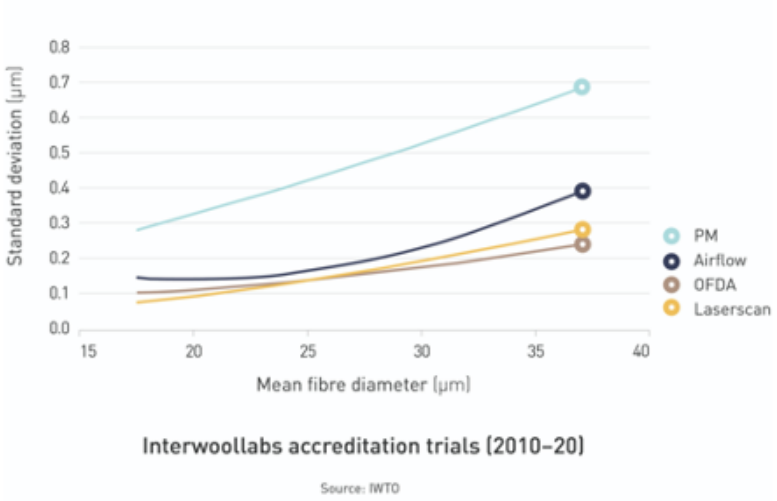
EXPLAIN THAT INTERWOOLLABS accredits laboratories for the use of the various instruments for measuring:

- fibre diameter distribution (projection microscope, airflow, Laserscan, OFDA)
- fibre length distribution characteristics (Almeter).

EXPLAIN THAT laboratories are required to measure the mean and standard deviation of the fibre diameter of supplied samples (in top form) in half-yearly round trials. The results of each lab are evaluated and, if correct, the lab is accredited for the measurement technology.

NOTE THAT Woolmark authorised laboratories that measure fibre diameter for Woolmark certification must be accredited for the use of the technology by INTERWOOLLABS.

INTERWOOLLABS ACCREDITATION TRIALS



Interwoollabs accreditation trials (2010–20)

Source: IWTO

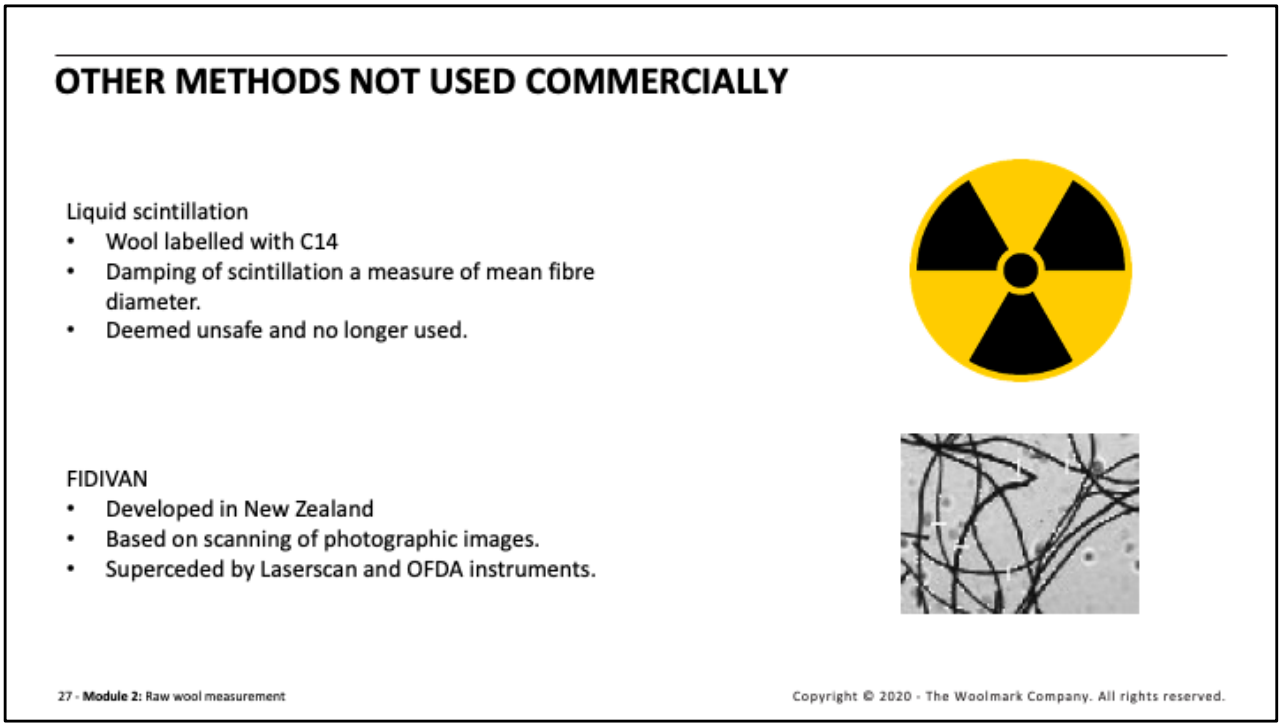
INDICATE THAT the INTERWOOLLABS committee reports annually to IWTO on the within- and between-laboratory variation in the measurement of wool fibre diameter by the laboratories seeking, or seeking to continue, their accreditation for their instruments and methods.

EXPLAIN THAT this slide is taken from a report by INTERWOOLLABS and shows that as the mean fibre diameter of the sample increases, the variation between laboratories for the measurement of this property also increases.

NOTE THAT as the variance of the sample increases, the variation between laboratories also increases.

EXPLAIN THAT the variations between laboratories for measuring mean fibre diameter of the airflow (IWTO-28), Laserscan (IWTO-12) and OFDA (IWTO-47) technologies are similar. The projection microscope method is much less reproducible than the alternative technologies.

EXPLAIN THAT this quality assurance process helps to underpin the accreditation of the test laboratories.



EXPLAIN THAT a number of other methods have been explored to measure the mean fibre diameter of wool fibres, but are not in use commercially.

OUTLINE THE following alternative options for measuring fibre diameter:

Liquid scintillation
In the 'liquid scintillation method' wool is treated with a known amount of a radioactive form of formic acid containing C14. The damping of the signal to a scintillation counter compared with the formic acid in the absence of wool provides a measure of fibre surface area. Although C14 was deemed at the time to be a 'relatively safe' radioactive material, concerns over safety and the health of laboratory staff, precluded the use of this method on a large scale. Moreover the method gave no more information on the fibre diameter than the safer airflow method.

FIDIVAN
The FIDIVAN technique, developed in New Zealand uses image analysis of photographic images of microscope projections. The technology has now been displaced by Laserscan and OFDA measurements.

***ASK** participants if they can recall the terminology used to describe the natural waves in the wool fibre before displaying the next slide*

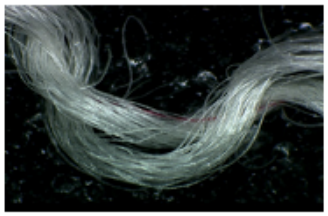
***ALLOW** sufficient time for participants to respond.*

***IF NECESSARY** remind participants the term is 'crimp' before proceeding.*

FIBRE CRIMP — CURVATURE

Measured using:
- Laserscan
- OFDA

Crimp is observable as 'waves' in the raw fibre.



Low curvature fibres

High curvature fibres

REINFORCE THAT wool fibres have a wave pattern know as 'crimp'. The frequency and clarity of the crimp varies with the breed of sheep and within individual breeds. Some broad English breeds have almost no observable crimp (e.g. Lincoln), while other breeds, such as the Merino, are renowned for high-frequency crimp. In fact before equipment was available to measure mean fibre diameter accurately, crimp frequency was the most common means of estimating mean fibre diameter and Merino ram breeders focussed on crimp as a vital breeding selection parameter.

HAND OUT *the samples of high-frequency crimp and low-frequency crimp wool as you continue to discuss the process for measuring fibre crimp.*

EXPLAIN THAT crimp is important in processing and for final product characteristics, such as yarn bulk and pilling.

EXPLAIN THAT curvature is related to the crimp in raw wool fibres.

INDICATE THAT the curvature of fibre snippets can be measured using Laserscan and OFDA instruments at the same time as the diameter measurements are made. There is a good correlation between curvature measurements made on Laserscan and OFDA.

Curvature	**Crimp frequency**
• <50 degrees/mm	2 crimps/cm
• 60-90 degrees/mm	4 crimps/cm
• >100 degrees/mm	7 crimps/cm

COLOUR (IWTO-56)

Measured using:
- CIE tristimulus values (X, Y, and Z)
- under a D65/10 illuminant.

The inherent colour of wool can be:
- White (Y–Z ~ 7)
- Creamy (Y–Z ~ 11)
- Yellow (Y–Z ~ 14).

- Base colour of raw wool is measured:
  - on core samples
  - after standard scour.

- Scoured or carbonised wool measured:
  - 'as-is'
  - after additional scouring to achieve base colour.

Wool colour

Image courtesy of AWTA Ltd

29 - **Module 2:** Raw wool measurement

EXPLAIN THAT the colour of wool is determined by its inherent colour as well as by the presence of dirt, wool wax, suint and other impurities.

EXPLAIN THAT the colour is specified using CIE tristimulus values (X, Y, and Z) under a D65/10 illuminant. The yellowness is specified as Y–Z where:
- Very white (Y-Z) ~ 7
- Creamy (Y-Z) ~ 11
- Yellow (Y–Z) ~ 14.

EXPLAIN THAT the base colour of raw wool, or of a commercially scoured sample, is measured to determine the inherent colour of the wool. This is often different from the 'as-is' colour even if the wool has been commercially scoured.

INDICATE THAT to determine base colour, a specimen is taken from the core sample. The specimen is washed under prescribed conditions and hand carded to remove as much contaminant as possible. The colour is measured using a spectrophotometer. The test is conducted on 'greasy' wool although may also be used for commercially scoured wool to assess the quality of scouring.

The spectrophotometer is calibrated with CERAM certified tiles. The measurement cells may be a constant volume or constant pressure design.

EXPLAIN THAT correction for the effect on colour measurement of the cell glass in which the specimen is placed must be made using multiple regression analysis.

RESIDUAL PESTICIDES (IWTO DTM-59)

Woolgrowers use pesticides (ectoparasiticides) to protect sheep from lice and flies.

Pesticides are:
- applied after shearing or to cure infestations
- have a withholding period to reduce residuals on shorn wool.

The method of analysis is not prescribed, but it must meet criteria of national laboratory accreditation organisations (e.g. NATA in Australia).

Sheep blowfly

Blowfly maggot infestation

REFER TO to the slide as you explain that the IWTO draft test method for residual pesticides (IWTO DTM-59) does not define the method used, but the parameters within which the test method must be performed.

INDICATE THAT the method:
- describes the sampling and testing procedures for the presence of ectoparasiticide residues (i.e. pesticide residues).
- is used with the specific requirements of ISO/IEC Standard 17025 and of the appropriate national laboratory accreditation organisation.

EXPLAIN THAT the actual methods used for analysis must be fully documented and approved by the national laboratory accreditation organisation compliant with IWTO DTM-59.

EXPLAIN THAT the classes of residues covered by the IWTO DTM-59 are:
- organochlorines (OC)
- organophosphates (OP)
- synthetic pyrethroids (SP)
- insect growth regulators (IGR).

INDICATE THAT in Australia, residue testing is carried out by the Australian Wool Testing Authority (AWTA). Few laboratories in the world carry out this form of testing.

ROUND TRIALS BETWEEN ACCREDITED LABORATORIES

Laboratories participating:

- AWTA — Melbourne (Aust)
- AWTA — Fremantle (Aust)
- NZWTA — Napier (NZ)
- WTBSA — Port Elizabeth (SA)
- WTAE — Gwynedd (UK).

Report annually to the IWTO on:

- wool base
- vegetable matter base
- airflow mean fibre diameter
- Laserscan mean fibre diameter
- Laserscan Standard Deviation of Fibre Diameter.

COUNTRY OF ORIGIN	NUMBER OF SAMPLES
Australia	81
New Zealand	11
South Africa	10
United Kingdom	2
TOTAL	104

Table from ILRT report 2016 (Courtesy of IWTO)

EXPLAIN THAT to meet the requirements of ISO/IEC Standard 17025, laboratories are encouraged to undertake regular 'round trials' to demonstrate harmony between results.

INDICATE THAT five raw wool testing laboratories (listed on the slide) undertake such round trials, involving about 100 samples per year. The results are reported to the IWTO annually to identify and diagnose any problem areas early.

INDICATE THAT in addition to core test regulations, the IWTO has published 'Staple Test Regulations' that relate to the sampling and testing of staples of greasy wool.

PLAY *the three-minute video as you explain that the footage shows the 'grab sampling' method.*

DURING *the video note that:*

- *the bale is slit open (~0:17 seconds)*
- *the mechanical clamps enter the bale and 'grabs' a sample (~0:19 seconds)*
- *the sample is dropped onto a conveyor, which places it in the sample bag (~:29 seconds)*
- *measurements are recorded onto a computer*
- *both core sampling and grab sampling are carried out in a single pass (~2:08 minutes).*

EXPLAIN THAT 'grab sampling' is described by IWTO-38 Method for Grab Sampling of Greasy Wool From Bales

INDICATE THAT the most important among the tests carried out on grab samples is IWTO-30 Determination of Staple Length and Staple Strength.

EXPLAIN THAT the samples obtained may also be used:

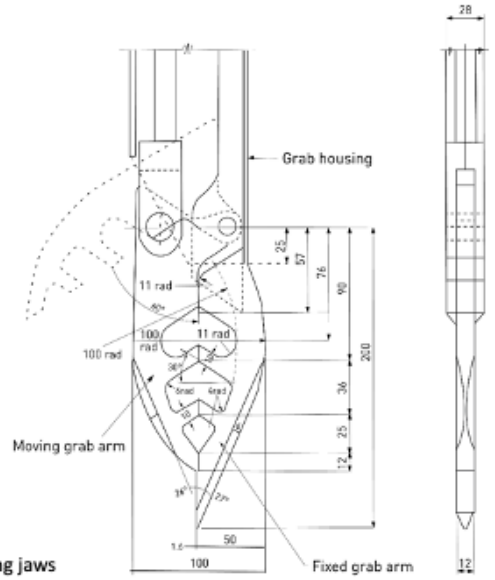
- as a display sample for sale by sample
- for the appraisal of other subjective fibre characteristics such as style.

EXPLAIN unlike the core sampling procedure, grab sampling does not cut wool fibres. Core samples cannot be used for tests that require intact fibres or staples of fibres (e.g. length and strength).

NOTE THAT like other forms of sampling, every bale in the test lot is grab sampled in accordance with IWTO-38.

GRAB SAMPLING (IWTO-38)

- The wool bale is slit.
- The grab jaws are
  - closed and inserted through the slit
  - opened and lowered further to grab the sample
  - closed so as to secure the grab sample
  - withdrawn so the grab sample is clear of, and separated from, the wool in the bale
  - opened to release the grab sample.
- The grab sample is typically ~250gm.



Courtesy of IWTO: from IWTO-38 Appendix A

INDICATE THAT the grab sampling machine has a set of jaws that can penetrate the wool bale and grab a sample of the wool. This approach:

- avoids contaminating the wool with the nylon bale packaging material
- avoids breaking or damaging the wool fibres.

EXPLAIN THAT the pack is slit before the jaws enter the bale, avoiding contamination of the wool by the pack material.

The closed grab jaws are inserted through the slit and lowered to the selected depth. The grab jaws are fully opened, lowered further in the opened position, and then closed so as to secure the grab sample. The grab jaws are withdrawn so the grab sample is clear of, and separated from, the wool in the bale. When separation is complete, the grab jaws are opened to release the grab sample.

INDICATE THAT the jaws should:

- 'grab' a representative grab sample of wool of suitable mass
- avoid contaminating the fibres from any damage to the pack.

EXPLAIN THAT a minimum of 20 grab samples are taken from the sale lot in Australia and South Africa, (16 grab samples in New Zealand). For classed grower sale lots of one, two and three bales only, a minimum of six grab samples per lot is permitted.

NOTE THAT in practice the mass of individual grab samples from a sale lot should be between 100g and 400g.

Note: Text derived from IWTO Staple Test Regulations

EXPLAIN THAT the IWTO-07 Sub-sampling Staples from Grab Samples test method sets out a method of sub-sampling staples from a grab sample of greasy wool, drawn in accordance with IWTO-38.

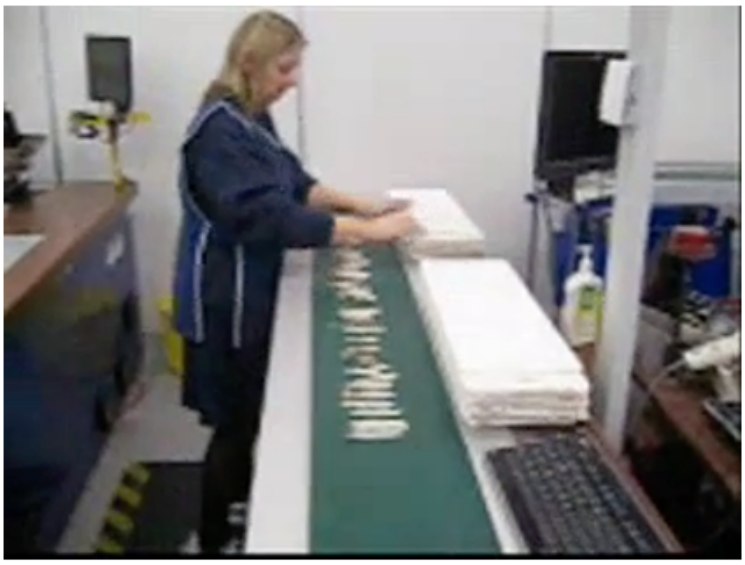
NOTE THAT the sub-sampling method applies to the selection of staples suitable for staple measurements of greasy wool.

EXPLAIN THAT where an IWTO certificate is to be issued, a minimum of four operators are used to select and prepare the staples.

***PLAY** the 15 second video as you explain that the footage, supplied by the AWTA illustrates the sub-sampling technique used.*

Opinions expressed in this video do not necessarily reflect the opinions of The Woolmark Company Pty Ltd or its affiliates. To the extent permitted by law, we exclude all liability (however arising) for any loss or damage arising from or in connection with the use of, or reliance on, the opinions and information in this video.

STAPLE LENGTH AND STRENGTH (IWTO-30) — ATLAS



Video courtesy of AWTA Ltd

35 - **Module 2:** Raw wool measurement

EXPLAIN THAT a measure of staple length and strength is normally made on fleece wools destined for worsted processing (often referred to as combing wools).

INDICATE THAT a total of 60 staples (with at least 55 being measured) are drawn at random from the grab sample, conditioned and then measured to determine:

- staple length
- average linear density
- the force required to break the staple
- the position of break (ends or middle).

EXPLAIN THAT in commercial laboratories, all measurements are made by one of two automated instruments (ATLAS or AGRITEST).

***PLAY** the 43 second video of the ATLAS machine as you point out:*

- *the staples placed on moving belt (0:05 seconds)*
- *the optical measurement of length (0:17 seconds)*
- *the breaking of the staple (0:27 seconds).*

REINFORCE THAT in the ATLAS machine, the staples are fed onto a moving belt. The length is measured using vertical light beams, which are interrupted by the passage of the staple.

The distance moved by the belt while the staple interrupts the light beam measures the staple length. The staple is fed into a set of jaws, which grip the ends and extend the staple to break. The peak force measures the strength of each staple. The broken ends of the staple are released from the jaws and weighed separately.

The machine reports:

- staple length in millimetres
- coefficient of variation of staple length
- total weight of the staple in grams
- the breaking load of the staple in N/dtex
- The position of break (% midbreaks)
    - midbreaks give two pieces of broken staple of similar weight
    - end breaks give two pieces of broken staple of different weights.

STAPLE LENGTH AND STRENGTH (IWTO-30) — AGRITEST

Image courtesy SGS Wool Testing Services Ltd

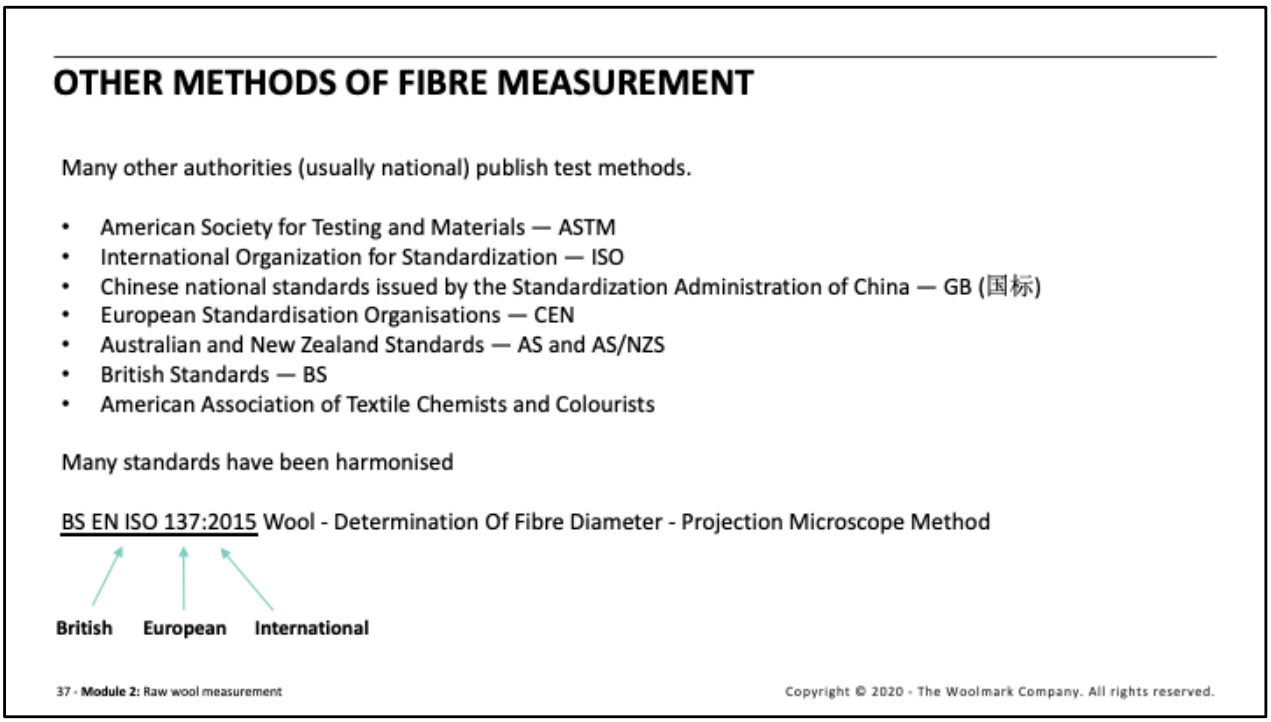
EXPLAIN THAT the AGRITEST staple measurement system has two components:

- staple length meter
- staple breaker.

The staple length is measured in a manner similar to ATLAS, using optical detection. The staple is manually transferred to the breaker component.

The jaws are positioned on the ends of the staple so there is no damage to the staple nor slippage in extension. The staple is broken if the maximum force is less than 5N or exceeds 400N the sample is rejected. The two pieces of broken staple are again weighed to determine the position of break.

INDICATE THAT the information reported is similar to that from the ATLAS machine.

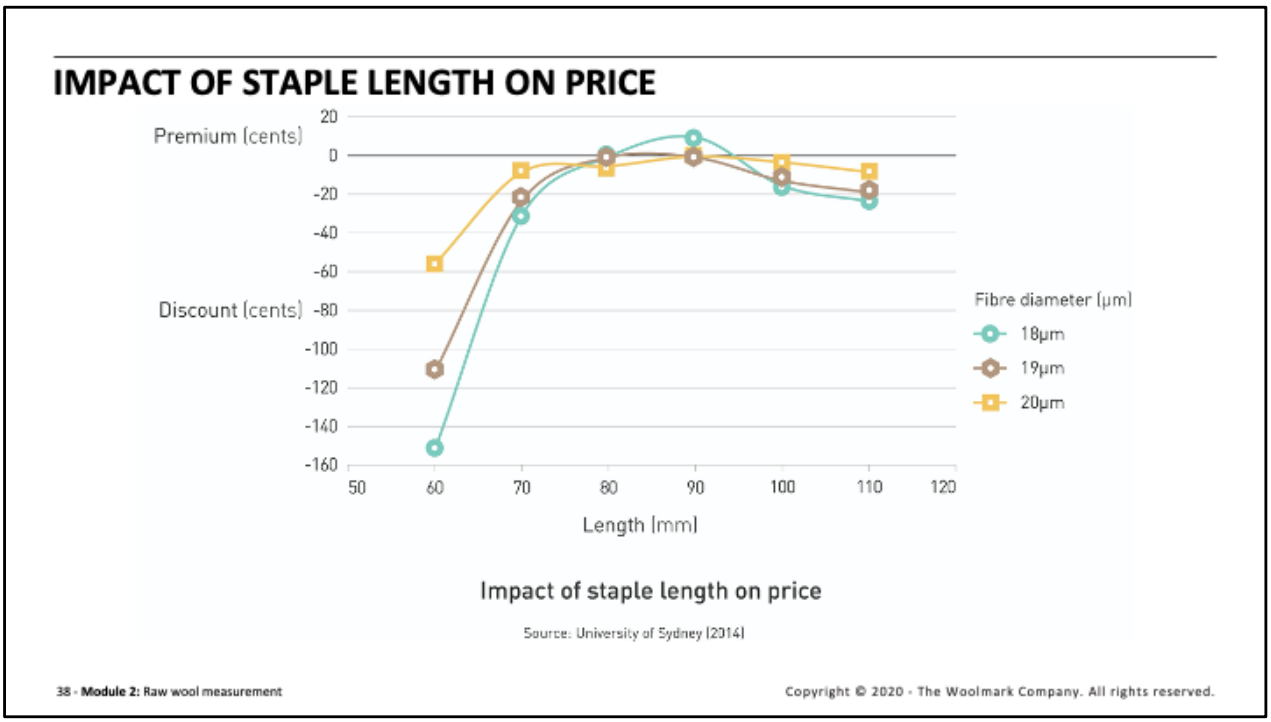


INDICATE THAT there are many methods and instruments for measuring the properties of raw and semi-processed wool in addition to those described in the IWTO specifications.

EXPLAIN THAT there is also a range of standard methods published by alternative standards organisations, such as:

- American Society for Testing and Materials — ASTM
- International Organization for Standardization — ISO
- Chinese national standards issued by the Standardization Administration of China — GB
- European Standardisation Organisations — CEN
- Australian and New Zealand) Standards — AS and AS/NZS
- British Standards — BS
- American Association of Textile Chemists and Colourists

NOTE THAT many standards have been harmonised, as indicated by the example on the slide.



EXPLAIN THAT the measurements made on raw wool can have a significant impact on the price paid at auction. This graph shows the discounts (and premiums) applied to wool of varying length and fibre diameter.

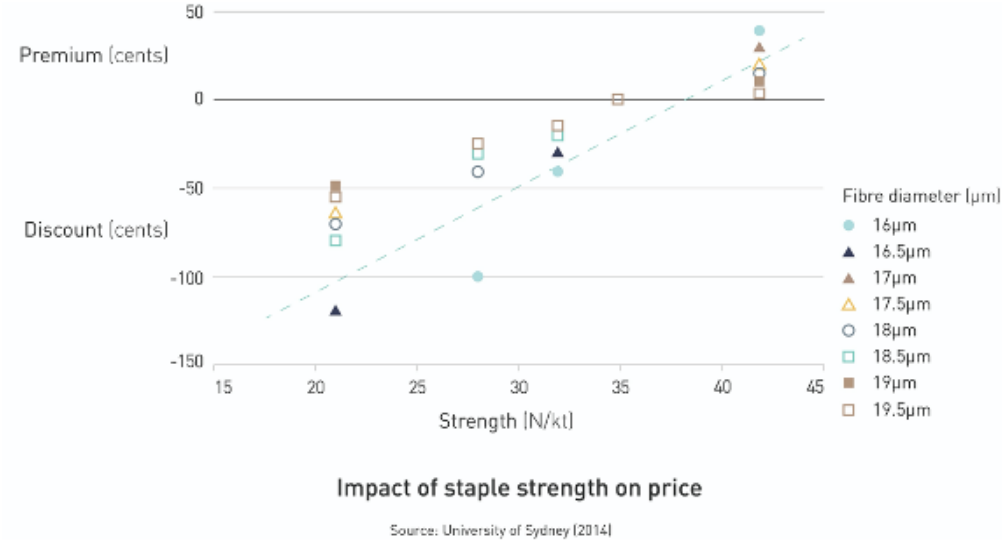
NOTE THAT discounts are the reduction in price paid compared to that paid for wool with an 80mm average staple length.

NOTE THAT premiums are the increase in price paid compared to that paid for wool with an 80mm average staple length

REFER TO the slide as you point out that broadly speaking, shorter wools are discounted (reduced) and the discount increases rapidly when the average staple length is less than 70mm. As illustrated on the graph, the discounts are greatest for superfine wool (<18.5µm).

NOTE THAT discounts also can be associated with longer wools (>90mm), but these are relatively small compared with the discounts for short wool.

IMPACT OF STAPLE STRENGTH ON PRICE



Impact of staple strength on price

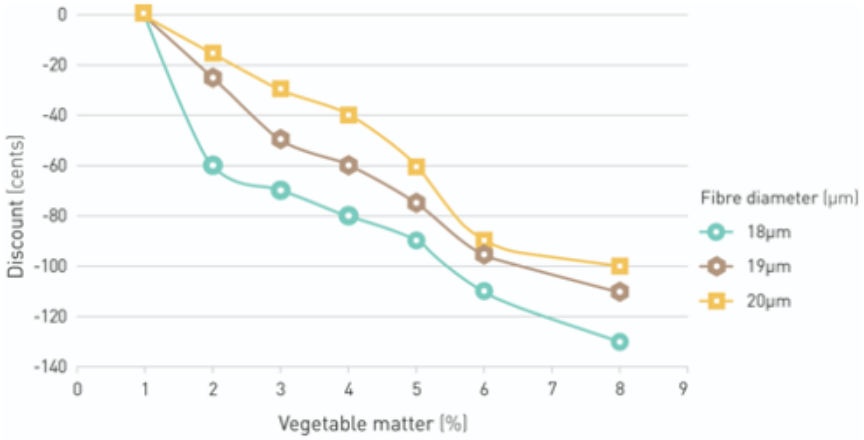
Source: University of Sydney (2014)

INDICATE THAT the discounts and premiums for staple strength compared with the price paid for wool with a staple of 35N/kt for wools of various fibre diameters are shown on the graph above.

NOTE THAT weaker wools are heavily discounted, especially in the case of the ultrafine wools (<16.5µm).

NOTE THERE is a slight premium for stronger wools (~42N/kt). This premium is greatest for the ultrafine wools (<16.5µm).

IMPACT OF VEGETABLE MATTER CONTENT ON PRICE

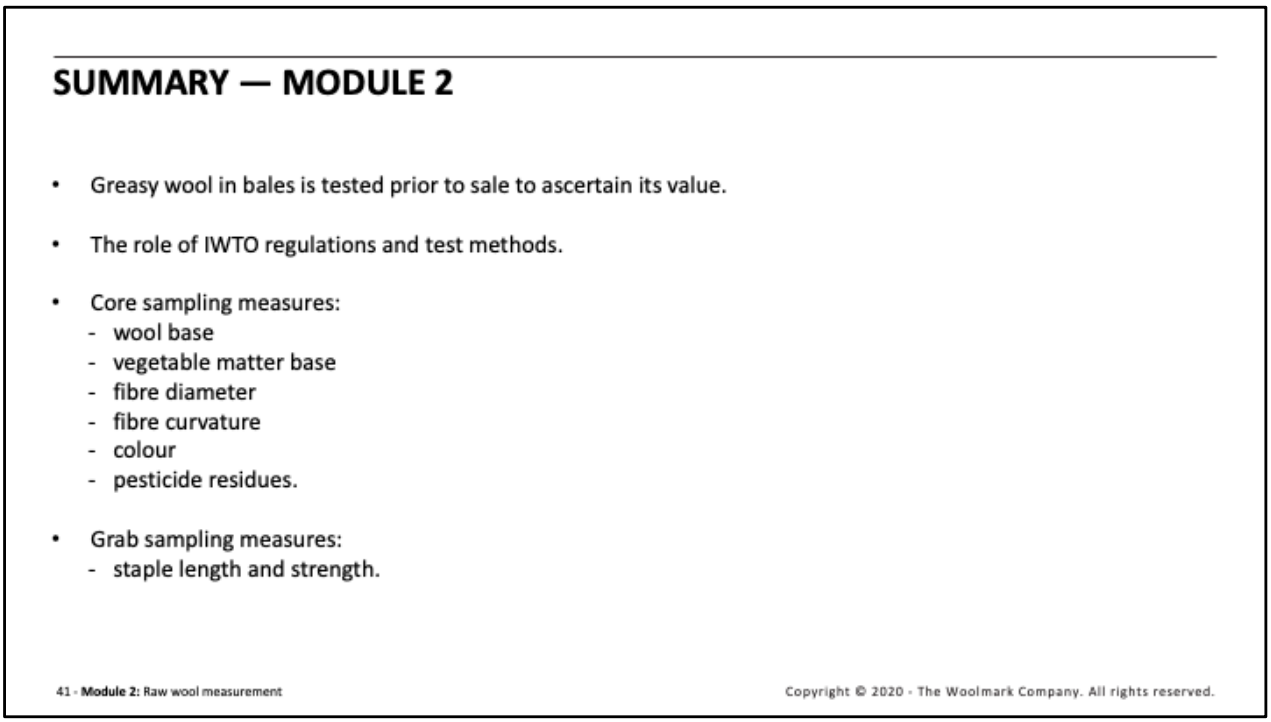


Impact of vegetable matter content on price

Source: University of Sydney (2014)

REFER TO the slide as you note that discounts escalate as levels of vegetable matter increase for all fibre diameters, although the discounts are greatest for finer wools.

NOTE THAT the discounts also vary according to the type of vegetable matter, although this is not illustrated on the slide.



SUMMARISE THIS module by reinforcing that greasy wool is tested as a sale lot to ascertain its value before being offered for sale.

REINFORCE THAT regulations and test methods developed by the International Wool Textile Organisation (IWTO) are the most widely used for sampling and testing in the international trading of wool.

REMIND PARTICIPANTS the IWTO has established regulations for:

- core sampling and testing – samples are taken from the bale using a sampling tube
- grab samples and testing – samples are taken from the bale using a claw, avoiding cutting of the fibres
- staple sampling and testing
- conditioning of raw wool for testing.

REINFORCE THAT these regulations and test methods form the basis for IWTO certification of:

- specific raw wool measurements
- laboratories that can conduct the measurements.

REVIEW THE two forms of sampling of bales in sale lots:

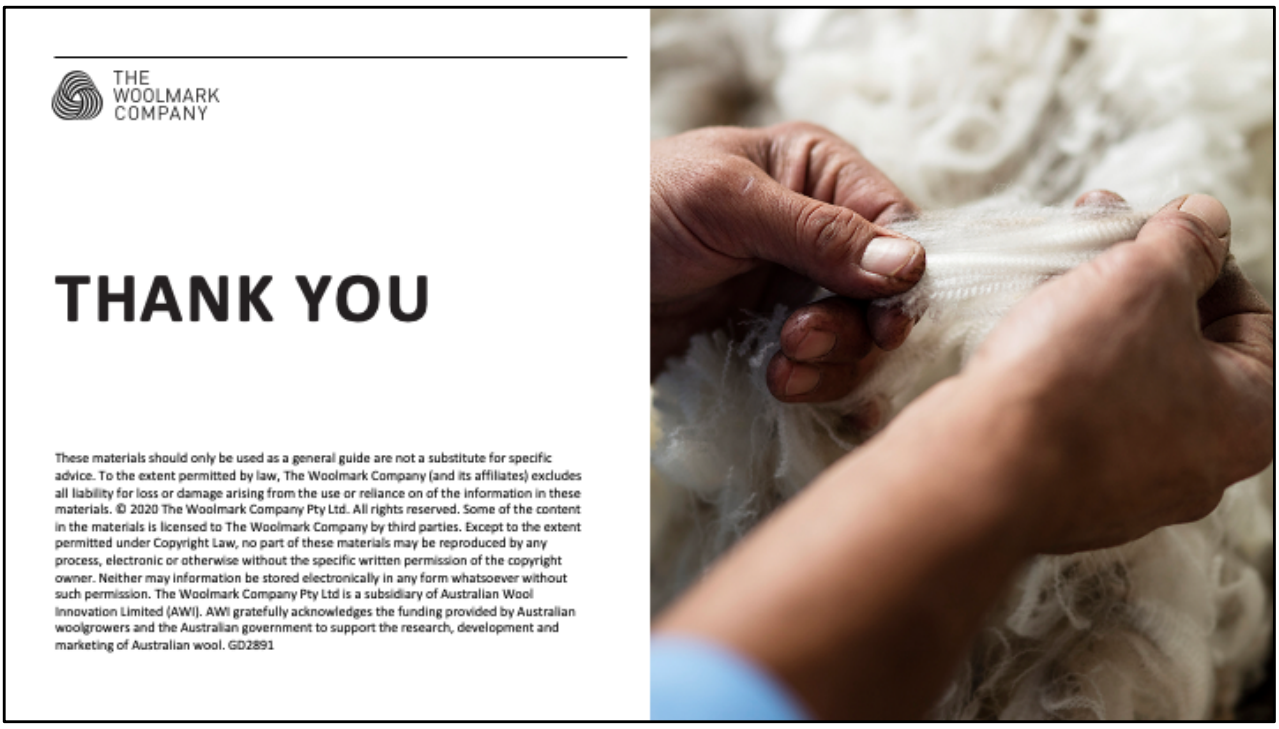
- core sampling, which is used to measure:
    - wool base
    - vegetable matter base
    - fibre diameter
    - fibre curvature
    - colour
    - pesticide residues
- grab sampling, which is used to measure:
    - staple length and strength.

REINFORCE THAT there are many other methods and instruments for measuring the properties of raw and semi-processed wool, in addition to those described in the IWTO specifications.

***ASK PARTICIPANTS** if they have any questions about the content covered in this module.*

***ALLOW TIME** for questions and discussion before proceeding to the final slide and closing the lecture.*

***COLLECT ALL** samples distributed during the lecture.*



INFORM participants of the time and location for the next lecture — *Module 3: Manufacturing wool yarns* — and ensure they read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 3

THE WOOLMARK COMPANY

MANUFACTURING WOOL YARNS

RESOURCES — MODULE 3: MANUFACTURING WOOL YARNS

Contained in the *Introduction to wool processing* Demonstration kit you will find the following resources for use as you deliver **Module 3: Manufacturing wool yarns**:

- sample of worsted yarn
- sample of woollen yarn
- sample of greasy (raw) wool
- sample of scoured wool
- sample of scoured and carbonised wool
- sample of unrefined wool wax
- sample of refined wool wax
- sample of a gilled sliver
- sample of a combed sliver (wool top)
- sample of a worsted roving
- sample of high-twist fabric
- sample of low-twist fabric

Additional resources to be sourced by the facilitator include:

- piece of A4 paper
- flat surface (e.g. table top)
- light object (e.g. mobile phone)
- jacket or sweater
- several lengths (1m) of wool yarn of various colours
- sample of wool/polyester blend fabric
- sample of wool/cotton blend fabric

WELCOME participants to Module 3 of *Introduction to wool processing — Manufacturing wool yarns*.

_____

ASK *participants if they can recall the two principle processing routes to produce wool yarns.*

ALLOW *sufficient time for participants to respond.*

IF NECESSARY *confirm that the two routes are worsted and woollen processing before proceeding.*

_____

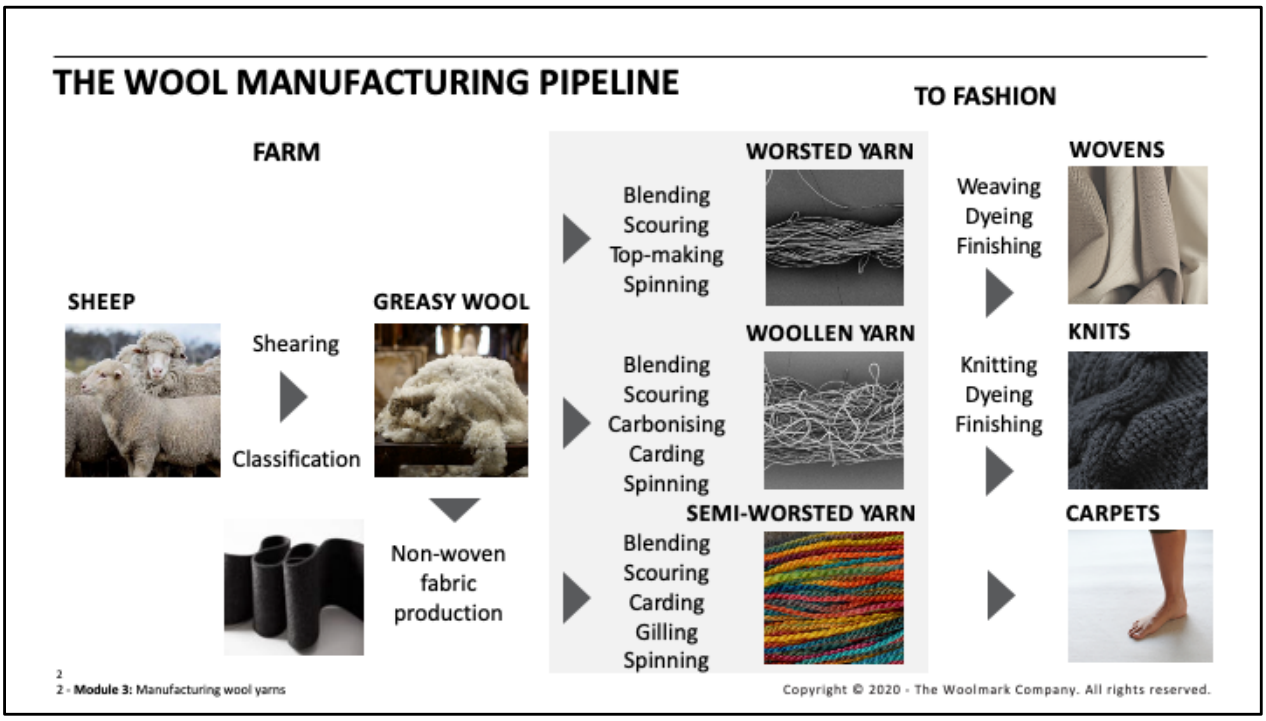
EXPLAIN THAT this module will provide a brief overview of the yarn manufacturing processes. The individual processes will be studied in greater depth in the later courses of the Wool Science, Technology and Design Education Program.

INFORM participants that by the end of this module they will be able to describe briefly:

- each of the major operations in the production of worsted yarns
- each of the major operations in the production of woollen yarns
- the difference in the properties of woollen and worsted yarn
- the quality attributes of yarn
- the criteria used to select yarn.

RESOURCES REQUIRED FOR THIS MODULE

- *sample of worsted yarn*
- *sample of woollen yarn*
- *sample of greasy (raw) wool*
- *sample of scoured wool*
- *sample of scoured and carbonised wool*
- *sample of unrefined wool wax*
- *sample of refined wool wax*
- *sample of a gilled sliver*
- *sample of a combed sliver (wool top)*
- *sample of a worsted roving*
- *sample of high-twist fabric*
- *sample of low-twist fabric*
- *piece of A4 paper (facilitator to supply)*
- *flat surface (e.g. table top) (facilitator to supply)*
- *light object (e.g. mobile phone) (facilitator to supply)*
- *jacket or sweater (facilitator to supply)*
- *several lengths (1m) of wool yarn of various colours (facilitator to supply)*
- *sample of wool/polyester blend fabric (facilitator to supply)*
- *sample of wool/cotton blend fabric (facilitator to supply)*



EXPLAIN THAT the production and manufacture of wool is a long and complex process, involving many different processes and people. It can take 12–18 months from the time the wool is harvested from the sheep (during shearing) to the point at which it is sold to the consumer as a wool (or wool blend) garment or other wool textile product (e.g. carpet, homewares etc).

REFER TO the slide as you indicate the manufacturing pipeline for wool products can be divided into four stages:

1. Farm to factory, which involves :
- shearing
- classification
- transport
- raw wool measurement (testing).

2. Manufacturing of yarn, which involves:
- raw wool scouring
- top-making
- spinning
- twisting.

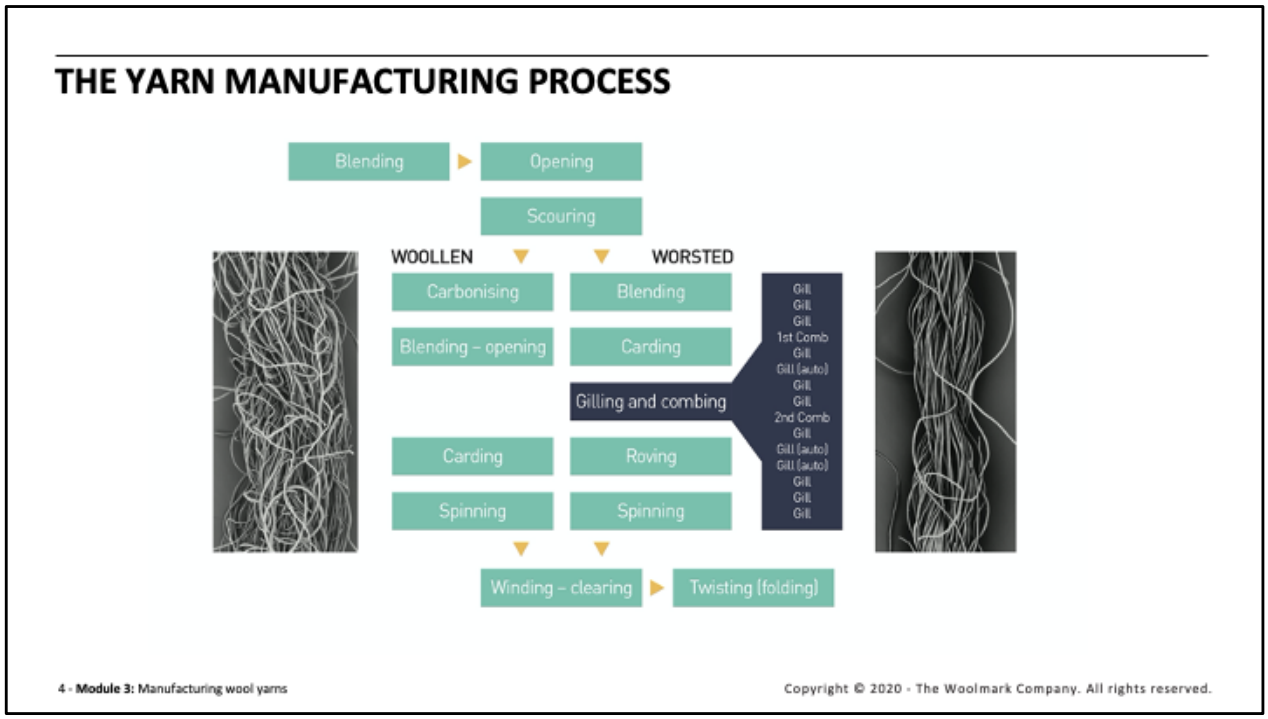
3. Manufacture of fabric, knitted garments, carpet etc:
- weaving and knitting
- dyeing (can occur at several points in the process)
- finishing.

NOTE THAT an additional process is carried out to produced non-woven fabrics, such as felts. This process will be discussed separately to weaving and knitting.

4. Manufacture of garments or other products (this stage is not shown on this slide or covered in this course).

EXPLAIN THAT this module will focus on the production of yarn by either the worsted or woollen processing route, as illustrated on the slide. A detailed discussion of semi-worsted yarn production is covered in the the Wool Science, Technology and Design Education course, *Worsted and woollen spinning.*

PLAY *the 2 minute 15 second video as you explain that the* Woolmark animation provides a quick overview of the wool processing pipeline.



EXPLAIN THAT the process for manufacturing worsted yarn is different from that used to manufacture woollen yarn.

Worsted yarn is normally made using the fleece wool obtained during shearing. Fleece wool generally contains the longest wool fibres, which are less variable in terms of fibre diameter and are generally less contaminated with vegetable matter.

EXPLAIN THAT the process for manufacturing worsted yarn is the more complex processing route. Worsted processing requires repeated steps of gilling and combing.

REINFORCE THAT woollen yarn is usually created from the shorter pieces of wool obtained during shearing. The wool fibres are more variable in length and are often more contaminated and discoloured.

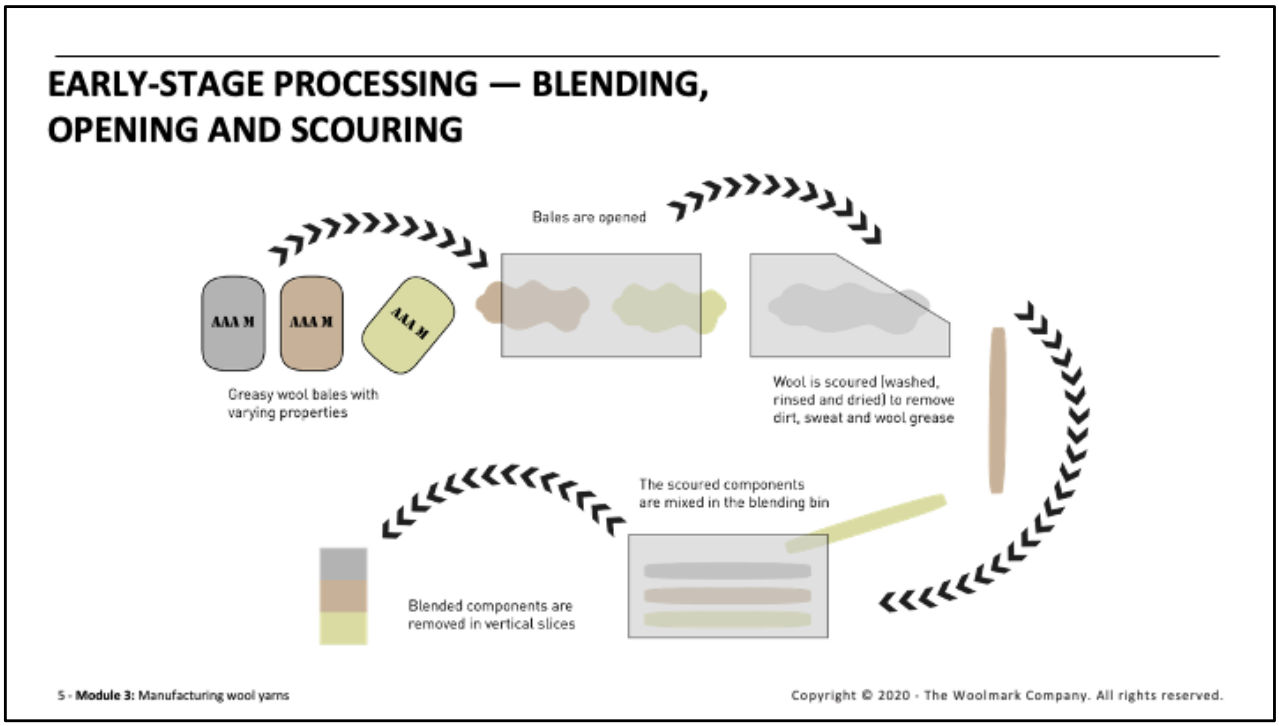
EXPLAIN THAT the process for manufacturing woollen yarn is shorter, mainly because it doesn't require gilling and combing (i.e. top-making).

INDICATE THAT the result obtained using the worsted process is quite different to that from woollen processing. Worsted yarns are smooth and uniform, and used to make lighter and smoother wool fabrics. Woollen yarn is bulkier than worsted yarn and used to make thicker, heavier woven or knitted fabrics.

HAND OUT *the samples of the worsted and woollen yarns.*

ENCOURAGE PARTICIPANTS *to share the differences they notice between the samples as they pass them among the group.*

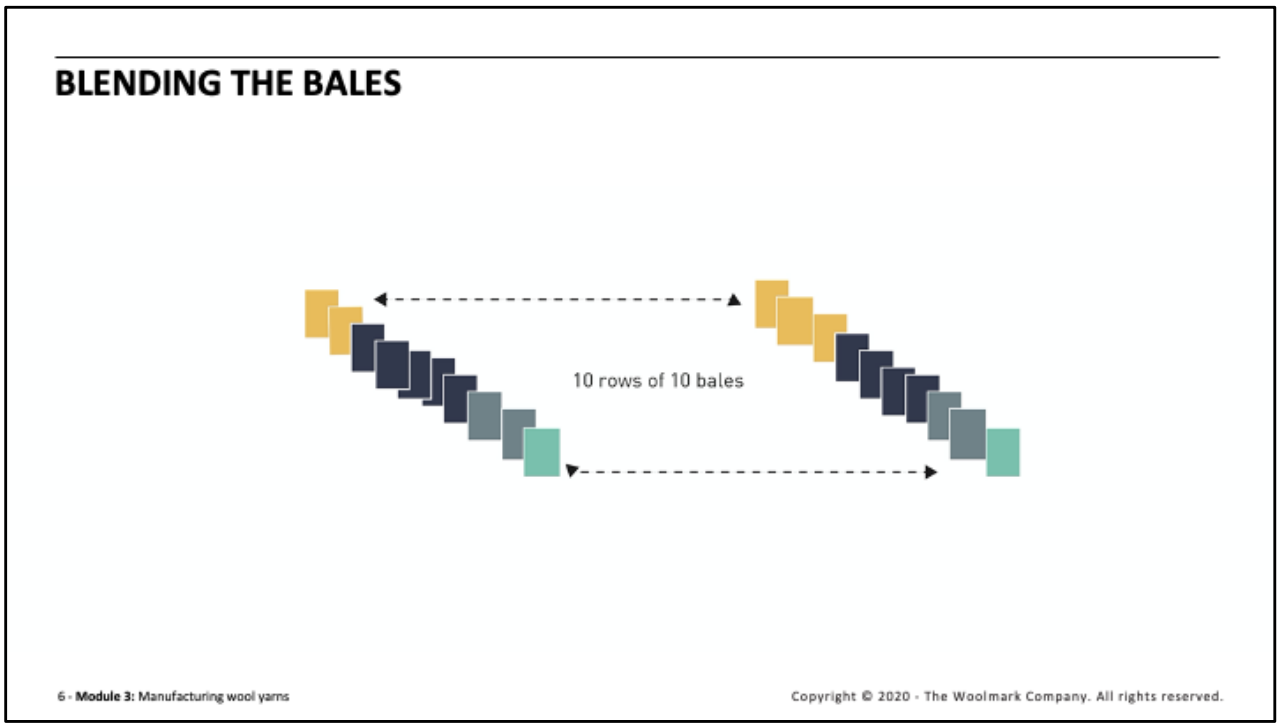
EXPLAIN THAT In this module, the common processes of blending, opening and scouring will be outlined first. Then worsted processing will be discussed and finally the woollen processing will be outlined.



EXPLAIN THAT blending can occur at several points during early-stage processing as indicated on the slide.

INDICATE THAT the aim of blending (regardless of where it occurs in early-stage processing) is to ensure the resultant top, yarn and ultimately product is as even and uniform as possible across all characteristics throughout its entire length.

EXPLAIN THAT this process will be outlined more clearly in the following slides.



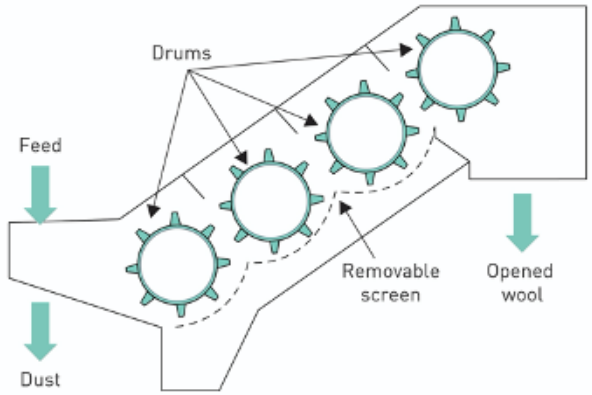
EXPLAIN THAT before any processing begins, consignments of bales of greasy wool of similar types are arranged so the component lots are randomised before the bales are opened.

EXPLAIN THAT a single processing lot may contain similar wool types from different farms. The wool from different farms may vary, usually over a small range, in terms of:

- fibre diameter
- staple lengths
- staple strengths
- colour
- amount of vegetable matter.

EXPLAIN THAT the diagram on the slide represents 10 rows of 10 bales with similar, but slightly different, characteristics or bales from different farms, represented by the different-coloured bales. Normally the variation in fibre characteristics is kept to a minimum in high-quality wools and the bales are fed to the opening line with the homogeneity of final top properties in mind.

OPENING



INDICATE THAT the purpose of the 'opening' process has the following objectives:

Break up clumps of wool:
- The opener breaks the fleece wool (worsted) or the pieces (woollen) into smaller clumps.
- If the wool is not reduced to smaller pieces, the feed to the scouring line can become uneven, leading to poor scouring performance.
- If a gentle opener cannot open the wool, it may be necessary to machine the wool using special openers.

Remove some dirt:
- The opener removes some contaminants from the raw wool, typically loosely-held dust and dirt.

Enhance the blending of the wool lots:
- The bales in each consignment are opened in a bale-breaker. This is usually followed by more opening, such as double-drum machines, to break the wool into approximately staple courses and remove some of the loose dirt.
- Many opening machines are also designed to ensure some mixing of the components of the blend.

EXPLAIN THAT opening is studied in detail in the Wool Science, Technology and Design Education Program course *Raw wool scouring.*

EXPLAIN THAT the wool must be washed before it can be processed to yarn. Scouring is designed to remove of some of the contaminants from raw wool including:

- dirt
- wool wax
- salts from suint (sweat)
- non-wool protein material
- skin pieces.

HAND OUT *the samples of the greasy and scoured wool samples.*

ENCOURAGE PARTICIPANTS *to share the differences they notice between the samples as they pass them among the group.*

EXPLAIN THAT scouring involves:

- washing wool in a detergent solution
- rinsing the fibres
- drying the clean wool.

INDICATE THAT during scouring wool is passed through a series of bowls containing water and detergent. The scour is a long machine. The first bowl normally immerses the wool in a detergent solution, which removes the bulk of the dirt and wool wax (the latter is extracted and collected for the cosmetic industry).

HAND OUT *the samples of the unrefined and refined wool wax.*

EXPLAIN THAT *in its refined form wool wax is called lanolin.*

EXPLAIN THAT excess dirty water is squeezed from the fibre before several rinses, during which the fibre becomes progressively cleaner.

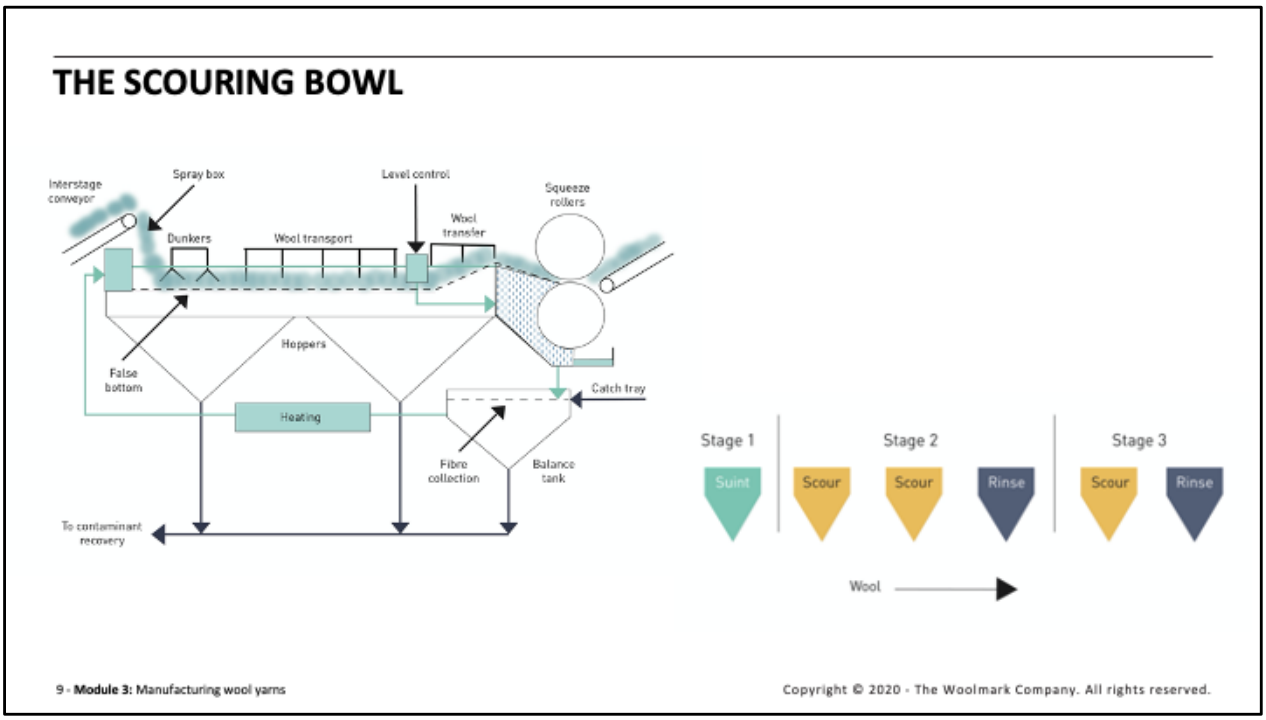
NOTE THAT most ccommonly, after drying the entire lot is re-blended in scoured form in a blending bin.

PLAY *the three-minute video to reinforce the overview of the scouring process.*

DURING *the video you may like to note that:*

- *the opening stages of the video (0:00 – 0:16 seconds) show:*
  - *the wool being removed from the bales and loaded into the opener*
  - *the wool passing through a scouring bowl*
  - *the dried wool passing onto the next processing stage*
- *the next part of the video explores each of these stages in more depth, with each stage being labelled on the screen*
- *at 0:2:10 minutes, note the relative cleanliness of the rinsewater compared with the scour liquor seen in the side tanks of the scour bowls*
- *at 0:2:39 the scoured and dried wool is put through a gentle opener again to remove any remaining dust.*

EXPLAIN THAT the scouring process is studied in detail in the Wool Science, Technology and Design Education Program course *Raw wool scouring.*



EXPLAIN THAT the scouring bowl is the main modular component of a scouring line, which can be made up of up to seven such bowls. The scouring line is made up of a range of mechanical features:

- a wool transport system
- a liquor handling system
- a basic scouring bowl design
- a contaminant recovery system.

NOTE THAT More detail on the construction and action of scouring bowls is found the Wool Science, Technology and Design Education course *Raw wool scouring*.

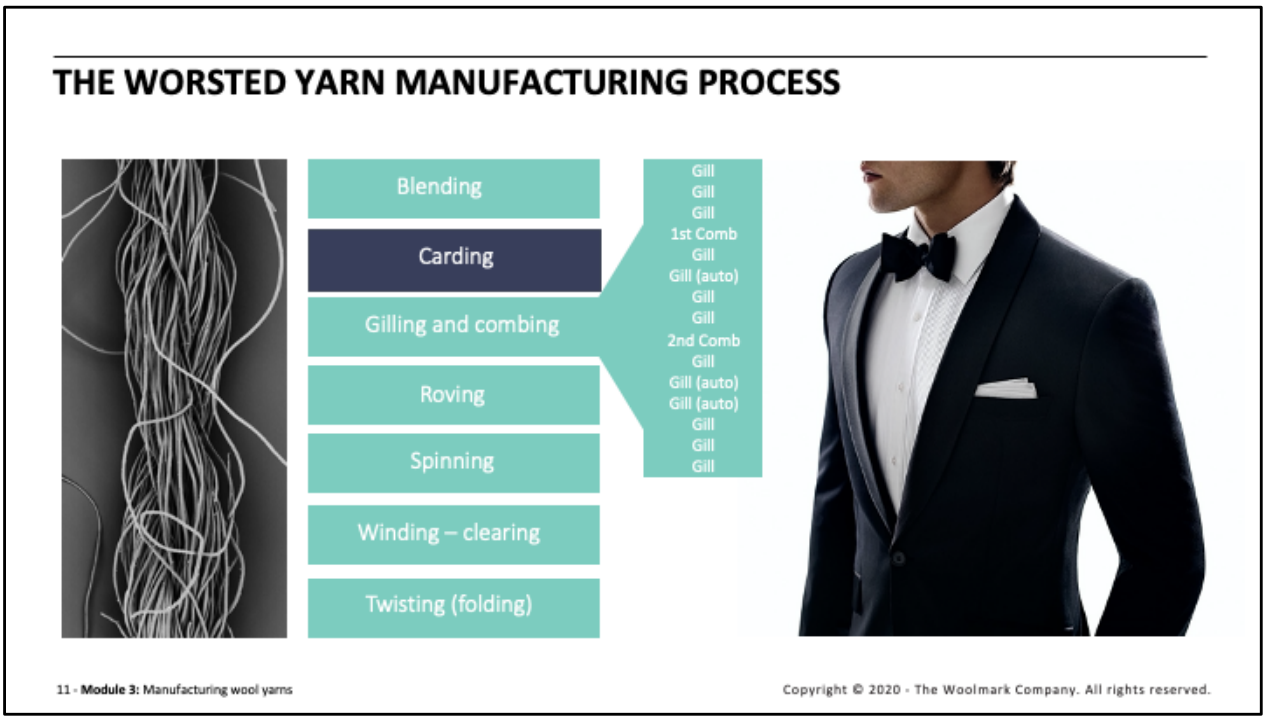
BLENDING THE OPENED WOOL

10 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT the output of the scour is loaded into the blending bin in horizontal layers as a stack similar to that shown on the slide. In the slide coloured layers have been used to demonstrate the effect.

EXPLAIN THAT the wool is then moved to the next process by slicing the stack like a cake, before feeding the wool into the various processing machines. This ensures each slice contains all the different fibre qualities and colours and the end of the lot is the same blend as the start of the lot. Blending also helps to open the fibre staple and remove the initial dirt.

EXPLAIN THAT as stated earlier, the aim of blending (before and after scouring) is to ensure the yarn is consistent in composition and colour and suitable to produce the best quality yarn for the lowest price.



EXPLAIN THAT the first process following the opening, blending and scouring processes in the worsted route is carding.

EXPLAIN THAT the carding process:
- untangles the locks and clumps of wool and separates the wool into individual fibres
- removes vegetable matter
- partially aligns the fibres
- forms the fibres into a sliver (untwisted, rope-like strands of fibre).

MENTION THAT carding is achieved by wired rollers 'competing for' and separating the fibres.

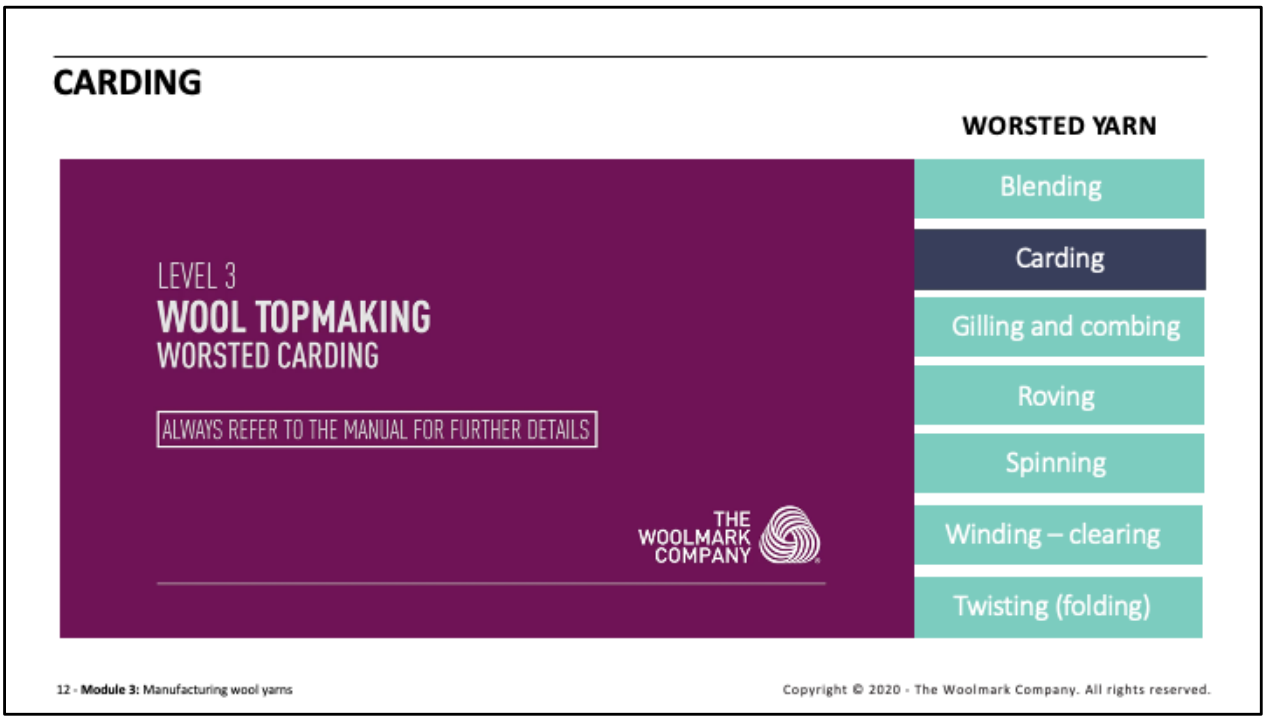
INDICATE THAT a range of roller types is used in a card, the most important are:
- swift rollers, which move fast
- worker rollers, which move slowly and compete with the swift for the wool
- stripper rollers, which transfer wool from the workers back to the swift
- doffer rollers, which remove the wool from the swift to form the sliver.

EXPLAIN THAT the wool is fed into the carding machine at a constant rate, so as not to create under or overloading.
- First the vegetable matter is removed.
- The wool is then fed onto wire-covered rollers, much like a hair brush, and as it passes from roller to roller the tufts of wool are opened.
- The wool is removed from the swift by a doffing comber.

EXPLAIN THAT the animation on the following slide shows how the wool is fed onto the various rollers and passed from one to the next.

Eventually the wool leaves the last swift and is collected as a continuous sliver ready for gilling.

EXPLAIN THAT a detailed technical discussion of carding is carried out in the Wool Science, Technology and Design Education Program course *Worsted top-making*.



PLAY *the three-minute video, produced by The Woolmark Company, which illustrates the carding process.*

DURING *the video you may like to point out:*

- *the staples being separated from the fibres using workers and strippers (~0:47 seconds)*
- *the separated fibres being gathered into a continuous stream called a sliver (~0:57 seconds)*
- *slivers being fed directly into a gilling machine or into cans.*

HAND OUT *the samples of card sliver.*

ENCOURAGE PARTICIPANTS *to note the partial alignment of the fibres and any remaining vegetable matter.*

EXPLAIN THAT before a worsted yarn can be spun, the sliver needs to be gilled (to straighten the fibres by stretching the sliver) and combed to remove the short fibres (noil) and any vegetable matter.

EXPLAIN THAT gilling is done to:

- align the fibres in a parallel direction so they can pass through the very fine comb on the combing machine
- produce a sliver with a more uniform weight per course length
- add processing aids to the fibre.

INDICATE THAT gilling makes the fibres more parallel by combining and extending the slivers (drafting). Commonly card sliver may be gilled about five times before the sliver moves onto the comb.

PLAY *the 46 second video, produced by The Woolmark Company, which shows the continuous rotation of a gill box-like components known as 'faller' bars acting both above and below the sliver.*

NOTE THAT *as the sliver passes through the machine, the speed of the fibres increases when they are gripped by the second pair of rollers. This action drafts the many input slivers, which are collected into a single output sliver, ready for another gilling operation or combing.*

HAND OUT *the samples of gilled sliver.*

ENCOURAGE PARTICIPANTS *to note the increased alignment of the fibres and any remaining vegetable matter.*

EXPLAIN THAT a detailed technical discussion of gilling is carried out in the course of the Wool Science, Technology and Design Education Program course *Worsted top-making*.

EXPLAIN THAT the combing process removes
- vegetable matter
- nep and
- short fibres (noil).

INDICATE THAT the process is similar to using a very fine comb to remove nits/lice from a child's hair.

EXPLAIN THAT the process of combing is as follows:
- A fringe of clamped fibres is presented to a pinned cylinder, which straightens the long fibres and removes short fibres, nep and vegetable matter.
- The cleaned fringe is then gripped and drawn through a single strip of very fine pins to complete the cleaning of the back end of the fibres.
- The fringes are recombined to form a sliver.

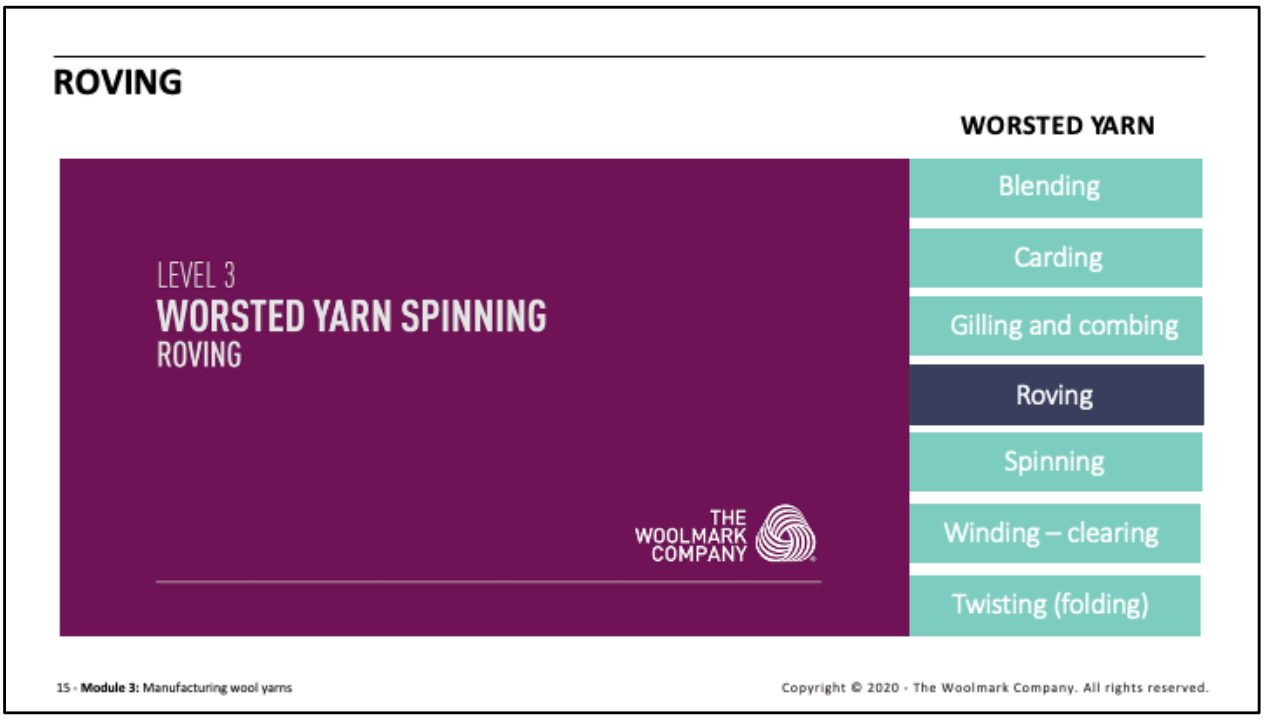
NOTE THAT after combing, the sliver is re-gilled 2–3 times. The sliver is now known as 'top'.

PLAY *the 38 second video, produced by The Woolmark Company, which shows the combing process, where the combing machine removes short fibres and vegetable matter from the wool.*

HAND OUT *the samples of combed sliver and indicate the sliver is now referred to as 'wool top'.*

ENCOURAGE PARTICIPANTS *to note the increased alignment of the fibres and the absence of any vegetable matter.*

EXPLAIN THAT a detailed technical discussion of combing is carried out in the Wool Science, Technology and Design Education Program course *Worsted top-making*.



EXPLAIN THAT before the newly-formed top can enter the spinning stage it has to be made some 40 times thinner by 'drawing' it down into a fine sliver, called a roving.

INDICATE THAT the objective of drawing, a process of repeated gilling and drafting (extending the top), is to reduce a 20g/m worsted top to <0.5g/m roving.

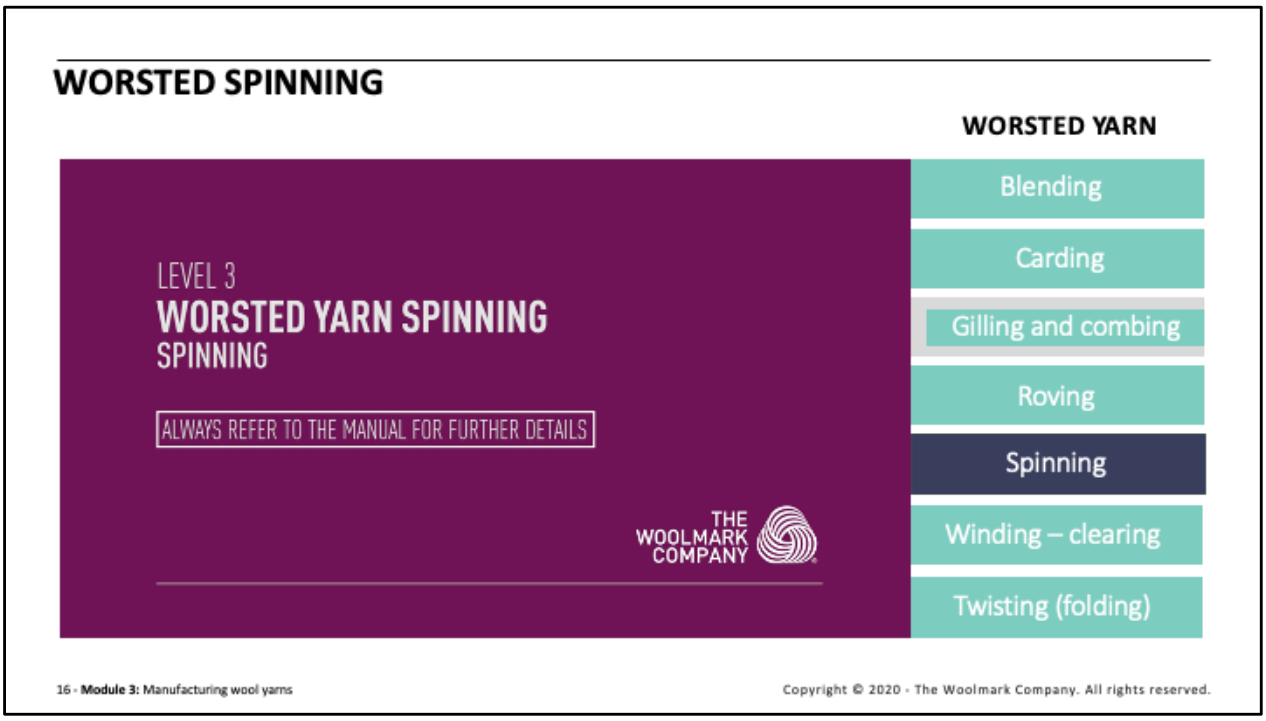
EXPLAIN THAT the roving is then 'spun' to form a worsted yarn.

PLAY *the 36 second video, produced by The Woolmark Company, which shows the top entering the machine, then the drafting zone and finally the roving being wound onto a bobbin.*

HAND OUT *the samples of worsted roving.*

ENCOURAGE PARTICIPANTS *to note how easily it is broken when stretched.*

NOTE THAT a detailed technical discussion of drawing and roving is carried out in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.



EXPLAIN THAT the purpose of spinning is to:

- extend the roving into a continuous strand of yarn, which has a specified fineness indicated by a count number
- insert sufficient twist into the yarn to bind the fibres together so it is strong enough to withstand the strains of subsequent processing.

DEMONSTRATION: TWIST INSERTION

Resources required:

- *worsted roving*

Pull a small selection of fibres from the roving sample and twist them between your fingers to demonstrate the concept of twist insertion. Pull each end of the twisted fibre sample to demonstrate the increased strength imparted by the twisting process.

INDICATE THAT there are several types of spinning including:

- ring spinning — most common for worsted and woollen industry
- mule spinning — sometimes used in the woollen industry
- open-end short-staple spinning — used for cotton.

PLAY *the 45 second video, produced by The Woolmark Company, which shows the spinning process.*

DURING *the video you may like to highlight:*

- *the process of drafting the roving (~0:08)*
- *the insertion of twist to the fibre strand (~0:19)*
- *the yarn being wound onto the bobbin (~0:30)*
- *the automatic removal of the bobbin (~0:34)*

DEMONSTRATION: THE IMPACT OF FRICTION DURING SPINNING

Resources required:

- *piece of A4 paper*
- *flat surface (e.g. table top)*
- *light object (e.g. mobile phone)*

Push the paper gently across the flat surface as you ask participants to note the ease at which the paper moves across the surface.
Place the object on the paper and repeat the process asking students to note the increase in difficulty of pushing the paper.

EXPLAIN THAT *the additional weight on the paper increases the friction between the two objects.*

EXPLAIN THAT *just as the weight increase the friction between the paper and the surface, the process of spinning forces wool fibres into close contact, increasing the friction between them, making the fibres 'stick' together.*

EXPLAIN THAT worsted spinning is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning.*

WORSTED SPINNING — TWIST INSERTION

17 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT during spinning the twist is inserted in either the 'Z direction' (clockwise) or 'S direction' (anti-clockwise).

DEMONSTRATION: Z TWIST vs S TWIST

Resources required:

- *Jacket or sweater sleeve*

Demonstrate Z twist (clockwise twist) and S twist (anti-clockwise twist) by twisting the sleeve of a jacket or sweater.

EXPLAIN THAT inserting a Z twist (clockwise direction) is the norm in worsted and woollen spinning.

REINFORCE THAT the friction between the fibres, which keeps them together, is significantly increased through the twisting action.

EXPLAIN THAT the twisted fibres in the spun yarn remain under some tension, which imparts a residual torque to the yarn.

INDICATE THAT this residual torque can cause the yarn to 'snarl' or twist on itself if not properly controlled. To reduce the torque and snarling the spun yarns are steamed.

DEMONSTRATION OF SNARL

Resources required:

- *Relaxed yarn*

Bring together the ends of the relaxed yarn — there may be some snarl, or perhaps no snarl. Release the ends and add twist to the yarn before repeating the process.

***NOTE THE** increased amount of snarl with the addition of twist to the yarn.*

***EXPLAIN THAT** the additional torque from adding twist to the yarn causes the increase in snarl.*

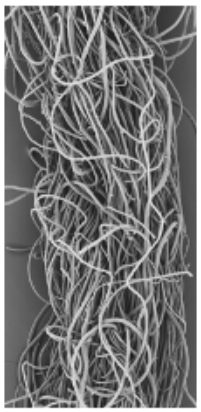
EXPLAIN THAT this process will be discussed more fully in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.

***ASK** participants if they have any questions about worsted spinning before you move on.*

***ALLOW** time for questions and discussion before proceeding to the next slide.*

THE WOOLLEN YARN MANUFACTURING PROCESS

WOOLLEN YARN



- Carbonising
- Blending – opening
- Carding
- Spinning
- Winding – clearing
- Twisting (folding)

18 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT manufacturing woollen yarn is a simpler and shorter process than manufacturing worsted yarn.

INDICATE THAT the key differences between the manufacturing of woollen and worsted yarn are:
- the additional stage of carbonising
- the absence of gilling and combing (top-making).

EXPLAIN THAT the following slides focus on the two steps that differ from worsted processing — carbonising and woollen carding.

INDICATE THAT although the final steps of the woollen processing route (spinning and winding) are similar to the worsted system, they also have distinct differences.

CARBONISING

WOOLLEN YARN

- Carbonising
- Blending – opening
- Carding
- Spinning
- Winding – clearing
- Twisting (folding)

Carbonising:

- sulphuric acid dehydrates vegetable matter
- vegetable matter becomes black and is easily crushed to dust
- dust falls out of the wool.

Additions tank on a carbonising line showing addition of sulphuric acid

EXPLAIN THAT carbonising uses sulphuric acid to remove vegetable matter, such as burrs or seeds, when levels exceed 5% of the weight of wool.

Although much of this vegetable matter could be removed through the process of combing, because combing is not used in the woollen processing route, carbonising is often required.

INDICATE THAT even in woollen processing, if the amount of vegetable matter is low, this step may not be required, in which case the process for vegetable removal is done through carding.

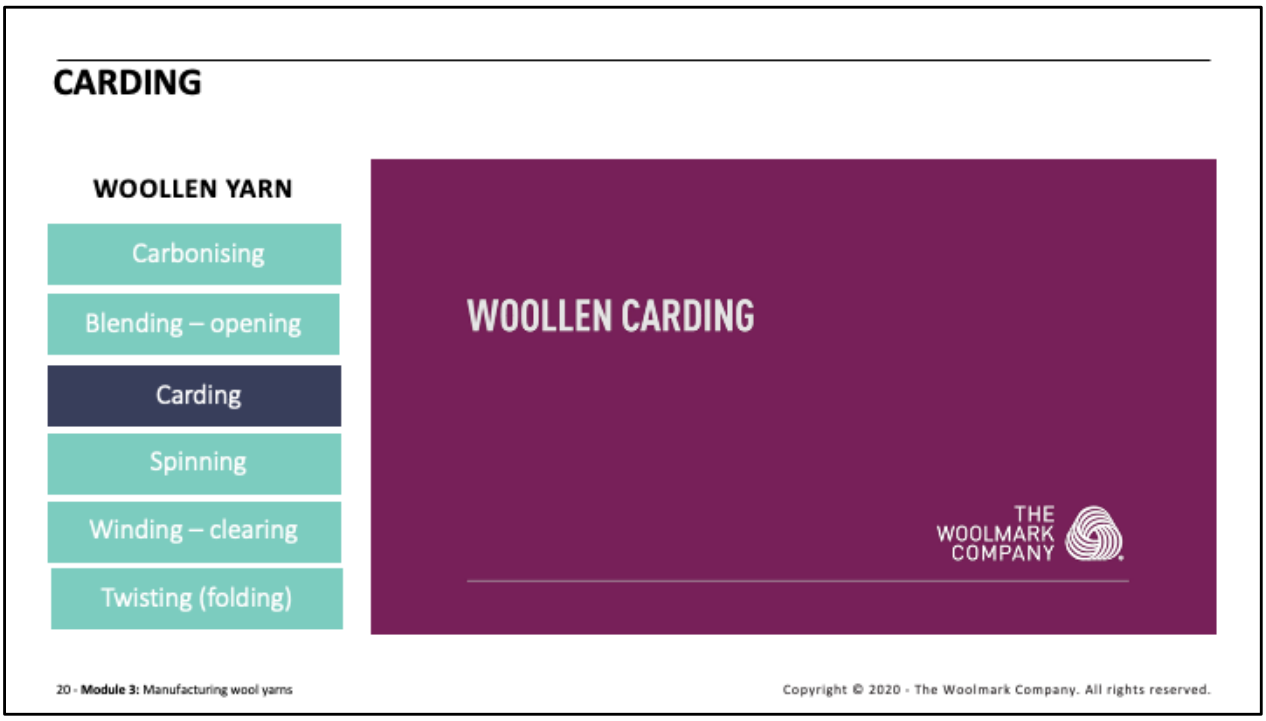
EXPLAIN THAT during carbonising:

- wool is treated with sulphuric acid in water
- the wool is dried and baked
- the acid dehydrates the vegetable matter
- the vegetable matter becomes black and is easily crushed to dust
- the dust falls out of the wool.

HAND OUT *the samples of scoured wool, and scoured and carbonised wool.*

ENCOURAGE PARTICIPANTS *to note the difference in vegetable matter and handle between the samples.*

EXPLAIN THAT carbonising is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.



EXPLAIN THAT there are distinct differences between how the wool is carded in the worsted and woollen carding processes — but the principles remain the same.

INDICATE THAT the carding action in woollen carding is similar to worsted carding except:

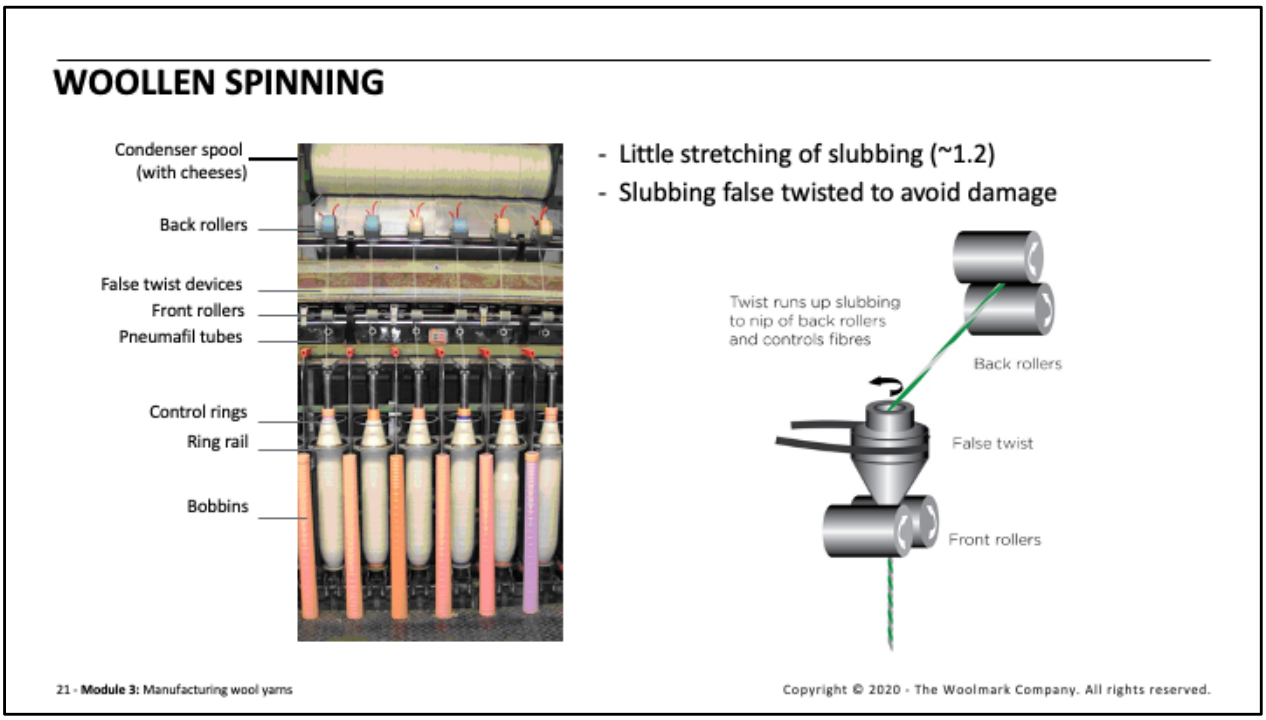
- mixing of the wool (blending) is encouraged by cross-lapping the sliver formed and re-carding the cross-lapped layer in the second part of the card
- at the end of the card, instead of being wound into a can as a single sliver ready for gilling the web is split into narrow strips called 'slubbings', ready for spinning.

***PLAY** the three-and-a-half minute video, produced by The Woolmark Company, which illustrates the woollen carding process.*

***DURING** the video you may like to note that:*

- *in the woollen system the scoured wool is often dyed before carding*
- *the fibre tufts are separated into fibres by workers and stripper, like the worsted system (~0:37 seconds)*
- *the emerging web is folded rather than drawn into a sliver (~0:48 seconds)*
- *the folded web is transferred to the next part of the card (~1:07minutes)*
- *the folded web is laid across the card (~1:46 minutes)*
- *tapes are used to split the final web into slubbings (~2:31 minutes)*
- *the slubbings are rolled into packages (note there are many packages coming from the car) (~2:46 minutes)*
- *the slubbings are rubbed to add strength (~2:53minutes)*

EXPLAIN THAT woollen carding is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.



EXPLAIN THAT woollen yarns are spun using the same principles as the process undertaken for worsted spinning.

NOTE THAT the differences are:

- the slubbings from the woollen card are given only a little stretch before twisting — just enough to maintain cohesion. This contrasts to the 20–30 times stretch used in worsted spinning
- a false twister is often used to give the slubbing strength so it survives the spinning process.

DEMONSTRATION: FALSE TWIST

Resources required:

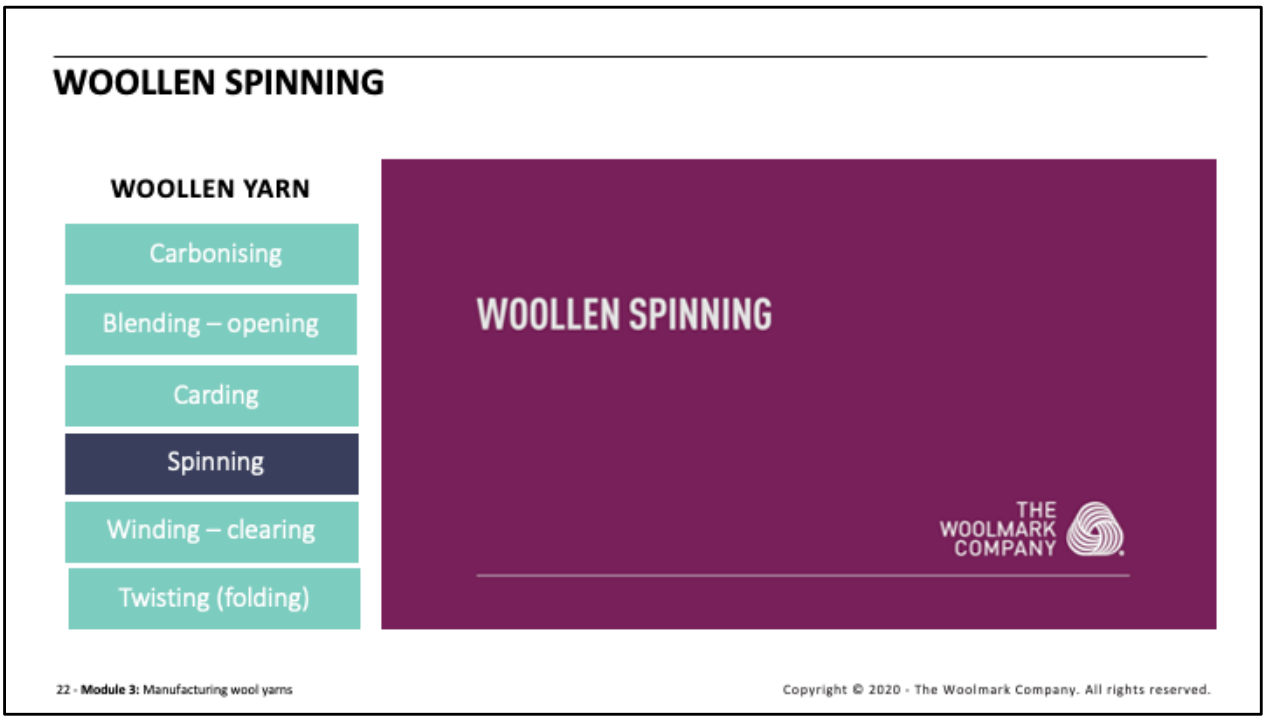
- *several yarns of differing colours (each about one metre in length).*

Ask two volunteers to face each other at a distance of about one metre and hold the opposing ends of the yarns in their right hands.

Using their left hands ask the volunteers to twist the mid-section of the yarn bundle to impart twist. Ask the volunteers to then release the twisted yarn.

***NOTE THAT** the twist disappears — demonstrating the concept of false twist.*

EXPLAIN THAT woollen spinning is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning.*



PLAY *the one-and-a-half minute video, produced by The Woolmark Company, which shows a woollen spinning machine. The draft in the spinning is small 1-1.5.*

NOTE THE *the spindles are much bigger than those found in most worsted spinning frames.*

HAND OUT *the samples of worsted and woollen yarn.*

REINFORCE THE *differences:*
- *Worsted — smooth and fine*
- *Woollen— bulky and hairy*

ASK *participants if they have any questions about woollen spinning before you move on.*

ALLOW *time for questions and discussion before proceeding to the next slide.*

YARN RELAXATION

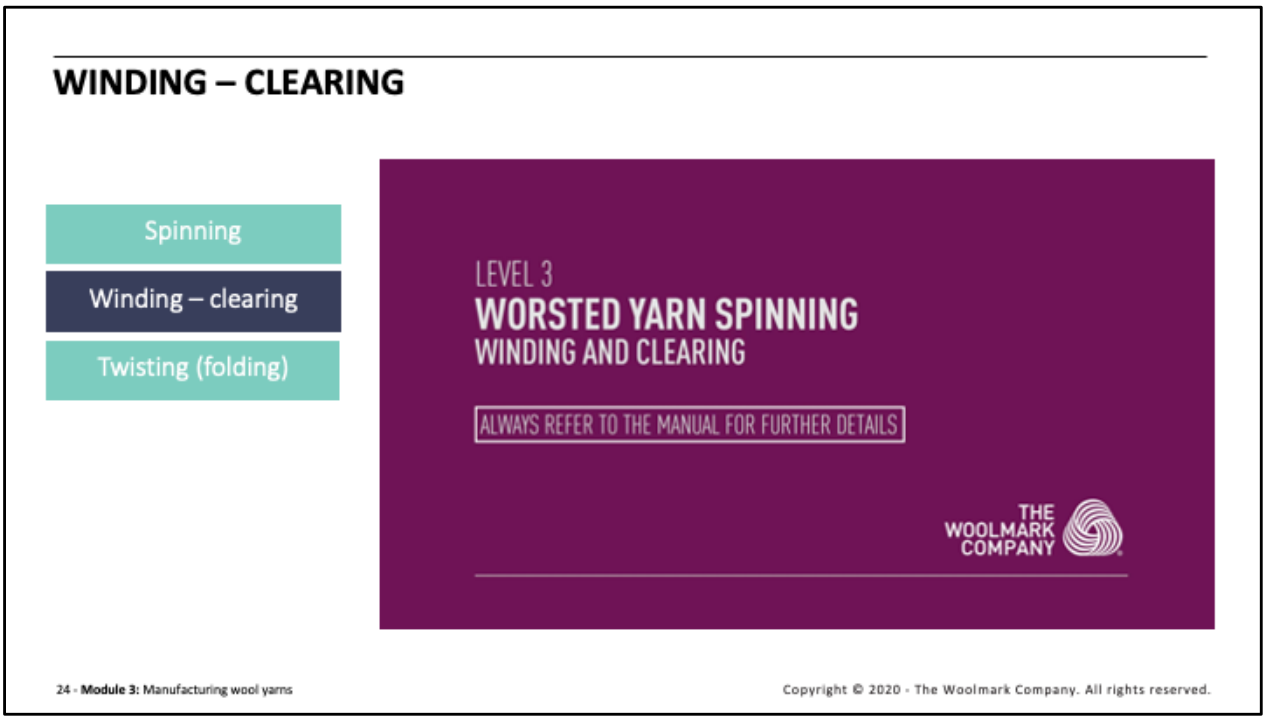
- Yarn is 'twist lively' following spinning.
- Unless relaxed, yarn tends to snarl under moderate to low tension.
- Yarn is steamed to impart temporary set in a sealed vessel or autoclave to prevent snarling.

Snarling

EXPLAIN THAT the yarn on the ring spinning bobbin is normally 'twist lively' and must be set in steam (relaxed) before it can be used in weaving or knitting, otherwise, under moderate to low tension, the yarn will tend to snarl.

In order to prevent fibre damage, a temperature of 80^{o}C should be adequate for steaming most worsted-spun yarns. If this is insufficient and some unacceptable snarling remains, longer steaming times, rather than higher temperatures, should be used to avoid yellowing of the fibre.

INDICATE THAT this process will be discussed more fully in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.



EXPLAIN THAT when the yarn has been spun it is wound onto cones. During winding the yarn is checked for faults (such as sections that are too thick or thin), a process called clearing.

NOTE THAT the single worsted yarn is not really usable until it has been 'cleared' of thick and thin faults.

EXPLAIN THAT yarn on the spinning bobbin is fed through a clearing device, which checks the thickness of every centimetre of yarn and deliberately breaks the yarn where it is too thick or too thin.

The yarn is reformed by using jets of air to intermingle the fibres at each end of the break, applying heat, which melts the lubricants on the yarn and glues the fibres together.

***PLAY** the 40 second video, produced by The Woolmark Company, which shows the winding and clearing process.*

***NOTE IN THE** video how the yarn is automatically broken to remove faults and reformed. This is difficult to see, so requires close observation.*

***REPLAY THE** video to allow participants to focus on this aspect.*

EXPLAIN THAT winding is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning*.

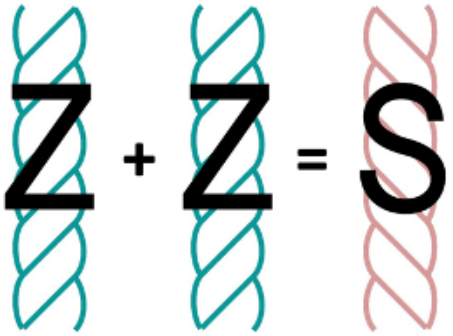
TWISTING (FOLDING)

Twisting (folding) combines singles yarn into a folded yarn by twisting the yarns together.

Two singles yarns create a two-fold yarn and so on.

Twisted yarn is:
- more even
- more resistant to abrasion
- stronger with better elasticity
- a more balanced structure if:
  - folding twist is imparted in the reverse direction as shown
  - folding twist is ~60% of spinning twist.

Spinning
Winding – clearing
Twisting (folding)



25 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT many yarns undergo a further process called 'twisting', 'folding' or 'plying'.

INDICATE THAT after clearing, singles yarns can be combined by twisting, which creates a compound yarn (e.g. two-fold or two-ply yarn). Combining two or more singles yarns into a two (or more)-fold yarn produces a technically superior final yarn.

EXPLAIN THAT S twist is used in twisting. In this way the torque (twisting force) in the final yarn is balanced and the yarn does not tend to snarl.

EXPLAIN THAT twisted yarn:
- is more even — improved regularity
- resists abrasion in fabric formation more effectively than singles yarn
- gives greater strength and elasticity than a singles yarn
- is a more balanced structure if the folding twist is in the opposite direction to the spinning twist. Normally a balanced yarn is achieved if the folding twist is around 60% of the spinning twist. This is not always adopted by spinners when other characteristic of the yarn are sought
- introduces certain desirable characteristics, including:
  - softness/hardness
  - colour effects
  - different structures.

DEMONSTRATION :TWISTING

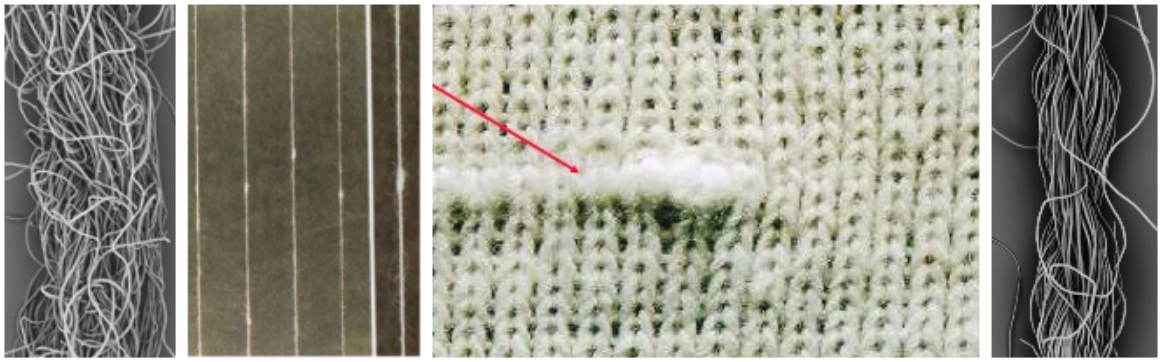
Resources required:
- *Two x 2m lengths of top*

Twist and fold the tops to demonstrate the concepts discussed.

REINFORCE THAT twisting is an additional process, which incurs additional expense. It is not always necessary for all yarn uses.

EXPLAIN THAT the process of twisting is studied in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning.*

YARN ATTRIBUTES — TYPE AND QUALITY



26 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT whether wool yarn is produced through the worsted or woollen processing routes, there are several different factors that affect the attributes of a yarn and the products made from it.

INDICATE THAT these factors generally fall into two broad categories:

- yarn type
- yarn quality.

EXPLAIN THAT you will now go on to discuss these attributes.

YARN TYPE — WOOLLEN VERSUS WORSTED

ATTRIBUTE	WOOLLEN YARN	WORSTED YARN
Wool source	Pieces/necks etc. Waste from worsted processing	Fleece wool
Fibre length	35 – 55mm	55 – 80mm
Number of fibres in the yarn cross-section	130	35 – 100
Processing route	Shorter	Longer
Count range	Less versatile 1 – 28 Nm	More versatile 10 – 120 Nm
Average spinning draft	1 – 1.5	20 – 30

EXPLAIN THAT a key determinant of the type of yarn is the manufacturing process — woollen or worsted.

INDICATE THAT the differences between yarns produced by the woollen and worsted processing routes are summarised in the slide.

SUMMARISE THE content on the slide by explaining that:

- woollen spinning uses the shorter, more variable wool harvested from the sheep and requires more fibres in the yarn cross-section to make a yarn that will perform acceptably in subsequent fabric or garment-making operations
- the route from fibre to yarn is a long process, but woollen spinning is the simpler yarn production route
- woollen yarn is more limited than worsted yarn in terms of count.

YARN TYPE — PRINCIPAL WOOL BLENDS

WOOL BLEND	COMMON USE
Wool/Polyester	Woven apparel
Wool/Polyamide	Woollen woven and knitted apparel, carpets, etc.
Wool/Acrylic	Knitwear
Wool/Cellulosic	Woven and knitted apparel
Wool/Elastane	Stretch products

WOOL RICH BLEND

WOOL BLEND PERFORMANCE

28 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT another attribute that determines yarn type is the fibre content or blend.

NOTE THAT modern consumers are demanding, in terms of what they expect from fabrics used in sports and activewear. It is a challenge for one single fibre to meet so it is logical to combine one or more fibres to create the desired performance.

MENTION THAT there are five principal wool blends, each of which are commonly used in a variety of ways (as outlined on the slide).

- Polyester imparts washability and shape stability and reduces cost.
- Polyamide (nylon) improves abrasion resistance and strength.
- Acrylic brings softness and reduces cost.
- Cellulosics (cotton and viscose) provide a casual appearance and add softness. In addition, the cost may also be reduced.
- Polyurethane fibres (e.g. elastane) impart stretch.

HAND OUT *the sample of the wool/polyester or wool/cotton blend.*

INDICATE THAT *only the wool fibres in the blend have been dyed.*

ASK PARTICIPANTS *if they have any wool blend garments.*

ALLOW TIME *for questions and discussion before proceeding.*

EXPLAIN THAT there are many two-component and three-component blends used by the textile industry. Each is usually developed for a specific application.

NOTE THAT The Woolmark Company has trademarks especially for wool blends shown in the slide. The difference between these trademarks will be discussed towards the end of the course.

REINFORCE THAT wool is often blended with synthetic fibres to achieve certain performance benefits and advantages, and new environmentally conscious options are now available including:

- DuPont Sorona®, contains 37 per cent renewable plant-based components. It is suitable for use in apparel, fishing lines and nets, medical end uses, nappies and footwear.
- DuPont Apexa®, is a biodegradable polyester, which decomposes through industrial composting without harming to the soil or environment.
- ECONYL®, is made from waste, such as fishing nets and old carpets. ECONYL is infinitely recyclable and offers various design possibilities.

YARN TYPE — COUNT

INDUSTRY	COUNT METHOD	UNITS	MEASURE	CONVERSION TO TEX
Synthetic	Tex (direct)	Tex	g / 1000 m	N/A
Wool	Metric (indirect)	Nm	hanks of 1000m / kg	40 Nm = 25 Tex
	Worsted (indirect)	Nw	hanks of 560yds / lb	40 Nw = 22.5 Tex
Cotton	Cotton (indirect)	Ne	hanks of 840yds/ lb	40 Ne = 14.8 Tex

30 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT the third determinant of the type of yarn is the yarn count.

Yarn count indicates how thick (heavy) or fine (light) a yarn is.

EXPLAIN THAT due to the differences in the production methods and historical development of the various industries, yarn count is measured using methods specific to each material (as outlined on the slide):

- The synthetic industry normally uses a direct measurement (Tex)
- The wool industry uses metric (Nm) and worsted count (Nw), which are indirect measurements
- The cotton industry uses metric and cotton count (Ne), also an indirect measurement.

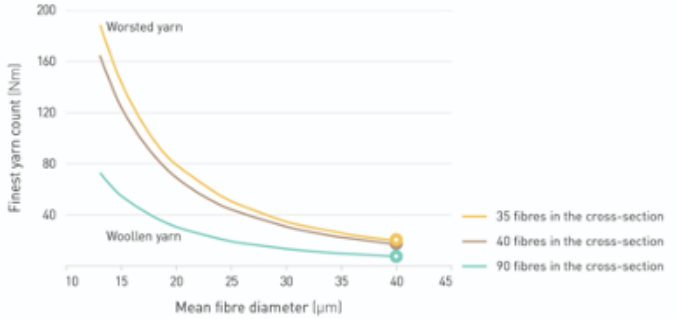
EXPLAIN THAT Tex is the only method that measures the weight of yarn directly in grams per kilometre (g/km). As a consequence the higher the Tex value (count), the thicker the yarn.

NOTE THAT metric, worsted and cotton systems measure the weight of yarn indirectly by measuring the length of yarn required to achieve a defined weight. As a consequence the higher the count (Nm, Nw or Ne), the finer the yarn.

EXPLAIN THAT care must be taken to ensure the correct method of determining yarn count is used when specifying and selecting yarn for any given purpose or end product.

YARN COUNT AND FIBRE FINENESS

- Worsted yarns normally require ~40 fibres in the cross-section of the yarn.
  - In some instances yarns with 35 fibres can be successfully spun
  - Below this figure
    - ends down increases
    - yarns are too uneven
    - yarns lack sufficient strength.
- Woollen yarns require at least 90 fibres in the cross-section.



Impact of fibre diameter on yarn count

EXPLAIN THAT the finest count of yarn that can be spun depends on the mean fibre diameter of the raw fibre and the spinning system employed to produce the yarn.

INDICATE THAT for worsted spinning, ~40 fibres in the yarn cross-section is considered a commercial minimum, although under some circumstances 35 fibres in the cross-section can be spun.

EXPLAIN THAT below this figure:

- ends down increases
- yarns are too uneven
- yarns lack sufficient strength.

NOTE THAT the finest yarn count that can be spun from wool of a specific mean fibre diameter is shown on the slide.

EXPLAIN THAT for woollen spinning, 90 fibres in the cross-section is considered the minimum for commercial spinning. As a result the finest woollen yarns are much thicker (lower metric count) than the finest worsted yarns from source fibres of the same mean diameter.

YARN TYPE — TWIST

- Knitting yarns generally have a lower twist than weaving yarns.
- High-twist yarns resist abrasion and generally have better knitting performance (provided twist is not too high).
- Twist affects performance during finishing of fabric and garments.
- Twist affects fabric handle and performance
  - High-twist yarns — products have crisper handle.
  - Low-twist yarns — products have softer handle but poorer pilling performance.
- Optimum balance of knitting performance and fabric properties.

32 - **Module 3:** Manufacturing wool yarns

EXPLAIN THAT the fourth determinant of the type of yarn is the amount of twist.

The twist in yarns affects the performance of the yarn during knitting and weaving as well as the performance of the product during wear. Tightly-twisted (high-twist) yarns bind the fibres more securely so the yarn can resist abrasion in the yarn guides and needles in knitting machinery.

NOTE THAT yarn twist also affects behaviour during finishing of the product. Fabrics from high-twist yarn resist felting during finishing.

EXPLAIN THAT yarn twist also affects the subsequent handle of the finished product. The higher the twist; the crisper the handle. The lower the twist; the softer the handle.

INDICATE THAT yarn twist affects the performance of the product during wear. The higher the twist; the lower the propensity to pilling.

EXPLAIN THAT pilling is discussed further, later in this course.

EXPLAIN THAT yarn twist can be assessed by measuring the number of turns required to 'untwist' a standard length of yarn. Two measures are used

- turns per metre (tpm)
- twist factor (alpha).

Twist factor (TF) = $\frac{\text{turns/metre}}{\text{(metric count)}}$

INDICATE THAT the common twist factor for a weaving yarn is TF ~ 90 – 100 although higher twist is used in crepe and poplin fabrics.

INDICATE THAT the common twist factor for a knitting yarn is TF ~ 80.

HAND OUT *the samples of fabric knitted using high-twist and low-twist yarns.*

ASK PARTICIPANTS *to describe the differences they can observe between the samples.*

REINFORCE THAT *the fabric knitted using high-twist yarn has a 'crisper' handle than the fabric knitted form the low-twist yarn.*

ASK PARTICIPANTS *if they have any questions about yarn type before you move onto yarn quality*

ALLOW TIME *for questions and discussion before proceeding.*

REMIND PARTICIPANTS that the second issue of concern to the manufacturer and the customer is yarn quality.

EXPLAIN THAT there are several attributes associated with yarn quality. Their importance in terms of yarn selection varies according to the end-use of the yarn.

INDICATE THAT quality affects a number of aspects of knitting and knitted products. These can be divided roughly into effects on:
- the knitting operation
- the product appearance
- the product performance.

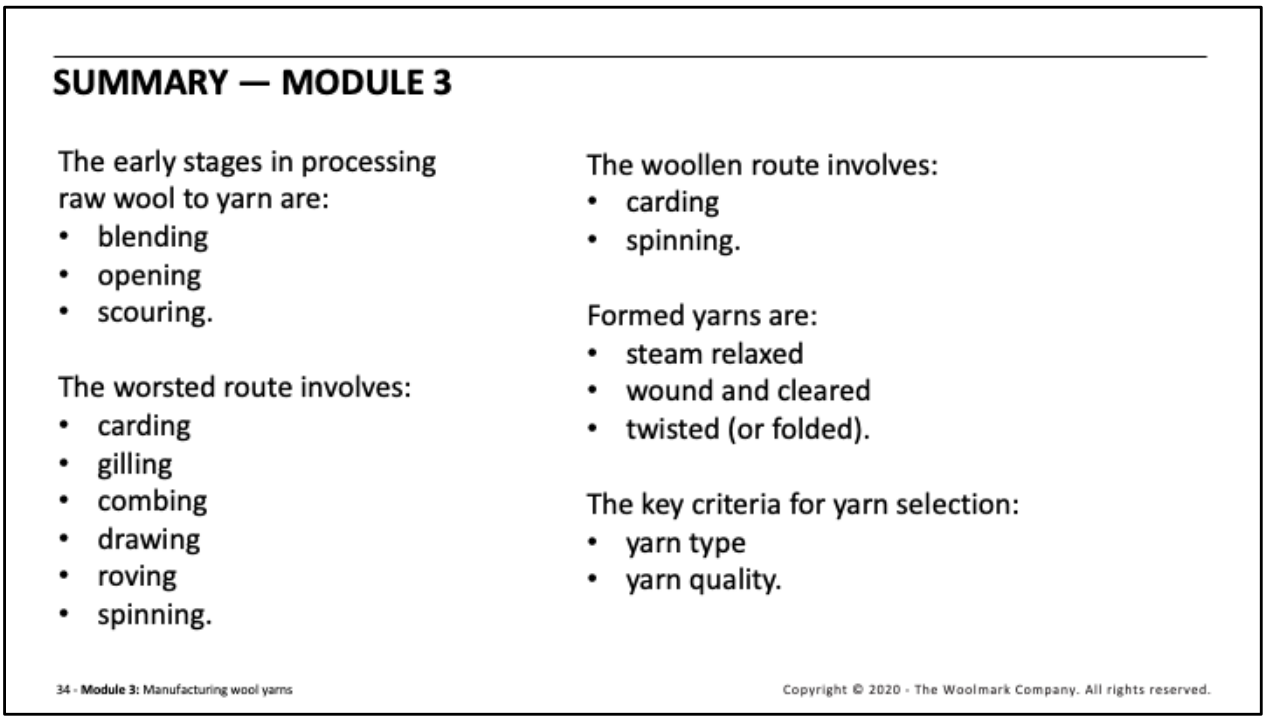
INDICATE THAT within each of these areas of concern are a number of different issues:

Issues affecting the knitting operation
- Yarn strength and extensibility.
- Yarn friction.
- Correct and even moisture content of yarn.
- Knots and splices.

Issues affecting product appearance
- Poor uniformity of count and twist.
- Thick and thin places (yarn consistency)
- Knots and splices
- Contamination (i.e. foreign fibre or vegetable matter)
- Hairiness.

Issues affecting product performance
- Colour fastness.

EXPLAIN THAT the methods for measuring these quality attributes of yarn will be covered in later courses in the Wool Science, Technology and Design Education Program.



REINFORCE THAT this module the steps in the production of yarns from raw wool were briefly outlined. The initial steps common to all types of yarn production are:

- blending: to evenly mix the production. Blending can occur as bales and as scoured wool
- opening: to open (break up the clumps) the wool so it is easier to scour
- scouring: to clean the wool.

REINFORCE THAT the worsted route involves:

- carding: to open the wool to individual fibres
- gilling: to align the fibres
- combing: to remove vegetable matter, neps and short fibres (noil)
- drawing: to reduce the weight of the top
- roving: to prepare a fine sliver for spinning
- spinning: to form the yarn.

REINFORCE THAT the woollen route involves:

- carding: to open the wool to individual fibres and form slubbings ready for spinning
- spinning: to form the yarn

REVIEW THAT formed yarns are:

- wound and cleared: to remove faults
- steam relaxed: to prevent snarling
- twisted or folded: to create a more even two-ply or multi-ply yarn.

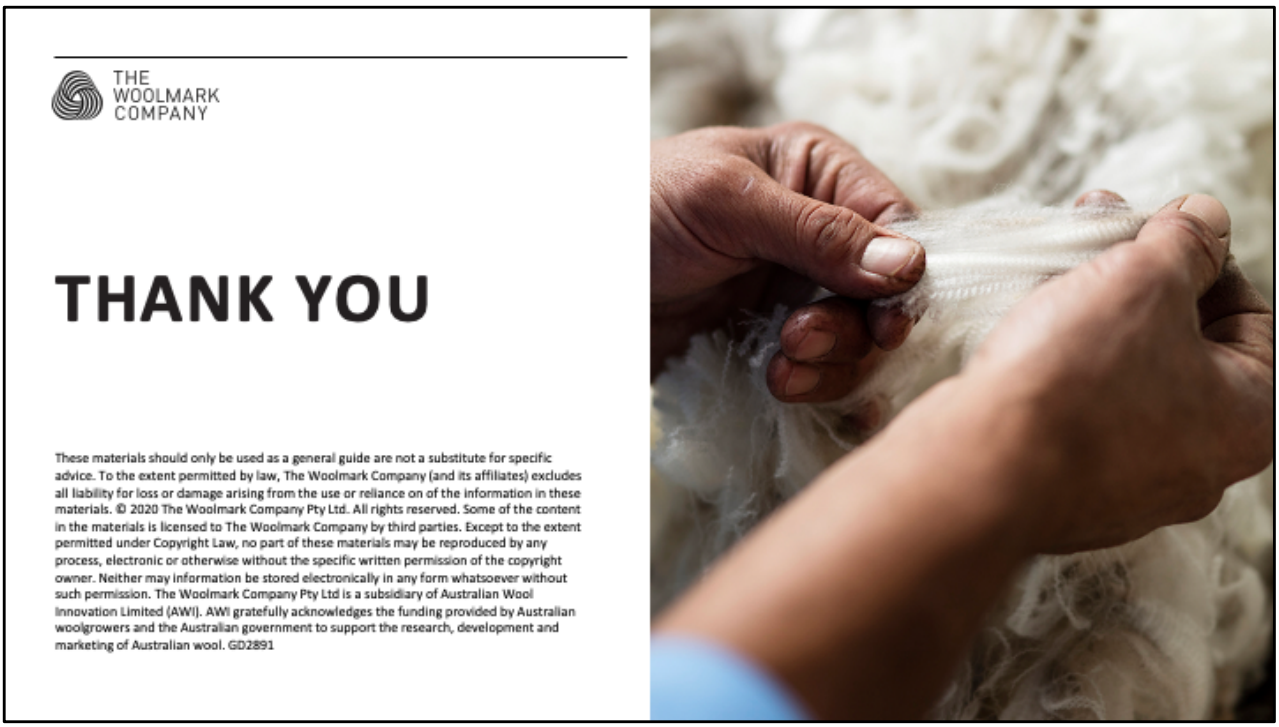
REINFORCE THAT the key criteria for yarn selection include:

- yarn type
  - woollen or worsted
  - pure wool or blend
  - count and twist
- yarn quality
  - evenness
  - strength and extensibility
  - thick and thin places.

ASK PARTICIPANTS *if they have any questions about the content covered in this module.*

ALLOW TIME *for questions and discussion before proceeding to the final slide and closing the lecture.*

COLLECT ALL *samples distributed during the lecture.*



INFORM participants of the time and location for the next lecture — *Module 4: Manufacturing wool products* — and ensure they read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 4

THE WOOLMARK COMPANY

MANUFACTURING WOOL PRODUCTS

RESOURCES — MODULE 4: MANUFACTURING WOOL PRODUCTS

Contained in the *Introduction to wool processing* Demonstration kit you will find the following resources for use as you deliver **Module 4: Manufacturing wool products**:

- sample of worsted-spun fabric
- sample of woollen-spun fabric
- sample of wool dyed as loose fibre
- sample of wool dyed as yarn
- sample of wool dyed as fabric
- sample of unfinished wool fabric
- sample of finished wool fabric

Additional resources to be sourced by the facilitator include:

- Lightweight woven wool product (e.g. shirt)
- Midweight woven wool product (e.g. suiting)
- Heavyweight woven wool product (e.g. overcoat)
- Unfinished wool garment
- Finished wool garment

THE WOOLMARK COMPANY

INTRODUCTION TO WOOL PROCESSING

MODULE 4:

Manufacturing wool products

WELCOME participants to Module 4 of *Introduction to wool processing — Manufacturing wool products*.

***ASK** participants if they can recall a range of examples of products made from wool and wool blends.*

***ALLOW** sufficient time for participants to respond before proceeding.*

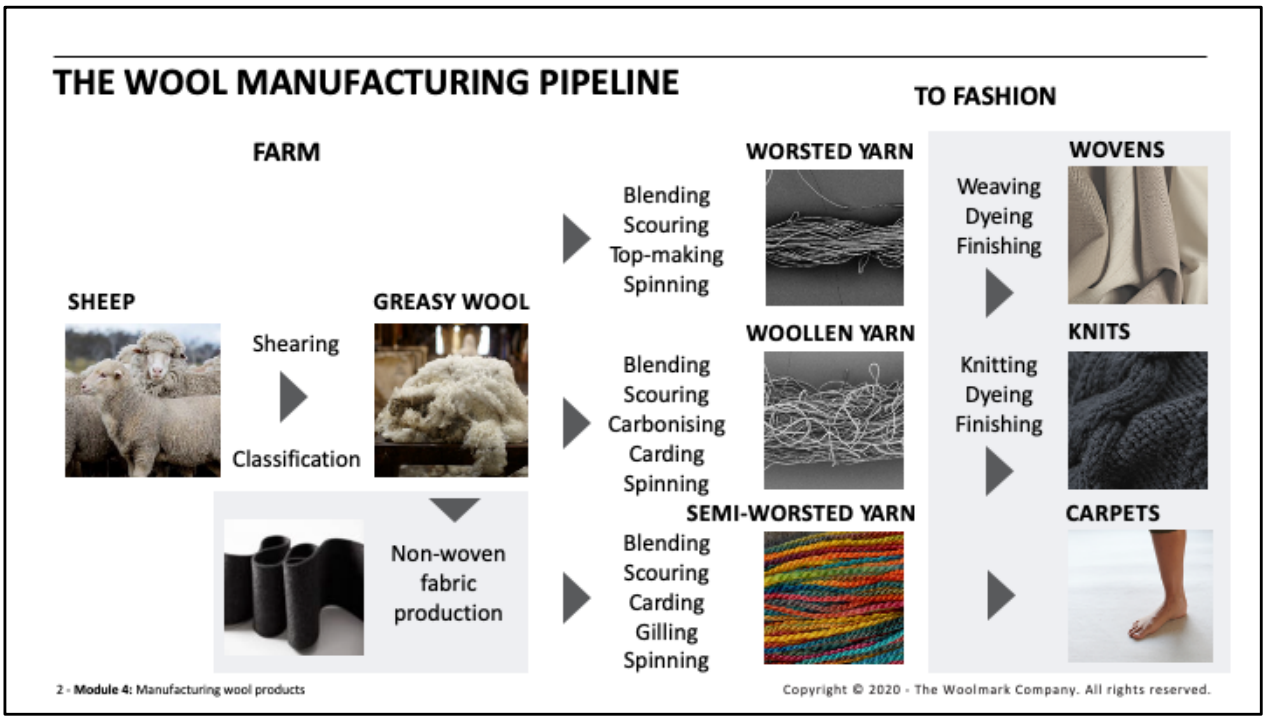
EXPLAIN THAT this module will explore the processes used to manufacture wool products (fabric and garments) from worsted and woollen wool yarns.

INFORM participants that by the end of this module they will be able to:

- describe three methods of wool fabric manufacture (knitting, weaving and non-woven)
- indicate the type of products manufactured using each method
- outline the mechanism of knitting in knitting machines
- describe five types of knitting machine
- indicate the key stitches used to pattern knitted fabric and give two examples
- describe the action of a weaving machine
- nominate four methods of weft transport and the suitability of each for wool
- describe four methods used to manufacture non-woven fabrics
- outline the aims of the dyeing process and the stages at which it can occur during both worsted and woollen processing routes
- explain the aims of finishing and outline the processes involved for knitted and woven fabrics and garments
- outline the processes and technologies used to recycle wool.

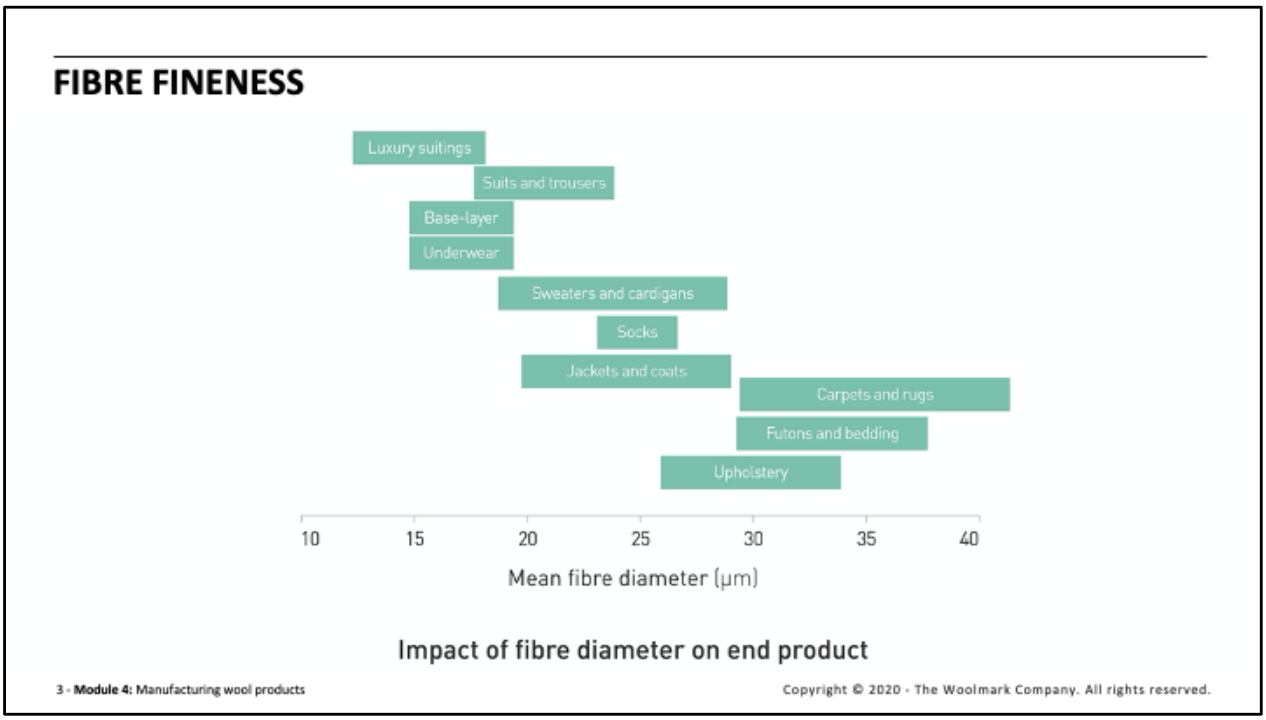
RESOURCES REQUIRED FOR THIS MODULE

- *sample of worsted-spun fabric*
- *sample of woollen-spun fabric*
- *lightweight woven wool product (e.g. shirt) (facilitator to supply)*
- *mid-weight woven wool product (e.g. jacket) (facilitator to supply)*
- *heavyweight woven wool product (e.g. coat) (facilitator to supply)*
- *sample of wool dyed as loose fibre*
- *sample of wool dyed as yarn*
- *sample of wool dyed as fabric*
- *sample of wool dyed as garment (facilitator to supply)*
- *sample of unfinished wool fabric*
- *sample of finished wool fabric*
- *sample of unfinished wool garment (facilitator to supply)*
- *sample of finished wool garment (facilitator to supply)*



EXPLAIN THAT, as discussed, the production and manufacture of wool is a long and complex process, involving many different processes and people. It can take 12–18 months from the time the wool is harvested from the sheep (during shearing) to the point at which it is sold to the consumer.

INDICATE THAT this module consists of an overview of weaving, knitting, dyeing and finishing as well as methods of non-woven fabric formation (e.g. felting).

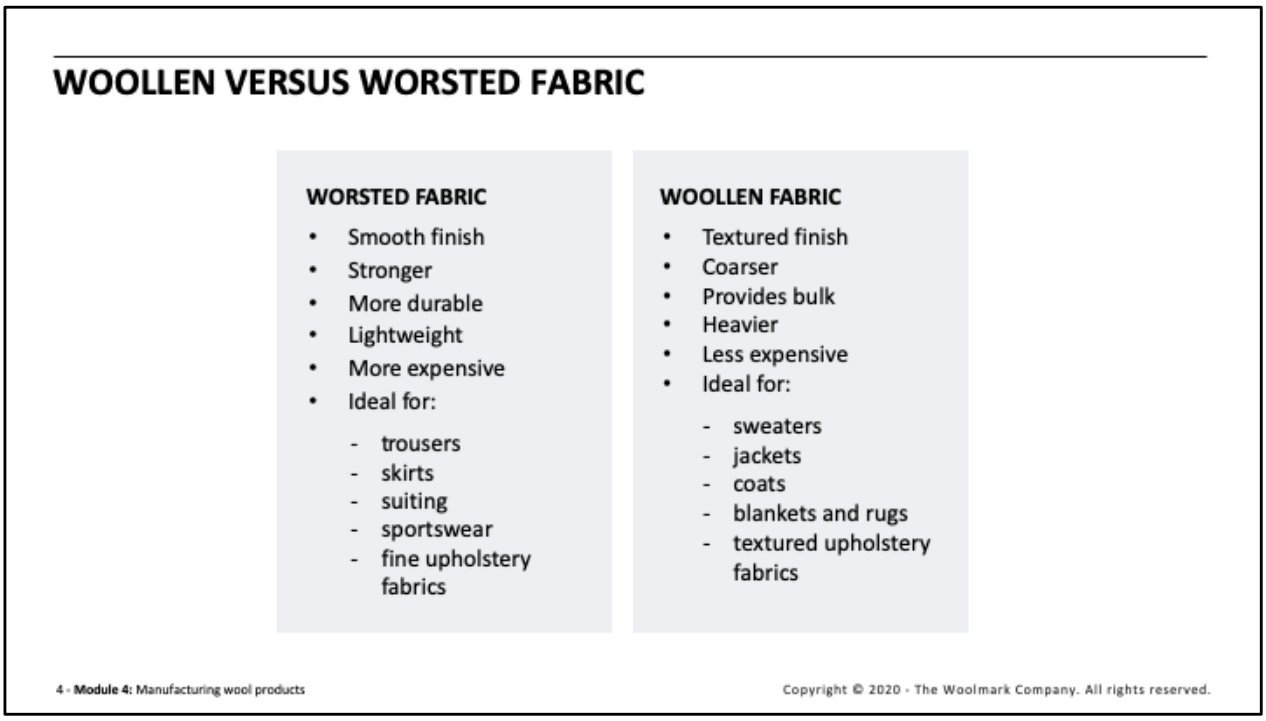


EXPLAIN THAT the fineness (mean fibre diameter) and the length of the fibres (staple length of raw wool or mean fibre length in top) are the most important determinants of the type of wool product that can be manufactured from the raw fibre.

INDICATE THAT as shown on the slide, wools with a mean fibre diameter <18.5µm (e.g. superfine, ultrafine and extrafine Merino) can be used to create fine yarns for lightweight products as well as heavier-weight luxury products. However, the broader the wool becomes, the heavier is the finest yarn that can be spun from that wool. Consequently the products derived using the heavier yarn also become considerably heavier.

EXPLAIN THAT medium wools can only be used for medium or heavyweight apparel.

Broad fibres (>29µm) are limited to relatively coarse yarns suitable for interior textiles and carpets.



EXPLAIN THAT this slide summarises some of the key differences between the fabrics (woven or knitted) produced from woollen and worsted yarns.

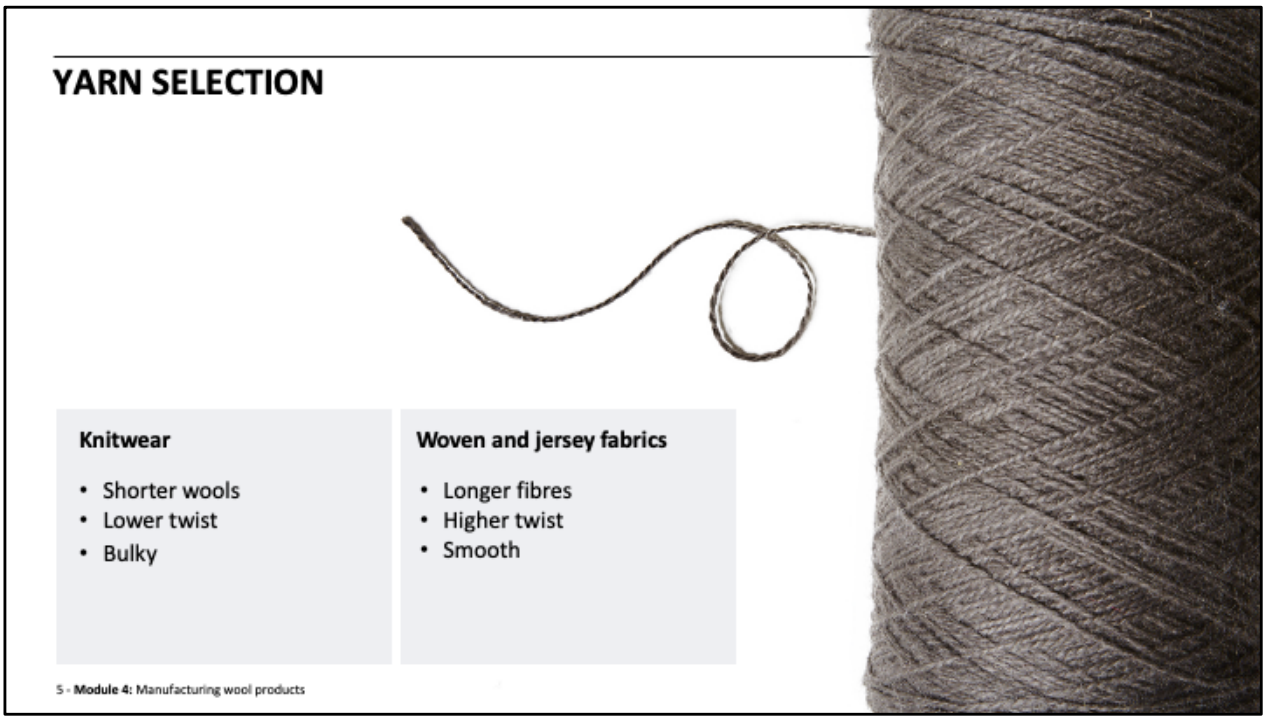
NOTE THAT worsted-spun fabrics:
- provide a smoother finish than woollen fabrics, because of the fineness of the wool
- are stronger and resist abrasion in wear better than a woollen-spun fabric of equivalent weave construction and fabric weight
- tend to be lighter weight than woollen fabrics
- are often more expensive than woollen-spun products, due to the longer processing route to bring the raw material to resultant yarn
- are preferred for skirts, trousers, suiting and upholstery fabrics where a smooth finish and durability are required
- are preferred for next-to-skin and sportswear applications made from fine wool.

NOTE THAT woollen-spun fabric:
- is usually used for jackets, pullovers, skirts, coats, rugs, blankets, and upholstery where a textured finish is desirable
- is coarser and provides more bulk and warmth.

HAND OUT *samples of worsted-spun and woollen-spun fabrics.*

ASK PARTICIPANTS *to describe the differences they observe in the fabrics as they pass them around the group.*

NOTE RESPONSES *on the whiteboard or flipchart. If necessary prompt responses by asking participants to describe aspects such as:*
- *feel (or handle)*
- *weight*
- *potential uses.*



EXPLAIN THAT wool fabrics can be made from different types of yarn. Soft and open knitting yarns are used to make bulkier knitted fabrics, and finer, leaner yarns are used to make woven fabrics.

INDICATE THAT this section of the course will look at how to turn yarn into either knitwear or fabric (woven or knitted jersey). This starts with selecting the right yarn for the item you wish to produce.

REMIND PARTICIPANTS that yarns for knitwear are generally spun from shorter wool than weaving yarns. The twist of knitting yarns is lower than that of weaving yarns so that, at the same count, the yarns are bulkier than weaving yarns.

INDICATE THAT an overview of the pathways from raw fibre (greasy wool) to finished garment and fabric is provided on the slide.

EXPLAIN THAT it is important to remember yarn can be converted directly into a knitted garment (knitwear) from either worsted or woollen yarn. The garment requires 'finishing' to develop the full properties of the wool. The finishing of knitted garments (knitwear) is covered in the Wool Science, Technology and Design Education Program course *Wool garment finishing* .

INDICATE THAT likewise, before woven or knitted fabric can be manufactured into products, the fabric must be finished. The finishing of wool fabric is covered in detail in the Wool Science, Technology and Design Education Program course *Wool fabric finishing*.

EXPLAIN THAT knitted and woven fabrics are normally converted into garments or other products by cutting the fabric into the necessary panels and sewing these panels together to form the garment.

MANUFACTURING WOOL FABRICS

Knitting:
- Yarn is formed into a loop.
- Through this loop another loop of yarn is threaded.
- The process is repeated row by row.

Weaving:
- Warp yarns are held on a frame.
- Yarns are raised and lowered in changing sequences.
- Weft yarn is inserted between warp threads.
- Insertion of successive weft yarns builds fabric.

Non-woven fabrics:
- Fabrics are formed directly from loose fibre.
- Several techniques used.

7 - **Module 4:** Manufacturing wool products

EXPLAIN THAT there are three routes for the manufacture of wool fabrics:
- knitting
- weaving
- non-woven fabric production

INDICATE THAT knitting is a fabric-forming technology that has been used for thousands of years. It can be used to create fabrics, which are then cut to create garments, or to create garments directly. Knitting can be carried out with:
- simple technology (i.e. hand knitting needles)
- sophisticated computer-controlled knitting machines.

INDICATE THAT weaving is the process of interlacing warp and weft yarns in a weaving machine, or loom. It is used extensively to manufacture fabrics used to create apparel and interior textiles. Weaving can use:
- simple frames to hold the threads
- complex weaving machines under computer control

EXPLAIN THAT the production of non-woven fabrics requires methods to form layers of fibres into coherent fabrics without the need to spin yarns. Although most non-woven methods of fabric formation are relatively new, one of the techniques available to make non-woven wool fabrics — felting — has been used for many years and used by many early cultures.

KNITTING

8 - **Module 4:** Manufacturing wool products

EXPLAIN THAT knitting is a fabric-forming technology that has been used for thousands of years. It can be used to make either fabric or garments, with

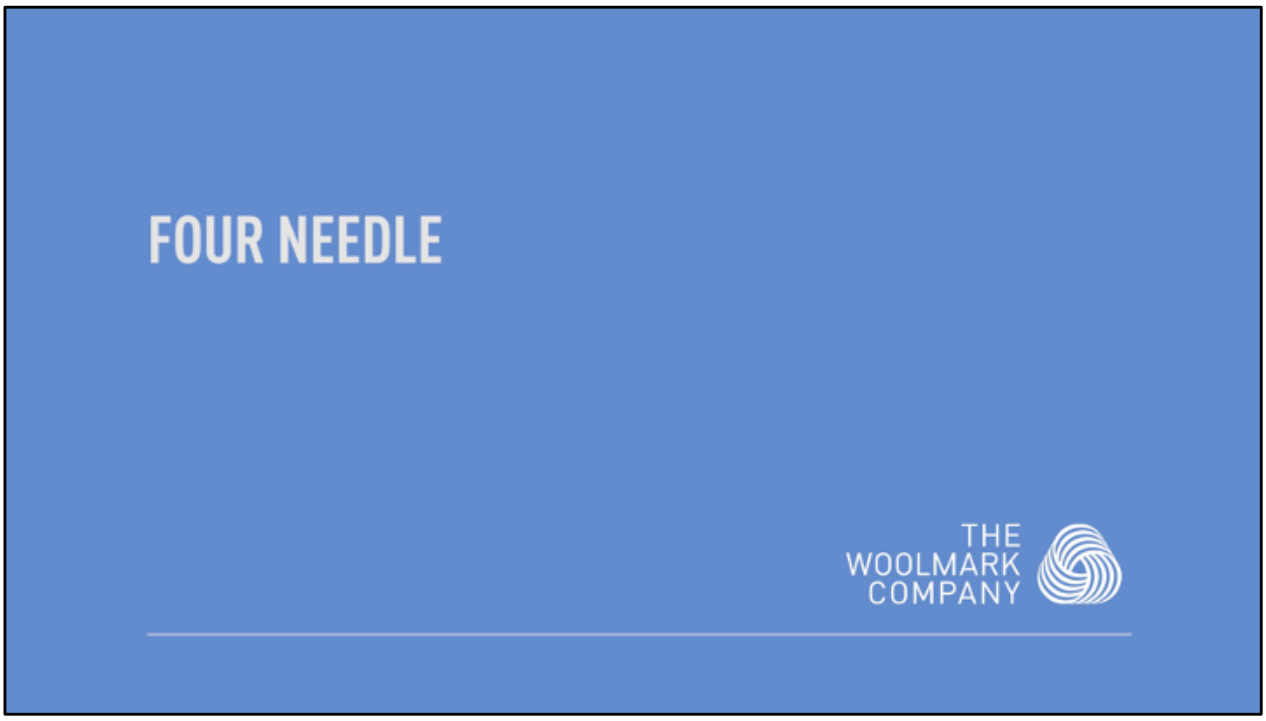
- simple technology (i.e. hand knitting needles)
- sophisticated computer-controlled knitting machines.

EXPLAIN THAT whether using simple technology, such as hand-knitting needles, or sophisticated computer-controlled knitting machines, the principles of knitting remain the same. The yarn is formed into a loop, by a needle, and through this loop another loop of yarn is threaded. As this is repeated row by row the loops are locked together. Each row of loops is known as a course. Where each course is formed from a single yarn, the method is known as 'weft knitting' . The yarn is fed from the side of the fabric, rather like a weft yarn in weaving but forming interlock loops rather than interlacing with warp yarns.

INDICATE THAT knitting machines use a large number of hooked needles, which can be arranged in a circle or in a straight line. The loops can be formed one by one or in batches depending on the machine type.

NOTE THAT knitted wool products range from:

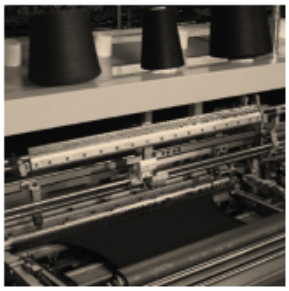
- lightweight next-to-skin wear (e.g. babywear, underwear, activewear and dresses)
- heavyweight apparel (e.g. jumpers, socks, scarves and beanies)
- furnishings.



PLAY *the two-minute* Woolmark Company video, which provides an overview of knitting action in a small circular machine.

AS THE VIDEO *plays, explain that in knitting machines, each stitch is controlled by an individual needle.*

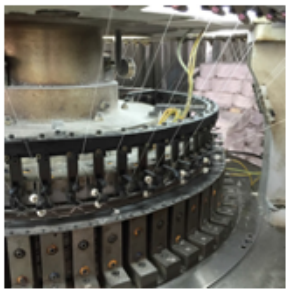
KNITTING MACHINES



Straight-bar or fully-fashioning machine

V-bed

Circular single cylinder



Circular cylinder-dial double jersey

10 - **Module 4:** Manufacturing wool products

EXPLAIN THAT there are three commonly-used machine types for wool knitting:

Straight-bar fully fashioning machines (Bentley-Cotton type):
The needles on this machine are arranged on a bar of steel in a straight line and all the yarn loops form at the same time before being interlocked into the previous row of loops to build up the fabric. This knitting machine produces shaped panels in single jersey only, with little or no yarn wastage.

V-bed (manual and automatic):
With the V-bed knitting machine, two lines of needles are set in two metal bars inclined towards each other to form a V-shape in cross-section with the needle hooks at the apex. The needles sequentially rise to catch the yarn being laid down a yarn guide (feeder), which travels backwards and forwards along the beds of needles. This versatile machine can make single and double structures as well as shaped panels.

Circular (single cylinder and cylinder-dial double jersey):
The needles of a circular knitting machine are arranged in a circle and the needles sequentially form loops in the yarn. Instead of one yarn guide there are multiple guides, up to 200 on large machines, simultaneously feeding yarn as the needle bed rotates.

These machines can have one bed for single jersey or two beds of needles to enable double-jersey fabrics to be knitted. This machine produces long lengths of tubular fabric, which are slit then cut and sewn into garments.

EXPLAIN THAT there are also warp knit machines (tricot and raschels), but these are not commonly used for wool because of the high strains placed on the yarns during the knitting process.

KNITTING GAUGE

KNIT GAUGE (npi)	FLAT BED (Nm)	CIRCULAR JERSEY (Nm)
3	2/2 – 4/2	
5	4/2 – 9/2	
7	10/2 – 14/2	
8	12/2 – 17/2	17/2 – 24/2
10	20/2 – 24/2	22/2 – 36/2
12	24/2 – 32/2	28/2 – 40/2
14	28/2 – 36/2	32/2 – 48/2
16	36/2 – 24/2	
18	42/2 – 60/2	40/2 – 30/1
20		48/2 – 32/1
22		28/1 – 36/1
24		32/1 – 40/1
26		36/1 – 44/1
28		48/1 – 60/1

11 - **Module 4:** Manufacturing wool products

EXPLAIN THAT knitting machines are defined by their 'gauge', which relates to the number of needles per inch (NPI). There is a strong relationship between the gauge of the machine and the thickness of the yarn that should be used. The higher the gauge of the machine, the finer the yarn count that must be used.

EXPLAIN THAT the machine gauge also affects the thickness of the knit being produced.
The higher the knit gauge of a machine, the finer the resulting fabric. For example:

- a knit gauge of 3npi is associated with chunky knitwear, such as sweaters.
- a knit gauge of 14npi is relevant for finer light-weight knitwear, such as babywear or other next-to-skin products.

NOTE THAT the table on the slide shows the yarn counts (metric) that are compatible with typical flat-bed and circular knitting gauges.

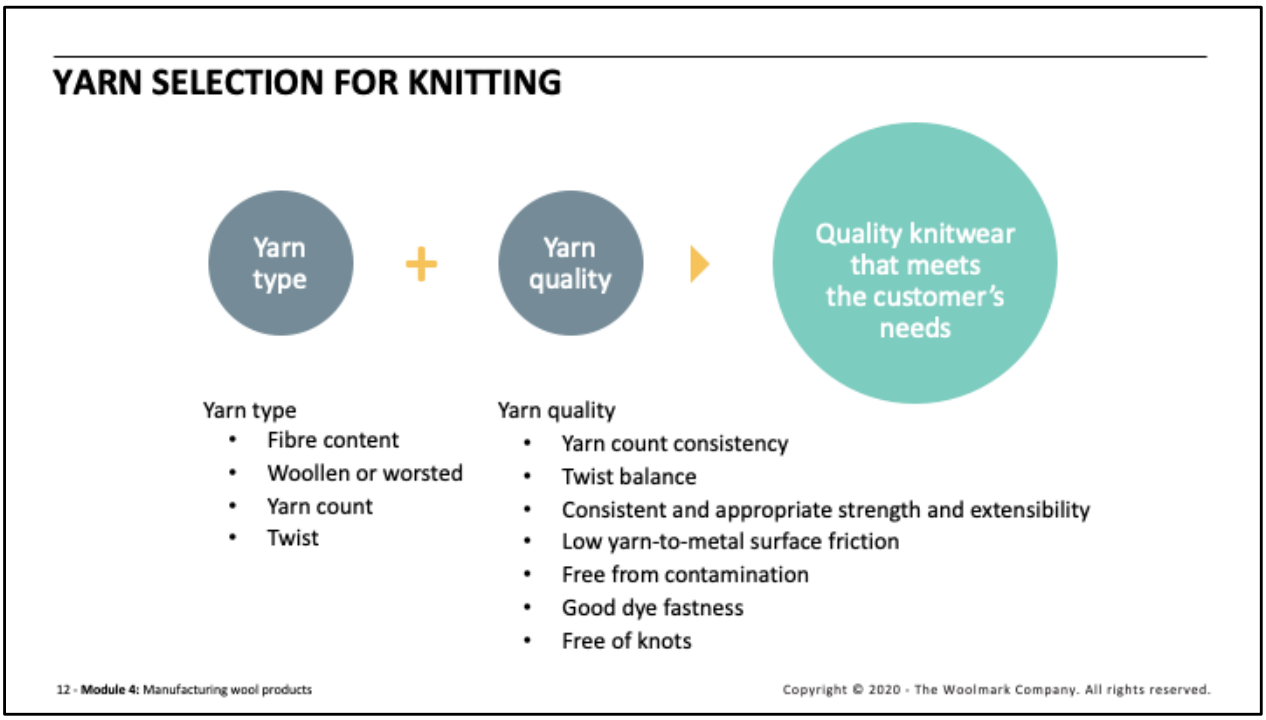
INDICATE THAT this table guides the choice of gauge for the garment as well as the choice of yarn (i.e. the higher —finer — the gauge on the machine, the finer the yarn to be knitted).

EXPLAIN THAT in contrast to flat-bed and circular knitting machines, straight-bar knitting machines use a different scale for knit gauge. The knit gauge of a straight-bar machine refers to the number of needles per 1.5 inches.

INDICATE THAT for wool, the highest (finest) knit gauges are found on circular knitting machines, which commonly have a gauge of 24 – 28Nm and can go as high as 32Nm. These machines require fine, high-quality yarns to knit efficiently.

ASK PARTICIPANTS *if they have any questions about the content covered so far in this module.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*



INDICATE THAT when selecting a yarn for a specific knitting application both yarn type and yarn quality are important.

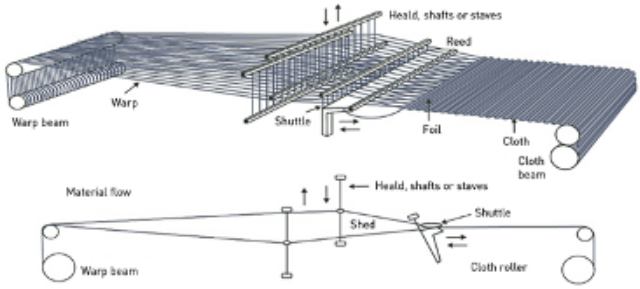
POINT OUT that suitable yarn selection is more critical for worsted-spun products. Worsted knitwear doesn't normally receive a milled finish during wet finishing, which can help mask any imperfections in the yarn. The term 'milled finish' will be explained later.

EXPLAIN THAT in contrast to woven fabrics (where finishing can help mask any yarn imperfections), any defects in knitwear caused by faults in the yarn are not only difficult to mend, but also increase the cost of production. Yarns of the best quality that can be afforded should be selected for knitwear.

NOTE THAT the key considerations associated with yarn type and yarn quality are shown on the slide.

INDICATE THAT yarn type and quality are covered in detail in the Wool Science, Technology and Design Education Program course *Worsted and woollen spinning.*

WEAVING



13 - **Module 4:** Manufacturing wool products

EXPLAIN THAT weaving is the process of interlacing warp and weft yarns in a weaving machine, or loom.

INDICATE THAT whether carried out manually, or by a range of different machine types, the weaving process follows the same basic principles.

EXPLAIN THAT warp yarns, which are held on a frame or on a beam at one end of the machine, are separated in changing sequences and the weft yarn is inserted between them across the width of the fabric. Insertion of successive weft yarns between different arrangements of the warp yarns builds up the fabric.

REMIND PARTICIPANTS that woven wool products range from:

- lightweight apparel, such as shirts and lightweight suits, skirts and dresses
- midweight apparel, such as outdoor sportswear
- heavyweight jackets and coats.

HAND OUT *samples of:*

- *Lightweight woven wool product (e.g. a woven shirt).*
- *Midweight (e.g. a midweight outdoor jacket)*
- *Heavyweight (e.g. woven wool coat).*

ASK PARTICIPANTS *to describe the differences they observe in the garments as they pass them around the group.*

PLAY *the one-minute Woolmark Company video, which shows the rapier loom in action.*

NOTE THE *changing sequence of the shafts that raise and lower the warp threads to form the 'weave pattern'.*

DURING *the video you may like to note:*

- *the warp yarns coming from the warp beam (~0:08 minutes)*
- *the heald shafts lift and lower the warp yarns (~0:18 minutes)*
- *the warp break detectors will stop the loom if a warp thread breaks (~0:20 minutes)*

- *the weft threads feeding in from the side. A number of different weft threads can be used. (~0:29 minutes)*
- *a rapier carrying the weft yarn to the middle, where it is picked up by a rapier from the other side, which carries the weft thread to the other side of the fabric (~0:37 minutes)*
- *the reed pushes the weft thread up to the forming fabric (~0:40 minutes)*

NOTE that this operation occurs quickly — up to 400 times per minute.

COMMON WEAVING MACHINES

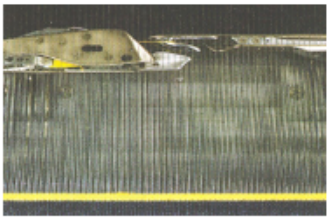
- Shuttle
- Rapier
- Projectile
- Air-jet
- Water-jet

Fabric density is measured as cover factor.

Weaving speed depends on yarn quality.

Shuttle

Projectile



Rapier

15 - **Module 4:** Manufacturing wool products

EXPLAIN THAT the weaving process can be carried out by a range of different machine types.

INDICATE THAT typical weaving machines include:

- Shuttle machine — a large wooden shuttle containing a small cone of yarn, which unravels as the shuttle passes across the warp. This old technology is relatively inefficient.
- Rapier machine — a thin metal rod or rapier inserts the weft yarn between the warp yarns. In some machine designs, at the midway point the yarn is 'handed over' to another rapier, which has entered the space between the warp yarns from the other side. This second rapier carries the yarn the full distance across the warp. The yarn is then released and cut.
- Projectile — the weft yarn is inserted across the warp with a small metal projectile, which grips the weft yarn and 'fires' it across the warp, where it is caught at the other side. The yarn is then released and cut.
- Air-jet — modern high-speed looms, which use a jet of compressed air to blow the weft yarn across the warp, rather than using a rapier or projectile. This loom type has limited use in weaving wool fabric.
- Water-jet — not used on wool.

EXPLAIN THAT the most common machines used for commercial wool weaving are the rapier and projectile. Shuttle looms tend to be restricted to the hand weaving industry. Air-jet looms can be used on a restricted range of worsted yarns. Water-jets tend to be used for synthetic filament yarns.

EXPLAIN THAT two key parameters need consideration when weaving:

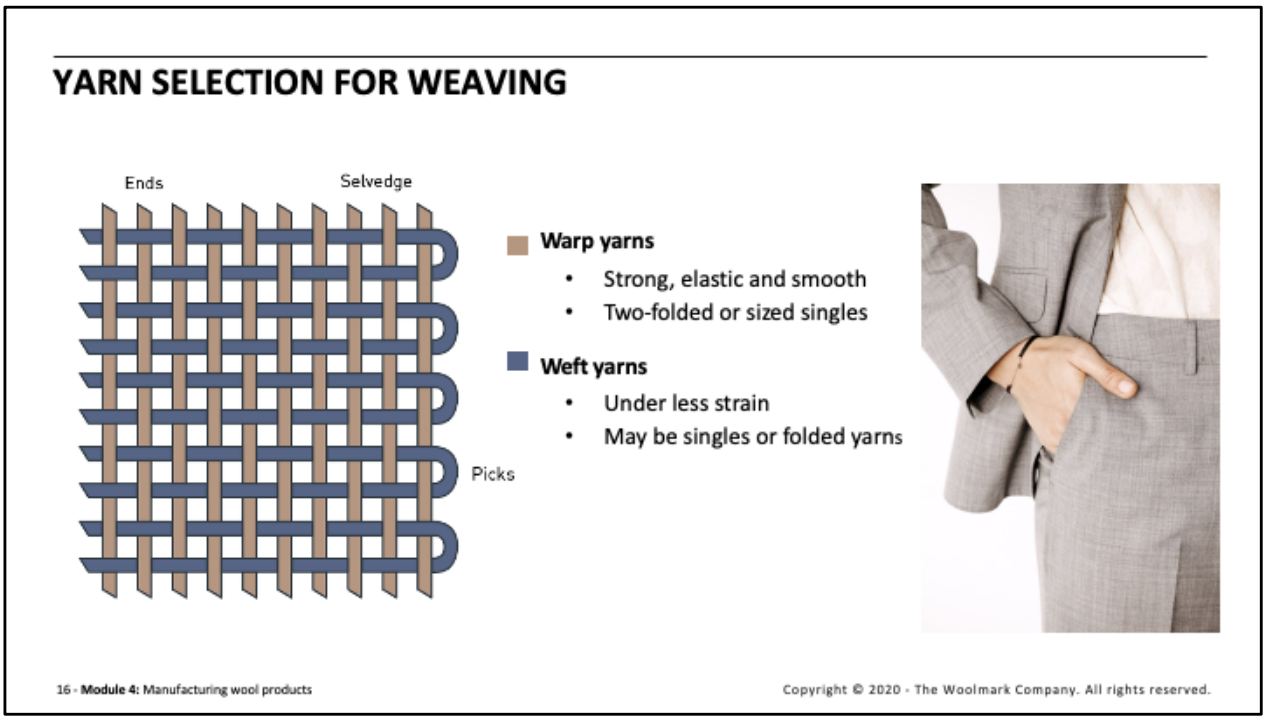
- the density of the fabric
- the weaving speed.

INDICATE THAT the density of the fabric can be described in terms of 'cover factor' or as the percentage of 'maximum sett' possible.

- The sett is the number of threads per metre. Weavers will refer to either a percentage of maximum sett (for wool, from 100 down to about 80) or percentage below maximum (i.e. 0% to 20%).
- Cover factor relates to the thread count (threads per metre) and the count of the yarn.

INDICATE THAT the weaving speed determines the efficiency of weaving, as does the warp tension.

- Higher weaving speeds increase the production rate, but might also cause breaks or stoppages so a compromise is ideal.
- The quality of the yarn affects the speed at which the machine can weave.



REINFORCE THAT like knitting, weaving also starts with yarn selection. To create woven fabric, two yarns are woven together. The two yarns in the woven fabric are called the 'weft yarn' and the 'warp yarn'.

INDICATE THAT although a woven fabric can be made using the same yarn in both the warp and the weft, often this is not the case.

EXPLAIN THAT warp yarns (which run the length of the material) need to be strong, elastic and smooth because they are placed under tension in the loom during the weaving operation and are subject to abrasive forces during weaving.

INDICATE THAT warp yarns are normally two-folded or sized (a type of glue) singles. Some newer spinning methods allow singles yarn to be used as warp in weaving without sizing.

EXPLAIN THAT weft yarns (which run left and right across the material) do not need to be as strong, as they are placed under less strain during weaving, and can be made weaker and softer. Weft yarns can be singles (without sizing) or folded yarns.

NOTE THAT warp yarns are often called 'ends'. Weft yarns are often called 'picks'.

EXPLAIN THAT the edge of the fabric (~10mm) is called the 'selvedge' and often has an alternative weave structure to give the fabric edge added stability or for decorative purposes.

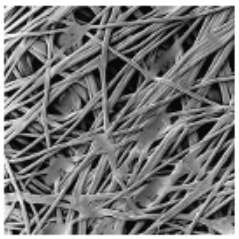
NON-WOVEN FABRIC

Non-woven fabric:
- is formed directly from staple fibre or filament
- does not involve yarn
- stability depends on entanglement or bonding of fibres.

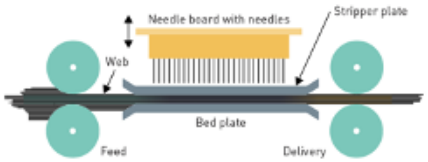
Non-woven fabrics can be formed in many ways.

For wool:
- felting
- needle punching
- stitch bonding.

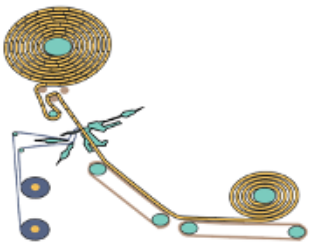
For wool–synthetic blends:
- thermal bonding.



Thermal bonding



Needle punching (needle felting) process
http://nptel.ac.in/courses/116102014/6



Stitch bonding
https://www.slideshare.net/himanshugupta3139/web-stitching-stitch-bonding-warp-knitt

EXPLAIN THAT non-woven fabrics are formed directly from loose fibre without the intermediate stages of yarn formation, knitting or weaving.

Because the formation process is quicker and less expensive than conventional fabric forming processes, it is widely used for high-volume, low-value industrial fabrics (e.g. geotextiles and domestic cleaning products) using synthetic fibres.

INDICATE THAT non-woven fabric forming methods are also used to make low-value wool products, such as insulation tiles and filling for cold weather clothing and bedding, such as quilts.

EXPLAIN THAT there are a number of ways wool can be formed into non-woven fabrics. Normally a sheet of fibres is laid down and then given a treatment to confer strength and coherence to the fibre layer.

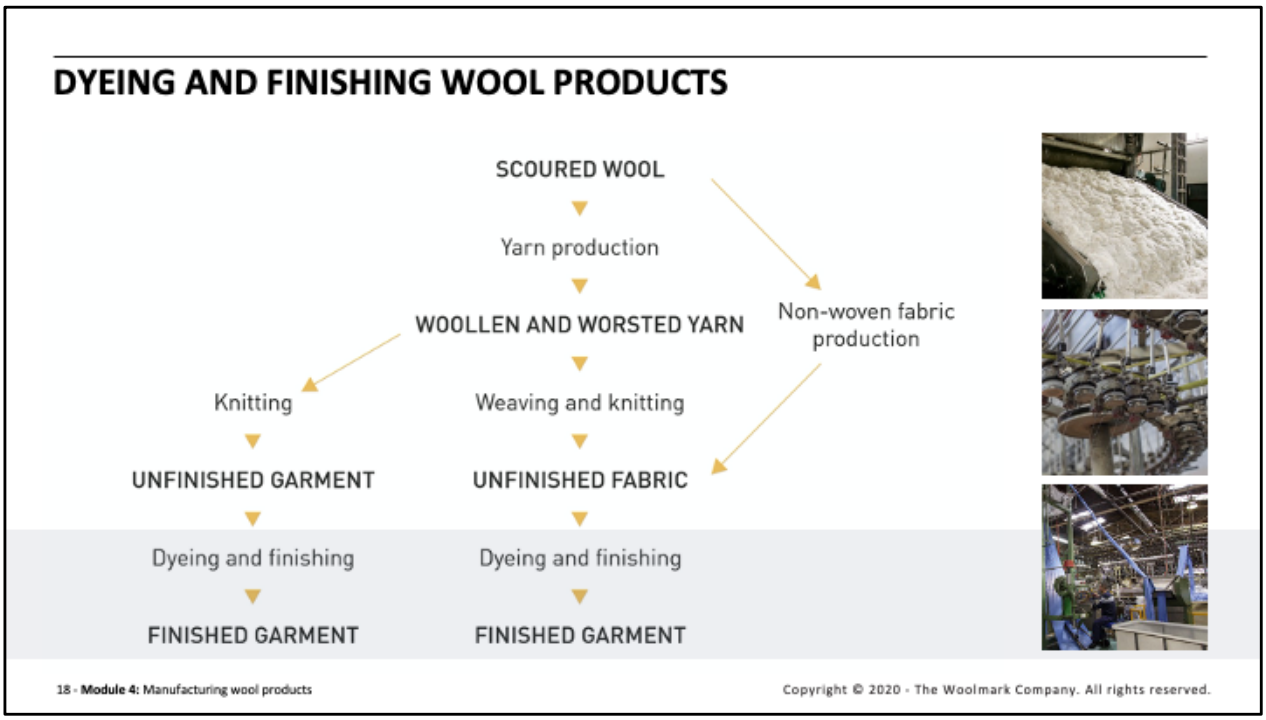
EXPLAIN THAT the machines used for forming fibre webs, which can be transformed into non-woven fabric, have much in common with conventional wool carding machines. The machines must first individualise the fibres using a carding action and then lay the fibres into a sheet, which is bonded in some way during a later process.

In a non-woven card, the final web is not split, as it is in a woollen card, nor drawn into a sliver, as it is in a worsted card, but laid on a moving belt, which transfers it to the bonding section of the machine.

NOTE THAT non-woven webs are much heavier than the webs that emerge from a woollen or worsted card and can be formed by folding the emerging web as it is laid on the moving belt.

EXPLAIN THAT wool webs are given strength and coherence by:
- **felting the fibres —** This is the traditional method used for making ‘felts’, which is also used in a variety of applications including paper-making.
- **needle punching (needle felting) the fibres** — In this process a bed of needles is forced into the fibred web and withdrawn many times. This entangles the fibres in the web giving the web cohesion and strength.
- **stitch bonding the fibres** — In this form of fabric manufacture the wool web is given cohesion by forming stitches within the web with a yarn. The yarn loops bond the fibres in the web together.
- **thermally bonding the fibres** — Thermal bonding requires the wool to be blended with a meltable synthetic fibre in the web. These fibres partially melt in a heat treatment and fuse together giving the web strength and cohesion.

REINFORCE THAT wool is an expensive fibre so non-woven production of wool is normally restricted to low-value wool (broad non-fleece wools). Recycled wool is also commonly used to produce non-woven fabrics.



EXPLAIN THAT after manufacture wool fabrics and knitted wool garments must be finished and sometimes dyed (although dyeing can occur at several points during the manufacturing pipeline).

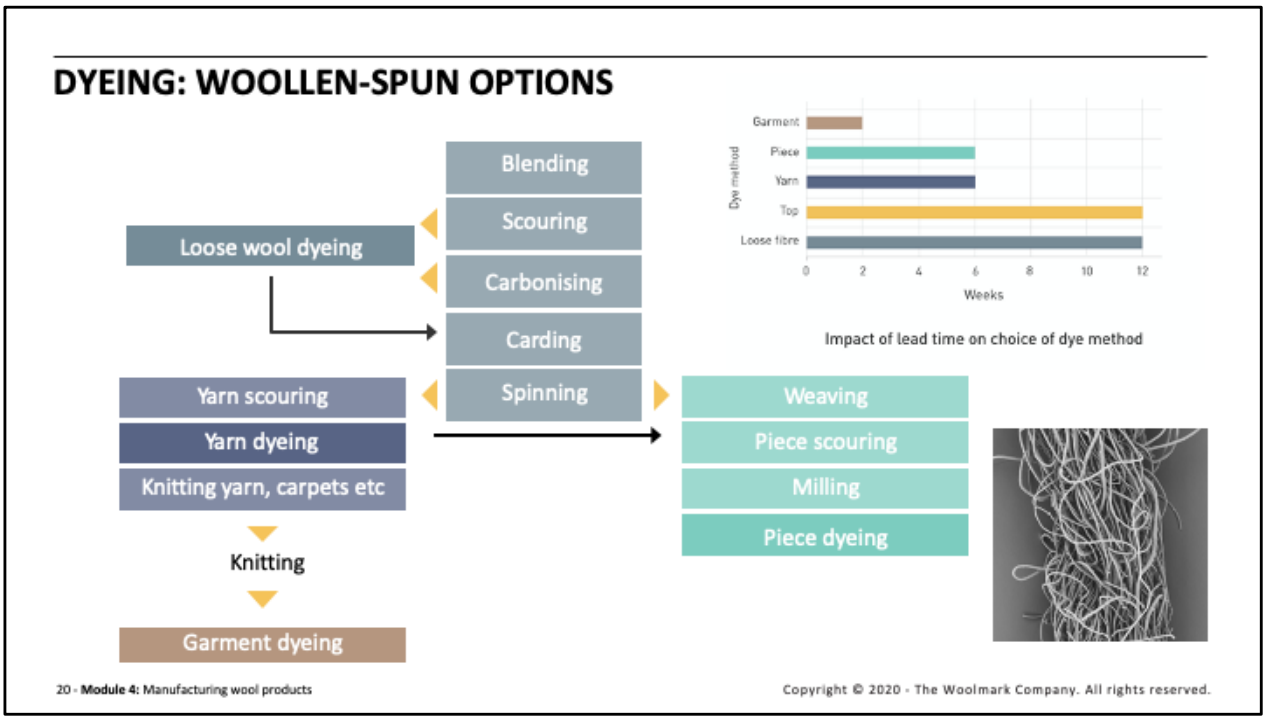
EXPLAIN THAT this section outlines the methods used to dye and finish knitted or woven fabric.

AIMS OF DYEING

- Correct shade
- Levelness (uniformity of shade)
- Meet product and processing fastness requirements
- Within cost limits
- On time
- Environmentally-responsible operation

EXPLAIN THAT there are six objectives of the dyeing process:

- achieving the correct shade
- achieving levelness (uniformity of shade)
- meeting product and processing fastness requirements
- producing a dyed fabric within cost limits
- delivering the product on time
- dyeing under conditions that ensure an environmentally-responsible operation.



INDICATE THAT as outlined on the slide, dyeing can occur at several points in the woollen-spun processing operation.

EXPLAIN THAT if dyeing loose wool, the dyeing occurs after scouring or scouring and carbonising.

EXPLAIN THAT if dyeing yarn, the dyeing occurs after spinning.
- Knitting yarns are dyed in hanks.
- Weaving yarns are dyed in packages.

INDICATE THAT woollen-spun fibre may also be dyed in fabric form — this is called piece dyeing.

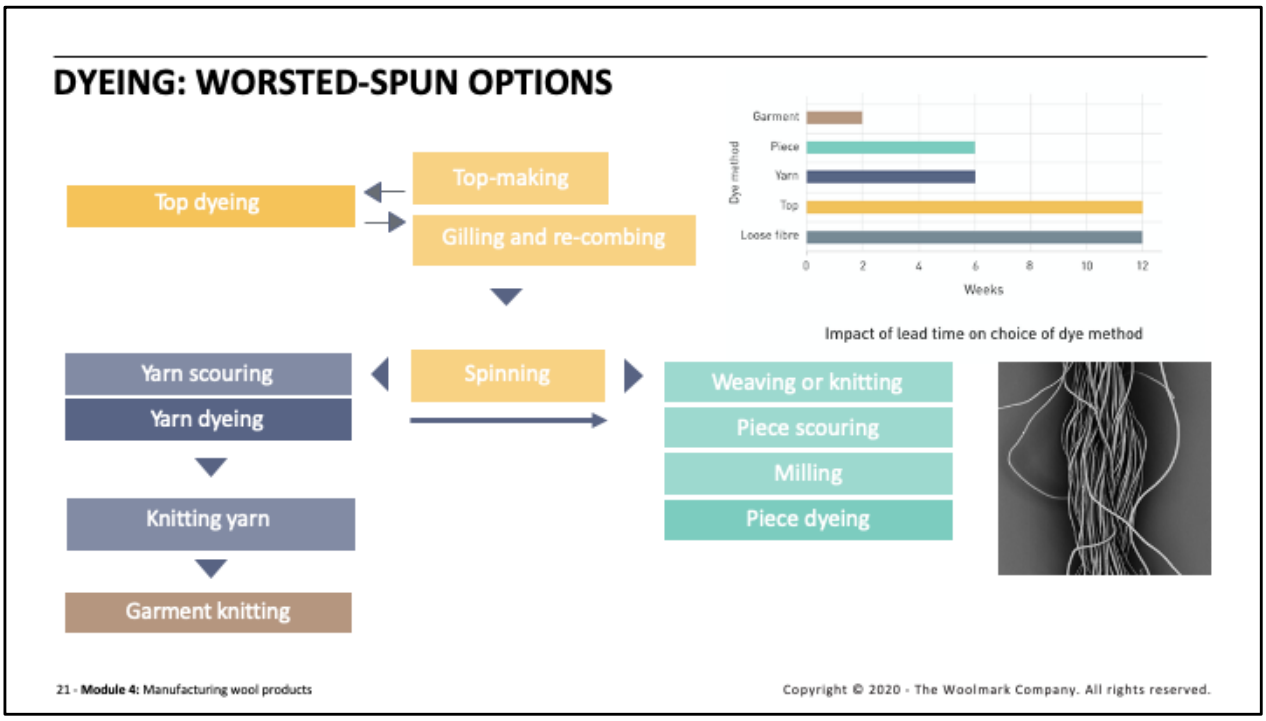
EXPLAIN THAT the final option for woollen-spun fibre is to dye garment panels or the whole garment.

INDICATE THAT the stage at which the wool is dyed affects the lead time required. Lead time is the time that normally elapses between the decision on the processing of a lot of wool and its appearance as a product on the shelves of a retailer.

***HAND OUT** samples of wool dyed as:*
- *loose wool*
- *yarn*
- *fabric*
- *garment.*

In the context of dyeing, it is the time between the colouration of the wool and the product being delivered to the retailer.

SUMMARISE BY explaining that lead time is important in all stages of manufacturing. The longer the lead time the more stock that is carried by the processing chain and the less flexibly the application of colour can respond to fashion changes.



EXPLAIN THAT as outlined on the slide, dyeing also can occur at several points in the worsted-spun processing operation.

INDICATE THAT there are three options available:

- Top dyeing occurs after top-making and before spinning.
- Yarn dyeing occurs after spinning.
- Piece dyeing is done on the fabric or (rarely) on the garment.

REINFORCE THAT the stage at which the wool is dyed during worsted-spun processing also affects the lead time required.

EXPLAIN THAT wool is naturally a cream colour — less white than cotton and synthetic fibres

INDICATE THAT bleaching wool is carried out if a brighter pastel shade is required and the wool is not white enough. This occurs in only about seven per cent of all the wool that is processed and so is relatively uncommon.

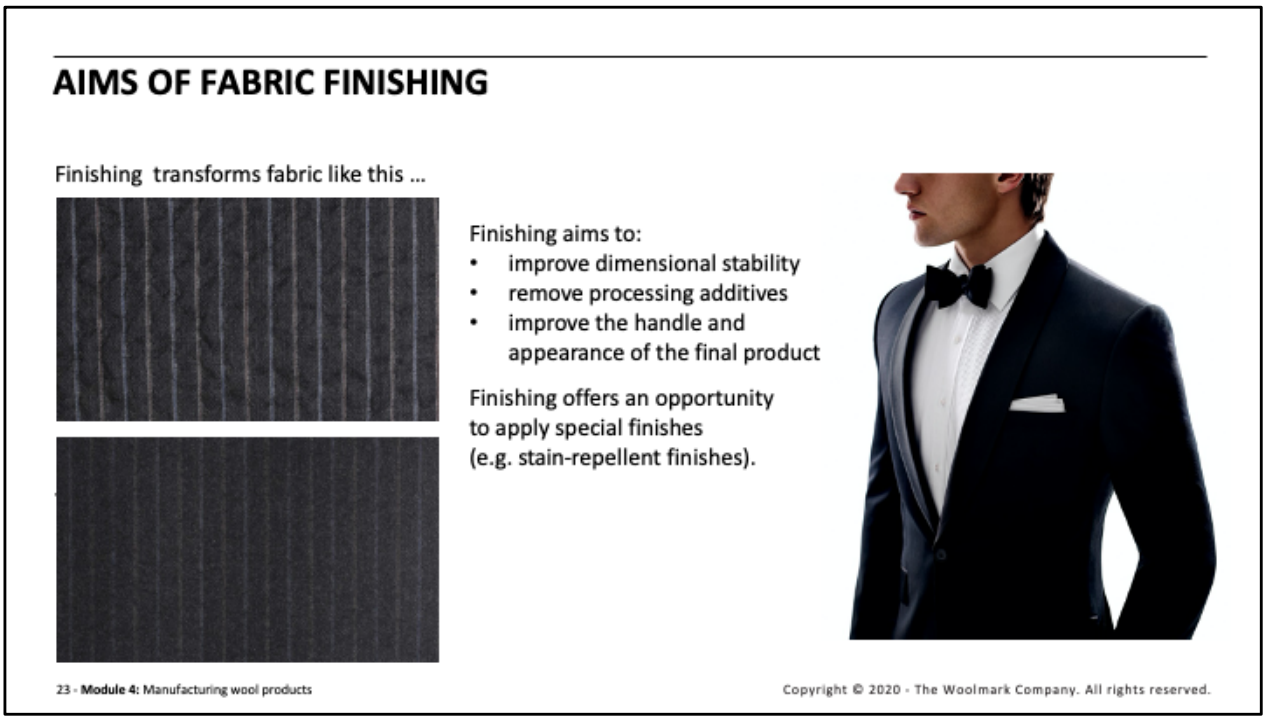
OUTLINE THE three methods use to bleach wool:

- Oxidative bleaching — Hydrogen peroxide is used to bleach the wool. This is similar to the process used to bleach hair.
- Reductive bleaching — Reductive bleaching is an alternative to oxidative bleaching and uses sodium dithionite. It is a gentler process than oxidative bleaching.
- Combination bleaching — In this process the wool is first bleached with an oxidising agent and then with a reducing agent. This combination process gives the best whiteness and is widely used.

EXPLAIN THAT fluorescent whitening agents can also be used to enhance the whiteness of wool, usually in combination with the bleaching methods above.

The use of fluorescent agents, which are commonly used to whiten cellulosic fibres and some synthetic fibres, is not recommended for wool due to the rapid yellowing that can subsequently occur in sunlight.

INDICATE THAT bleaching is studied in detail in the Wool Science, Technology and Design Education Program course *The dyeing of wool.*



EXPLAIN THAT the last step in the manufacturing process for fabric (and garments) is finishing.

INDICATE THAT finishing is done to:

- improve the dimensional stability of fabrics so the fabric may be made up into garments without excessive dimensional change and the dimensions of the garment will not change shape in use
- remove processing additives, which might smell or impair the 'handle'
- improve the handle and appearance of the final product as shown in the images on the slide.

EXPLAIN THAT as well as achieving these aims, the finishing process is also an opportunity to incorporate 'added value' attributes, such as anti-static, machine-washable and stain-repellent finishes.

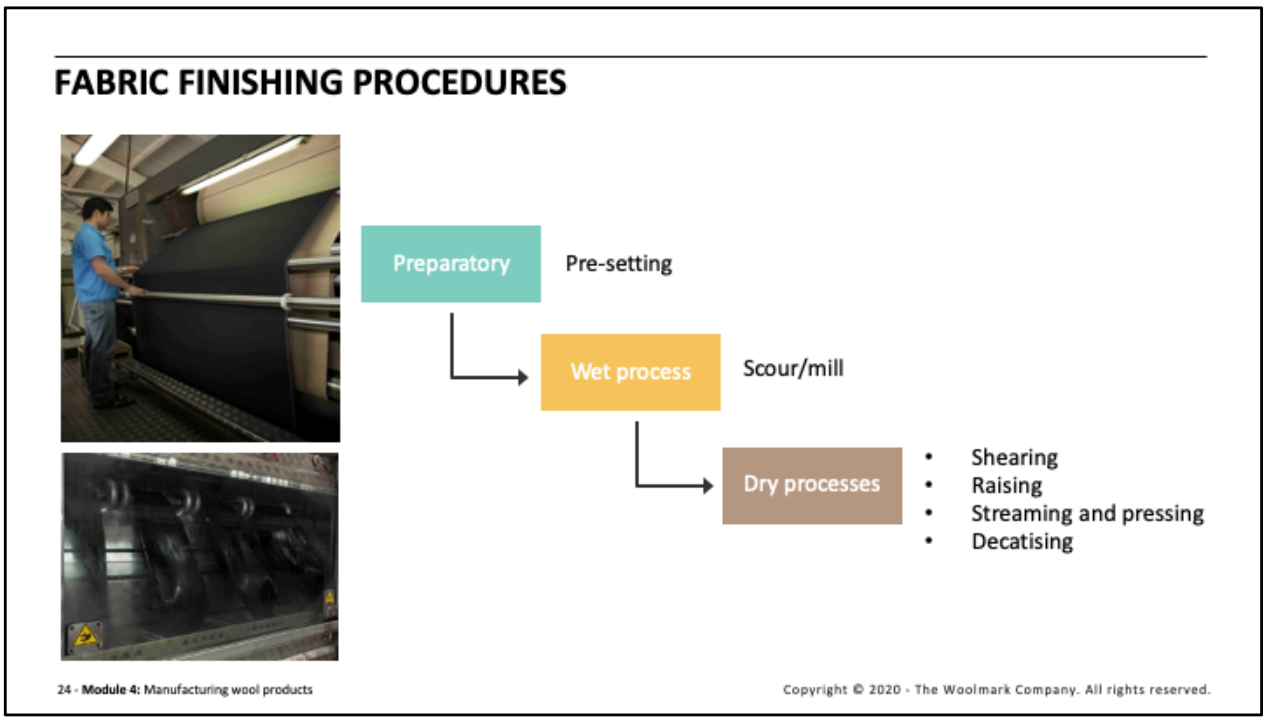
INDICATE THAT although the principles are the same, the finishing routes for knitwear and wovens are different.

HAND OUT *samples of:*

- *finished wool fabric*
- *unfinished wool fabric*

ASK PARTICIPANTS *to describe the differences they observe in the fabrics as they pass them around the group.*

REINFORCE THAT *the finished fabric has a superior flat finish and handle.*



EXPLAIN THAT the process of wool fabric finishing is carried out in three stages. While the precise techniques and processes used within each stage will differ depending on whether the fabric is woven or knitted and depending on whether it is made from woollen-spun or worsted-spun yarns, the three stages essentially apply to all wool fabrics.

OUTLINE THE following processes:

1. Preparatory processes

- Pre-setting: to reduce the chance of the fabric distorting (cockling or cross-feet) during finishing. This is more important for worsted-spun fabrics, as opposed to woollen-spun fabrics. Processes such as crabbing (boiling water) or wet-decatising (using steam on wet fabric) are typical preparatory processes for worsted-spun fabrics.

2. Wet processes

- Scouring: Scouring washes the wool to remove any residual oils and smells. This is particularly important for fabrics made from woollen yarn because of the higher oil content.
- Milling: Milling is a process of controlled felting of the fabric or garment and is normally conducted on woollen fabrics. It brings the loose fibres on the surface of the fabric making it look more hairy and bulky.

3. Dry processes

Represent a variety of different processes, including:

- Raising: A process that pulls fibres to the surface to increase the fabric's bulkiness.
- Shearing: A process to remove all the fibres that appear on the surface of the fabric giving a much smoother, cleaner finish.
- Steaming and pressing: A process to remove any creases in the garment or fabric.
- Decatising: A process that is used to flatten the surface of the woven fabric and set it in that state.

EXPLAIN THAT not all of these processes are always necessary for all fabrics and some can be performed more than once.

The precise combination of processes and the conditions under which they are performed are part of the finisher's art and are regarded by some as closely-guarded secrets.

INDICATE THAT fabric finishing is studied in detail in the Wool Science, Technology and Design Education Program course *Wool fabric finishing.*

_____

***PLAY** the 2:45-minute award-winning Woolmark Company video, which reviews the journey of wool from farm to fashion.*

***ALLOW TIME** for questions and discussion before proceeding to the next slide.*

_____

GARMENT FINISHING

Garment finishing aims to:

- clean the garment (remove processing additives)
- improve the handle and appearance of the final product
- improve dimensional stability
- apply special finishes (e.g. felt-resist finishes).

EXPLAIN THAT the four main reasons for finishing garments are:

- to clean the product, removing additives such as oil and dirt added during the manufacturing process
- to develop the required handle and appearance of knitted garments
- to ensure dimensional stability when a garment is worn and laundered
- to provide added value to garments, such as machine washability, additional softness, anti-static or moth-resistance.

HAND OUT *samples of:*

- *finished wool garment*
- *unfinished wool garment*

ASK PARTICIPANTS *to describe the differences they observe in the garments as they pass them around the group.*

REINFORCE THAT *the finished garment has a superior finish and handle.*

GARMENT FINISHING PROCEDURES

FINISHING TYPE	DESCRIPTION	TYPES OF GARMENT
SOLVENT	Garments washed in **organic solvent** in dry-cleaning machine.	All types of knitwear, but not commonly used.
DRY	Uses only **steam** to relax garments.	Cannot be used on woollen-spun garments.
WET	Garments washed in **water-based solution.**	Most common finishing technique for all types of knitwear.

EXPLAIN THAT most wool apparel that undergoes finishing in garment form are knitted, although occasionally woven products are finished in garment form.

INDICATE THAT knitwear is finished in batches of made-up garments.

NOTE THAT three main techniques are used to finish knitwear:

- solvent finishing
- 'dry' or steam finishing
- 'wet' or aqueous finishing.

OUTLINE THE techniques as follows:

Solvent finishing describes the finishing procedure where garments are washed in an organic solvent in a dry-cleaning machine. Organic solvents include perchloroethylene, trichloroethylene and white spirit.

Dry or steam finishing is a term used for a finishing procedure using only steam to relax garments. The knitted garment is placed on a steam table, possibly in a forming device, and steamed. Manual procedures may also be used to smooth and shape the garment. An air draft is used to cool the garment before release from the former (if used).

EXPLAIN THAT the advantages of 'dry' or 'steam' finishing techniques are:

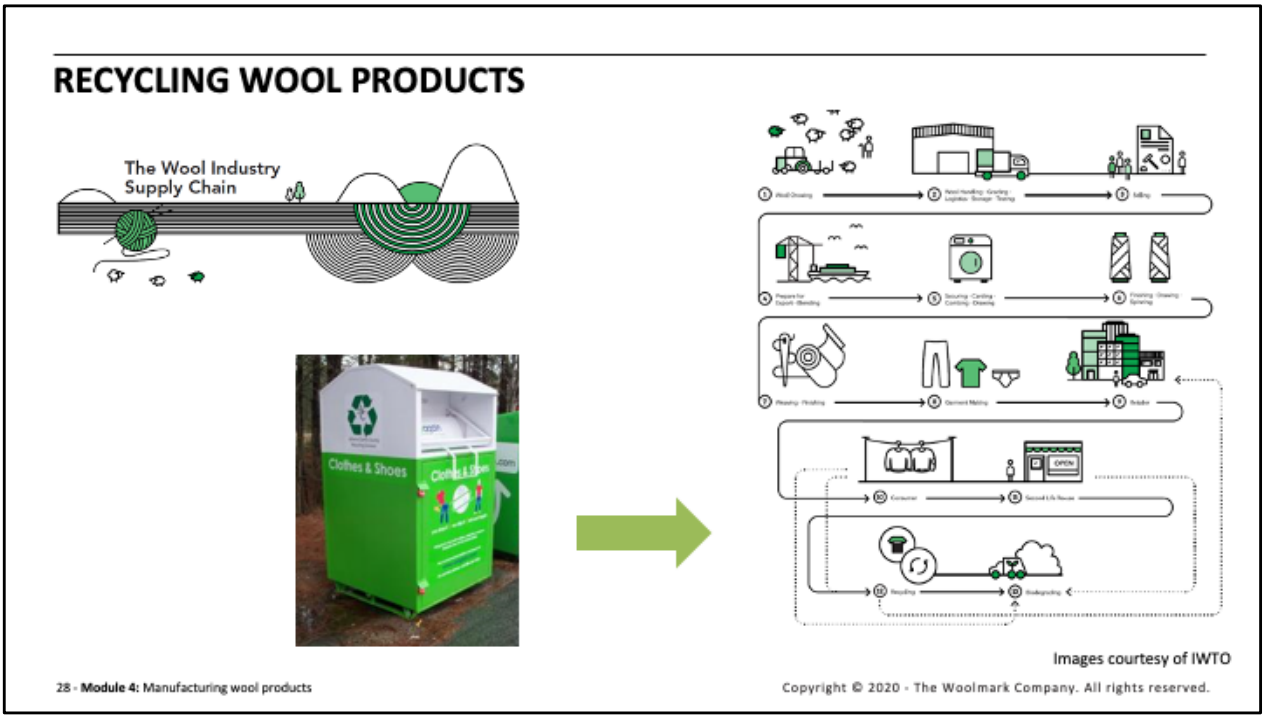
- Dry or steam finishing avoids any washing of the garment in water or organic solvent. Garments are simply steamed on a steam press.
- Dry finishing is the least expensive of the three finishing techniques.

Wet finishing is the term used to describe knitwear finishing procedures where garments are washed in a water-based solution. Wet finishing is the most common finishing technique used on knitwear garments. With few exceptions, it can be used for all types of product.

EXPLAIN THAT the main advantage of wet finishing is that it produces the best results in terms of a garment's handle and appearance.

INDICATE THAT the main drawback of wet finishing is the high volume of water used and liquid effluent produced.

EXPLAIN THAT garment finishing is studied in detail in the Wool Science, Technology and Design Education Program course *Wool garment finishing.*



EXPLAIN THAT in addition to using 'pure new wool' to produce apparel or other wool products, wool can be recycled from products at the end of their first life. This effectively gives wool products a second life and can lengthen the time between growing the wool and its final disposal as waste in landfill or composting facilities.

NOTE THAT as a natural fibre, wool offers many opportunities to keep a wool product in circulation for a relatively long period of time, thereby reducing the product's environmental footprint. Research by Textile Materials and Technology at Leeds University has shown that wool products have the potential for two or more uses or 'lives' and a total 'active life' of 20-30 years.
The same research shows that wool already is one of the most re-used of all fibres, accounting for up to 5% by weight of total clothing donated by consumers for recycling and re-use. This is substantially higher than wool's share of the virgin fibre supply, which is about 1.2%.

INDICATE THAT wool, with a recycling history dating back over 200 years, fits well into the circular economy production model. The circular economy aims at using resources for longer and encouraging consumers to think twice before throwing away their used clothing and instead giving it for reuse or recycling.

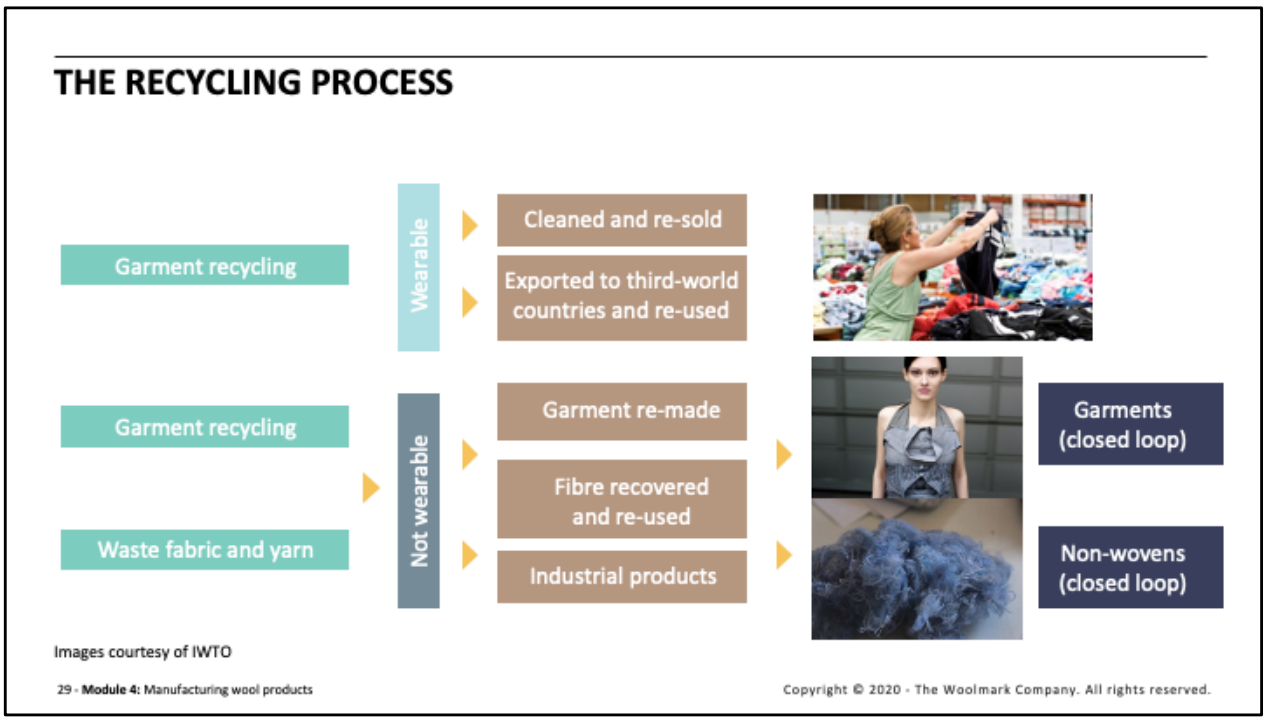
ASK PARTICIPANTS *to indicate, by raising their hands, if they participate in recycling in any way.*

ALLOW TIME *for a brief discussion about local recycling initiatives if appropriate.*

NOTE THAT discarded clothing is a growing problem. In the UK, a 2016 survey conducted by a supermarket chain revealed that 75% of consumers throw away used garments, instead of reselling or recycling them.

INDICATE THAT The US Environmental Protection Agency estimates that more than 16 million tonnes of used textile waste is generated each year in the United States, and the amount has tripled during the past 25
years.

REITERATE THAT wool is readily recyclable and has been recycled for centuries.



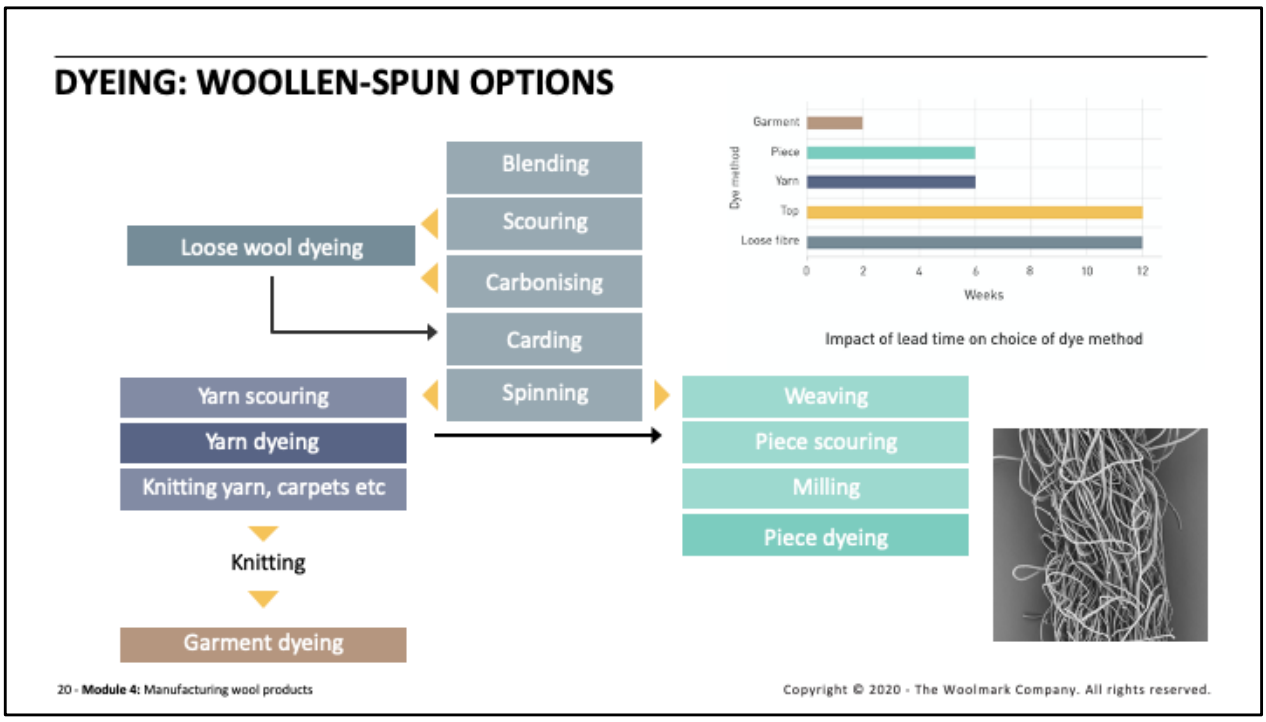
EXPLAIN THAT there are three commercial approaches to the recycling process:

Garment collection and re-sale: Garment recycling initiatives can also give a second life to wool garments. Wool garments that are considered re-wearable can be cleaned and re-sold or exported to third-world countries.

Closed loop system: This is a mechanical process through which garments are 'pulled' back into raw fibre state and re-used as a raw material to make yarn again, producing garments with a high economic value. Wool knitwear is particularly well suited for this process and can yield yarn with which a new garment can be created.

Open loop system: In an open loop system the wool product becomes the basis for industrial products such as insulation or mattress padding. These products can also have a long life.

(Source: www.iwto.org)



INDICATE THAT as outlined on the slide, dyeing can occur at several points in the woollen-spun processing operation.

EXPLAIN THAT if dyeing loose wool, the dyeing occurs after scouring or scouring and carbonising.

EXPLAIN THAT if dyeing yarn, the dyeing occurs after spinning.

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EXPLAIN THAT the final option for woollen-spun fibre is to dye garment panels or the whole garment.

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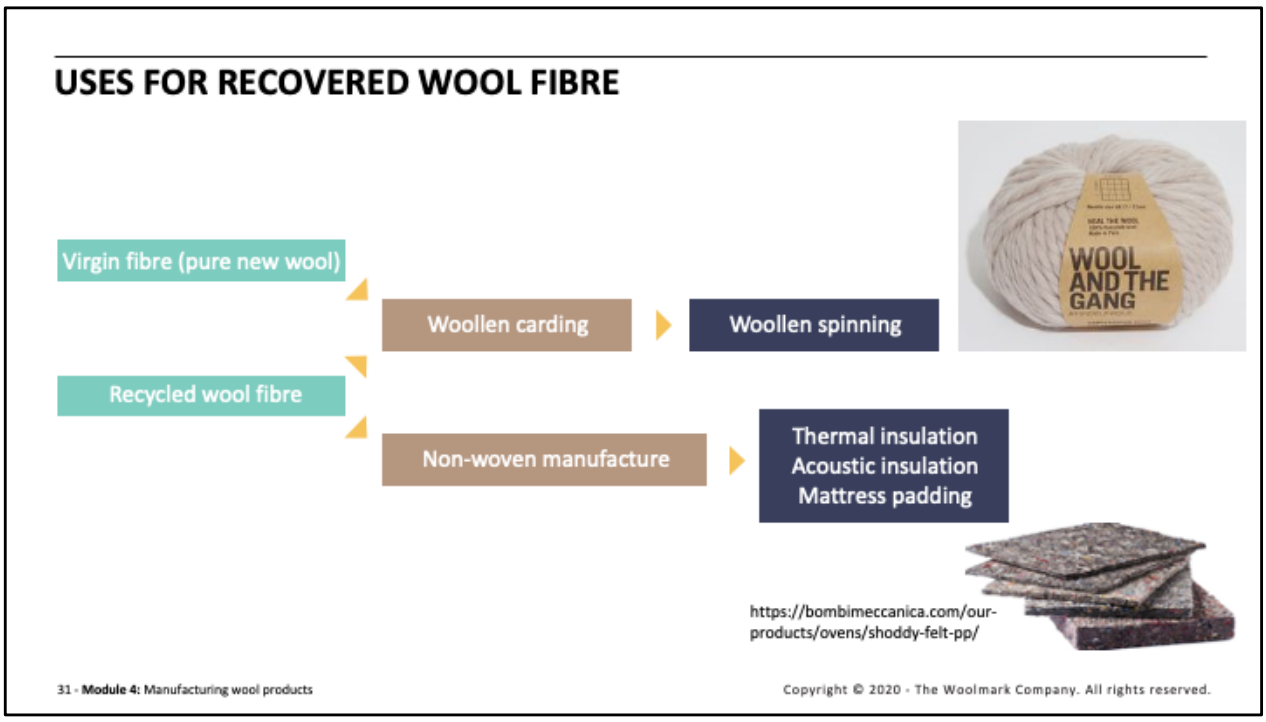
SUMMARISE BY explaining that lead time is important in all stages of manufacturing. The longer the lead time the more stock that is carried by the processing chain and the less flexibly the application of colour can respond to fashion changes.



NOTE THAT the recovered wool fibre can be used in a number ways:

- It can be mixed with virgin wool (pure new wool) or other fibre types and spun into a yarn. Generally recovered fibre is not long enough to be made into woollen-spun yarns on its own, so it is usually mixed with longer fibres to give the yarn adequate strength.

- Recovered fibre also can be made into relatively low-value, non-woven products, such as acoustic tiles. The recycled wool may be mixed with other recycled fibres in such application.

SITES FOR RECYCLING

Bradford 'shoddy and mungo' mill

https://commons.wikimedia.org/wiki/File:Machell_Bros_Ltd_-_Bradford_Road_-_geograph.org.uk_-_691175.jpg

CARDATO RECYCLED
MADE IN PRATO

https://www.patagonia.com/blog/2018/09/introducing-woolyester/

32 - **Module 4:** Manufacturing wool products

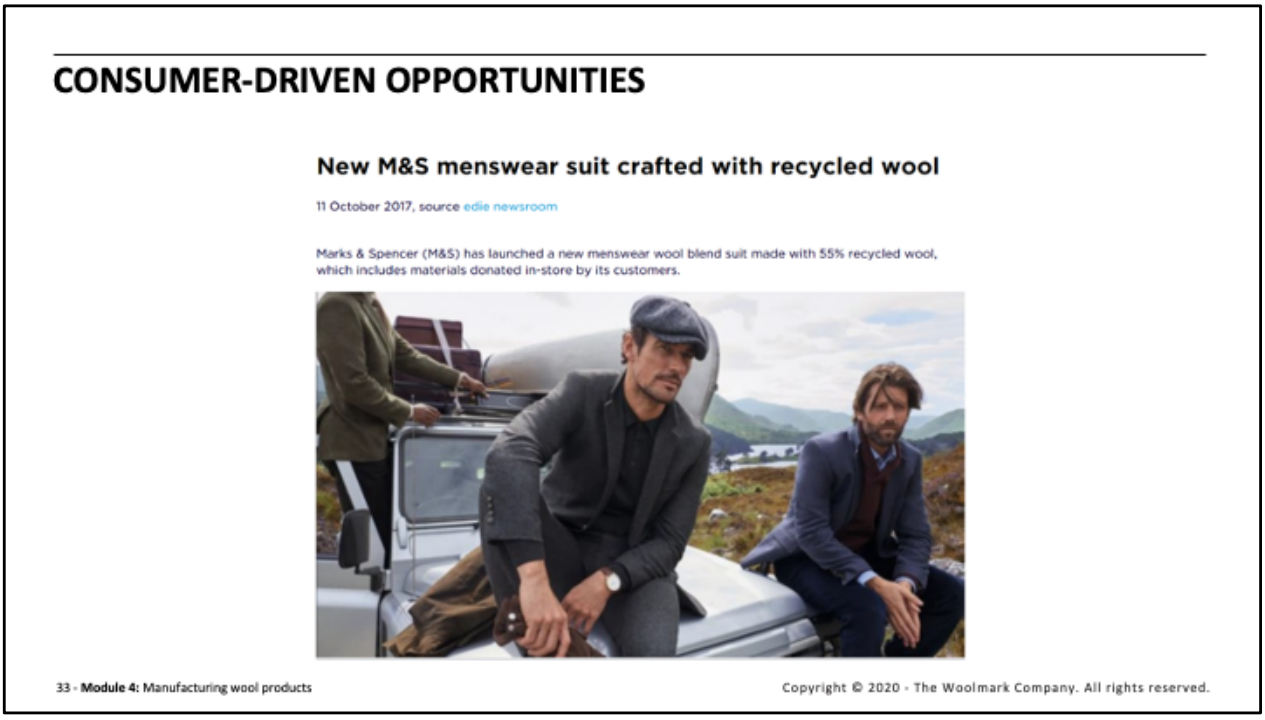
INDICATE THAT recycling wool is a traditional industry in many parts of the world particularly in Europe. Bradford (UK) and Prato (Italy) are two centres renowned for their woollen recycling industries.

EXPLAIN THAT in the UK terms like 'shoddy and mungo' were used to describe the process of fibre recovery and the fibre produced as can be seen on the slide.

INDICATE THAT Prato's Cardato Regenerated CO_2 neutral trademark certification system shown on the slide guarantees that:

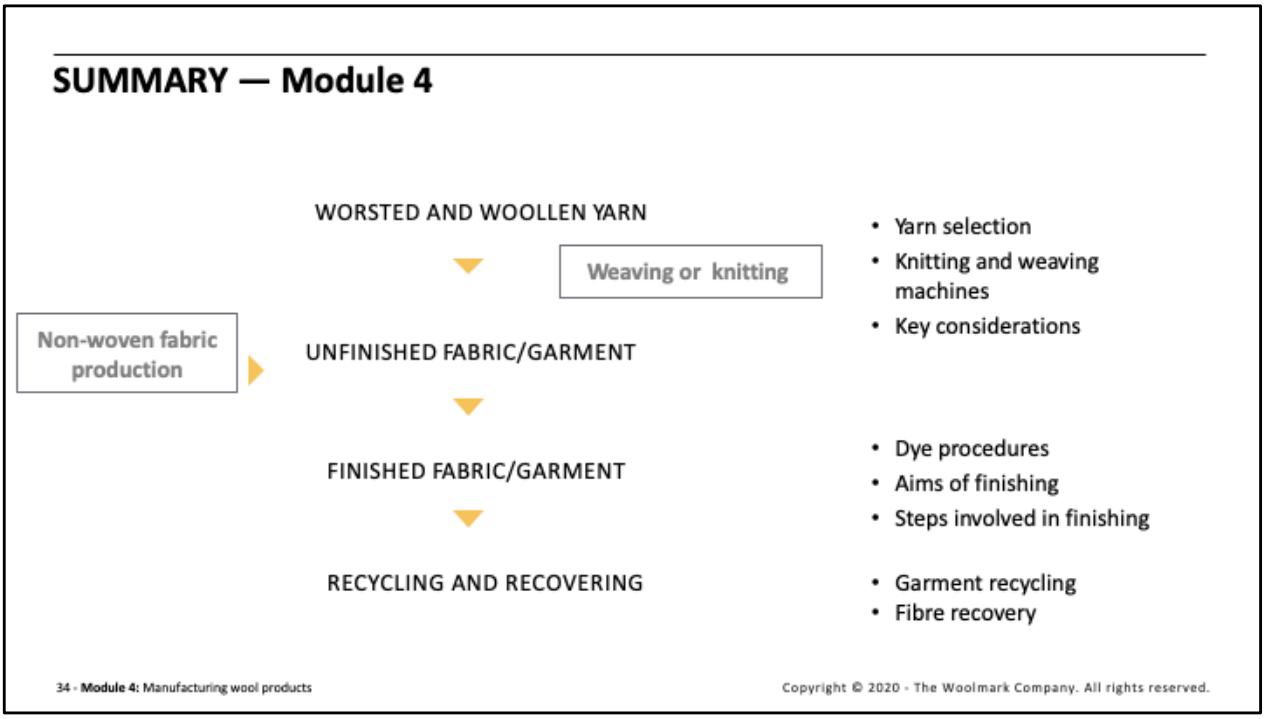
- yarns contain at least 70% of wool fibre derived from rags, recycled clothing or off-cuts
- production is carried out exclusively in the Prato district
- the manufacturing process of the new garment has a limited impact on the environment and also guarantees that zero levels of CO_2 are produced during the regeneration process.

NOTE THAT there are number of fibre recovery facilities are also found across China and India.



EXPLAIN THAT increasing consumer concern about the environmental impacts of textile consumption and waste, particular fashion waste, offers an opportunity for brands to produce and promote recycled wool products, as can be seen by the examples on the slide.

INDICATE THAT the advertisement on the slide is from Marks & Spencer, an important UK high street retailer. Marketing and selling garments that incorporate recycled wool forms part of the company's environmental strategy.



REINFORCE THAT this module has covered how wool yarn is converted into both woven and knitted fabric or garments.

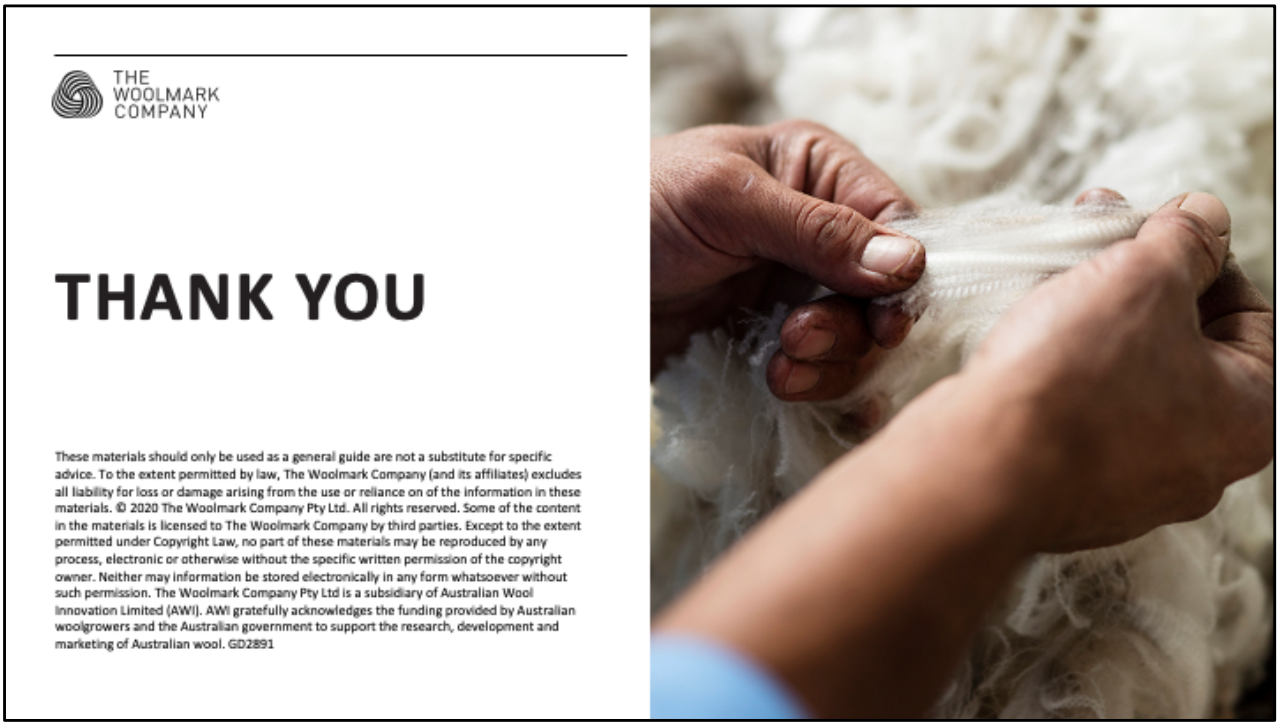
- Yarn selection is the first step. There are different considerations that impact in the choice of yarn for a knitted or a woven garment.
- There are different types of knit and weave structures, which affect the appearance, performance and handle of the garment.
- There are different types of knitting and weaving machines and parameters associated with each of these, such as knitting gauge, weave density and speed.
- The dyeing and finishing of fabrics and garment involves different dye options.
- The main objectives in fabric and garment finishing are to optimise the aesthetic and functional properties of the fabric or garment. There are many steps involved.
- Each of the three stages (preparation, wet finishing and dry finishing) in fabric finishing can involve several operations.
- There are three types of process for knitwear finishing (solvent, dry and wet).
- Wool may be recycled by recovering the fibre from garments at the end of their life and using it again in the production of woollen spun or non-woven products.

REMIND PARTICIPANTS many of these areas are significantly expanded in subsequent Wool Science, Technology and Design Education Program courses.

ASK PARTICIPANTS *if they have any questions about the content covered in this module.*

ALLOW TIME *for questions and discussion before proceeding to the final slide and closing the lecture.*

COLLECT ALL *samples distributed during the lecture.*



INFORM participants of the time and location for the next lecture — *Module 5: The quality of wool products* — and ensure they read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 5

THE WOOLMARK COMPANY

THE QUALITY OF WOOL PRODUCTS

RESOURCES — MODULE 5: THE QUALITY OF WOOL PRODUCTS

You will require the following resources for use as you deliver **Module 5: The quality of wool products**:

- Garment with poor handle
- Garment with good handle
- Garment with evidence of pilling

WELCOME participants to Module 5 of *Introduction to wool processing — The quality of wool products*.

EXPLAIN THAT this module will cover:

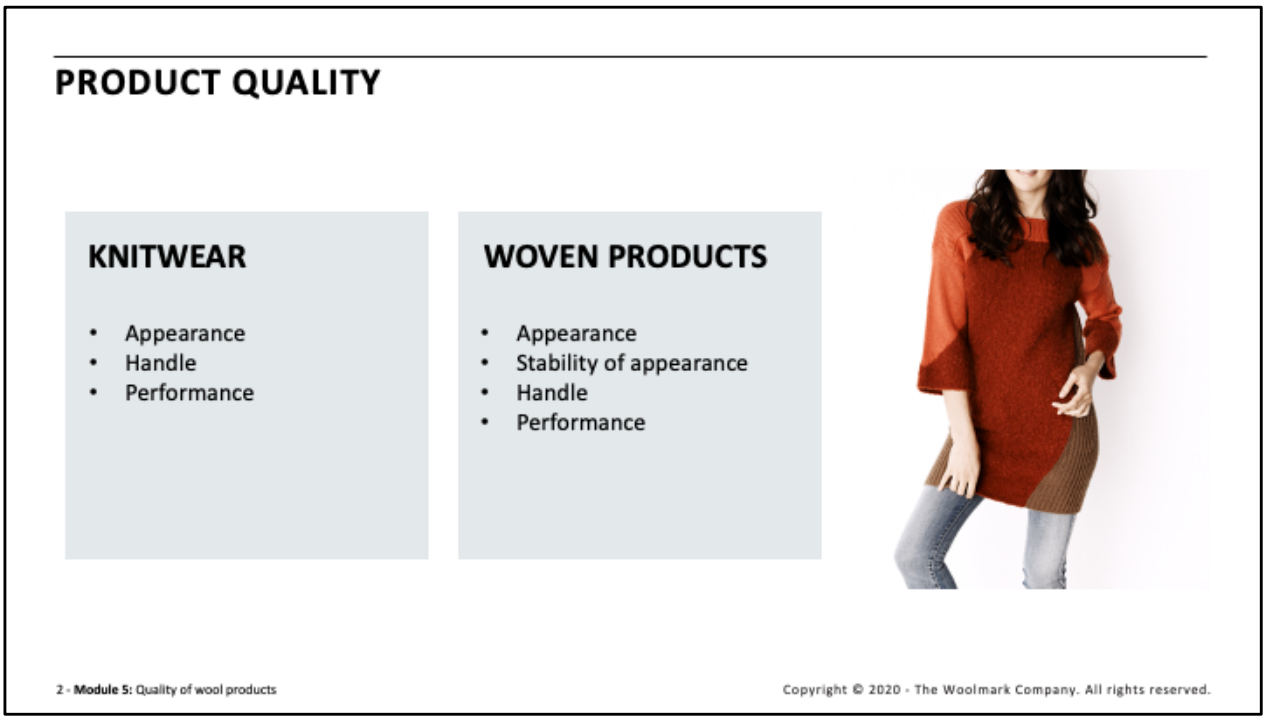
- some characteristics of wool products associated with its quality
- how these quality characteristics are assessed in quality assurance (QA) programs
- how faults can be avoided.

INFORM participants that by the end of this module they will be able to:

- describe the key features of knitted and woven products that determine quality
- outline the approach adopted by The Woolmark Company to test and ensure quality in branded products.

RESOURCES REQUIRED FOR THIS MODULE

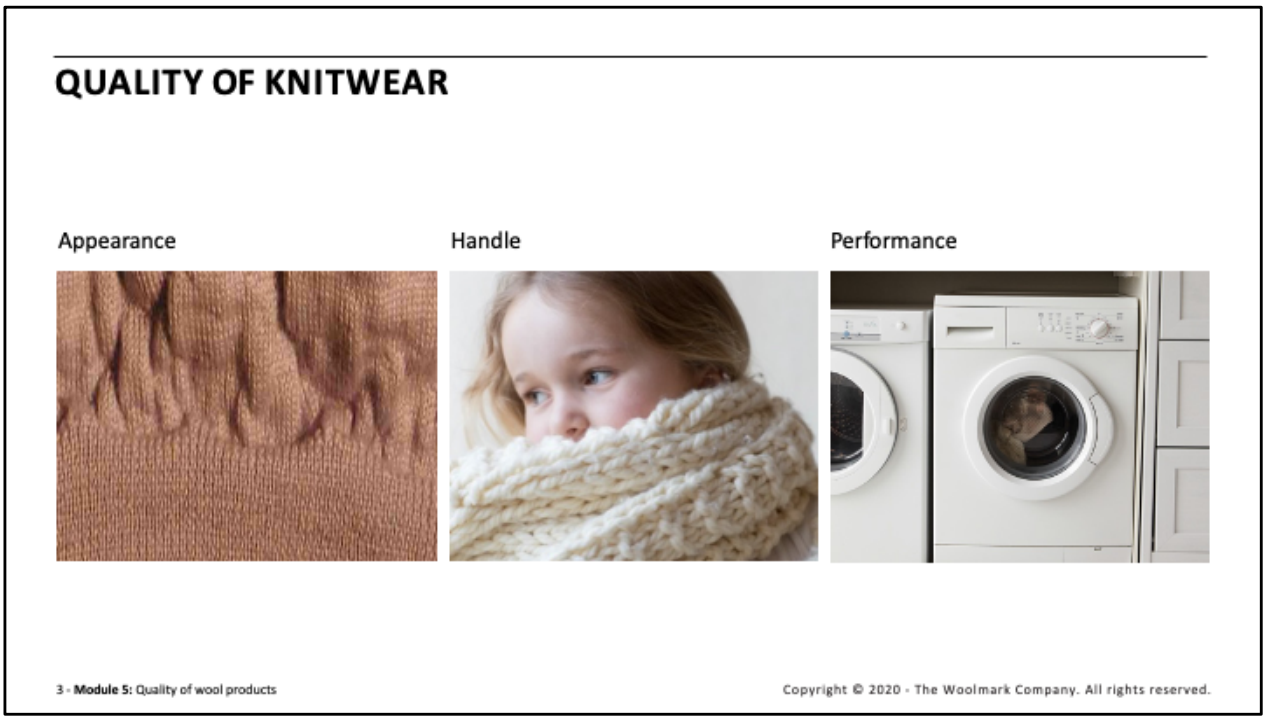
- *a wool garment with poor handle (facilitator to supply)*
- *a wool garment with good handle (facilitator to supply)*
- *a wool garment with evidence of pilling (facilitator to supply)*



EXPLAIN THAT this module will be covered in two parts as outlined on the slide:

For knitwear the focus will be on:
- appearance
- handle
- performance.

For woven products the focus will be on
- appearance
- handle
- stability of appearance during wear
- performance.



INDICATE THAT every day, in the course of their work, knitters talk about quality, both within their company and with their suppliers and customers.

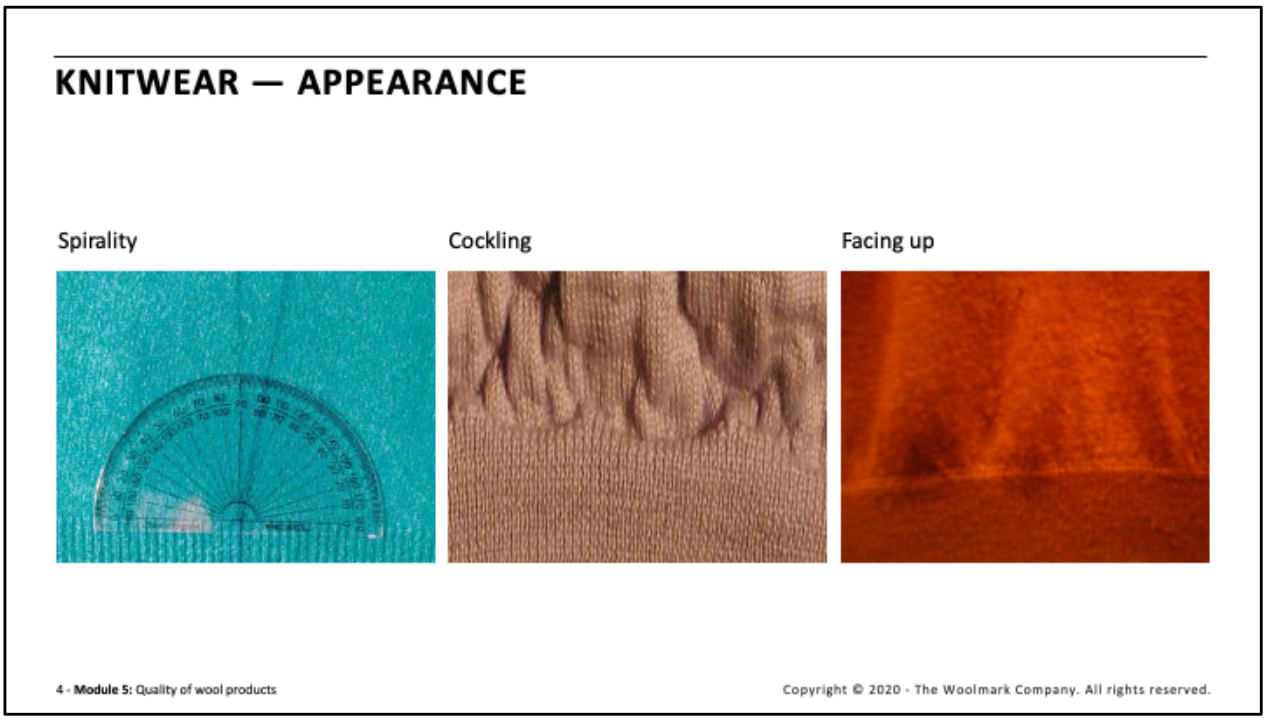
EXPLAIN THAT to manage the quality of their knitted product, it is important knitters have a clear understanding and vision of what is meant by 'quality'.

REINFORCE THAT this understanding must be related to the concepts and requirements of their customers — the retailer, the retailer's customers and, in addition, the consumers' expectations of quality.

EXPLAIN THAT quality in knitwear comprises three vital components:

- appearance
- handle
- performance (wearing and laundering properties).

EXPLAIN THAT to 'manage' the quality of knitted products, made from wool, it is essential to focus on these three aspects.



EXPLAIN THAT the appearance of knitwear is a key feature determining the attractiveness of a garment or other knitted product. If a knitted product does not 'look good', or there are faults in the appearance, the consumer will not buy the product and it will be disposed of or sold as seconds.

INDICATE THAT there are many aspects to appearance. Three of the more important aspects of appearance in knitted products are shown on the slide:

- spirality
- cockling
- facing up.

INDICATE THAT there are many more potential appearance problems, including:

- stains
- contamination
- bars (the appearance of dark or otherwise visible bars appearing irregularly across the fabric). Bars are often associated with unevenness in yarns within a course.

EXPLAIN THAT each of these aspects of knitted product appearance is discussed more fully in the Wool Science, Technology and Design Education Program course *Product quality*.

HAND OUT *samples of garments with:*
- *a poor handle*
- *a good handle.*

ASK PARTICIPANTS *to describe the differences they observe in the fabrics as they pass them around the group.*

EXPLAIN THAT handle relates to the touch of a knitted garment. Handle is also referred to as 'hand', 'feel' or 'touch' and 'fluidity'.

INDICATE THAT often handle characteristics are described as polar opposites (e.g. harsh – soft, bulky – lean).

NOTE THAT if the handle of a garment is poor, it is unlikely the retail buyer will accept the shipment. If they do accept the product, the consumer may not buy the garment on this basis.

EXPLAIN THAT the handle of wool knitwear depends on many factors. These factors fall into four groups:
- fibre characteristics
- yarn construction
- fabric construction
- finishing methods.

INDICATE THAT handling faults (or poor handle) can be articulated as:
- too harsh or dry
- too sticky or too slippery
- too bulky or too lean.

INDICATE THAT generally the handle must be agreed between the knitter and the customer — with the customer (usually a retailer or brand) having the final say. The procedures and responsibility to achieve the correct handle and correct an incorrect handle lie with the knitter.

KNITWEAR — PERFORMANCE

6 - **Module 5:** Quality of wool products

INDICATE THAT product performance is also an important quality attribute of knitted wool products.

OUTLINE THAT performance has a number of components, which depend on the fabric type and application.

EXPLAIN THAT performance relates both to a garment's wearing and laundering properties, such as:

- How well does the product perform during wear?
- How easy is the product to launder or care for?

EXPLAIN THAT consumers buy garments with a desirable handle and attractive appearance, but are dissatisfied if the garment doesn't wear well or is difficult to care for. Consumers may not purchase the same products again or other products from the retailer. Consumers may also return the garment and ask for a refund if they are dissatisfied with how the garments measures up to these quality parameters.

NOTE THAT more often than not, consumer complaints relating to performance can be categorised as follows:

- shrinkage and colour change during laundering
- appearance during wear (predominantly pilling).

PERFORMANCE DURING WEAR

Determined by:

- burst strength
- tensile strength
- abrasion resistance
- susceptibility to pilling.

Performance claims:

- stretch
- water resistance
- wind resistance
- stain resistance.

Water resistance

INDICATE THAT a number of properties of wool fabrics and garments contribute to their performance during wear.

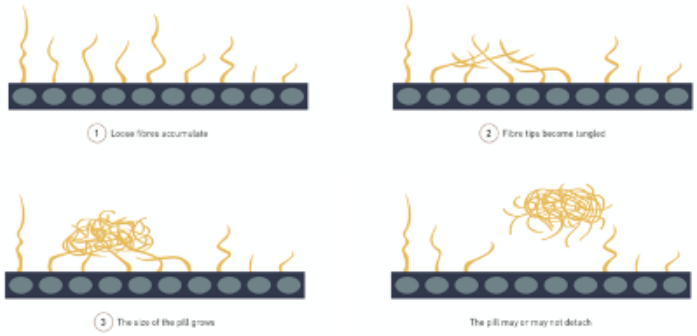
In addition to the requirement for adequate resistance to abrasion, tensile failure, tearing or bursting, wool fabrics should also resist the formation of an excessive number of surface pills or surface fuzz when a clean finish is required.

Those fabrics for which additional claims are made must also meet the expected performance during the period of use related to such claims, for example, stretch or water, wind and stain resistance.

PERFORMANCE — PILLING

Influencing factors:

- fibre selection
- yarn properties
- density of the knitted fabric
- finishing procedures.



Life cycle of a pill

***HAND OUT** the samples of a garment that shows evidence of pilling.*

***EXPLAIN THAT** pilling describes the development of tiny balls of fibre on knitted garments.*

EXPLAIN THAT rubbing action on knitted, and some woven, garments during wear can tease out loosely-held fibres onto the surface of the fabric.

INDICATE THAT many of the fibres are so short they can drop off without forming pills. However, when some fibres are teased out, or protrude, the continued rubbing action leads to formation of fibrous balls, known as pills.

EXPLAIN THAT pills are attached to the fabric by anchoring fibres. Interlacing, rolling of the fibre tips and the presence of contaminants that adhere to the pills permit an increase in size. When a certain size is reached, the forces on the anchoring fibres become so great the pill detaches.

INDICATE THAT the process of pill formation is outlined on the slide. The main areas where rubbing actions occurs on garments are the chest and abdomen.

NOTE THE main factors affecting pilling are:

- yarn properties
- fabric density
- finishing procedure.

Yarn properties affecting pilling

- *Fibre fineness* – products from fine wool pill more readily than those from broad wool.
- *Twist levels* — the higher the twist the greater the compactness and interfibre friction and the lower pilling.
- *Twist regularity* — uniform twist prevents regions of low twist, which permit fibre migration and pilling.
- *Yarn ply* — two-fold yarns are less hairy than singles and pill less.
- *Hairiness of the yarn* — hairy yarns tend to promote pilling due to the number of fibres available to fuzz.
- *Yarn count* — finer yarns have more turns of twist per course length and therefore more friction between fibres. Finer yarns create more yarn intersections for a given fabric weight, reducing migration and pilling.
- *Spinning technique* — Some spinning techniques give products that exhibit less pilling than those from alternatives spinning methods.

Density of the knitted fabric

The density of the knitted fabric has an impact on pilling — the more solid or firm the fabric; the less it will pill. The softer the fabric; the more it pills.

Finishing procedures

- *Dyeing* — affects pilling through changes in the strength of the fibre and the changes in the hairiness of the fabric surface.
- *Scouring and milling* — tends to increase hairiness and thus pilling.
- *Felt resist treatments* — degradative treatments, such as chlorination, tend to reduce pilling, whereas subsequent polymer treatments that strengthen the fibre tend to make pilling worse.

AN ANTI-PILLING PROCESS

- **Three approaches:**
  - increase inter-fibre friction
  - bond fibre to fibre
  - weaken surface fibres.
- Treatments that reduce pilling often impair handle and softness.
- Commercially used treatments minimise but can't prevent pilling.

EXPLAIN THAT there are three theoretical approaches to preventing pilling:

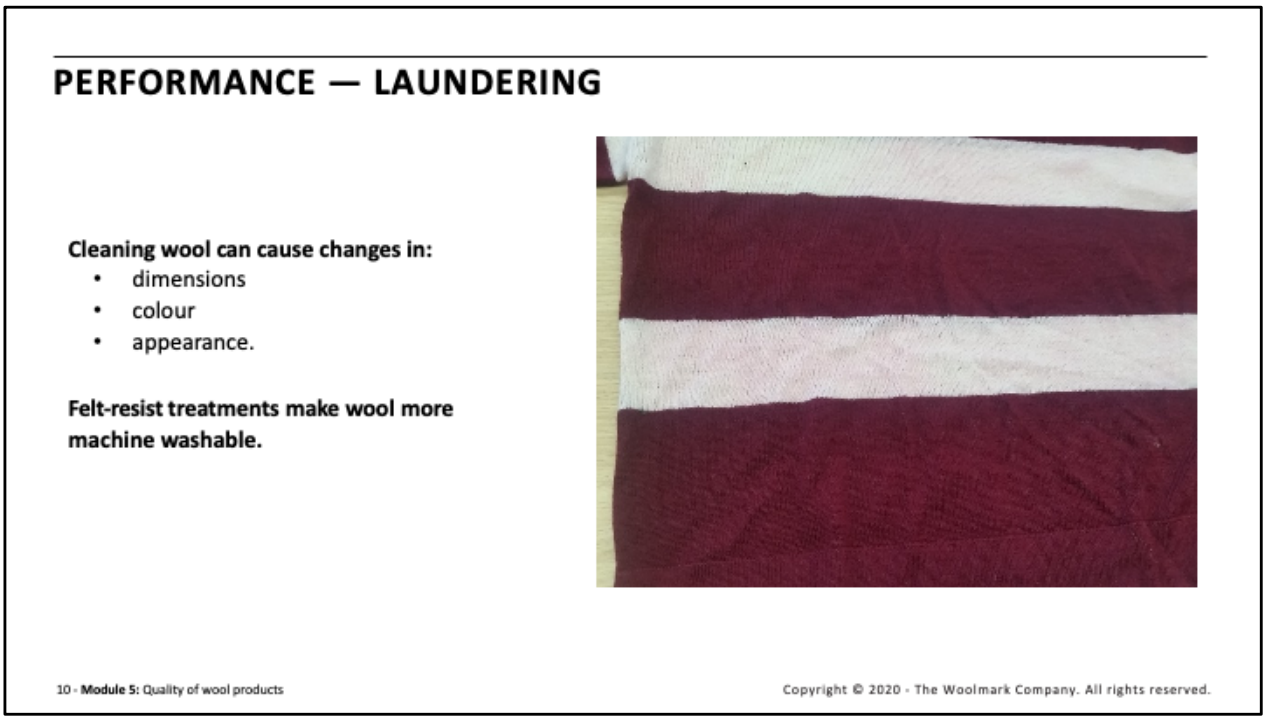
- increase the friction between the fibres to prevent them moving
- fibre-to-fibre bonding (i.e. glue the fibres together)
- weaken the surface fibres.

INDICATE THAT the first two approaches invariably have an adverse effect on handle. The third approach can improve handle, but it can weaken the whole garment if done badly.

EXPLAIN THAT there is often a balance required between pilling (performance) and softening. Since there are so many factors involved in pilling, there is no simple answer to controlling it or finding the optimum balance between pilling performance and handle.

NOTE THAT in actual fact there is a three-way balance, because cost has a bearing, either through better-quality raw materials or through the extra finishing costs.

EXPLAIN THAT there are a number of commercially-used anti-pilling processes, but while they do help to reduce the amount of pilling, none of them can completely prevent pilling.



EXPLAIN THAT during cleaning the following changes can occur:

Dimensional change:
- Can be either shrinkage or extension (stretching).
- Depends on fibre and garment construction.

Colour change:
- Can be loss of colour, or staining onto other garments.
- Depends on dyestuff and washing detergent.

Appearance changes:
- The garment can start to look old or worn.
- Depends on garment construction and cleaning regime.

***ASK PARTICIPANTS** to raise their hand if they have experienced any of the issues mentioned above.*

REITERATE THE processes surrounding dimensional change as follows:

Dimensional change
Garments do not always change their size and shape or appearance during washing, but if they do one or more of several things may have occurred.

Dimensional change can have two causes:
Relaxation shrinkage
- If the garment is stretched during knitting or steaming (during finishing), it will revert back to its unstretched dimensions when wet during washing. Relaxation shrinkage or expansion is temporary and can be recovered by re-pressing.

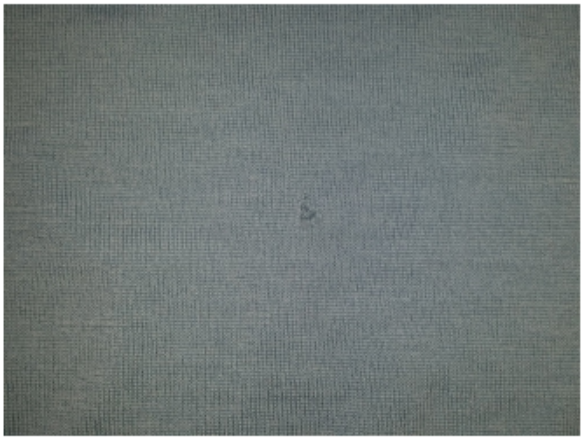
Felting shrinkage
- Felting shrinkage is permanent and irreversible. Agitation of the wool garment while it is wet is the main reason why felting shrinkage occurs. Felt-resist treatments help make wool machine washable and reduce the impact of cleaning on the wool fibres.

REMIND PARTICIPANTS that dimensional change and the properties of wool associated with these changes are covered in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

CAUSES OF POOR QUALITY

The main causes of quality faults in knitwear are associated with:

- poor yarn quality
- loose knitting
- faults in knitting
- poor garment finishing.



Fault in knitted fabric

11 - **Module 5:** Quality of wool products

EXPLAIN THAT the main causes of quality defects in knitwear are associated with:

- poor yarn quality
- loose knitting
- faults in knitting (dropped stitches)
- poor garment finishing.

NOTE THAT there is no simple answer for achieving high-quality knitwear. It is a matter of controlling parameters along the entire manufacturing pipeline. Doing so requires a balanced approach. Once spotted, faults are difficult to remove. The best option is therefore to prevent them from happening in the first place.

ASK PARTICIPANTS *if they have any questions about the issues surrounding the quality of knitted wool products.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

EXPLAIN THAT the quality of a woven fabric or garment is determined by its:
- handle
- appearance
- stability of appearance
- performance during wear.

INDICATE THAT handle for woven wool fabric or garments is assessed in terms of:
- extensibility
- flexibility
- smoothness.

EXPLAIN THAT the appearance of woven fabric and garments is assessed in terms of:
- seam flatness
- lustre (shine)
- clarity of weave.

INDICATE THAT stability of appearance refers to characteristics such as:
- seam flatness
- crease sharpness
- wrinkling.

EXPLAIN THAT performance during wear includes:
- durability
- crease recovery
- dimensional change.

NOTE THAT three of these categories are similar in concept to those used in knitwear although the nature of desirable product characteristics can differ. For example, a desirable woven fabric may be soft and smooth, while desirable knitwear is normally soft and bulky. These different handles are each suitable for an individual product type.

NOTE THAT the concept of stability of appearance is an additional requirement of woven goods.

EXPLAIN THAT there are at least two aspects to the stability of the appearance of woven garments — appearance before sale and appearance during wear.

INDICATE THAT for appearance before sale characteristics to meet quality parameters

- there should be no deterioration in appearance during storage
- seams should be flat (there should be no seam pucker)
- creases should be sharp.

EXPLAIN THAT for appearance during wear to remain stable:

- seams should remain flat during wear
- garment panels should not distort
- woven garments should exhibit good wrinkle recovery during wear.

PERFORMANCE

Stable to laundering:
- stable to dry cleaning
- stable to machine wash.

Adequate dye fastness:
- light and rub fastness
- dry cleaning or wash fastness.

Good physical properties:
- abrasion resistance
- tear strength.

14 - **Module 5:** Quality of wool products

EXPLAIN THAT there are a number of aspects to the performance of woven garments.

Appearance after laundering
- No distortion of garment panels
- Stable to dry cleaning (where appropriate)
    - No delamination of fusibles
    - No seam pucker
- Stable to machine washing
    - No shrinkage
    - No felting – facing up
    - Easy to iron

Adequate dye fastness
- Light and rub fastness
- Fastness to dry cleaning or washing

Good physical properties
- Abrasion resistance
- Tear strength

CAUSES OF POOR QUALITY

The main causes of faults in woven goods are associated with:

- poor yarn quality
- faults in weaving
- poor finishing
- incorrect fabric selection
- poor making-up.

15 - **Module 5:** Quality of wool products

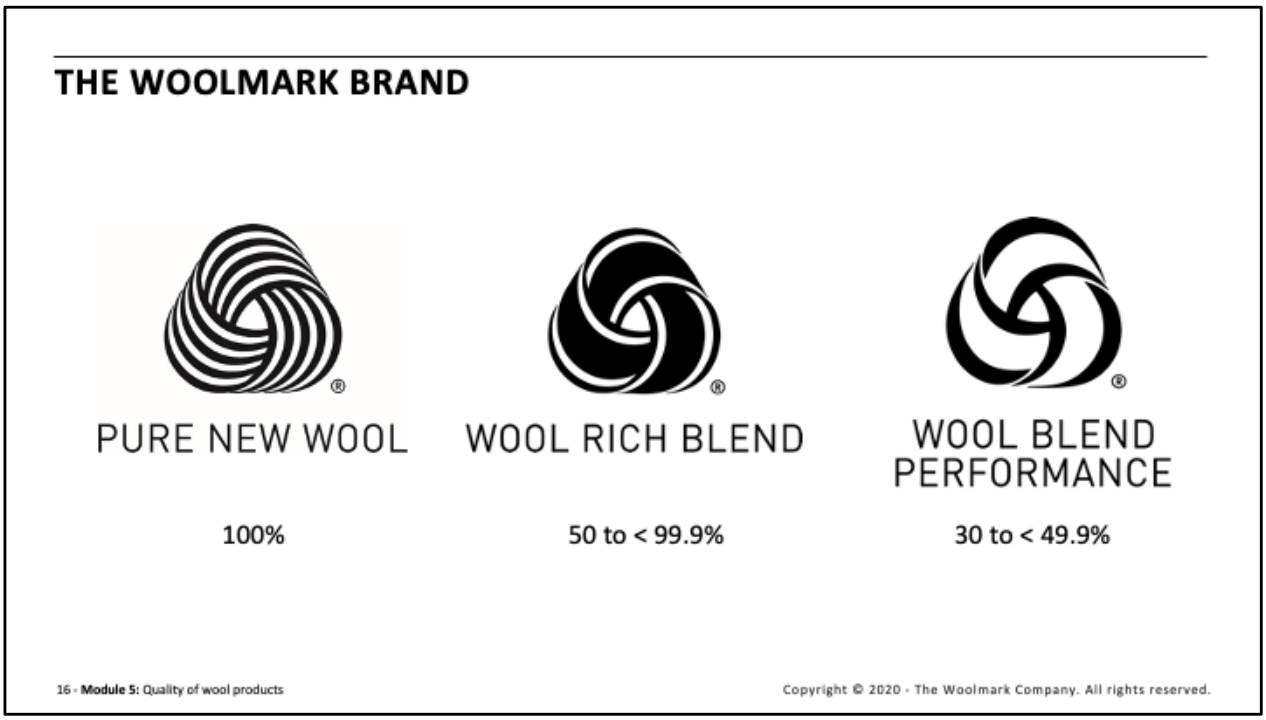
INDICATE THAT the main causes for quality defects in wovenwear are associated with:

- poor yarn quality
- faults in weaving
- incorrect fabric selection
- poor finishing
- poor making-up.

EXPLAIN THAT there is no simple answer for achieving woven garment quality. It is a matter of controlling parameters along the entire manufacturing pipeline.

ASK PARTICIPANTS *if they have any questions about the issues surrounding the quality of woven wool products.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*



EXPLAIN THAT the Woolmark logo is one of the world's most recognisable textile symbols and has been applied to more than five billion products since its creation in 1964. It indicates the product consumers purchase meets the key performance standards associated with quality wool products. The Woolmark brand and its associated quality assurance (QA) system ensures when customers buy a Woolmark labelled product, they know it's of the highest standard.

EXPLAIN THAT the Woolmark brand helps reassure consumers about:

- the type of wool in the garment
- the micron of the wool; representing softness and comfort
- how the garment will perform
- the density and strength of the fabric
- the colourfastness of the garment
- the stability of the garment, especially after washing
- the accuracy of the care claim.

INDICATE THAT brands that regularly create garments that bear the Woolmark trademark are subsequently viewed as quality brands in the eyes of the consumer. Customers are willing to pay a premium for quality brands they know will last.

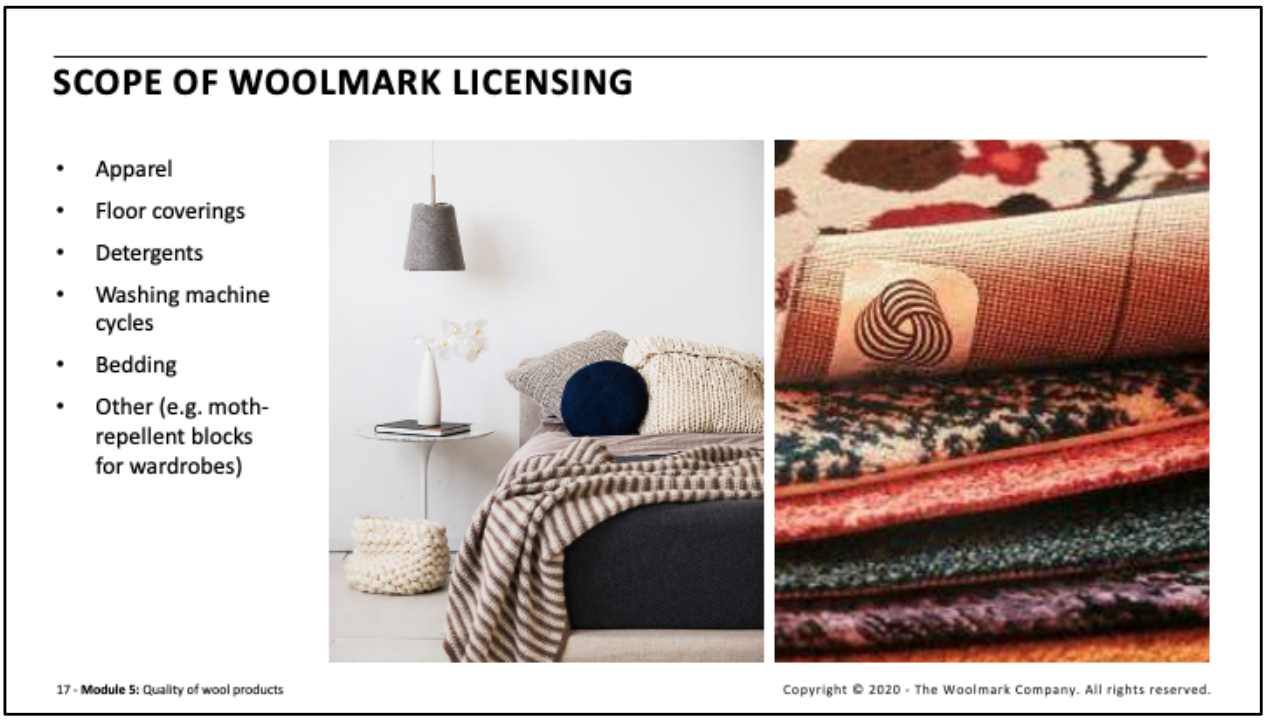
EXPLAIN THAT there is more than one Woolmark trademark — all the Woolmark trademarks are owned by The Woolmark Company.

OUTLINE THE Woolmark trademarks as follows:

Pure New Wool
The original Woolmark logo indicates the product is composed of 100% pure new wool — wool that has never been used before. This means it has not yet been recycled, re-used or re-purposed in any way. Only 0.3% of the garment can be due to accidental contamination by a non-wool fibre. Up to 5% of non-wool fibre can be added for purely decorative purposes (e.g. the stripe in a pin stripe).

Wool Rich Blend
The Wool Rich Blend brand indicates the product contains more than, or equal to, 50% new wool. Only one non-wool component is allowed in the singles yarns that makes up a folded blend yarn or a blend fabric.

Wool Blend Performance
The Wool Blend Performance brand indicates the product contains between 30% and 49% new wool. It is the newest logo (established in 1999). As with Woolmark Blend, only one non-wool component is allowed in intimately blended singles yarns.



EXPLAIN THAT the Woolmark Company operates a global licensing program, which licenses the logos to qualifying companies to enable them to use one of the Woolmark trademarks on products that comply with the relevant specifications.

NOTE THAT this program makes sure any products carrying the Woolmark trademark have been tested to ensure they meet the relevant product specifications defined by The Woolmark Company.

EXPLAIN THAT only licensed manufacturers are allowed to attach Woolmark-branded tickets and labels to their products.

INDICATE THAT companies applying for a Woolmark license must send their products to an independent authorised laboratory for quality testing. When an existing licensee wants to add the trademark to a new product, it must also be tested.

Testing can also include spot check testing of a manufacturer's eligible products, as well as spot check testing of goods at retail.

EXPLAIN THAT Woolmark's quality assurance system extends to a range of goods and items, as listed on the slide. It isn't just about woollen garments!

AIMS OF THE QUALITY ASSURANCE SYSTEM USED BY THE WOOLMARK COMPANY

- Promote highest quality wool products
- Augment a retailer's own brand
- Meet or exceed consumer's expectations
- Reassure retail buyers and sourcing managers
- Identify the most competent manufacturers

18 - **Module 5:** Quality of wool products

REINFORCE THAT the Woolmark quality assurance system aims to:

- promote highest quality wool products
- support/augment a retailer's own brand
- ensure the consumer's expectations are always met or exceeded.

EXPLAIN THAT Woolmark specifications are consumer-focused to:

- reassure retail buyers and sourcing managers
- identify the most competent manufacturers.

INDICATE THAT Woolmark has the responsibility for meeting and controlling specifications.

***PLAY** the 45-second Woolmark Company video, which highlights the rigorous testing that delivers reassurance to wool customers.*

***ALLOW TIME** for questions and discussion before proceeding to the next slide.*

APPAREL SPECIFICATIONS

CONSUMER EXPECTATION	PROPERTY
Fibre type	Wool content
Softness	Fibre micron, comfort factor
Appearance	Cockling, pilling, spirality
Care claim	Dimensional stability, colourfastness, after-wash appearance
Performance	Burst strength, cover factor, tensile strength, additional claims

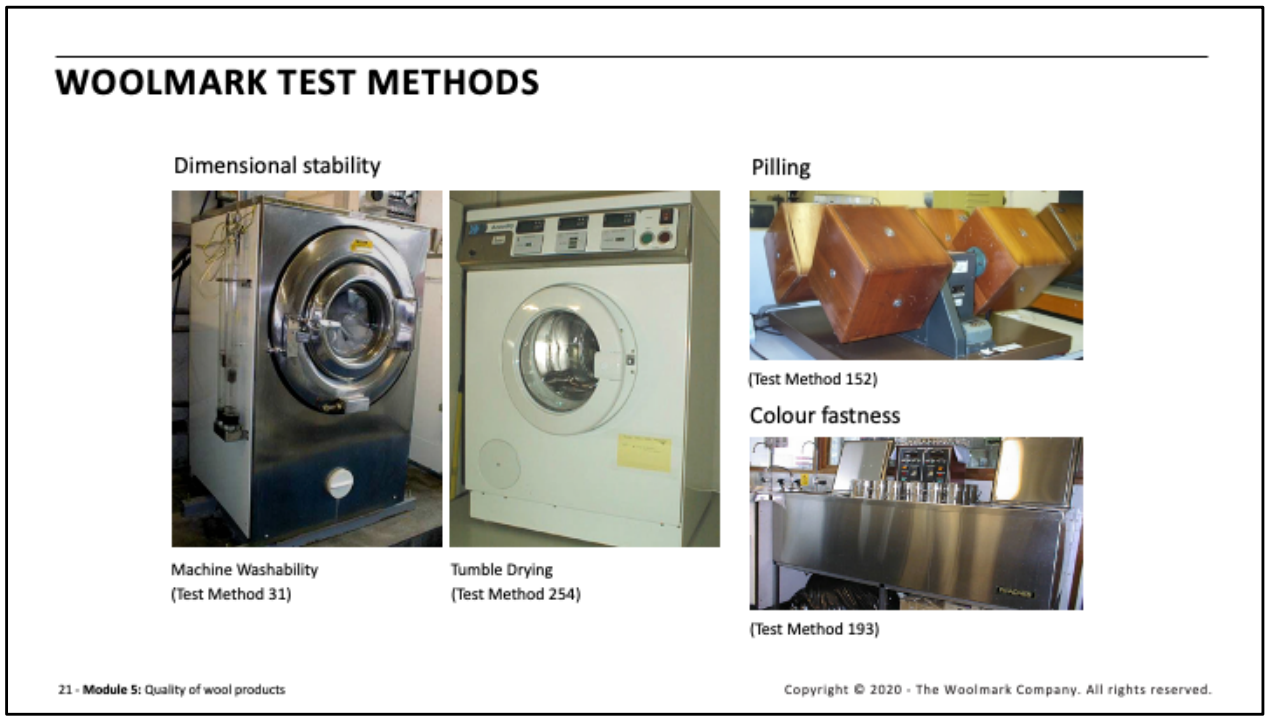
EXPLAIN THAT there is a range of common attributes consumers want in their wool products. Based on these attributes The Woolmark Company has defined apparel specifications (listed on the slide), which ensure apparel products carrying the Woolmark brands meet consumers' expectations.

INDICATE THAT the right-hand column on the slide lists the apparel product specifications Woolmark has both defined and regularly tests for to ensure the products bearing the Woolmark label meet consumers' expectations.

EXPLAIN THAT the tests and specifications are designed to ensure the consumer is satisfied across five key parameters:

- fibre type
- softness
- appearance
- ease of care
- wear performance.

INDICATE THAT some of the most common test methods used to assess these attributes are shown on the next slide.



OUTLINE THE following test methods:

Test Method TM 152: ICI Pilling
- is used to test pilling in knitwear and knitted fabric samples.
- uses an instrument known as the ICI Pilling Box tester.

EXPLAIN THAT during the test the material is wrapped on rubber tubes which are tumbled in a cork-lined box for a time period. The degree of pilling is assessed by comparison with standard photographs, with a rating from 5 to 1, where 5 is the best.

Test Method TM196
- is used to test pilling in woven products.

Test Method TM 193: Colourfastness to washing
- tests a garment's degree of colourfastness to washing.

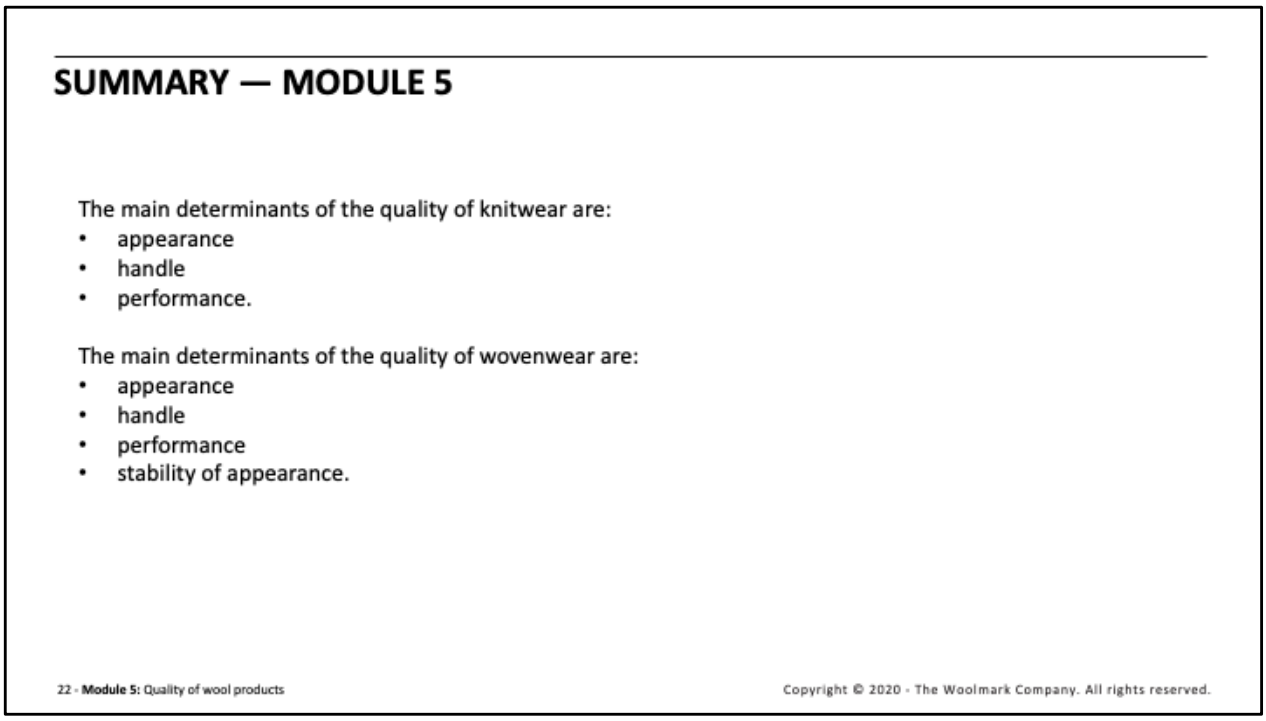
Colourfastness is determined to assess the stability of colour after repeated home laundering as part of regular care. Colourfastness is the primary factor that leads to customer dissatisfaction.

EXPLAIN THAT the test is an accelerated washing test that is roughly equivalent to five or more home or commercial launderings. The sample is attached to a multifibre strip, and washing is performed in a canister that is placed in a Launderometer. Standard reference detergent solutions are used. Evaluation of results is similar to the use of grey scales.

ASK PARTICIPANTS *if they have any questions about the Woolmark brand, licencing or product testing.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

NOTE THAT *the following handout is available if students want further information about the test methods used by Woolmark:*
- The Meaning Behind the Woolmark Logo



REINFORCE THAT the main quality parameters for knitwear are:
- appearance
- handle
- performance.

REITERATE THAT there are many aspects to appearance. Three of the more important aspects of appearance in knitted products are:
- spirality
- cockling
- facing up.

REMIND PARTICIPANTS that knitwear handle is a subjective quality and is often balanced with performance.

The handle of wool knitwear depends on many factors. These factors fall into four groups:
- fibre characteristics
- yarn construction
- fabric construction
- finishing methods.

REINFORCE THAT handling faults (or poor handle) can be articulated as:
- too harsh or dry
- too sticky or too slippery
- too bulky or too lean.

REITERATE THAT more often than not, consumer complaints relating to performance can be categorised into the following categories:
- shrinkage and colour change during laundering
- appearance during wear (predominantly pilling).

REINFORCE THAT the quality of a woven fabric or garment is determined by its:
- handle
- appearance
- stability of appearance
- performance during wear.

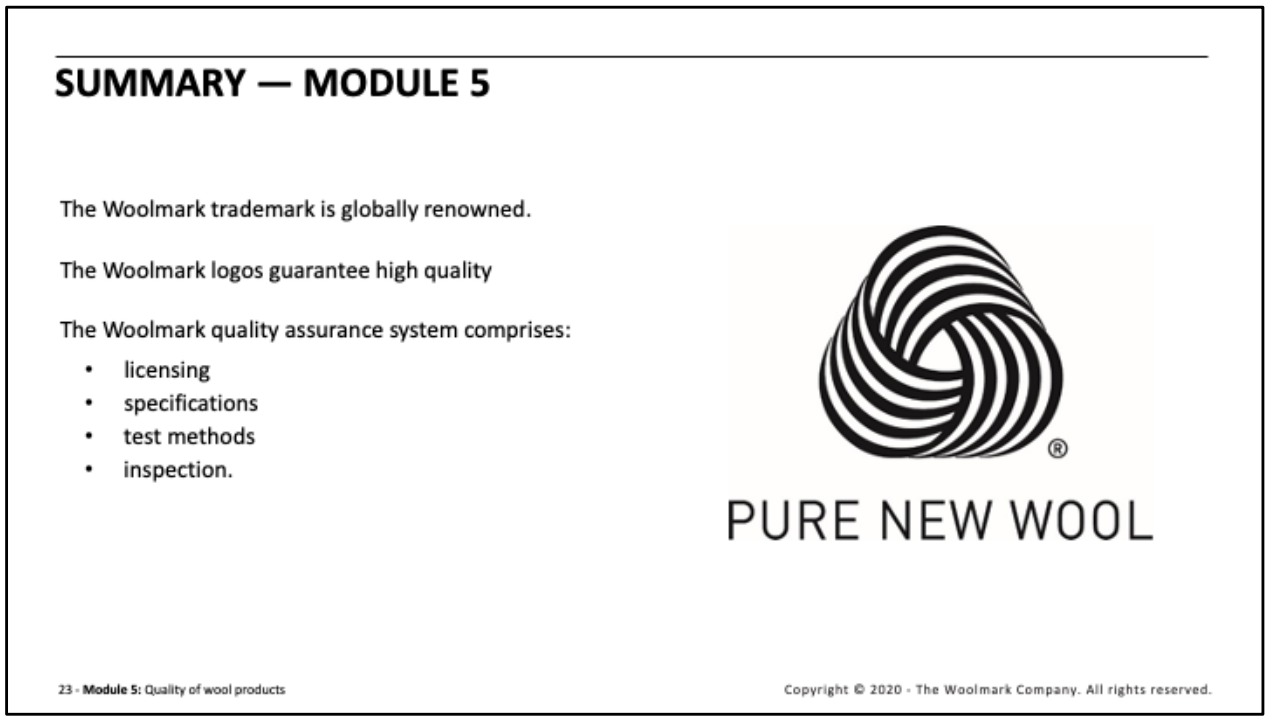
REMIND PARTICIPANTS handle for woven wool fabric or garments is assessed in terms of:
- extensibility
- flexibility
- smoothness.

REINFORCE THAT the appearance of woven fabric and garments is assessed in terms of:
- seam flatness
- lustre (shine)
- clarity of weave.

REITERATE THAT stability of appearance refers to characteristics such as:
- seam flatness
- crease sharpness
- wrinkling.

REMIND PARTICIPANTS that performance during wear includes:
- durability
- crease recovery
- dimensional change.

SUMMARISE BY noting there is no simple answer for achieving good product quality in knitted or woven garments — it is a matter of controlling parameters along the entire manufacturing pipeline.



REMIND PARTICIPANTS that the Woolmark logo is one of the world's most recognisable textile symbols. It indicates the product consumers purchase meets the key performance standards associated with quality wool products. The Woolmark brand and its associated quality assurance (QA) system ensures when customers buy a Woolmark labelled product, they know it's of the highest standard.

CONFIRM THAT the Woolmark brand helps reassure consumers about:
- the type of wool in the garment
- the micron of the wool; representing softness and comfort
- how the garment will perform
- the density and strength of the fabric
- the colourfastness of the garment
- the stability of the garment, especially after washing
- the accuracy of the care claim.

REITERATE THAT The Woolmark Company operates a global licensing program, which licenses the logos to qualifying companies to enable them to use one of the Woolmark trademarks on products that comply with the relevant specifications.

REMIND PARTICIPANTS only licensed manufacturers are allowed to attach Woolmark branded tickets and labels to their products. Companies applying for a Woolmark license must send their products to an independent authorised laboratory for quality testing. When an existing licensee wants to add the trademark to a new product, it must also be tested.

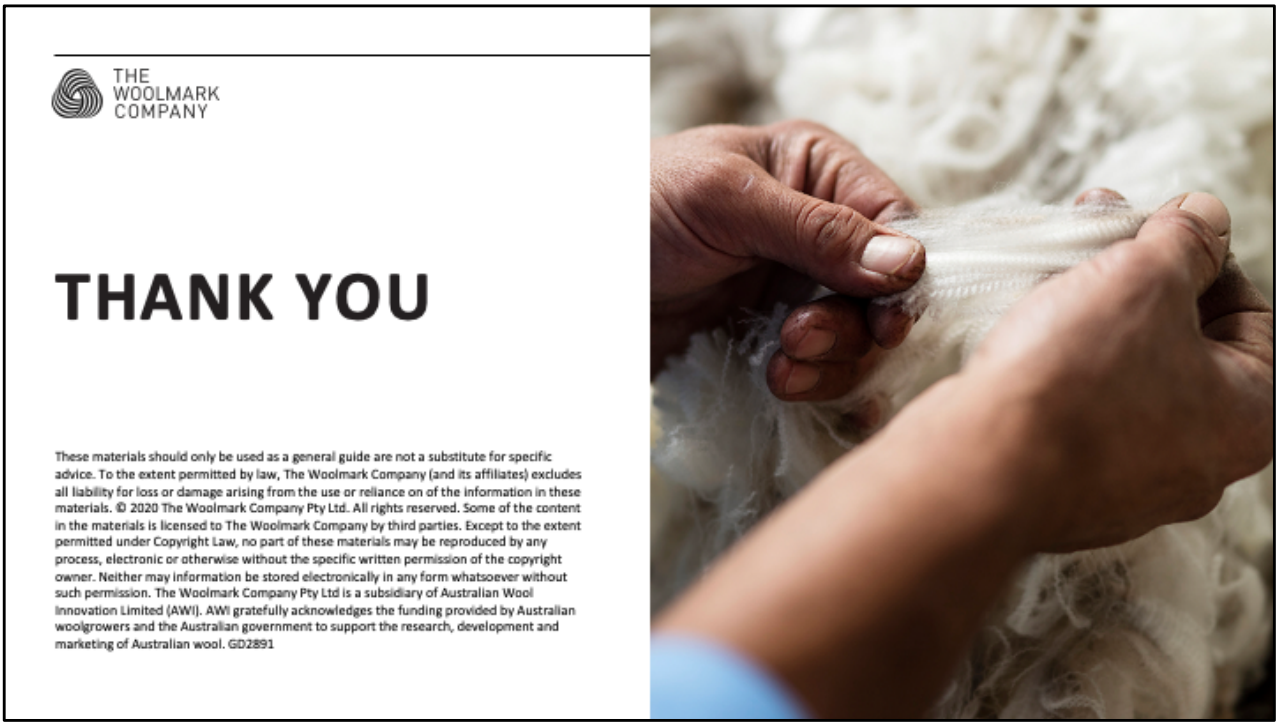
REINFORCE THAT Woolmark's quality assurance system extends to a range of goods and items. It isn't just about apparel.

FINISH BY reinforcing that the Woolmark tests and specifications are designed to ensure the consumer gets five key benefits:
- fibre type
- softness
- appearance
- ease of care
- wear performance.

ASK PARTICIPANTS *if they have any questions about the content covered in this module.*

ALLOW TIME *for questions and discussion before proceeding to the final slide and closing the lecture.*

COLLECT ALL *samples distributed during the lecture.*



INFORM participants of the time and location for the next lecture — *Module 6: Innovations In wool products* — and ensure they read through the relevant notes in their Participant Guides before attending the lecture.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in today's lecture.

Participants can register with and explore the Woolmark Learning Centre here: www.woolmarklearningcentre.com

MODULE 6

THE WOOLMARK COMPANY

INNOVATION IN WOOL PRODUCTS

RESOURCES — MODULE 6: INNOVATION IN WOOL PRODUCTS

Contained in the *Introduction to wool processing* Demonstration kit you will find the following resources for use as you deliver **Module 6: Innovation in wool products**:

– TWC Innovation swatches

WELCOME participants to Module 6 of *Introduction to wool processing — Innovations in wool products*.

EXPLAIN THAT the versatility of wool lies at the core of a range of cutting-edge product innovations. Product developers continue to explore the potential of this adaptable natural fibre.

INDICATE THAT The Woolmark Company and its partners are continually pushing the boundaries to develop new, innovative wool products to meet consumers' needs.

EXPLAIN THAT this module will describe some of the recent innovations in wool products, which capitalise on the fibre's inherent properties and new processing technology. It also explores some textile fibre innovations that could be combined with wool to produce novel fibre blends.

INFORM participants that by the end of this module they will be able to:

- list the inherent features of wool that support product innovation
- describe some of the innovations being used to create new wool products
- outline some of the methods used to create the wool innovations covered in this module.

NOTE TO FACILITATOR *The demonstration kit for this course contains a range of textile innovations covered in this final module. Ensure participants have the opportunity to explore these innovations as they are covered throughout the module.*

INDICATE THAT the value of wool as a consumer product lies in its versatility, derived from its inherent physical structure, as well as its chemistry and physics.

REINFORCE THAT the structure, physics and chemistry of the wool fibre translate into a range of properties and benefits, which deliver sound reasons for choosing wool across a wide variety of applications (from apparel through to carpets and home furnishing and industrial applications).

EXPLAIN THAT these reasons include:

- Wool is natural — wool is a natural fibre and is a renewable resource.
- Wool is comfortable — comfort is derived from a combination of softness, moisture management and temperature control
- Wool is easy to live with — wool is durable, has soil and stain resistance properties, may be laundered easily and is ideal for sensitive skin
- Wool is safe — wool has fire resistant and UV adsorption properties
- Wool is visually appealing — the structure and physics of the fibre impart qualities that offer a superior handle and drape. Additionally, wool has good wrinkle recovery.
- Wool is environmentally responsible — wool's inherent properties also contribute to its environmental footprint. In addition to being a renewable and biodegradable natural fibre, wool is also recyclable. Reclaimed fibre is used in the creation of a wide range of new wool products, extending the useful life of wool.

PLAY *the two-minute award-winning video produced for The Woolmark Company, which takes a light-hearted look at the serious benefits this natural fibre has to offer.*

ASK PARTICIPANTS *to describe three benefits of wool portrayed in the video.*

ANSWERS INCLUDE*:*

- *Wool is soft.*
- *Wool manages body odour.*
- *Wool keeps you warm and keeps you cool.*
- *Wool manages body temperature and perspiration during exercise.*
- *Wool is flexible and moves with your body, making it comfortable during exercise.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

REMIND PARTICIPANTS that the benefits of wool are covered in detail the Wool Science, Technology and Design Education Program course *Wool fibre science*.

REINFORCE THAT wool has crimp — so we can:

- create bulk without weight
- create warmth without clamminess.

REMIND PARTICIPANTS that the natural crimp in wool fibres makes them stand apart from each other, trapping air between the fibres. Still air is one of the best natural insulators and the ability of wool to trap still air is central to wool's ability insulate against both heat and cold.

EXPLAIN THAT wool's ability to adsorb and desorb moisture maintains a moisture-controlled environment within the air pockets, ensuring efficient insulation and a dry microclimate in damp conditions.

INNOVATION USING FIBRE CRIMP

4 - **Module 6:** Innovations in wool products

INDICATE THAT wool has long been used for insulation in bedding products and building insulation. Recent innovations have seen wool fibre filling used in a range of apparel applications, offering a natural and effective alternative to synthetic fibres or down.

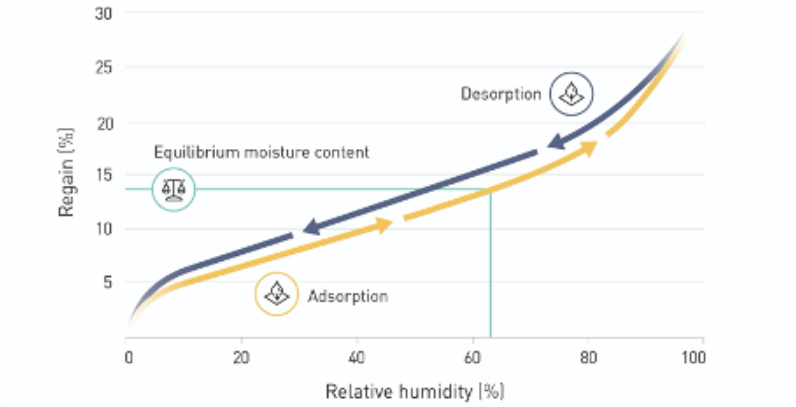
INDICATE THAT puffer jackets and other products, such as sleeping bags, are usually created either by blowing in down and/or feathers, or by trapping a thick layer of carded fibre between two layers of woven fabrics and quilting them to stabilise the filling. In this innovation the down and feathers are replaced with wool neps, 0.5mm diameter balls of wool noil, or the polyester wadding is replaced by layers of carded wool batts ranging from 85gsm to 250gsm depending not the insulation required.

EXPLAIN THAT its superior insulation properties are seeing wool being incorporated into the traditional construction of denim, elevating the denim into a premium and higher-performing fabric. Available as either a wool/cotton blend or 100 per cent wool fabric, wool denim is offered in a traditional twill weave construction. Using the wool fibre as the weft yarn, the inside of the denim is enhanced with added warmth and resilience due to the natural crimp of the wool fibres.

INDICATE THAT wool denim is also produced as a knitted fabric, and the resulting garments have enhanced insulation properties when compared with the traditional pure cotton alternative, lifting denim from a typically comfortable, casual garment into a luxury item.

WOOL ADSORBS AND DESORBS MOISTURE, SO WE CAN…

- create comfortable garments

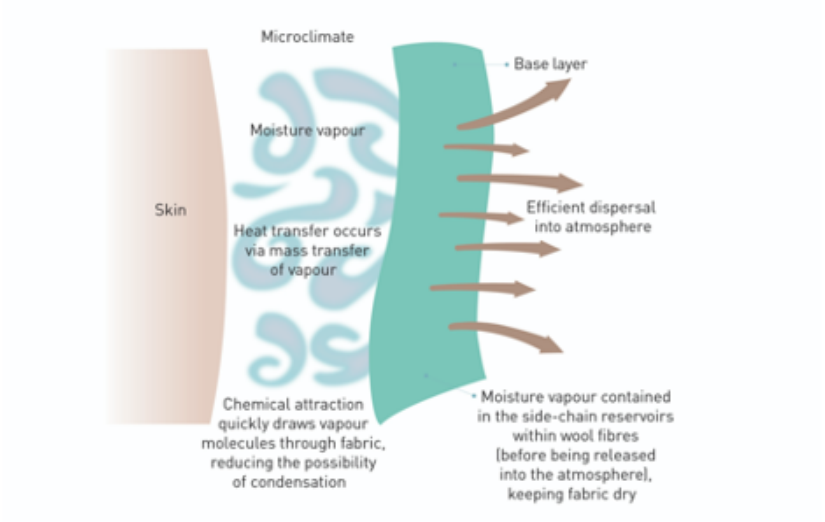


6 - **Module 6:** Innovations in wool products

REFER TO the slide, and remind participants that as discussed in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science*, wool fibres can absorb and desorb moisture vapour as conditions around the fibre change. This action gives wool its 'comfort' properties during high-intensity activity and makes it 'breathable'.

INDICATE THAT it is these adsorption and desorption properties that are the basis for innovations related to moisture management.

INNOVATION USING MOISTURE MANAGEMENT



7 - **Module 6:** Innovations in wool products

EXPLAIN THAT the ability of wool to manage moisture, through its inherent chemical and physical properties, combined with the softness and natural elasticity of fine wool types (such as superfine Merino) has lead to a range of wool innovations in sports and activewear.

EXPLAIN THAT as outlined on the slide, in hot climates, or during exercise, when the wearer is sweating, a wool garment adsorbs the moisture close to skin. Wool can absorb up to 35 per cent of its dry weight in moisture vapour. The fibre holds the moisture vapour within the fibre structure so the garment does not feel wet.

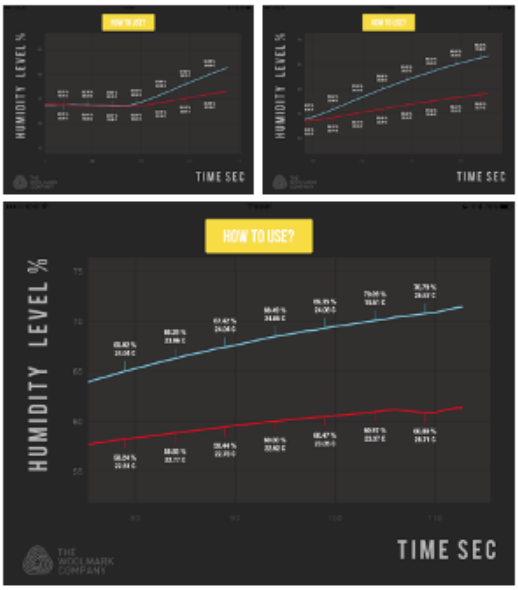
EXPLAIN THAT the wool structure can then transfer the moisture away from the body to the surrounding air. Heat transfer across wool garments occurs with the mass transfer of water vapour.

These processes cause the micro-climate above the skin to become less saturated with water vapour, so the wearer feels less clammy from the formation of sweat droplets on the skin's surface.

EXPLAIN THAT in essence, wool fabric acts like another layer of our skin.

NOTE THAT recent wool innovations in single layer and double layer constructions capitalise on, and enhance, these inherent properties of the fibre and are explored on the following slides.

MOISTURE MANAGEMENT MERINO



Single layer

8 - **Module 6:** Innovations in wool products

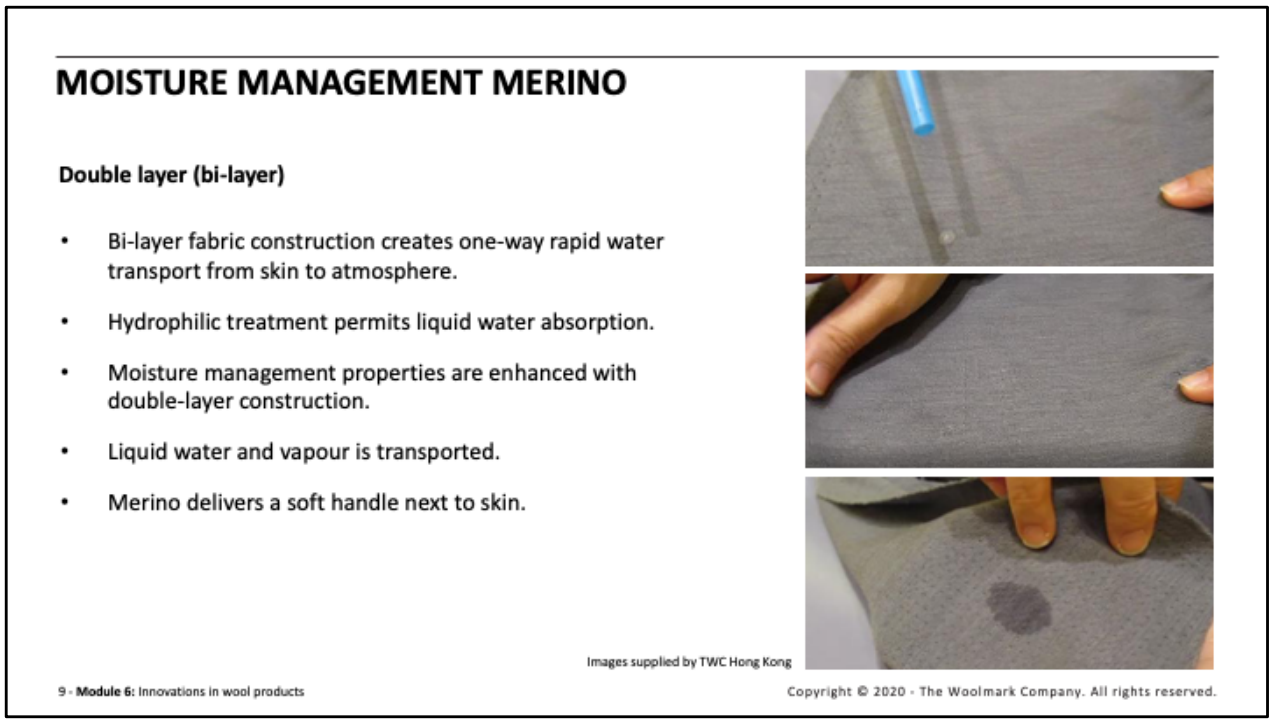
INDICATE THAT single layer moisture management Merino products combine the moisture management properties of wool and the use of fine Merino fleeces to ensure the finished garment retains its functional properties and is soft and comfortable to wear next to the skin.

EXPLAIN THAT moisture management Merino technology is employed to enhance total moisture management by more rapidly absorbing liquid sweat on the skin and moving it away from the body to the outside of the fabric where it can evaporate. Removal of liquid water in this way increases wearer comfort during strenuous exercise.

EXPLAIN THAT the wool fibre is treated with a hydrophilic softener after dyeing. The finish is rendered permanent under heat treatment — the higher the temperature, the better the durability of the product.

INDICATE THAT as a result of this processing technology, moisture management Merino products wet rapidly on contact with liquid water in the skin — wetting in less than 10 seconds.

NOTE THAT the impact of the innovation can be seen on the humidity of the microclimate against the skin in the graphs on the slide. In a garment made from a synthetic fibre (blue line) the humidity is higher than inside a wool garment (red line). The next-to-skin humidity is lower, so the wearer is more comfortable wearing the wool product.



EXPLAIN THAT double-layer moisture management Merino fabrics have been created with 'hydrophobic' wool on the inside and 'hydrophilic' wool on the outside.

INDICATE THAT when this structure is used in a double jersey fabric a high degree of liquid moisture transfer can be achieved, allowing the next-to-skin part of the fabric to adsorb water vapour, but not to become 'wet'.

NOTE THAT in contrast, the hydrophilic outer surface will become wet, drawing the moisture to the outside of the fabric and away from the body.

INDICATE THAT this can be seen visually in the slide.

EXPLAIN THAT this double-layer moisture management Merino material is breathable and comfortable to wear. In hot climates, the wearer feels cool and dry, while in cold climates, the wearer feels warm.

CLARIFY THAT this wool innovation combines a moisture management function and, at the same time, helps regulate body temperature, so following exercise the wearer will not experience chill in cold-climate countries.

WOOL FOOTWEAR

10 - **Module 6:** Innovations in wool products

INDICATE THAT advances in knitting technology have seen footwear developments continue to be an important growth area for wool, extending into lifestyle and fashion markets. Fully fashioned knitwear uppers reduce manufacturing waste by directly mounting the shaped piece onto the sole of the shoe.

EXPLAIN THAT yarn developments have enabled better strength and abrasion resistance. For outer layers of a shoe upper, the wool fibre may be core spun with a nylon filament to promote strong abrasion resistance. Inner layer footwear uppers, which sit next to skin, can easily be 100 per cent wool, or a wool blend.

Combining wool with different yarns in a shoe upper draws on wool's natural properties to 'breathe', manage moisture transport and regulate temperature, delivering a shoe that is both comfortable under a range of conditions and keeps the feet dry and odour free.

NOTE THAT through the use of felt-resist processing technologies, wool shoes are machine washable, helping to maintain a fresh appearance over the longer term.

INDICATE THAT leading brands have launched wool and wool blend shoes for the sports and outdoor markets.

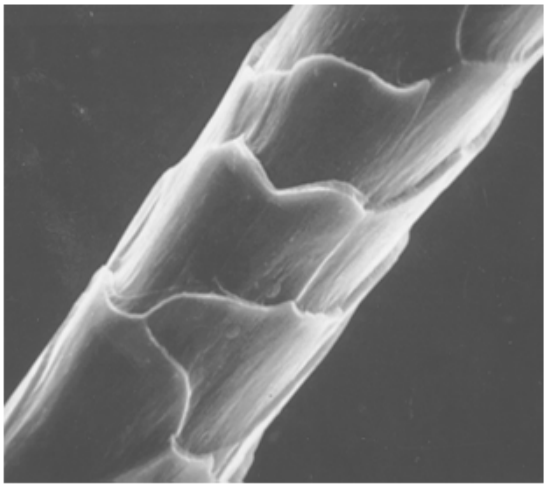
WOOL FOOTWEAR FOR FASHION

11 - **Module 6:** Innovations in wool products

NOTE THAT wool is also used in footwear for fashion.

WOOL HAS SCALES, SO WE CAN…

- make the fibre soother and more lustrous
- make wool feel like cashmere and look like silk
- create texture and density in felted products.



12 - **Module 6:** Innovations in wool products

REMIND PARTICIPANTS that the scales (cuticle cells) on the surface of the wool fibre have been discussed several times in this course and are discussed in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science.*

INDICATE THAT we can modify these scales to change the appearance of the fibre, making it smoother and more lustrous (like silk or cashmere).

REITERATE THAT the scales on the fibre's surface are associated with the felting of wool products. Felt resistance (and machine washability) is imparted by modifying these scales. Selective use of felting can be used to create new effects in wool products that are difficult to achieve with other fibres.

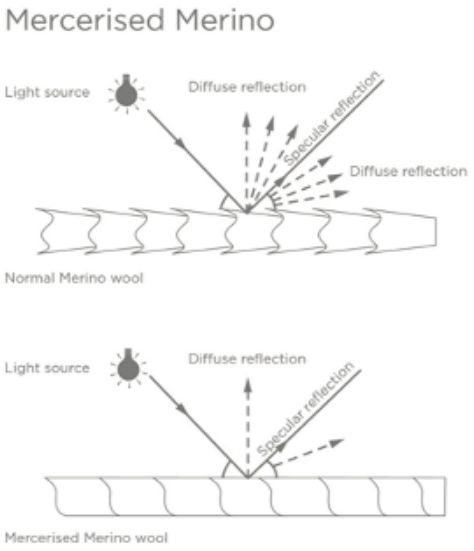
MERCERISATION — SOFT LUSTRE

Mercerisation and soft lustre is a single process that improves the lustre and handle of treated top.

The process involves:

- treating the top with high levels of chlorine (~4%)
- removing the solubilised protein
- treating the top with a silicone micro-emulsion.

Mercerised top must be re-gilled and re-combed to re-separate and re-align the fibres for further processing and spinning.



13 - **Module 6:** Innovations in wool products

EXPLAIN THAT mercerisation and soft lustre are names for a single process that improves the lustre and handle of treated top to produce softer and more lustrous garments with a cashmere-like feel.

INDICATE THAT the process involves degrading the scale structure from the surface of the wool fibre to create a smoother fibre surface. The effect is to increase the reflectance, or sheen, of the fibre.

EXPLAIN THAT the second part of the process involves applying a fine layer of silicone polymer, which is grafted permanently onto the fibre surface. The application of the silicone polymer brings about significant improvement in the handle of the wool and subsequent products.

NOTE THAT while the actual diameter (micron) of the fibre does not change significantly as a result of the treatment, the perceived improvement in hand feel (handle) is the equivalent of using wool 2–3µm finer.

EXPLAIN THAT the process involves:

- treating the top with high levels of chlorine (~4.5%)
- removing the solubilised protein
- treating the top with a silicone micro-emulsion.

REINFORCE THAT as with the felt-resist treatment, the mercerised top must be re-gilled and re-combed to separate and re-align the fibres for further processing and spinning.

MERCERISED MERINO

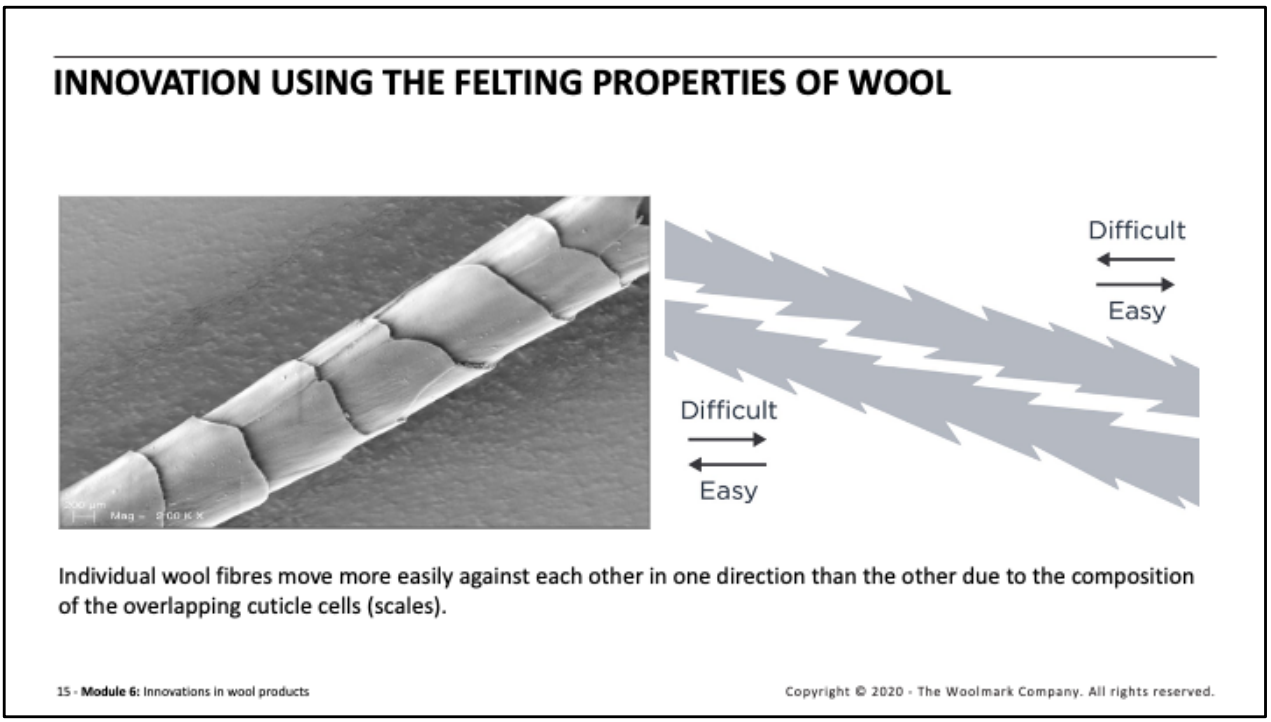
- Softness and luxury
- Next-to-skin comfort
- Machine washability
- Vibrant colours

14 - **Module 6:** Innovations in wool products

EXPLAIN THAT this slide shows an example of mercerised wool fabrics. These products are characterised by:

- a softer handle, making the innovation suitable for next-to-skin products
- machine washability, enhancing the ease of care attributes of the garment produced using this fabric.

NOTE THAT mercerised products maintain the vibrant colours achievable when dyeing wool.



REMIND PARTICIPANTS that felting is caused by the physical structure of the wool fibre, which allows individual fibres to move more easily in one direction than in the other when agitated in water.

NOTE THAT the propensity of wool yarn and fabric to 'felt' when the fibres have a high moisture content or are wet and are subject to mechanical action is often seen as an undesirable characteristic, not least because it is normally associated with garment shrinkage and cannot be reversed.

POINT OUT that on the other hand, the ability of wool to felt has been used for a very long time to enhance the warmth of wool fabrics. More recently, felting has been used across a range of recent innovative applications to create a range of visual effects.

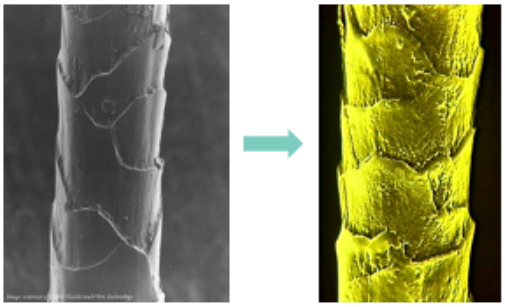
EXPLAIN THAT these effects often incorporate a component of 'felt-resist-treated' wool to deliver a range of innovative products.

INDICATE THAT a brief overview of felt-resist technology will be followed by examples of wool innovations that capitalise on wool's natural felting properties.

REMIND PARTICIPANTS that felting shrinkage and felt-resist treatments are covered in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

FELT-RESIST TREATMENT

- Machine wash
- Tumble dry performance
- Minimum or easy-iron performance



16 - **Module 6:** Innovations in wool products

REMIND PARTICIPANTS that felt-resist processes, to prevent wool garments from felting (shrinking) during machine washing, have been used for many years to develop 'easy-to-care' for wool products.

EXPLAIN THAT fabric and garments can be:

- produced from felt-resistant treated yarns, where the treatment is carried out when the wool fibres are still separated (as top or loose fibre). This is most common for knitted fabrics.
- treated in fabric form to impart felt resistance. This is most common for woven fabrics.

POINT OUT that two methods are used to impart felt resistance to wool fibres in loose fibre or top form:

- degradation of the scales using oxidation
- an oxidative pre-treatment, followed by application of a polymer (as depicted on the slide). This mechanism involves modifying the frictional properties of the fibre and 'scale masking'.

NOTE THAT two methods are used to impart felt resistance to wool fabrics and garments:

- applying a polymer, which forms bonds between the fibres, preventing relative fibre movement
- an oxidative pre-treatment, followed by application of a polymer. The mechanism is a combination of scale degradation, scale masking and the formation of interfibre bonds.

INDICATE THAT more recently, methods have been developed to ensure the garment does not felt during subsequent tumble drying. This involves a combination of a felt-resist treatment of the wool fibres with precise methods of constructing the fabric.

EXPLAIN THAT Woolmark tests are available to ensure garments meet this more demanding test of 'washability' (called 'machine wash-tumble dry performance').

NOTE THAT felt-resist processes are also used to impart easy-iron or minimum-iron properties to woven garments. This performance is called 'easy care' or 'easy-iron' in some sectors of the garment industry.

FELT-RESIST TREATMENT OF YARN — MERINO RETRACT

- One 'untreated' yarn plus two 'treated' yarns.
- Washing felts untreated yarn and causes contraction.
- Soft treated yarns buckle onto surface.
- Fabric looks like 'boiled wool' but retains a soft feel.
- Closer-fitting garments possible.

EXPLAIN THAT 'boiled wool' is a term given to knitwear that has been 'pre-shrunk' using a wet process in very hot water to the extent it has felted and lost most of the resilience and softness associated with wool.

NOTE THAT boiled wool is popular for casual wear because it gives a 'casual' look to garments and an alternative texture to traditional knitted garments.

POINT OUT that boiled wool garments suffer from pilling and a 'stiff' feel and are limited to being hand washed or dry-cleaned. The lack of resilience means garment styling has to be loose fitting, rather than next to skin.

EXPLAIN THAT Merino Retract knitwear looks like boiled wool, but has the resilience and pilling performance of conventional knitted wool garments. Yarns spun using felt-resist treated wool are combined with yarns spun from untreated wool during knitting. When the garment is wet finished the untreated yarns retract and the knit structure contracts. The garment is knitted 15 to 20% looser than normal so the retracted garment does not end up too dense after finishing.

NOTE THAT the technique works best in coarse to medium knit gauges (i.e. <10gauge).

INDICATE THAT a machine washable Merino Retract option is also possible.

EXPLAIN THAT the greater extensibility and resiliency of garments manufactured using the Merino Retract technology means there is the potential to manufacture tighter-fitting and fully-fashioned garments that cannot be made using conventional 'boiled wool' technologies.

MERINO RETRACT

INDICATE THAT this slide shows some examples of garments made with Merino Retract fabric.

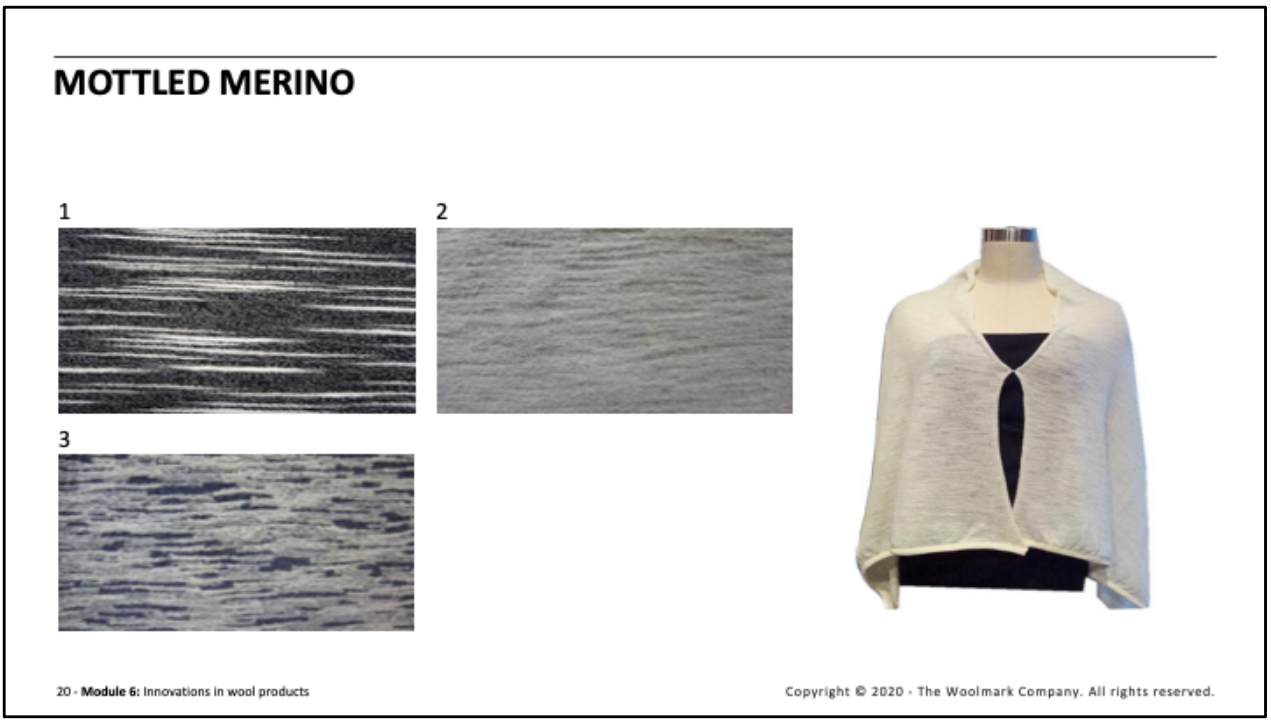
FELT-RESIST TREATMENT OF YARN — MOTTLED MERINO

- Yarn printing system or 'fancy spinning'
- Transparent polymer print prevents felting in specific areas
- Untreated areas felt and consolidate to create distortions and texture
- Random texture for Merino knitwear

EXPLAIN THAT the Mottled Merino effect is obtained by treating parts of the yarn with a felt-resist finish and leaving other parts untreated, or through a process of 'fancy pinning'. When using the felt-resist treatment the effect is achieved by intermittently printing the yarn with a felt-resist treatment.

INDICATE THAT the garment is manufactured and is wet finished so parts of the yarn felt and other parts do not. The untreated sections of the yarn shrink, while the treated sections remain relatively unchanged.

This creates areas of distortion in the fabric for an innovative textured surface appearance described as 'mottled'.



EXPLAIN THAT an alternative approach to obtain a mottled appearance — fancy spinning — also can be used to create a 'mottle' effect

EXPLAIN THAT a fancy spinning machine is combined with Sirofil spinning technology. Two rovings (one felt-resist treated and another untreated) are fed by turns into the drafting system. Polyamide (PA) filament is fed to the back of the front roller.

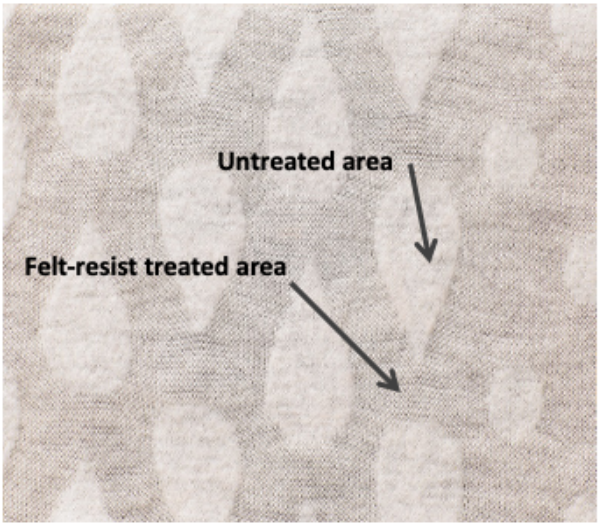
INDICATE THAT the resultant yarn has a felt / non-felt effect, which is sometimes combined with a colour contrast effect as illustrated on the slide.

The yarns used to obtain the fabrics illustrated the slide are:

- 85% W/15% PA, 1/20 Nm solid colour (shown in image 2 and the garment on the slide)
- 86% W/14% PA, 1/18 Nm black with white (shown in images 1 and 3).

FELT-RESIST TREATMENT OF FABRIC — MERINO DEVORÉ

- Transparent polymer print prevents felting.
- Unprinted pattern felts and becomes opaque.
- Mock 'burn-out' effect possible for knitwear.
- No need to 'burn' or dissolve fibres.
- No loss of fabric integrity.



21 - **Module 6:** Innovations in wool products

EXPLAIN THAT traditional devoré products are created by 'dissolving' one of the fibres in a blend in sections of a fabric — the treated sections become more transparent.

INDICATE THAT a 'mock devoré' can be created on loose, open-knit structures made from worsted yarns, which does not require any fibres to be dissolved.

EXPLAIN THAT Merino Devoré is an innovation created by felt-resist treating fabric selectively through a range of polymer-printing processes.

To create Merino Devoré fabrics or garments are knitted from untreated yarns to a relatively loose stitch density. The fabric is then screen printed using a transparent polyurethane, which is capable of preventing wool knitwear from felting. The polymer is applied from a thickened print paste, which prevents spreading and loss of definition.

The polymer is fixed by heat curing or batching for 10 to 12 hours at room temperature.

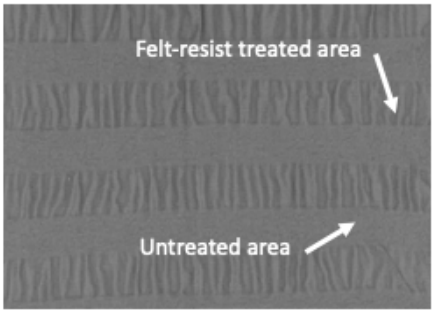
The devoré pattern is created during subsequent wet finishing of the fabric or garment when the non-printed areas felt and consolidate to become opaque relative to the printed areas.

OUTLINE THE advantages of this approach as follows:

- Pure wool fabrics can be used.
- 'Burn-out' or devoré effects are achieved without need for fibre dissolution.
- The effect is durable to hand-washing.
- The process can be applied to the whole fabric or garment, or to specific areas to accent fashion effects.

FELT-RESIST TREATMENT OF FABRIC — 3-D MERINO

- Milled / non-milled effects in wool knitwear.
- Transparent polymer printed onto fabric prevents milling and felting in selected areas.
- Unprinted areas become denser and thicker.
- Design can be subtle or dramatic.



22 - **Module 6:** Innovations in wool products

EXPLAIN THAT 3-D Merino is another innovation for wool knitwear created by limiting milling or felting to specific areas to produce a subtle three-dimensional pattern, using a similar process to Merino Devoré. The felted and non-felted areas vary in thickness giving a three-dimensional appearance.

EXPLAIN THAT knitted fabrics or garments are screen printed using a polyurethane capable of preventing wool knitwear from milling or felting.

The polymer is applied and is fixed by heat curing or batching for 10 to 12 hours at room temperature. Subsequent milling in normal-garment wet finishing causes felting in the unprinted areas, which creates a subtle pattern on the fabric.

INDICATE THAT if felting is extensive, then a seersucker effect can be created.

EXPLAIN THAT felt / no-felt patterns for worsted knitwear and for woollen-spun knitwear can be achieved.

The difference between 3-D Merino and Merino Devoré is that the technology used to create devoré effects is only applied to achieve a difference in transparency. In contrast, in 3-D Merino effects, felting is continued until the untreated fabric shrinks to levels that cause the treated fabric to distort or pucker.

3-D MERINO

EXPLAIN THAT this slide shows some examples of garments made with the 3-D Merino process.

3-D MERINO COLOUR

- Polymer plus colour printed onto fabric
- Unprinted areas become denser and thicker
- Design can be subtle or dramatic
- Felting softens the edges of the print design

24 - **Module 6:** Innovations in wool products

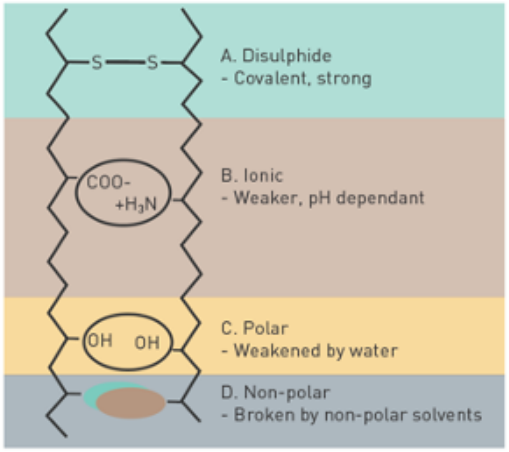
EXPLAIN THAT 3-D Merino colour adds an extra dimension to the three-dimensional effects that can be given to wool knitwear. Screen printing is used to both create areas of felting / non-felting as well as add colour to those areas. The areas of varying thickness giving a three-dimensional aspect are augmented by colour.

ASK PARTICIPANTS *if they have any questions about the innovations in wool products created by manipulating the felting process before you move onto innovations using the setting properties of wool.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

WOOL HAS REACTIVE CROSSLINKS, SO WE CAN…

- modify fabric structure using fibre-setting properties



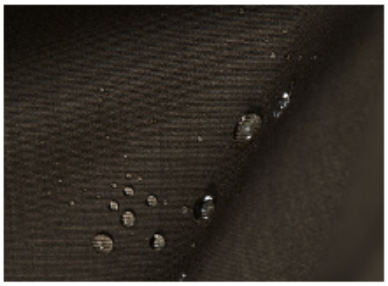
25 - **Module 6:** Innovations in wool products

REMIND PARTICIPANTS that the covalent disulphide bonds in wool fibres were discussed in the modules on the chemistry and setting of wool in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

EXPLAIN THAT new wool innovations have been created by manipulating these crosslinks and the setting properties of the fibres.

INNOVATION USING THE SETTING PROPERTIES OF WOOL

- The **NEULANA Protect** range of fabrics is made from 100% wool constructed at very high levels of thread density in warp and weft.
- The fibre is stretched during processing and released during fabric finishing, contracting the fibres and enhancing the wind-proof and water-resistant properties of the fabric.



EXPLAIN THAT the temporary (and cohesive) setting properties of wool can be used to make ultra-high-density wool fabrics, which can be used in applications requiring wind-proof and water-resist performance.

INDICATE THAT while still in top form, the wool fibres are stretched during processing, but only temporarily set in this new form. The stretched fibre is then spun into yarn and the yarns are woven in the normal way.

When the woven fabric is wet-finished, the stretch in the fibre is released, causing the yarns to contract.

This leads to extreme tightening of the fabric structure and blocking most of the interstices (spaces between the yarns) in the fabric. This considerably enhances the wind-proof and water-resist properties of the fabric.

REMIND PARTICIPANTS that the setting properties of the wool fibre are covered in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science.*

INNOVATION USING THE SETTING PROPERTIES OF WOOL

Merino Air:
- knitted garments from high-bulk yarns
- worsted spun
- bulked after spinning.

Neulana Air:
- range of woven fabrics
- worsted spun
- bulked in fabric form
- high level of comfort
- 'warmth without weight'.

NEULANA Air

INDICATE THAT another innovation using the setting properties of wool fibres creates high-bulk fabrics.

EXPLAIN THAT wool fibres that have been stretched and temporarily set are blended (in top form) with unstretched wool.

The yarn is spun and then woven or knitted.

When the fabric (or garment) is wet finished the stretched fibres contract, but the normal fibres merely buckle.

INDICATE THAT this creates a high-bulk fabric suitable for:
- ultra-soft knitwear (sometimes called Merino Air and shown on the slide)
- high-bulk woven products (marketed by the Nanshan Group as Neulana Air).

INNOVATION USING THE SETTING PROPERTIES OF WOOL

Neulana Double

- The outer face is constructed immensely high thread density in warp and weft using fine Merino wool yarns.
- The inner-side is air-like, soft to touch and is suitable next to skin.
- The fabric is woven, not bonded.

EXPLAIN THAT Neulana Double is an innovative double-layer fabric, which:

- contains a high-density wool fabric structure, obtained using stretched (and temporarily set) fibre, on one side, and
- has a high-bulk fabric, achieved by creating yarns from blended stretched and unstretched fibre, on the other side.

INDICATE THAT the outcome is a unique fabric, which combines many of the attributes required by outdoor wear in cool-to-cold climates.

NOTE THAT Neulana Double fabric is also ideal for high-end casual jackets; the face of the fabric is smooth, like a traditional outer-shell, while the other side is soft, bulky and brushed.

INNOVATION USING THE SETTING PROPERTIES OF WOOL

- The **NEULANA ELITE** range of fabrics is made from 100% wool.
- Neulana Elite fabrics are made from a fibre that is stretched and permanently set.
- The resulting fibres are extremely smooth (feels like cashmere) and straight (looks like silk).

EXPLAIN THAT a fourth innovation using the setting properties of the wool fibre involves the stretching of wool fibres and, in this case, permanently setting them in their extended state.

INDICATE THAT the effect reduces the fibre diameter of the fibre and makes it smoother and more lustrous. The treated fibres and products have a 'cashmere-like' feel.

EXPLAIN THAT during this process the fibre is also straightened, which adds to the lustre of the final product.

NOTE THAT this Neulana Elite innovation has been specially processed in a machine, developed by CSIRO in Australia, which can stretch the wool fibres by about 25% then permanently set them in that configuration.

ASK PARTICIPANTS *if they have any questions about the innovations in wool products created by using the setting properties of wool before you proceed to discuss innovations created manipulating yarn relaxation.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

EXPLAIN THAT in the construction and finishing of knitwear considerable effort is made to avoid 'uncontrolled relaxation' of the yarns, which can cause unsightly distortion of the garment in specific areas or over the whole garment.

INDICATE THAT the effect is called 'cockling' and procedures are available to prevent its occurrence.

EXPLAIN THAT by deliberately avoiding those procedures, and by using yarns prone to distortion, fashion effects, like those shown on the slide, can be created.

REMIND PARTICIPANTS that the relaxation properties of the wool fibre are covered in detail in the course of the Woolmark Wool Education Course *Wool fibre science.* The processes used to manage relaxation during garment finishing are covered in detail in the Wool Science, Technology and Design Education Program course *Wool garment finishing.*

EXPLAIN THAT sculptured Merino is another innovation using the tendency of wool knitwear to 'cockle' to create innovative effects. These effects are unusual for Merino wool knitwear because it so readily sheds creases.

NOTE THAT the technique involves breaking many of the rules of knitting fine gauge worsted-spun knitwear.

EXPLAIN THAT the effect is achieved by:
- using a combination of a wider-than-normal range of fibre diameters in the blend
- steam-setting the yarn in singles
- using a loose knit-density
- overloading wet-finishing machines.

NOTE THAT the sculptured effect is created by permitting the garment to cockle (normally random and unsightly creasing) in the most severe and complete way.

EXPLAIN THAT controlled processing conditions can be used to create consistent cockling in worsted-spun knitwear.

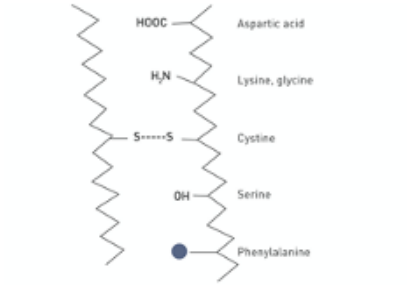
NOTE THAT the sculptured Merino innovation creates a situation where:
- each garment is unique
- the effect is durable to machine washing
- the garments retain the soft handle of pure Merino wool.

ASK PARTICIPANTS *if they have any questions about the innovations in wool products created by using the relaxation properties of wool before you proceed to discuss innovations created through dyeing.*

ALLOW TIME *for questions and discussion before proceeding to the next slide.*

WOOL HAS REACTIVE GROUPS, SO WE CAN…

- dye wool many colours



Some of the side groups on protein molecules

32 - **Module 6:** Innovations in wool products

REITERATE THAT the complex chemistry of the wool fibre, especially the behaviour of the reactive groups, was discussed in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

EXPLAIN THAT this chemistry can be manipulated to achieve new dyeing effects in wool products.

INNOVATIONS USING DYEING PROPERTIES OF WOOL

- Faded and wash-out effects for Merino wool
- Created by rapid unlevel dyeing
- Reactive dyeing permits high fastness
- No binders so handle is soft
- Works best with ribs and cable structures

33 - **Module 6:** Innovations in wool products

REINFORCE THAT the conventional aims of dyeing are to develop the correct colour on the product and ensure it is dyed to a uniform shade. Wool can be dyed to a vast array of colours using different types of dyestuff.

NOTE THAT the fastness of the dyeing can also be varied according to the requirements of the customer.

POINT OUT that faded and washed out effects are currently popular in casual garments. These effects are normally difficult to create in Merino wool, which is renowned for its vivid, vibrant and durable colours.

EXPLAIN THAT the classic approach to creating a casual look is to use pigments, which can be bonded to the fibre. Such garments are characterised by poor handle and poor rubbing fastness.

INDICATE THAT when garments fade during washing they do so unevenly, fading especially rapidly on seams and raised areas. This effect is recreated using dyeing innovations to produce Vintage Merino products, like those illustrated on the slide.

EXPLAIN THAT the Vintage Merino look can be created by:

- unlevel dyeing — achieved by applying the dyes too quickly
- dyeing under atypical conditions — using less levelling agent.

INDICATE THAT using these approaches, the dye tends to exhaust more deeply in easily-accessible regions of low yarn twist or fabric density. After the dyes are exhausted, they can be fixed using normal boiling times. If the correct clearing cycle is used, normal levels of washing and rubbing fastness can be obtained.

EXPLAIN THAT vintage or washed-out effects achieved by garment dyeing meet Woolmark standards of washing and rubbing fastness. These effects work best on heavily textured structures, such as ribs and cables. The technologies can be used for both worsted-spun and woollen-spun piece-dyed garments.

EXPLAIN THAT digital printing is another recent printing technology that has paved the way for intricate, almost photographic printing on wool. Counter to traditional print methods, digital printing is quick and personalised, using direct-to-fabric machines, which minimise the investment in screens, print tables and additional washing equipment.

NOTE THAT digital printing works in a similar way to a home inkjet printer, in which the fabric is passed beneath the head of the printer and allows for printing on boutique, smaller lengths of fabric, helping to eliminate textile waste.

POINT OUT that chemical and water usage are significantly reduced compared with traditional printing methods and inks can be recycled to minimise environmental impact.

NOTE THAT dyeing of wool is covered in detail in the Wool Science, Technology and Design Education Program course *The dyeing of wool.*

SUPER-WHITE WOOL BLENDS

- Bleached wool is white but not the bright white achieved with cotton and synthetics.
- Optical brightening agents (OBAs) used on cotton cause wool to yellow.
- Blends of wool and synthetic fibres can be used to obtain excellent whiteness.

REMIND PARTICIPANTS that natural wool has a cream colour. When required, the whiteness can be improved by bleaching. However, the whiteness achieved by bleaching is not as bright as that achieved on cellulosic or synthetic fibres.

INDICATE THAT whiteness can be further improved by adding optical brightening agents, but these accelerate the 'photoyellowing' of the wool fibres and are not recommended for use on wool, because their whitening effect lasts only for a short time.

EXPLAIN THAT super-whites can be achieved on wool–synthetic blends by:

- applying optical brightening agents to the blend that have affinity for the synthetic fibre, under conditions that favour their exhaustion onto the synthetic fibre, then
- bleaching the wool under conditions to improve the whiteness of that fibre as well as remove any residual OBA from the wool to prevent rapid yellowing.

***ASK PARTICIPANTS** if they have any questions about the innovations in wool products created by dyeing or brightening before you proceed to discuss innovations that enhance wool's natural UV adsorption properties.*

***ALLOW TIME** for questions and discussion before proceeding to the next slide.*

ENHANCED UV-ADSORPTION PROPERTIES

REITERATE THAT one of the advantages of wool is the natural sun-protection afforded by the fibre. Other fibres (e.g. cotton) usually require the addition of chemical treatments to confer sun-protection — especially if the product will get wet during use.

INDICATE THAT these chemicals can be used to further enhance the sun-protection properties of wool, raising it to levels consistent with the those required for superior sun protection (e.g. by outdoor workers).

NOTE THAT more information on the UV-adsorption properties of wool and other fibres is covered in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

***ASK** participants if they have any questions about the UV-adsorption properties of wool before you move onto some wool innovations that are providing more environmentally conscious options for traditionally synthetic fabrics.*

***ADDRESS** any questions in a timely manner.*

REINFORCE THAT as consumers become increasingly concerned about the environmental impact of their textile choices, wool textile innovations that reduce the synthetic component or completely replace synthetics are proving an attractive option for the conscious consumer.

REFER TO the slide as you note that corduroy trousers are a classic men's garment and a particular favourite during winter. This woven fabric is characterised by the ribbed, velvety texture on the outer surface. The incorporation of wool into a traditional corduroy fabric enhances its handle, warmth, resilience and wrinkle resistance.

Wool corduroy is a welcome alternative to jeans on cold days. The robust fabric is particularly hard-wearing and durable, keeps your legs warm in low temperatures but is breathable at the same time.

INDICATE THAT as an increasing number of brands continue to ban traditional fur from their collections, Merino wool presents a natural alternative, eliminating the need for animal hide or synthetics for faux fur. Innovatively knitted from Merino wool yarns, Merino wool fur fabrics are cropped and brushed to replicate a traditional fur or shearling look and feel. Using Merino wool also maximises the fibre's natural benefits, such as superior warmth, breathability and odour resistance. In addition, wool being 100 per cent natural, renewable and biodegradable means wool fur offers a more environmentally sympathetic solution than synthetic faux fur.

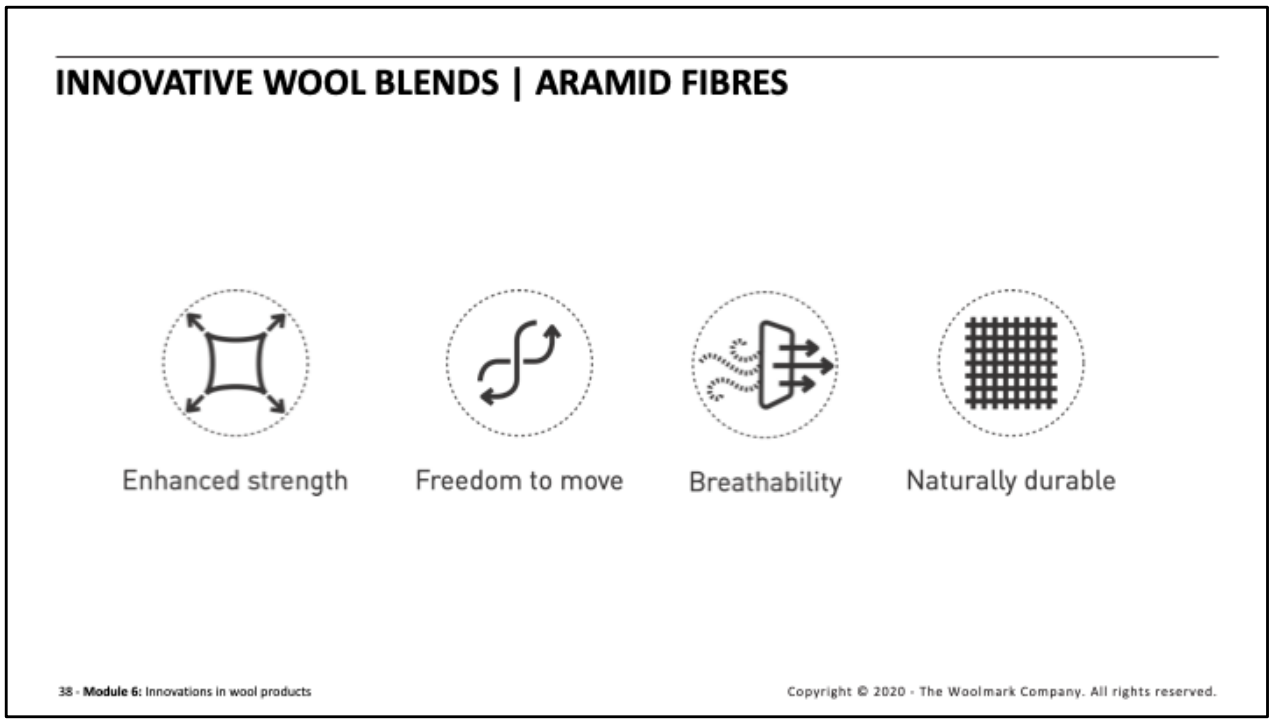
NOTE THAT velvet and velour are synonymous with luxury, but traditional manufacturing of both products includes a shaving or thread-cutting process, which results in fibre shredding.

EXPLAIN THAT The Woolmark Company's technical team has co-developed a wool velvet with several manufacturers, reducing the amount of synthetic fibres typically used to create this fabric. Wool's natural properties mitigate excessive landfill contribution while avoiding chemical waste generation associated with synthetic velvet.

NOTE THAT the natural, renewal and biodegradable properties of wool are covered in detail in the Wool Science, Technology and Design Education Program course *Wool fibre science.*

***ASK** participants if they have any questions about the the way wool is being used to reduce or replace the proportion of synthetic fibres to address consumer concerns about environmental impacts before you go on to introduce some of the newer textile fibres, which offer the opportunity for unique products incorporating wool.*

***ADDRESS** any questions in a timely manner.*



EXPLAIN THAT novel textile innovations are combining wool with a range of 'aramid' fibres (a family of synthetic polyamides that offer enhanced performance and strength).

INDICATE THAT during recent years there has been a growth in the availability of high-tenacity synthetic yarns, which were previously tough and rigid. By blending wool with aramid fibres, today's fabrics have a super-soft handle and enhanced flexibility, well suited to the sports and performance sector.

NOTE THAT a key benefit of such fabrics for extreme sports, including road cycling and rock climbing, is the endurance they can withstand. The appeal of this trend also influences the growing 'lifestyle' sector; from urban activities through to leisure and camping.

EXPLAIN THAT CORDURA®, developed by Dupont (INVISTA), was originally used during WWII for the production of tyres. Classified as nylon, it is spun as a filament fibre, but is also available as staple for blending with wool. During 2016 Invista's CORDURA® brand announced the development of CORDURA® COMBAT WOOL™ fabric in collaboration with a leading Italian producer of fabrics for high-end casualwear. During the early 1990s, INVISTA's CORDURA® brand and Woolrich, the iconic America outdoor apparel brand, collaborated to create Wool-Dura™, a specialty blend of iconic Woolrich wool and nylon 6,6 CORDURA® fabric used in hunting apparel.

NOTE THAT woven fabrics constructed with an intimate blend of CORDURA nylon and Merino wool offer up to 10 times better abrasion resistance, twice the tensile strength and 1.4 times better tear resistance in compared with 100% Merino wool fabrics, while maintaining the same look and feel.

REITERATE THAT because of its inherent properties, wool is increasingly blended with other fibres and products to create novel textile innovations. Graphene, discovered and isolated in the UK at the University of Manchester during 2004, is probably one of the most exciting materials being studied carefully globally for its use across a range of industries and applications, from textiles to water filtration devices.

EXPLAIN THAT a descendant of graphite, graphene is the world's first two-dimensional atomic crystal material, made up of a hexagonal lattice of carbon atoms. It is stronger than steel, more conductive than copper, lightweight, transparent, flexible and one million times thinner than a human hair. — it is only one atom thick. You would need to stack around three million layers of it to make a 1mm thick sheet.

NOTE THAT graphene is not without its challenges. Extracting graphene is difficult and expensive so effective and efficient derivatives need to be used, such as graphene oxide (GO). GO is derived from the oxidisation process of graphite using acids and oxidants. GO can be mixed easily with other polymers, including wool. Research is currently being undertaken to incorporate graphene into a range of textiles in the following ways:

- **Yarn:** A strong and flexible yarn can be made using GO through a wet spinning process, this yields a highly porous, yet dense and robust, flexible filament. These yarns have a large surface area and excellent electrical conductivity and can be woven, knitted or sewn into textiles.
- **Coating:** GO can be coated onto almost any substrate. Graphene's cytotoxicity means it can kills and prevents the growth of bacteria by destroying the bacteria's membrane.
- **Nanomembrane:** It is possible to layer two sheets of graphene, to produce a nanomembrane of which tiny pores can be etched into creating a thin skin, which is breathable yet waterproof. Directa Textile Solutions based in Italy use graphene within membranes and are investigating its applications, working hand in hand with a number of commercial brands. They have produced two membrane products, Grafyshield® and Grafytherm®, which are not only highly efficient and safe, they are also extremely flexible as they can be laminated to any substrate – from wool to polyester and polyamide.

More information:
https://link.springer.com/article/10.1007/s10853-019-03948-0
https://link.springer.com/article/10.1007/s12221-016-5838-8
https://www.acsmaterial.com/blog-detail/the-role-of-graphene-in-the-textile-industry.html

EXPLAIN THAT as discussed in *Module 4 Manufacturing wool products*, the textile industry is mobilising to counter the devastating effects of fashion waste.

EXPLAIN THAT bi-product fibres are fibres derived from waste and their use encourages circular and closed-loop processes in textile manufacturing. The life-cycle of wool as a textile fibre can be circular in nature, but its versatility also allows it to be blended with bi-product fibres, keeping wool competitive and satisfying a growing market demand for environmentally responsible textiles.

NOTE THAT bi-product fibres can also bring performance benefits to the end product.

REFER TO the image of the crab on the slide as you explain that 'chitosan' is a substance extracted from the shells of crabs and shrimps, which has natural antibacterial and antimicrobial properties. Clothing made with chitosan remains odourless during wear, even if drenched in sweat, because the bacteria that cause body odour cannot survive on the fabric. Like wool, chitosan is soft to the touch, breathable, non-toxic, odour-free and hypoallergenic. Chitosan also promotes wound healing and skin cell regeneration, so can be used to produce biocompatible wound dressing and military uniforms.

REFER TO the image of the coffee grounds on the slide as you explain that the coffee industry is valued at about $20 billion per year and its popularity as a beverage continues to rise. On average, 500 billion cups of coffee are consumed each year.

EXPLAIN THAT coffee grounds are cleaned to extract the oils (which are in turn used in cosmetics) and then ground down to a nano scale. They are then mixed with nylon or polyester—in the case of S.Café, it's mixed with recycled versions of these compounds—to create a technical yarn with qualities like anti-odour capability. Singtex recovers 500kg of coffee grounds free each day for its textile production.

REFER TO the image of the orange peel on the slide as you explain that in Italy every year, more than 700,000 tonnes of citrus waste are produced. Fabric can be formed from a silk-like cellulose yarn produced from the orange rind, which can be blended with other materials. When used in its purest form, the citrus textile features a soft and silky hand-feel, is lightweight and can be opaque or shiny according to production needs.

REFER TO the image of the milk on the slide as you explain that 'Q-Milk' is a fibre derived from the proteins found in milk no longer suitable for consumption. The fibres can be spun into staple yarns, used within non-wovens or as part of composite materials. Milk molecules exhibit many of the moisture absorption and thermoregulation properties of protein fibres, such as wool. It also contains antibacterial properties and has achieved positive results in dermatological tests.

SUMMARY — MODULE 6

Crimp:
- wool-filled garments
- wool denim.

Moisture management and comfort:
- sportswear
- footwear.

Felting properties:
- machine wash – tumble dry
- Merino Retract
- Mottled Merino
- Merino Devoré
- 3-D Merino

Setting properties:
- high density fabric
- high bulk fabric
- silky handle
- Sculptured Merino.

Dyeing properties:
- Vintage Merino
- Digital printing
- Super-white fabric.

Enhanced UV protection

Natural, renewable and biodegradable:
- Replacement or substitution for synthetic fibres.

New fibres:
- Novel blends.

REINFORCE THAT a number of innovations have been developed for wool products based on the inherent properties of the fibre.

Wool filling — Wool-filled garments capitalise on the thermal insulation properties derived from the natural crimp in wool fibres.
Wool denim — incorporating wool into a tradition cotton product enhances it comfort and warmth.

Wool footwear — Sportswear and fashion footwear capitalise on the moisture and odour management properties of wool fabrics.

Visual and performance effects created by manipulating the felting properties of wool include:
- machine wash and tumble dry wool garments
- Merino Retract
- Mottled Merino
- Merino Devoré
- 3-D Merino
- 3-D Merino colour

Improved performance and novel fabric appearance can be achieved by using the temporary and permanent setting properties of the fibres:
- Neulana Protect (wind-proof and water-resistant)
- Merino Air and Neulana Air (high-bulk and ultrasoft)
- Neulana Double
- Neulana Elite (extremely smooth, high-lustre)

The tendency of wool to 'relax' during processing can be used to effect to produce highly individual Sculptured Merino garments.

Vintage dyeing effects can be achieved with unconventional dyeing techniques, which manipulate the natural dyeing properties of the wool fibre. Digital printing technology has paved the way for intricate, almost photographic printing on wool.

By combining wool with synthetic fibres and applying specific chemical treatments, a super-white wool blend can be achieved.

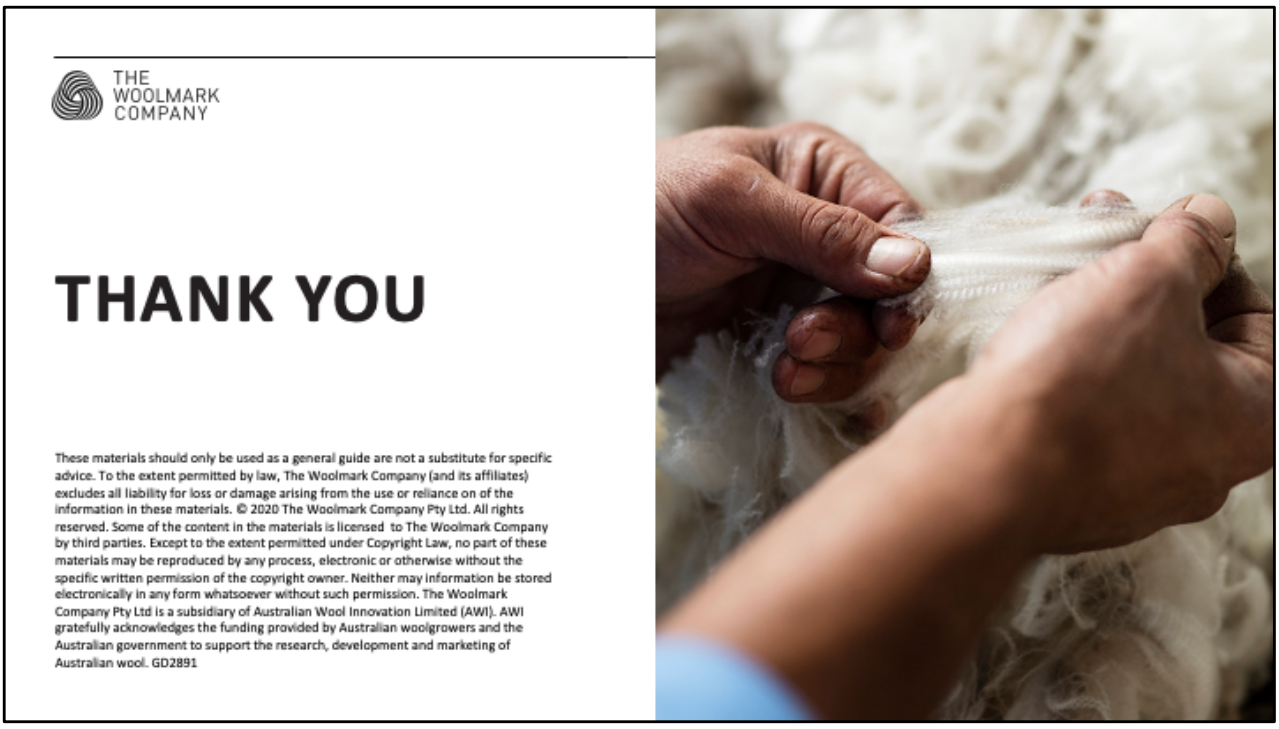
Enhanced sun protection products can be created by augmenting the natural UV adsorption characteristics of wool.

In an increasingly environmentally conscious world, as a natural fibre, wool is becoming an attractive option for replacing or substituting synthetic fibres in textiles such as velvet, corduroy and fur. As new textile fibres are being created, there are increasing opportunities for wool to be incorporated into a range of novel fibre blends and textile products.

_____***ASK PARTICIPANTS*** *if they have any questions about the content covered in this module.*

ALLOW TIME *for questions and discussion before proceeding to the final slide and closing the lecture.*

COLLECT ALL *samples distributed during the lecture.* _____



REMIND participants that this module completes the course *Introduction to wool processing*.

ENCOURAGE participants to explore the Woolmark Learning Centre to reinforce and build on what they have covered in the Wool Science, Technology and Design Education Program course *Wool fibre science*.

Participants can register with and explore the Woolmark Learning Centre here:

www.woolmarklearningcentre.com

BEFORE participants leave ensure you have collected all fibre samples distributed during the lecture.

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