Introduction

- It is hoped that this short presentation will provide some understanding of how the characteristics of different fibres can affect the properties of paper.
- The properties of fibres can be well understood if we consider their physical properties, specifically their length, diameter and wall thickness. We refer to these properties as the *morphological* properties of the fibres. The dictionary defines morphology as “the science of form”
- These slides only deal with wood based fibres, however the general principles apply to all cellulose fibres and hence to annual fibres too.
FIBRE MORPHOLOGY
What is Fibre Morphology?

- The “science of form”
- Fibre shape (curl, kink)
- Fibre dimensions (length, width, etc.)
- Their impact on pulp properties
Hardwoods or softwoods

- Hardwoods are also often known as deciduous trees
- Softwoods are often known as coniferous trees

- Softwoods are the more primitive plants
  - fibre is used for mechanical support and to conduct food (sap).
  - 90% fibres, 10% parenchyma cells

- Hardwoods are the more evolved plants
  - fibres only provide mechanical support, nutrients are conducted by the vessels.
  - 65% fibres, 25% vessels, 10% parenchyma
HW versus SW

- Hardwoods can be denser, hence the name i.e.
  - HW 0.3 - 0.7 g/cm²
  - SW 0.3 - 0.5 g/cm²

- Softwood fibres (tracheids) are long with relatively wide lumens.
  - 2.5 - 4 mm long, 16 - 35 mg/100m coarseness

- Hardwood fibres are short, and thick walled
  - 0.8 - 1.5 mm long, 9-15 mg/100m coarseness
What holds a sheet of paper together?

- Cellulose fibers, are the main component of the raw material “pulp”. The individual fibers are present in a network of fibres. This can easily be seen by looking at the torn edge of a piece of paper. The more softwood is used, the longer will be the prominent fibres at the torn edge of a sheet.
- Each cellulose fiber is bonded to its neighbouring fibers by thousands of relatively weak hydrogen bonds. Mechanical entanglement of the fibers makes only a small contribution to holding fibers together in a sheet.
- Textiles use similar fibres, but rely on entanglement.
Fibre Coarseness

- Fibre length and cross section are two of the key properties of fibres.
- These properties vary between species and even with trees. As a result variation exists.
- Fibre coarseness is a way of rapidly measuring these parameters, and of controlling or explaining them.
- Coarseness is defined as:
  The weight per unit length of fibre expressed in milligrams per 100 metres.
  Numerically, coarseness = 11.1 * denier.
Wet-Web Tensile Strength vs Fibre Length

Unbleached, dried SW kraft pulp

$\text{Wet-Web Tensile Strength at 30\% Solids, m}$

$r^2 = 0.87$

Source: Seth Tappi, 1995
Fibre Coarseness

- Simple
- Useful
- Describes the weight of a constant length of fibre
  
  100 metres!

- Low numbers mean fine fibres
- High numbers mean coarse fibres
- Fibre wall thickness and diameter make the difference
- Fibre length has no role
Wet-Web Tensile Strength vs Coarseness

Source: Seth Tappi, 1995
Fibre Coarseness

Lower coarseness = More fibres/gram of pulp
= Greater bonding area
= Higher tensile strength
### Fibre Coarseness of typical BC species

<table>
<thead>
<tr>
<th>Species</th>
<th>Coarseness (mg/100m)</th>
<th>Wall Thickness (µm)</th>
<th>Fibres/gram (x10^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir</td>
<td>24</td>
<td>4.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Hemlock</td>
<td>20</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Spruce/pine</td>
<td>18</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Cedar</td>
<td>16</td>
<td>1.6</td>
<td>4.2</td>
</tr>
</tbody>
</table>
**Fibre Coarseness**

**Coarse Fibres**
- High Tear
- High Bulk
- High Porosity
- Rough

**Fine Fibres**
- High Tensile
- Low Bulk
- Low Porosity
- Smooth
Significance of Fibre Coarseness

Low Coarseness
- High wet web strength
- High breaking length
- High sheet opacity (at given density)
- Good sheet formation
- Smooth sheet

High Coarseness
- Good drainage
- High tear
- High porosity
- High sheet bulk
Typical Fibre Dimensions

Fibre diameter in microns

Wall thickness in microns

Weight weighted lengths measured by Kajaani FS200
Typical Fibre Dimensions

Fibre diameter in microns

- White Spruce: 28 µm, Wall thickness: 2.2 µm
- Lodgepole Pine: 32 µm, Wall thickness: 2.1 µm
- Alpine Fir: 35 µm, Wall thickness: 1.8 µm

“Weight weighted lengths measured by Kajaani FS200”
Typical Fibre Dimensions

Wall thickness in microns

Fibre diameter in microns

Southern Pine: 47 (4.8), Coastal Douglas Fir: 42 (4.0), Spruce/Pine: 30 (2.2)

"Weight weighted lengths measured by Kajaani FS200"
Typical Fibre Dimensions

Fibre diameter in microns

- **Eucalyptus (Typical)**
  - Wall thickness in microns: 2.9
  - Fibre diameter: 35

- **Scandinavian Pine**
  - Wall thickness in microns: 2.1
  - Fibre diameter: 32

- **Lodgepole Pine**
  - Wall thickness in microns: 2.2
  - Fibre diameter: 28

- **White Spruce**
  - Wall thickness in microns: 3.5
  - Fibre diameter: 25

- **Birch**
  - Wall thickness in microns: 3.4
  - Fibre diameter: 16

"Weight weighted lengths measured by Kajaani FS200"
Douglas-fir Handsheet

Microphoto courtesy of Pulp and Paper Research Institute of Canada
Douglas-fir Handsheet

Microphoto courtesy of Pulp and Paper Research Institute of Canada
Cedar Handsheet

Microphoto courtesy of Pulp and Paper Research Institute of Canada
Cedar Handsheet

Microphoto courtesy of Pulp and Paper Research Institute of Canada
But fibres are really not that simple, they are much more complex in reality!
Sketch of a Typical Tracheid

- Tertiary wall (T) (a few laminae)
- Inner layer (S₂) of secondary wall (no laminae except after pulping)
- Outer layer (S₁) or secondary wall (many laminae 50° - 90° to axis)
- Primary wall (P) (a few laminae)
- Middle lamella
- Pit

Legend:
- Warty layer
- Thin lamina between T and S₂ layers
- S₂ fibril angle not over 30°
- Thin lamina between S₁ and S₂ layers
- Lumen