Woolscapes: Re-Connecting Nova Scotian Agriculture And Craft

by

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Submitted in partial fulfilment of the requirements
for the degree of Master of Architecture

Dalhousie University
Halifax, Nova Scotia
March 2016

CONTENTS

DEDICATION

To Ursel Buchholz for her infectious generosity and love.

ABSTRACT

Wool is a natural, renewable and biodegradable resource. It is used by the sheep to protect them from the elements; a natural form of architecture. Its properties as a thermally and acoustically insulating, water resistant, fire retardant, and volatile absorbing material make it ideal for the built environment. Today in the industry of sheep farming, wool is considered a waste material as meat is the main output. In recent decades Nova Scotia's farm revenues have been decreasing, and wool has become a further expense for farmers as it does not stop growing and needs to be shorn.

Since the invention of petroleum based synthetic fibres, wool as a fibre for the textile industry has been displaced. While this was happening, textile production was concentrating in developing countries, creating a market that was too competitive for production in countries like Canada to continue. The geographic divide between resource production, manufacturing and product use is reflected in a culture that does not understand materials. This thesis explores the material qualities of wool, aiming to re-connect the agricultural resources of the wool industry with craft and other place based manufacturing to inform and invent new forms of architecture and architectural products.

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my committee, Catherine Venart, Cristina Verissimo and Brian Lilley, for your invaluable guidance, critiques and energetic encouragement. Beyond sharing your wisdom, you made it fun.

To Dr. Wayne Watson for encouraging students like myself to pursue their interests.

To Toshiko MacAdam for being the geyser of inspiration that she is.

To my friends and family who have cheered me on.

And mostly to my parents, for making it all happen and supporting me throughout.

CHAPTER 1: INTRODUCTION

Today more than half of the world's population lives in cities (United Nations 2007, 2). This shift away from our agrarian roots is caused by advances in technology and the global market. According to Lewis Mumford, we are living in the neotechnic era. This theory was published in 1934 and is still relevant today. The neotechnic era is defined by our use of electricity and synthetic materials, communications, and the reign of science (Mumford 1955, 212). These practices have made it difficult for rural communities to modernize. The availability of imported food and goods negates a city's dependence on its surrounding rural communities, resulting in a struggle for these regions to remain economically viable. Agriculture, resources and industry are homogenous in today's global economy with severe environmental, economic and human consequences. CO2 levels, soil degradation, biological uniformity, and resource depletion are among the environmental repercussions of the neotechnic era. Furthermore, our economic system depends on continuous growth, which does not coincide with the world's limited resources. Maintaining growth is often done by moving production to countries with low wage economies, exploiting workers for financial gain. These practices cannot be maintained indefinitely and sustainability has emerged as a crucial movement in the neotechnic era. A branch of sustainability is a "think local" movement, this counter narrative focuses on rejuvenating and helping dying rural communities.

Urbanization has greatly affected Nova Scotia. Since 1941, the province's urban population has almost tripled, while the rural population has declined (CANSIM Table 051-0005). Closures in textile production, mining, shipbuilding and fishing, as well as the decrease in agricultural revenue has lead to many rural job cuts. The low cost of imported foods has resulted in a market that is too competitive for local farmers, forcing people to find work outside of agriculture. In the recently published *Food Counts: Halifax Food Assessment*, Halifax ranked last out of 33 Canadian cities in terms of food security, with the average food item travelling 4000km to get to Halifax (MacGregor 2012, 15). The word *culture* stems from *colere*, Latin for cultivation of the land. The word *culture* is itself metaphorical, deriving from *agriculture*, meaning cultivation of the soul/mind. This linguistic connection represents agriculture's essential role in distinguishing a society. Without the ability to provide for its population, Nova Scotia loses the character of a productive society. This thesis aims to re-connect Nova Scotian (agri)culture and craft through the revitalization of the wool industry.

Wool provides opportunities for both farmers and textile manufacturers, and has a rich history of use in Nova Scotia. The fibres are thermally and acoustically insulating, water and fire resistant, renewable and biodegradable. These qualities give wool considerable potential as an architectural material. Wool has been used by people for thousands of years and was once a dominant fibre in the textile industry. Modern technologies have made synthetic fibres cheaper to manufacture so they have replaced natural fibres; wool is now effectually obsolete. The price of wool has declined to a point where it is no longer a source of income for sheep farmers. (Stiles and Corscadden 2013, 3) In fact, farmers lose money because of wool: sheep have been bred so their wool is continually growing, with shearing done at the expense of the farmer, making it an economic drain. It is estimated that 60, 500 lbs of wool in Atlantic Canada is discarded or stockpiled every year: this is half of the wool produced (Stiles and Corscadden 2013, 12). Creating a market for this wool will make use of waste, increasing revenue but not workload. This will likely attract more farmers into sheep rearing, increasing the availability and reducing the cost of local sheep products, such as meat, milk, lanolin and wool.

In order to re-inform architectural "shelter" in ways that are both permanent and ephemeral, the use of wool as a textile was a starting point for design explorations. Textile development has a long history of informing architecture. Gottfried Semper believed that architecture has its origins in the textiles of nomadic tents and saw architecture as clothing. (Semper 2004, 106) The act of shelter is an animal instinct which has evolved with us to become modern day construction. This is seen in primitive regional architecture such as the nomadic tents of the Sahara desert, the Mongolian ger, and North American tipi, to more elaborate structural systems like Frei Otto's vast modern structures. These examples of textiles operating in architectural systems offer insight when designing with wool. This thesis takes on experimentation with wool, allowing the material's properties to re-inform architectural ideas of shelter in ways that are sterotomic, tectonic, formal and informal. The intention is to develop building products and assemblies that contribute to an industrial network, connecting industries with people through a multiplicity of wool architectures.

Design began with the development of a material palette, composed of coatings and different techniques (felting, sprang and batts) which could be combined into assemblies that strengthen and add properties to the wool. Coatings can be used to stiffen fabrics, or maintain their flexibility, increase abrasion resistance, waterproofing and windproofing. Techniques of felting, batting and sprang determine qualities such as density, thickness, stretch and strength, as well as different methods of production. Combining these techniques with rigid elements, such as wood and metal, and using coatings to treat the wool, create various products and assemblies. The assemblies considered to have the most architectural potential were further developed. The wool elements were thought of both as stereotomic and tectonic, adaptive and permanent. These assemblies and products, of which there were five, were brought to a final design phase concluding as detail drawings or architectural prototypes; a kepenek (wearable architecture), chair, panel system, wall and tent.

The products developed in this thesis aim to strike a balance between craft and industry. Wool can have architectural uses that involve low processing, such as batt insulation, or highly crafted products such as carpets. The highly crafted products respond to the increase in high-value agricultural sales in the province, while the mass produced products introduce new industry to Nova Scotia. Achieving economic viability in local products is a significant challenge which has lead to many failed attempts at reintroducing industry in Nova Scotia. High value products are able to succeed here because the additional cost of local sourcing is less significant with infrequent novelty purchases than in everyday purchases. The results from these architectural explorations are designed to bolster rural industry, agriculture and communities. Therefore, there is opportunity for these new wool products to engage with other Nova Scotian industries, building a network. For example, ship building offers a skill set with materials such as fibreglass. Also, fish nets are made in the province and can be used to add tensile strength to wool fabrics. Local wood can also be used for its rigidity and compressive strength. These industrial/agricultural pairings can be a mutually beneficial practice.

In this way, this thesis contributes to rural communities' ability to reestablish themselves as an evolving part of Nova Scotian identity. Tim Ingold says, "Making creates knowledge, builds environments and transforms lives." (Ingold 2013, Making: Anthropology, Archaeology, Art and Architecture) Reintroducing the act of making to the province will bring a modern identity with strong connections to a remarkable past.

CHAPTER 2: GLOBAL TRENDS

The Neotechnic Era: Globalization and Urbanization

Lewis Mumford explains humanity through our use of technology, breaking up history into three phases: eotechnic, paleotechnic and neotechnic. The determining factors of the phases include energy sources, resulting materials and capabilities as well as people's views towards science and human rights. He analyzes human's relationship to their built environment, fabrication and craft, and reasons for the evolution that has occurred. We are living in the neotechnic era, defined by our use of electricity, synthetic materials, the reign of science and communications (Mumford 1955, 212). Since this theory was published in 1934, we have seen the effect technologies have had on rural communities.

The neotechnic era is known as the age of cities. Early this millennium the global population shifted from being predominantly rural to urban (United Nations 2007, 2). This reflects major changes in the way people make their living and the practices sustaining our societies. As well as urbanizing, countries are establishing themselves by trade, with most production happening in countries with low wage economies. Some concerns associated with the neotechnic era are quality of life, food production, and sprawl.

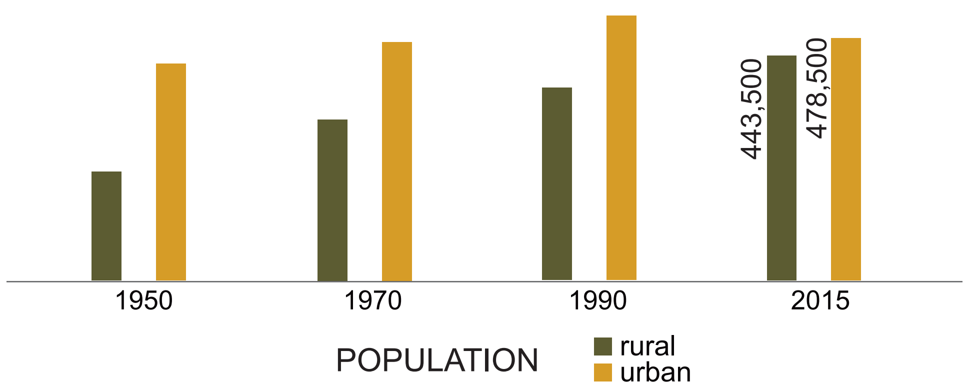
Sustainability

Sustainability has emerged as the counter movement to the practices defining the neotechnic era. The global economy depends on continuous growth and exploits our people and resources to achieve this growth. As well as the misguided ethics of this model, endless growth is not possible on a planet with limited resources. Sustainability has become the primary concern of our generation and has worked its way into many architectural practices. Building materials require transportation, manufacturing and eventually need to be discarded. The choices behind these building materials are important in determining the sustainability of a building. Wool is a local, natural and biodegradable material that offers a solution the quest for sustainable building products.

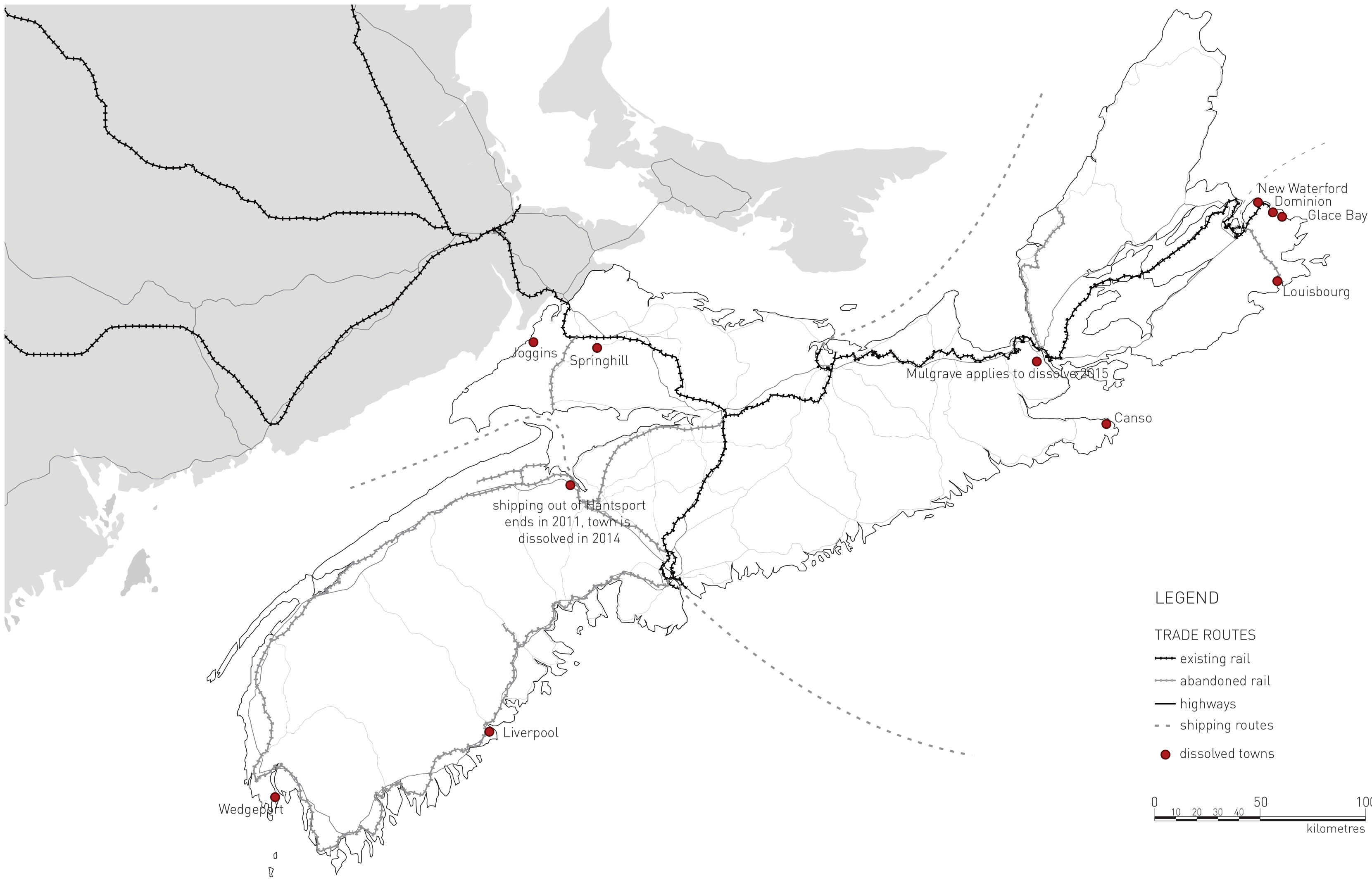
CHAPTER 3: RURAL NOVA SCOTIA

Closures, Abandonment and Dissolution

While Halifax, New Glasgow, Sydney and Truro have been steadily increasing in population, rural Nova Scotia has begun to shrink in population. Along with 10 towns that have dissolved in the past 60 years and another one about to dissolve, Nova Scotia's rural economy has been shrinking as well. When the railroad was first built throughout the province it brought goods to market while bringing tourists out of the city. Now all that is left of the rail connects Halifax and Cape Breton to the rest of Canada.



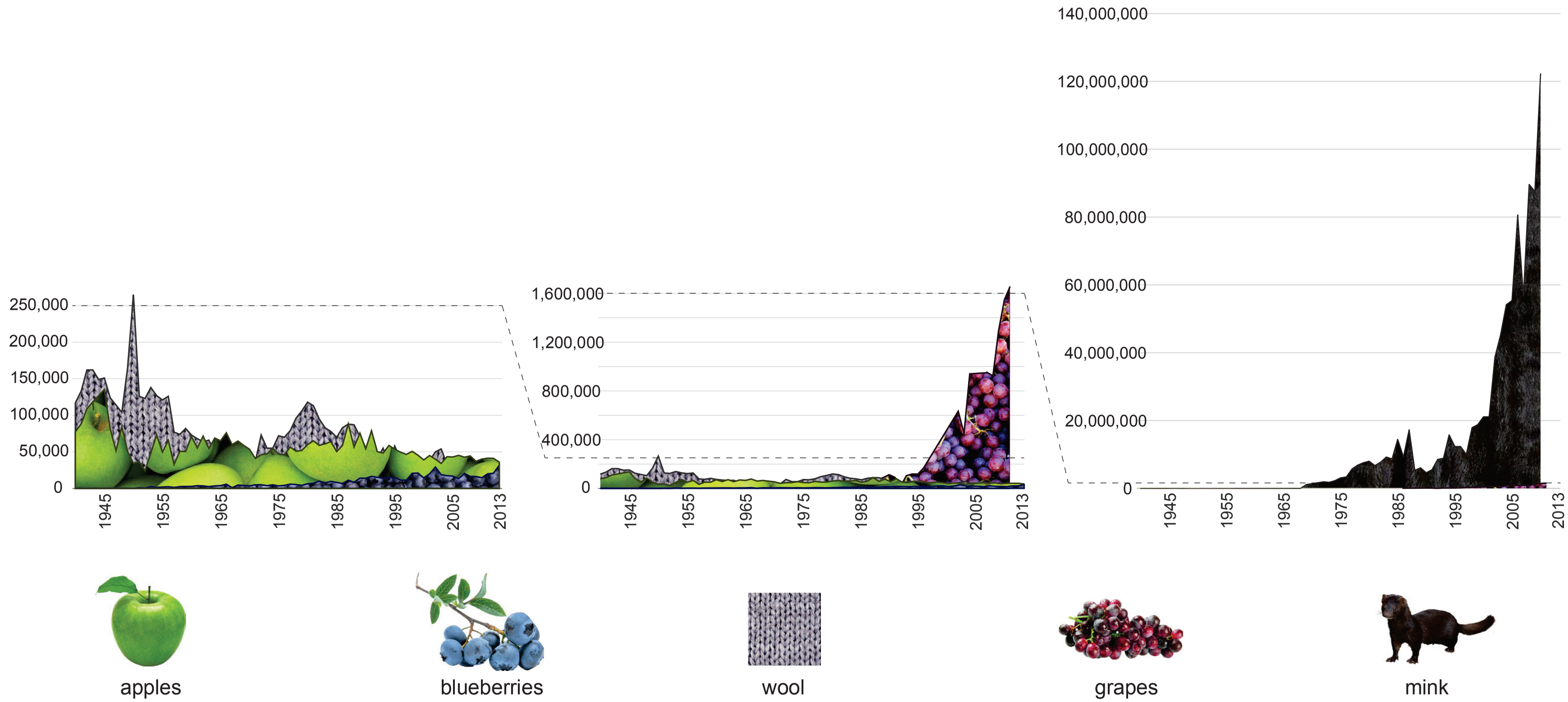
Nova Scotia's urban population has been steadily increasing but the rural population has started to decline (data from Statistics Canada, Table 051-0005).



This map illustrates the recent decline of Nova Scotia’s rural communities. Ten towns have dissolved and the rail service only runs to Halifax and Sydney (base map from Bing Maps).

A Shift in Agriculture

Farmers are not able to compete with the price of imported foods and as a result, they've turned to high value agriculture. Mink pelts are Nova Scotia's largest agricultural export and since the first vineyard opened in 1987, the wine industry has flourished. While this is a great thing for the rural economy, it does not fill the needs of Nova Scotian's. In *Food Counts: Halifax Food Assessment* it was revealed that Halifax ranked last out of 33 Canadian cities in terms of food security, with the average food item travelling 4000 km from its origin (MacGregor 2012, 15).



The first graph shows the decline in revenue from apples and wool, while blueberries are increasing in revenue. The next graph shows the growth in grapes for wine production, and the last graph show the revenue from mink pelts. Wine and mink are able to success because they are high-value novelty products, unlike apples which can be imported cheaper. The blueberries grown in Nova Scotia are mostly frozen and shipped to the United States. Blueberries are the most profitable crop export in the province and the most profitable agricultural export is mink which is shipped mostly to Japan (data from Statistics Canada).

CHAPTER 4: WOOL

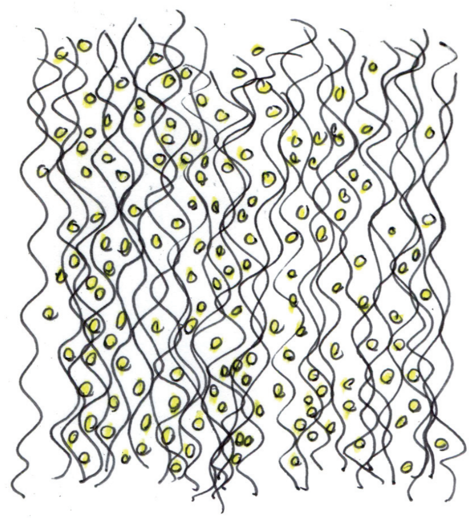
Properties

Wool has many qualities that give it enormous potential as a building material. The fibre's disadvantages also need to be understood when considering applications.

Thermal Insulator

Wool's strength as a thermal insulator is in its ability to hold air still (Corbman 1983, 281). Air pockets between the fibres, as well as air pockets within the fibres do this. This property allows wool to insulate in both hot and cold climates.

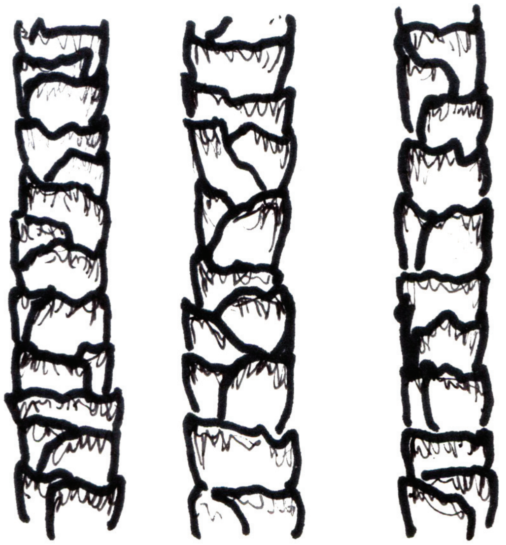
The medulla is an air pocket within a wool fibre. It can be continuous, scattered or not exist at all. Courser fibres are more likely to contain a medulla.



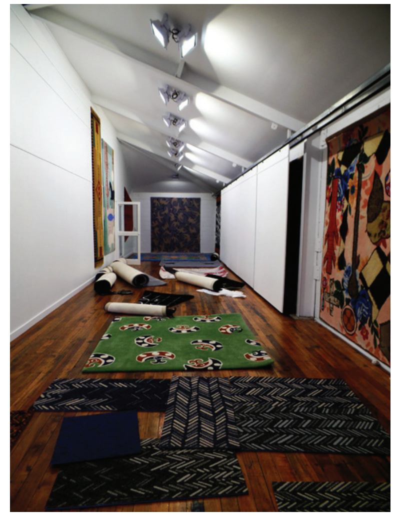
Wool has a crimp which creates loft. Air is kept in the pockets between fibres.

Water Resistant

Wool is water resistant because of the scales formed by the epithelial cells of the fibre, interfacial surface tension, uniform distribution of pores, and low bulk density. When coated with lanolin the fibres become waterproof. In the form of vapour, water can enter the fibre where it will be absorbed by capillary action. Wool can absorb 20% of its weight in moisture before feeling wet (Corbman 1983, 282). Once it is wet, drying is a slow process.



Scales on the outer layer of the wool fibre.



The showroom at Dilana Rugs
in Christchurch, New Zealand.

Volatile Organic Compounds (VOCs)

VOCs are gases emitted from building materials, such as plywood which contains formaldehyde. These gases contribute to indoor air pollution and have negative health implications. It has been estimated that a wool carpet can continue to absorb VOCs for 30 years (New Zealand Merino Company Ltd. 2014, 2).

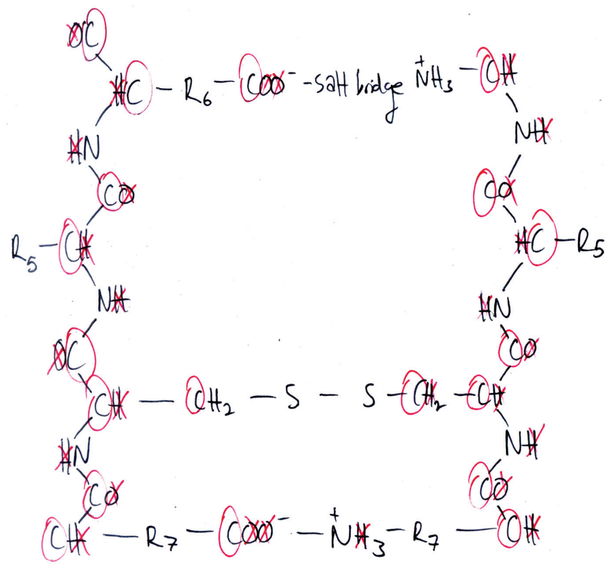
Acoustic Insulator

Wool performs as an acoustic insulator. The finer the fibre and denser the application, the better wool's ability to absorb sound waves (International Wool Textile Organization 2011, 26). It has uses in many instruments such as drum beaters, brass keys and piano hammers. Auditoriums will often use wool seats or wall finishes to absorb sound.

Illustration of flow resistivity as it relates to
fabric density and fibre diameter.

Fire Resistant

Dry wool will burn slowly when directly exposed to flame, once removed from the flame it self extinguishes. Rather than melting, it chars because of its chemical composition (Smith and Block 1982, 94). Wool is used in fire fighter's apparel as well as upholstery on boats and airplanes.



When exposed to flame, hydrogen and oxygen are removed with mostly carbon left over, resulting in char.

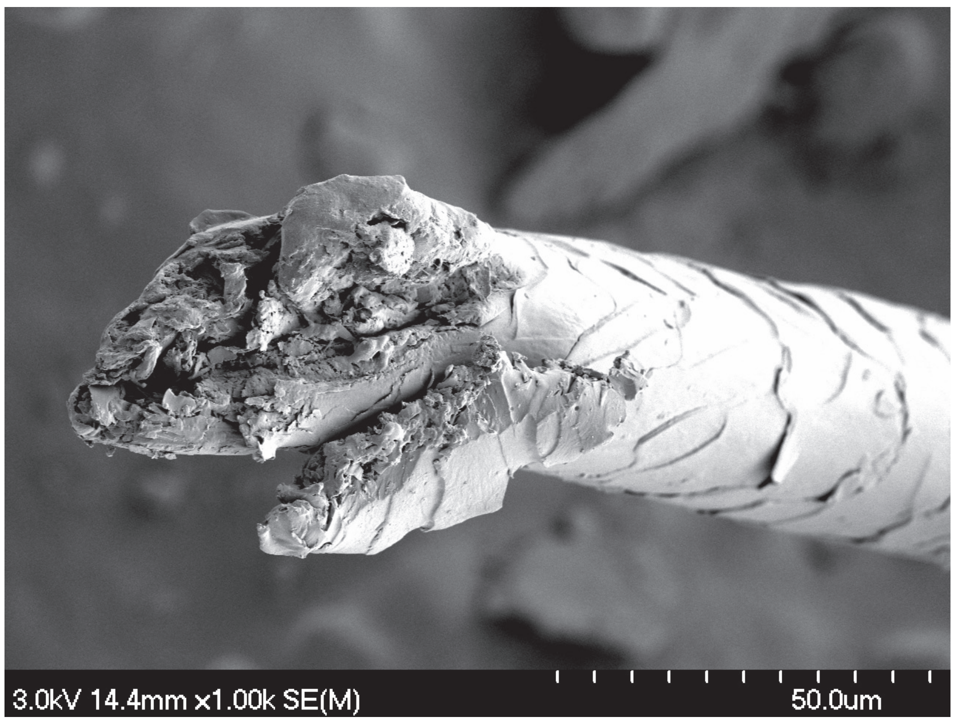
Elasticity

Wool's crimp allows it to be stretched without permanently altering its shape. Within the fibre, molecules folded into a helical shape are straightened when stretched, but the cross linkages resist permanent alteration. Wool fibres can be stretched from 25-30% of their original length before breaking (Corbman 1983, 280).

The crimp of the fibre can be stretched as well as the helical shape of the fibre's cells.

Strength

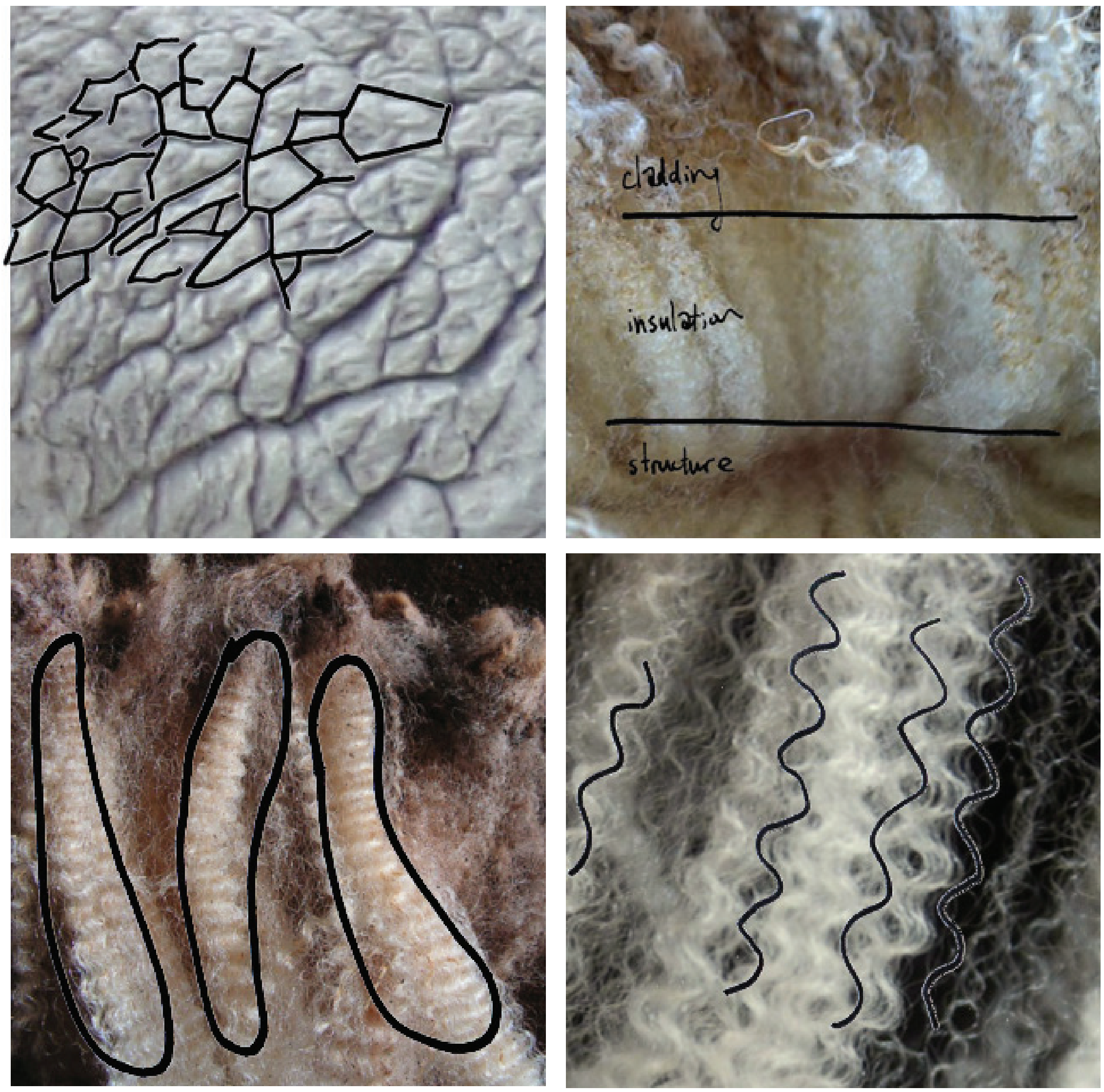
Hydrogen bonds create the chain of molecules within the wool fibre while cystine linkages and salt bridges hold the chains together. Though the cross-links are strong, the hydrogen bonds are weak. Because these bonds are easily broken under stress, wool is a weak fibre. Hydrogen bonds weaken when exposed to moisture, making the fibre weaker when wet. A fibre's strength is influenced by the sheep's diet, as well as fibre diameter and the rate of change in diameter along the fibre. (CSF and CCWG 1986, 6)



A broken fibre seen through a scanning electron microscope (image taken by Patricia Scallion).

On the Sheep

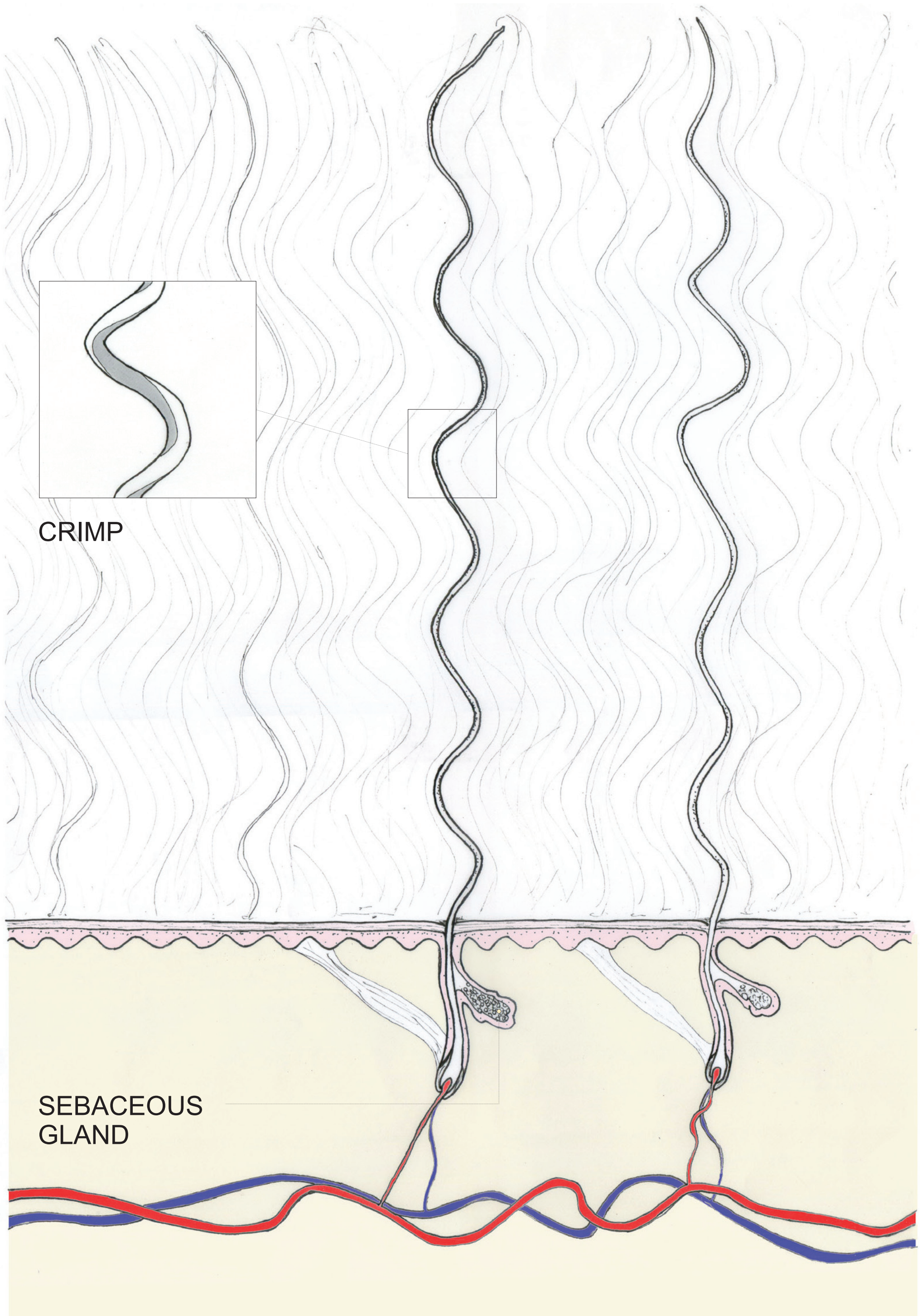
Wool is a fibre grown by sheep as a protective layer over their skin, it composes the sheep's fleece. Wool is different from hair in that it is crimped and grows in clusters known as staples. Sheep are bred for the quality of their fleece, considering fibre strength, staple length and colour. Thousands of years of breeding have made sheep domestic animals, without being shorn their wool will disable the sheep and cause wool blindness.



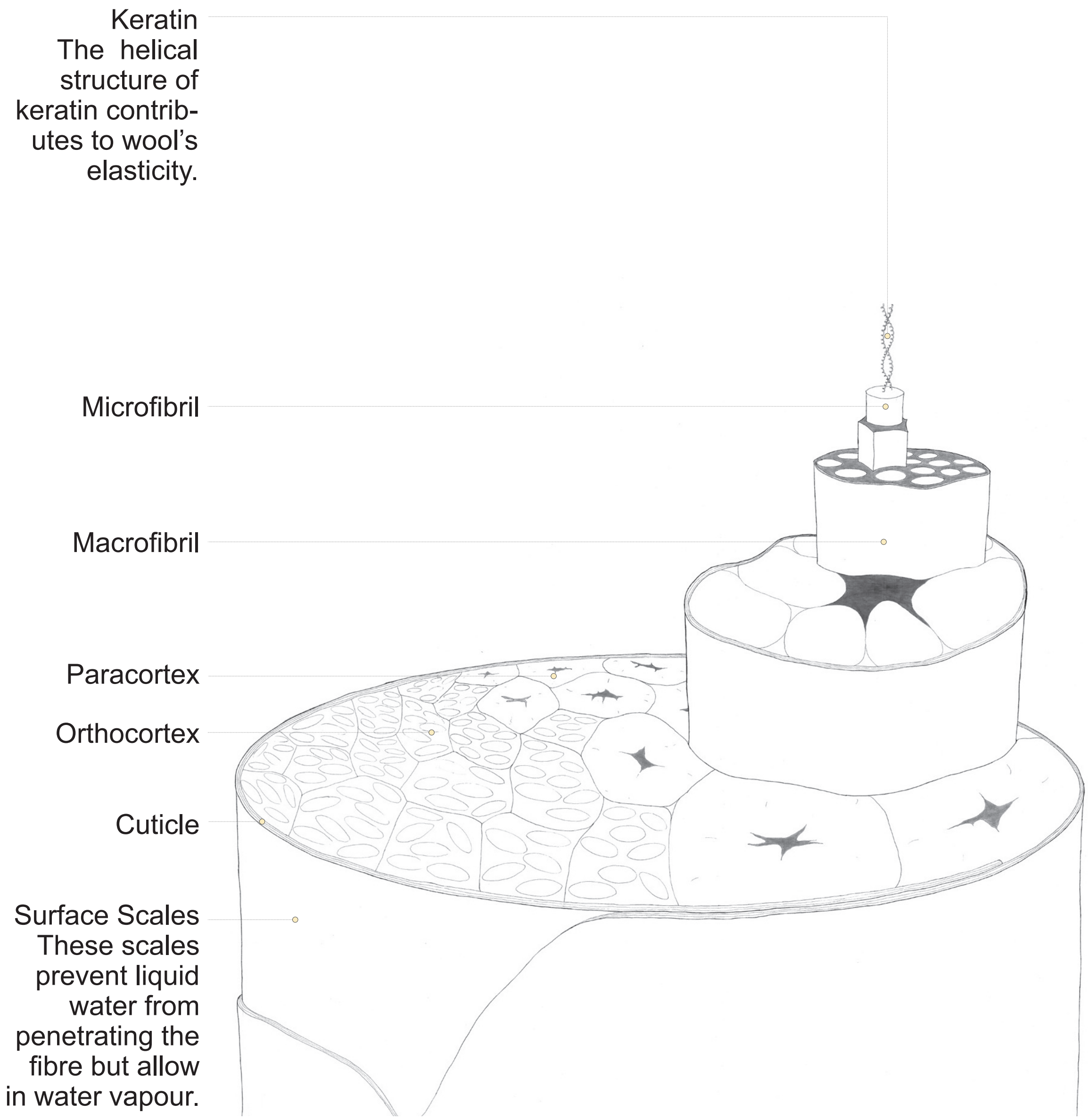
Patterns formed in nature reveal the way wool functions.
Top left: the outer layer of wool matts with dirt and lanolin forming a crust.
Top right: the outer crust acts as cladding, underneath is a clean, insulating layer.
Bottom left: the fibres from in clusters called staples.
Bottom right: wool has a natural crimp.

Shrek was a New Zealand merino who became famous after dodging the shearer for six years. Weighing 6 times more than the average fleece, his wool was used to make 20 men's suits (photo from the Arc Animal Blog).

Wool is made waterproof by the lanolin that coats the fibre. Lanolin is a waxy substance that is primarily used in cosmetics. During the scouring process 50% of the lanolin is extracted and the other 50% is washed away, because of the large market for lanolin there is interest in making the extraction process more successful.

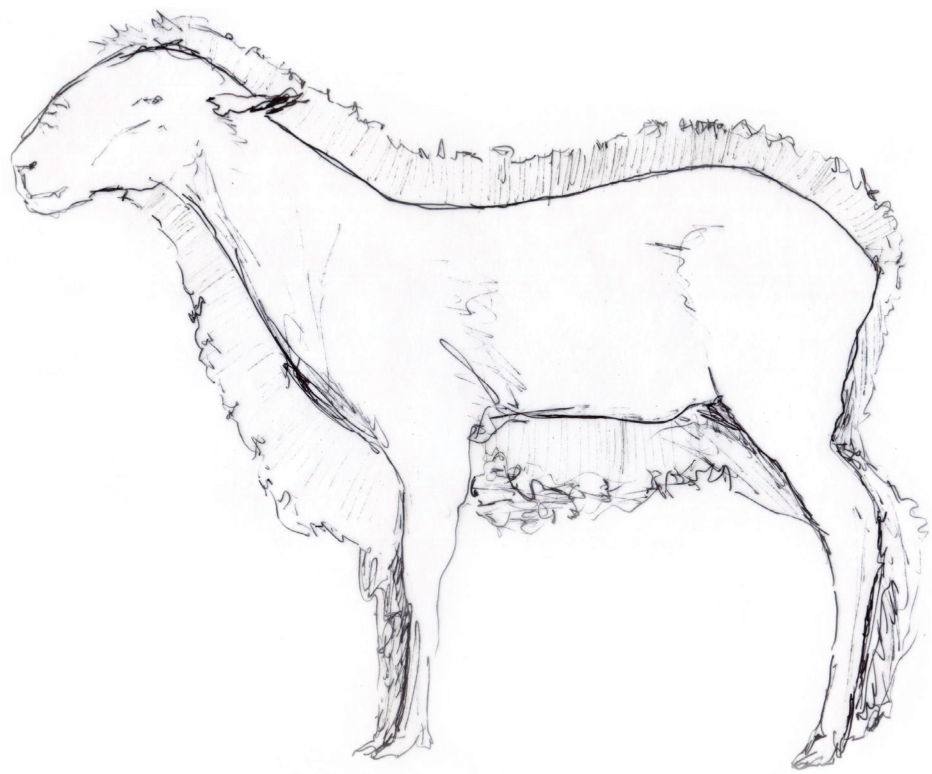


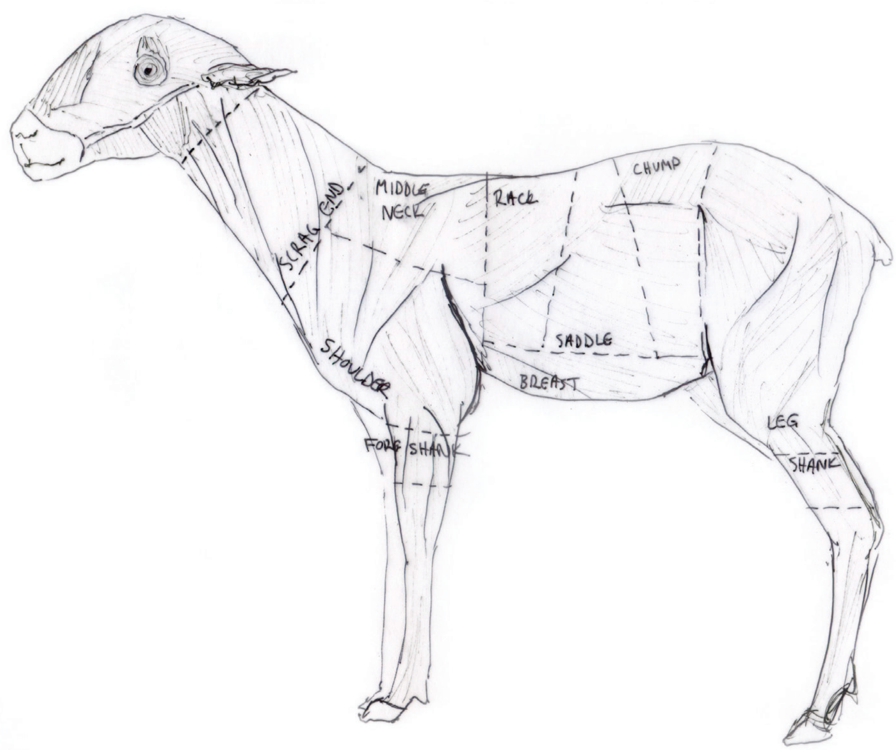
Lanolin is secreted from the sebaceous gland under the skin, just like the oil from humans' skin (information from The Free Medical Dictionary).



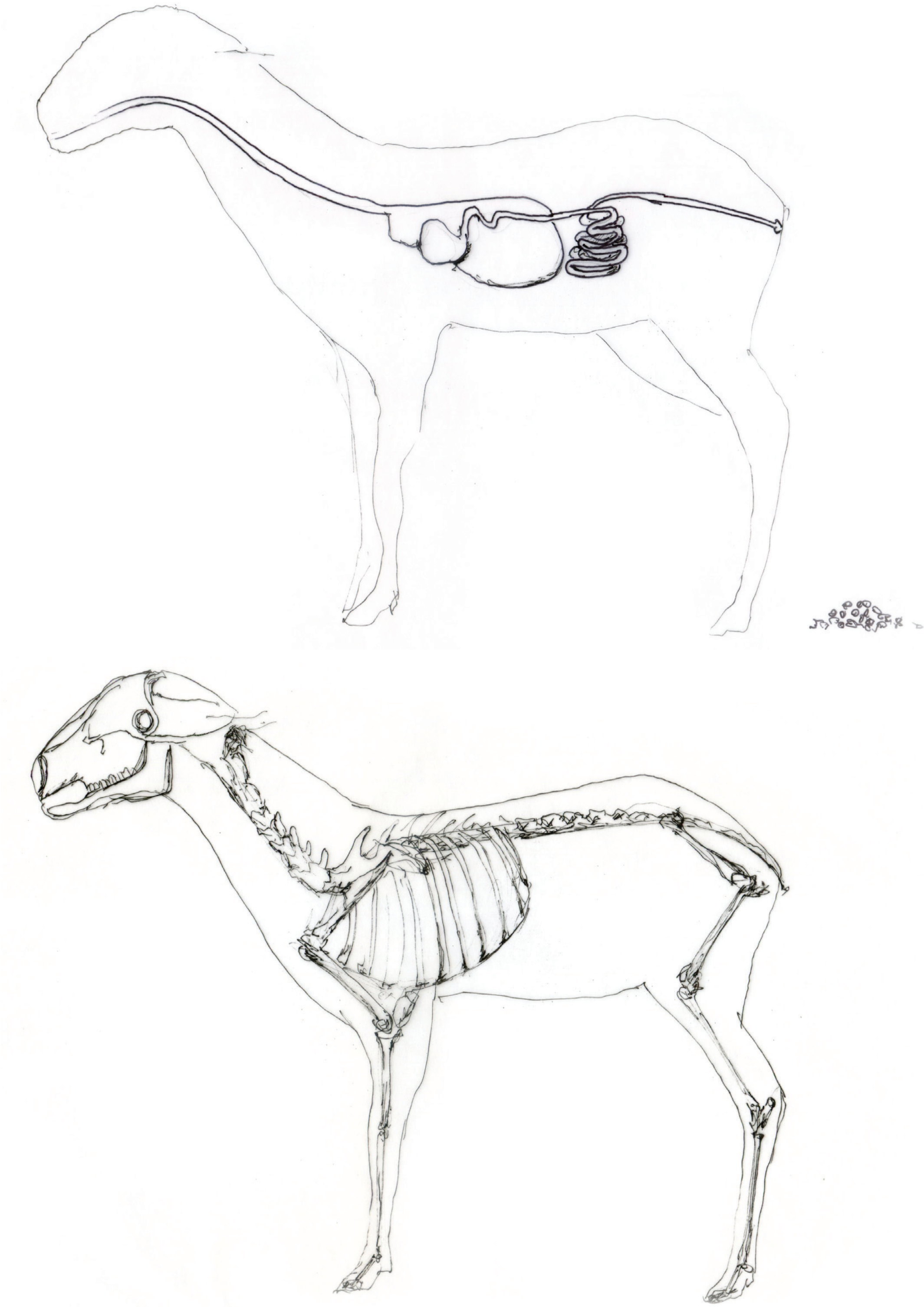
The crimp in a wool fibre is a result of a bilateral structure in the cortex. The paracortex is very stable, forming the inside curve, while the less stable orthocortex spirals around it (information from Havelock Wool).

Sheep Products





Top: wool and lanolin come from the outer layer of the sheep.
Bottom: sheep meat has a large market in Nova Scotia, the province imports meat to meet this demand.

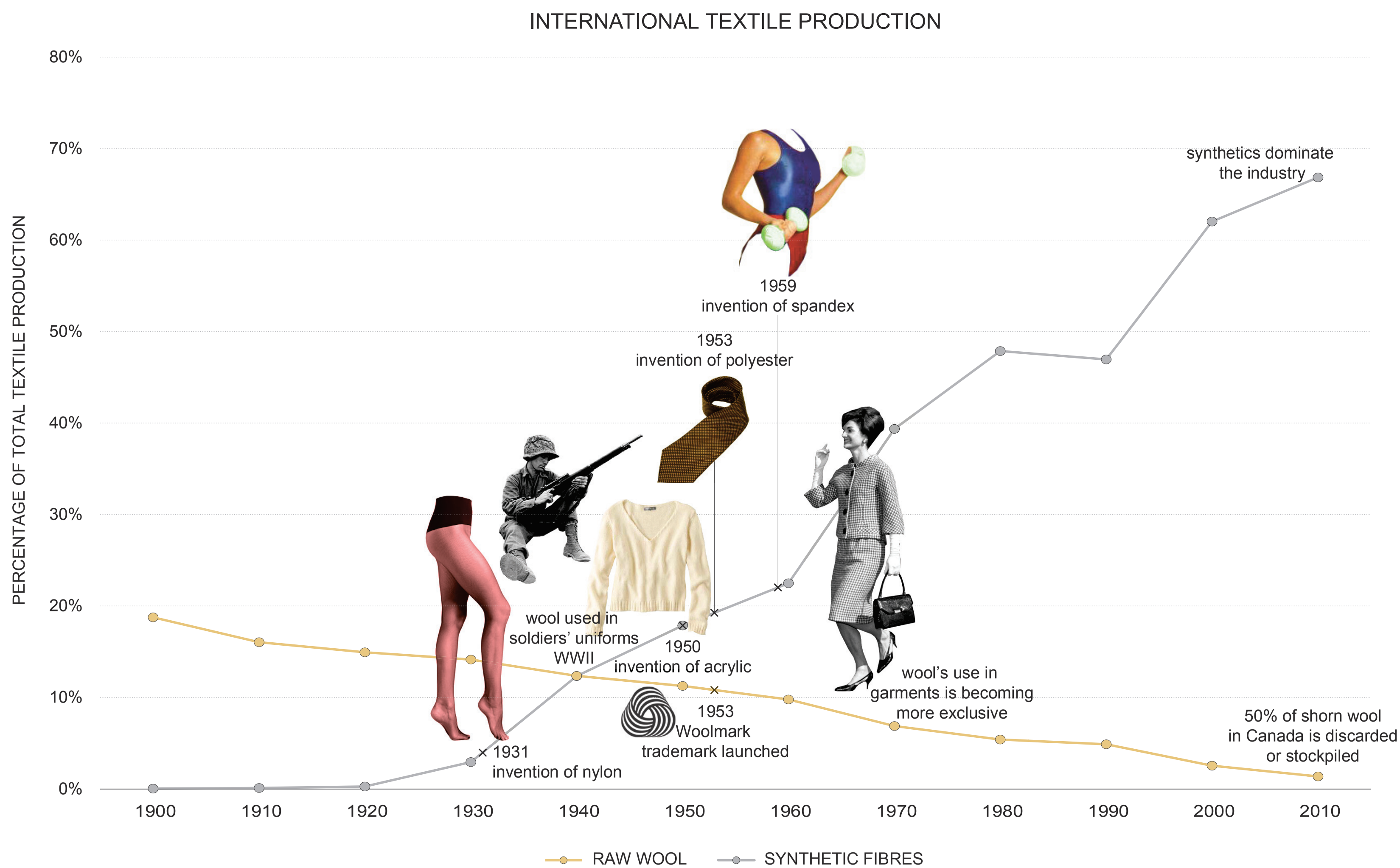


Top: sheep only digest a portion of the fibre they eat. Their excrement contains intact fibre, which is washed and used to make paper. What is washed out of the fibre is used as a high quality fertilizer.
Bottom: historically, bones were used as fasteners, such as buttons, and in playing dice.

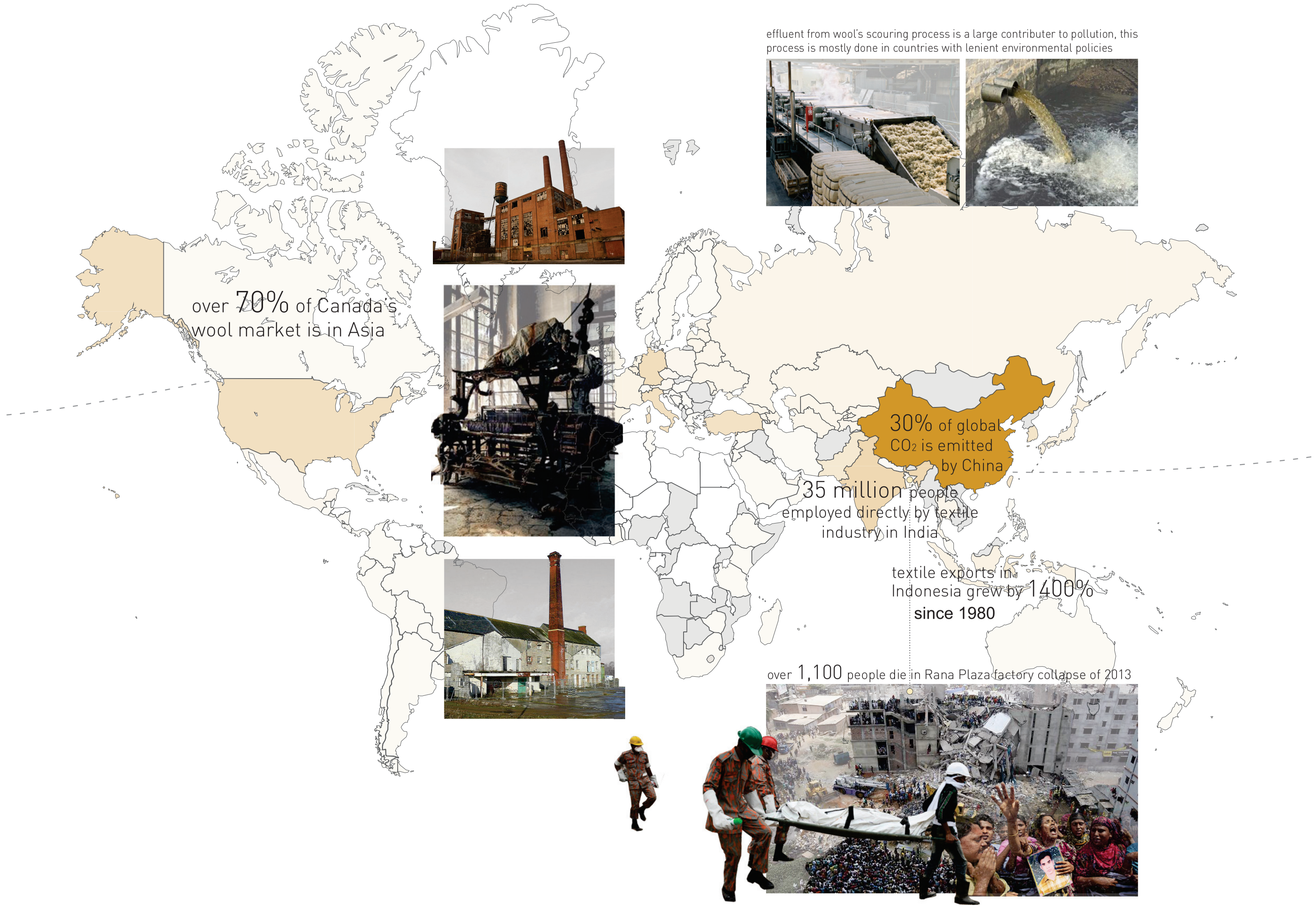
Recent History: Wool as Waste

Given the availability and characteristics of wool, it is surprising that there is virtually no market for it. Wool and cotton have historically dominated the textile industry over more specialized fibres such as silk, sisal, jute and linen. Synthetic fibres were first invented at the end of the 1800's and became commercially available in the 20th century. Developments in technology resulted in nylon, acrylic, polyester and spandex. These fibres created new possibilities in fashion and became cheap to manufacture. They are derived from petroleum and can now be made from recycled plastics. Like most plastics, their decomposition takes so long that they are not considered biodegradable.

As wool's popularity has been decreasing, the textile industry has drastically changed. Production has concentrated in countries with low wage economies and low environmental policies. The scouring process, during which dirt, vegetation and lanolin are removed from the wool, uses harsh chemicals and is energy intensive. Most of the wool products available in Canada were scoured in Asia. This geographic change has resulted in a loss of skill in countries which used to process wool. North America is littered with abandoned textile mills and attempts to manufacture textiles in North America find it difficult to compete with the quality of products coming from Asia.



Wool used to dominate in the textile industry but has been replaced by synthetic fibres such as nylon, acrylic, polyester and spandex (photos from Google Images, data from the Canadian International Merchandise Trade Database).



Textile production in North America, most of Europe, Australia and New Zealand has collapsed. Production has concentrated in China, with many Asian and Middle Eastern countries greatly increasing their production (photos from Google Images).

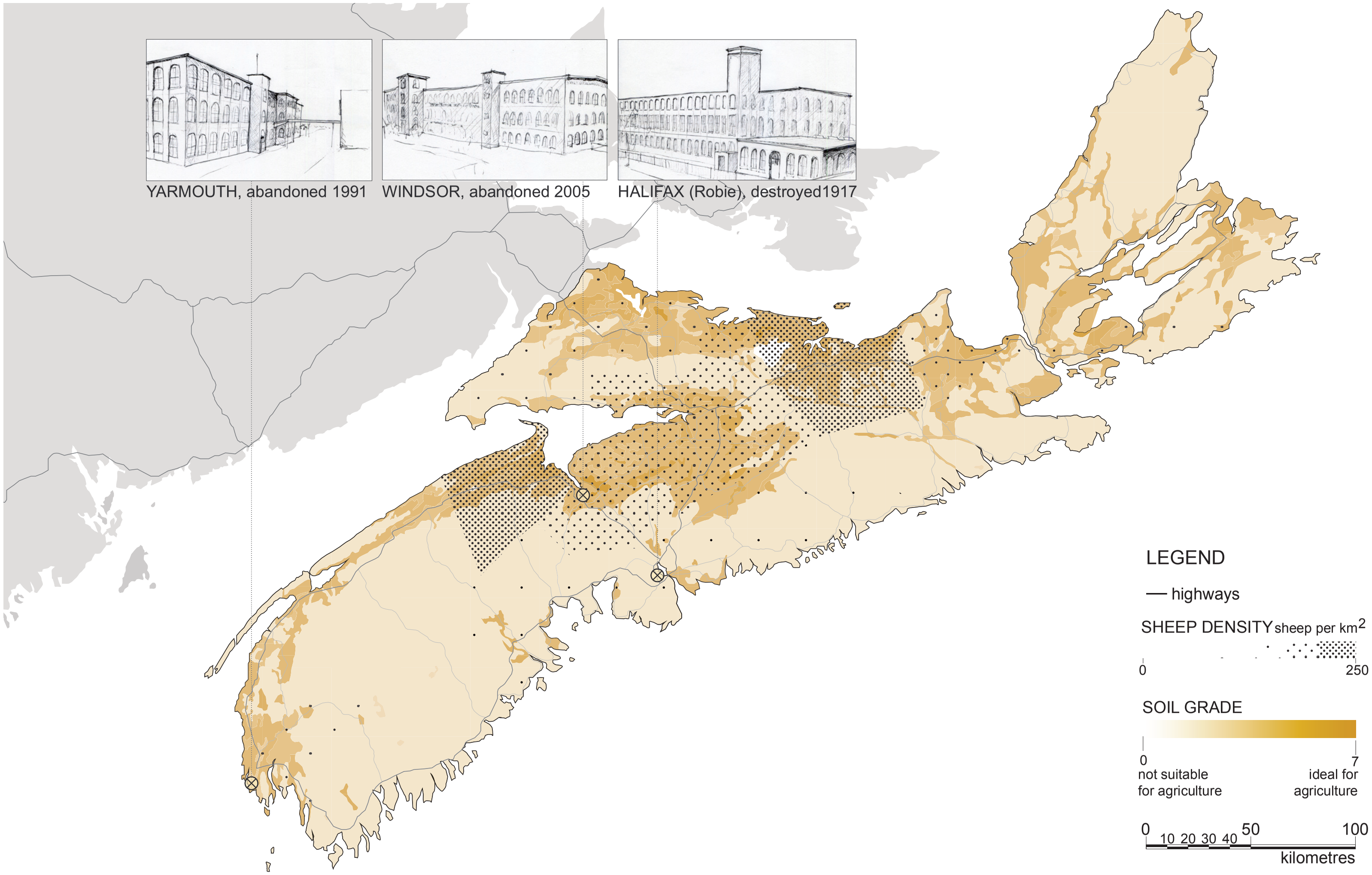
The Wool Industry in Atlantic Canada

It is estimated that 60,500lbs of wool is discarded or stockpiled each year, that is 50% of the wool produced. Of the 50% of wool that is sold, 70% of it is sold to Asia (Stiles and Corscadden 2013, 12). Some of the wool sold to Asia is brought back to Canada after processing. The closest wool mills to Nova Scotia are in New Brunswick and PEI.

Nova Scotia's most popular breeds of sheep are Suffolk, Dorset, Finn and North Country Cheviot. (MacGregor 2012, 90) These are considered high bulk, mid-micron breeds, with fibre that is courser than desired in apparel. Architecture is a better use for courser wools because it will not be in constant contact with skin.

Sheep do well in medium grade land, this land is not suitable for crops but able to grow vegetation for sheep. Sheep are concentrated in Kings and Pictou County. Because Nova Scotia does not currently export any sheep meat, and imports to meet demand, there is plenty of room for growth in sheep farms.

Nova Scotia once had three large mills operating in the province. A mill in Halifax was destroyed in the Halifax explosion, two still stand although no longer operating, one in Windsor and the other in Yarmouth. They are easily accessible by highway and water. The mill in Yarmouth has been divided into units for small businesses. Yarnsmith Fibreworks was a small wool mill that operated out of the Yarmouth building, they went out of business in October of 2015. Re-opening Yarnsmith, with the equipment and staff from the closed operation, with new architectural products could be resourceful way of beginning production. The mill in Windsor has been empty since it closed in 2005, it has not been divided into smaller units and is a potential site for a larger wool production facility.



Nova Scotia's soil is well suited for pasture land. Kings and Pictou county have the highest density of sheep currently. There is room for growth within sheep farming. There are abandonned textile mills in Yarmouth and Windsor, a mill on Robie Street in Halifax was destroyed in the Halifax Explosion (base map from Agriculture and Agri-Food Canada).

CHAPTER 5: MATERIAL PALETTE

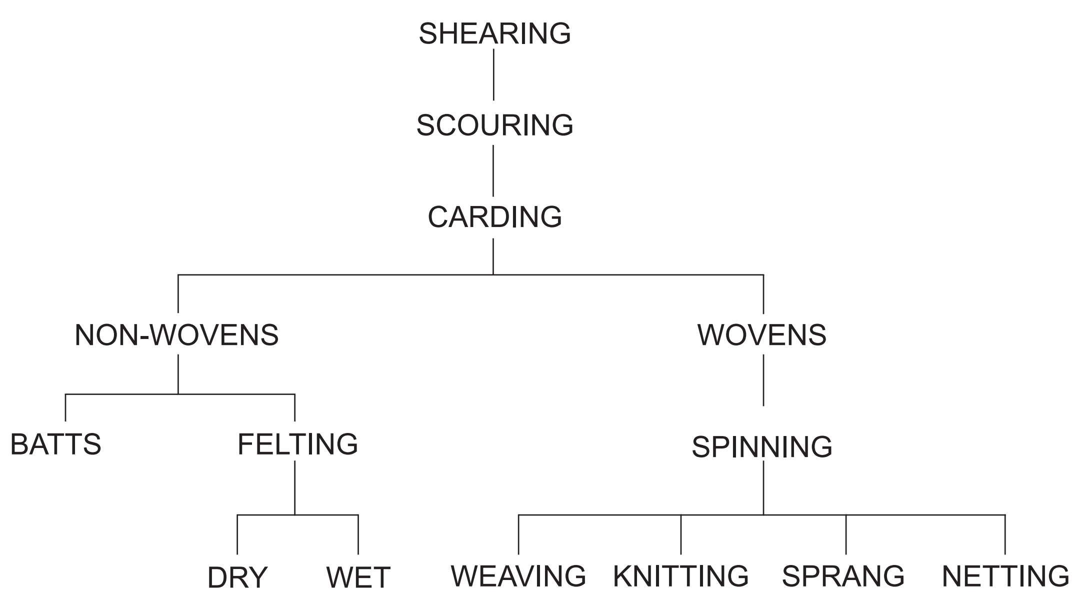
To design with wool a material palette needed to be established. This palette is composed of techniques and coatings that consider and bolster wool's qualities and drawbacks. Using the palette, technologies were developed with an architectural agenda.

Techniques

Techniques of working with wool have been refined over thousands of years. Existing approaches served as a starting point before expanding into new techniques for architecture.

Traditional Techniques

Traditional techniques for processing wool always begins in the same way, with shearing, but depending on the desired outcome, various equipment, skills and labour will be involved. Woven applications are more labour intensive because the wool has to be spun into yarn first, non-woven applications require less processing.



A sheep before, during and after shearing (photo by Allen Russell).

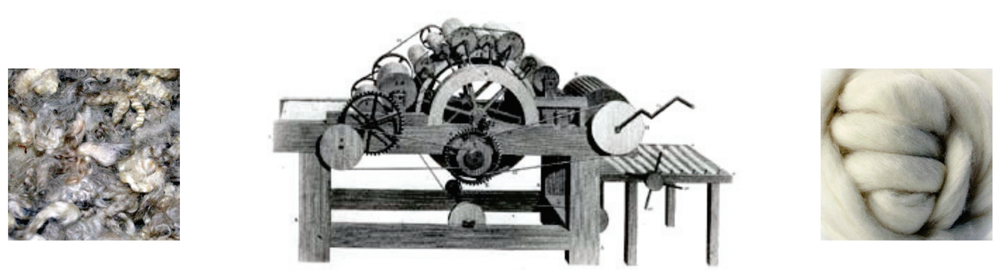
Shearing

Shearing is done once or twice a year. Shearers travel from farm to farm and often work in multiple provinces.

Wool before, during and after scouring (photo from New Zealand Wool Services).

Scouring

The scouring process uses soap and hot water to remove dirt and lanolin from the fibres. It's a highly polluting, energy intensive process. Many wool producing countries send their wool to countries with low environmental policies for scouring.



Wool before, during and after carding (photo from the Trowbridge Museum).

Carding

The carding machine pulls apart locks, aligns fibres and removes vegetation. Once carded, wool is in a roving.

Non-wovens

Left: batt building insulation.
Right: quilt batting.

Batts

Batting is a low-process way of attaining a lofty fabric, it is great as an insulating layer. The fibres are often held in place with synthetic materials which act as a glue. Batting is easily pulled apart and needs to be protected by other layers in an assembly. Batts are used inside wall cavities as insulation and inside quilts.

Felt

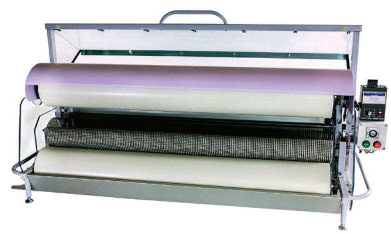
Felt is a fabric made from matting wool fibres together. Wool's crimp makes it possible to felt. The more felted a fabric is, the denser it becomes. Denser felts are better suited to receive a coating and to protect from wind and water, more porous felts are better insulators.

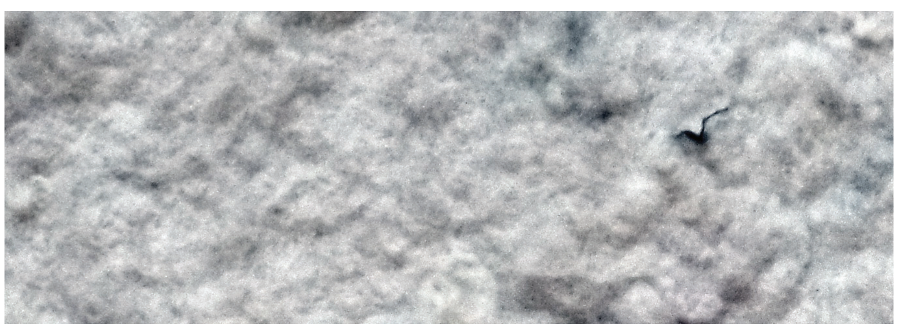
A felting bed (photo from Belfast Mini Mills). A felting loom (photo from feltloom.com).

Felt made on a felting bed at Belfast Mini Mills.

Dry Felting

Needles, much like that of a porcupine, pull fibres through each other, getting the wool to form a fabric. This can be done on a felting bed or with a needle loom, fabric made on a loom can be continuous in length.



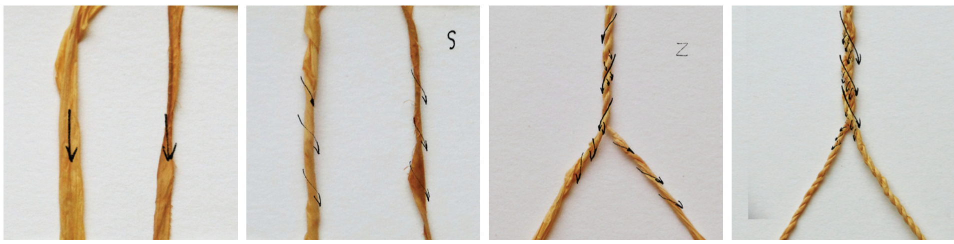


Top: a roller felting machine for wet felting (photo from Snowy Creek Engineering).
Right: felt made by hand in a wet felting process.

Wet Felting

Wet felting uses agitation to get the wool to matt, hot water and soap speed up the process. Wool is laid out and rolled so it can be put on a machine for the agitation stage.

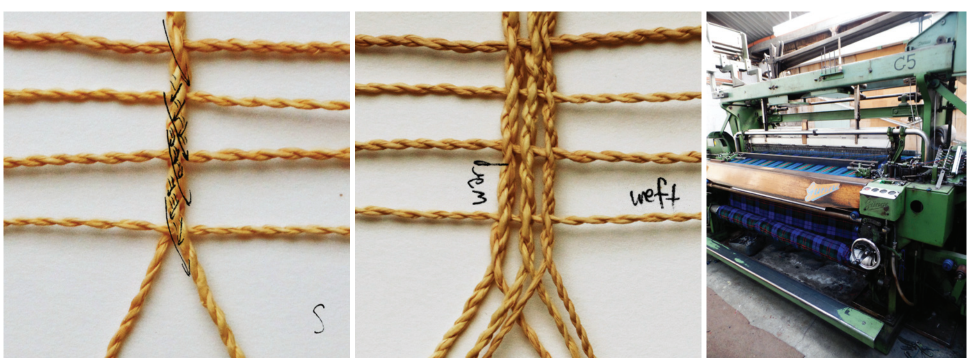
Wovens



Above: spinning machine making yarn (photo from Yarns and Fibres website).
Below: the direction of the spin alternates as the yarn is built up.

Spinning

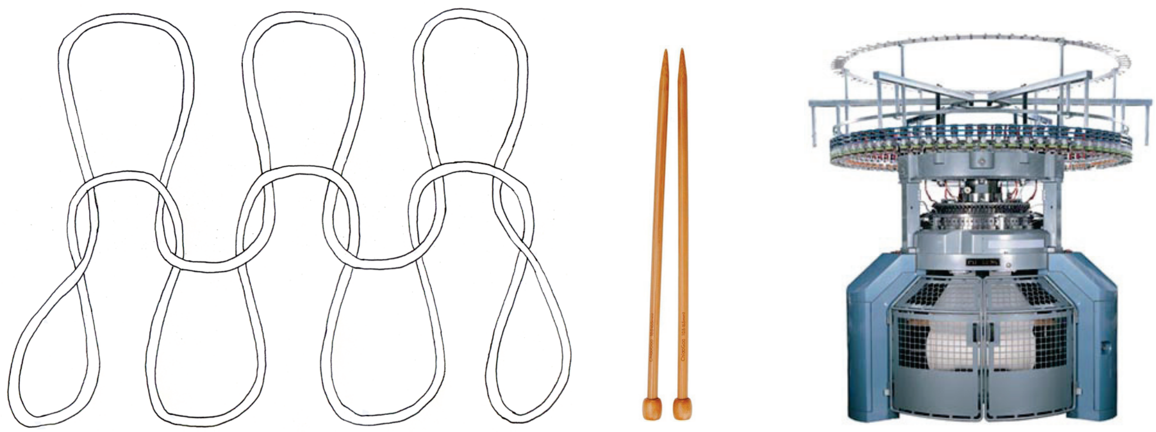
Spinning allows fibres to become a continuous yarn. A roving is spun into a single ply yarn, to add another ply, the two yarns are spun together opposite to the direction they were originally spun. This pattern can be repeated to build up strength. The spinning structure is happening inside the wool fibre, as well, with the orthocortex spiralling around the paracortex and the helical structure of keratin. See page 17.



Yarn becomes a woven fabric as a weft is added.
Right: an indutrial loom (photo from Google Images).

Weaving

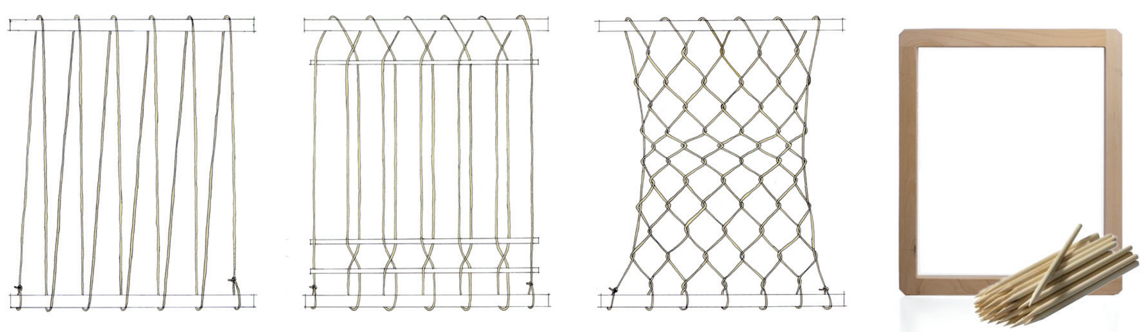
Weaving is just adding a horizontal yarn between spins, known as the weft. Weaving is done on a loom to make large pieces of woven fabric.



Left: knit structure.
Middle: knitting needles.
Right: knitting machine (photo from Textile Learner).

Knitting

Knitting makes a very flexible and stretchy fabric, thickness and density of the fabric is controllable. Knitting can be done by hand with needles or industrially with a machine.

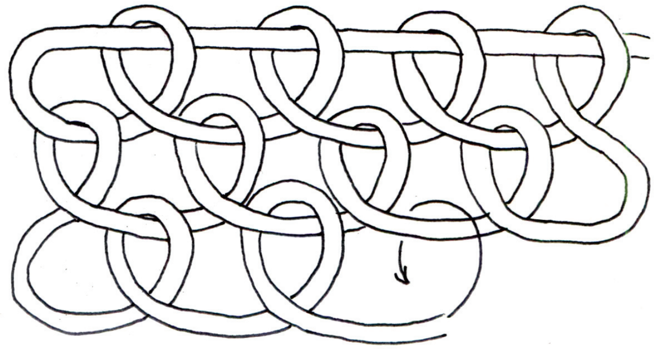


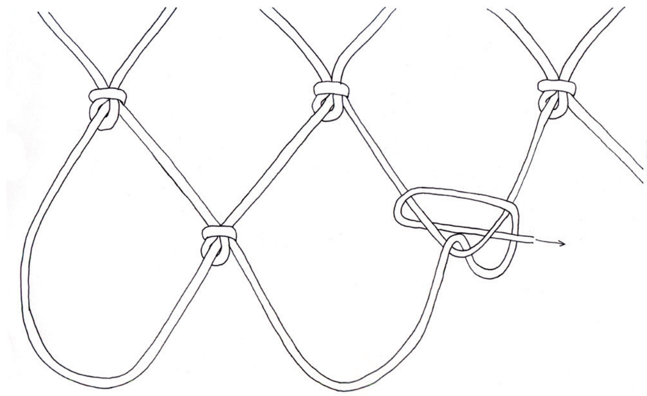
Left: Sprang technique explained.
Right: frame and dowels.

Sprang

Sprang creates a fabric that is symmetrical along a horizontal centre line. Like knitting, it creates a flexible and stretchy fabric. The technique requires a frame and pointed dowels, there is no method of industrial fabrication.

Netting





Top: looped structure.
Second from top: knotted structure.
Second from bottom: flying shuttle for making nets by hand (photo from Baltimore Industry Tours).
Bottom right: net making machine (photo from Gabion Machine).

Netting can be stretchy if the points are looped rather than knotted. Knotted netting is less malleable. Knotted nets perform better in tension than a looped net.

Wool and Architecture

Expanding on these traditional techniques, modifications were made for architectural use. Because wool is a weak fibre, it makes a weak fabric. Wool is often blended with other fibres for strength. In the felting process, this study adds other fibres to give the felt tensile strength. A technique was developed to felt textiles made from other fibres directly into wool, creating a composite fabric. Felt can be made to any thickness and density in a simple process, in this technique, felt reinforces the woven structure underneath, allowing the weave of the interior structure to be looser than it otherwise would be. Samples were made with cotton, sisal and nylon using a looped, knit and fishnet technique.

Cotton plant (photo from Jake Davis).

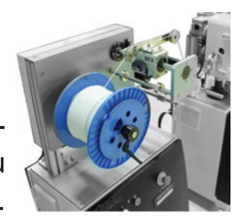
Cotton

Cotton is a soft, natural fibre. It's readily available, although not locally grown.

Sisal plant (photo from Pinterest).

Sisal

Sisal is a strong, durable and natural fibre that maintains its integrity when wet. It is grown in warmer climates than Canada and cannot be locally sourced.

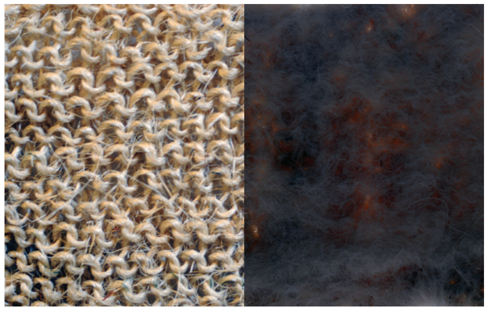
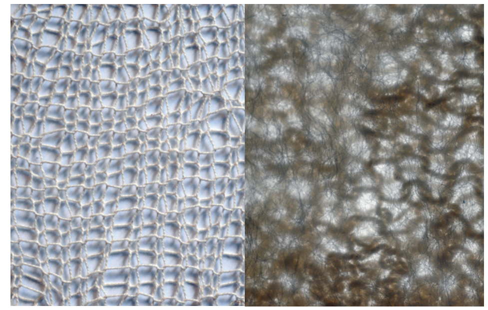
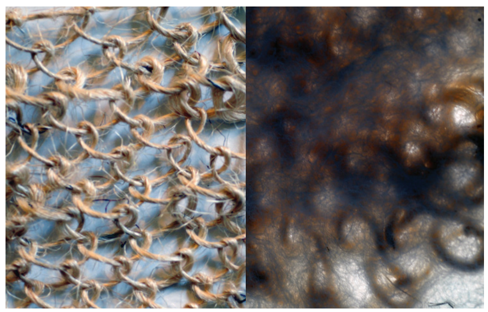
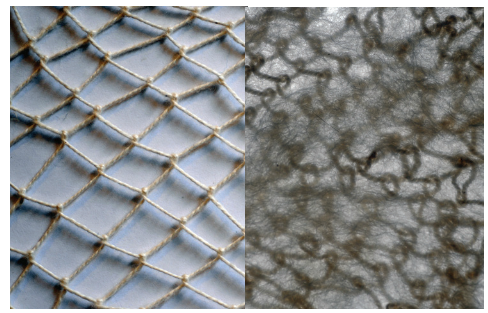
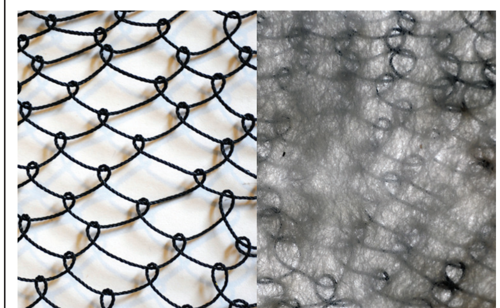
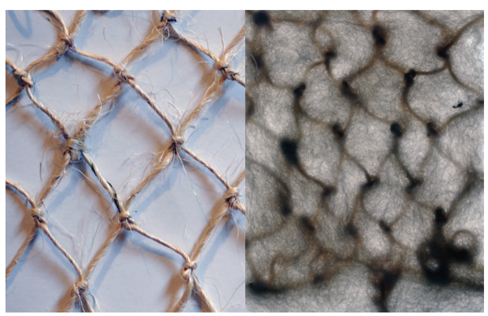


Extruding nylon (image from Suzhou ACC Machine Co.).

Nylon

Nylon is very strong and resistant to breaking down. Being a synthetic material it negates the natural advantages of wool. Because of its use in the fishing industry, the material is easily available as well as the labour to make it into fabric.

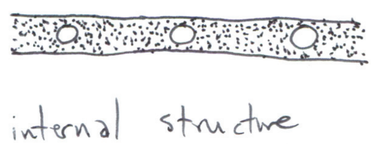
The double structured textiles that came out of this experiment combine strength with insulation and wind/water resistance. They can be used in tension withstanding much more force than they would be able to without the internal structure. Light exposes the internal structure, which could be used as a design feature.

	SISAL	COTTON	NYLON
KNIT			
LOOPED			
FISH NET			

Each fabric is seen here, first before it was felted (on the left) and then after felting (right). The most interesting results were from the knit sisal which became very thick and stiff, and the nylon fishnet which was very strong. The cotton was flimsy, a different cotton yarn should have been used. The internal structures are visible through the wool and the fabrics are translucent, responding well to lighting.

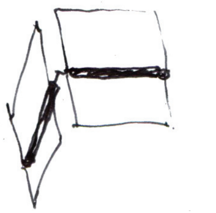
Rigid Internal Structure

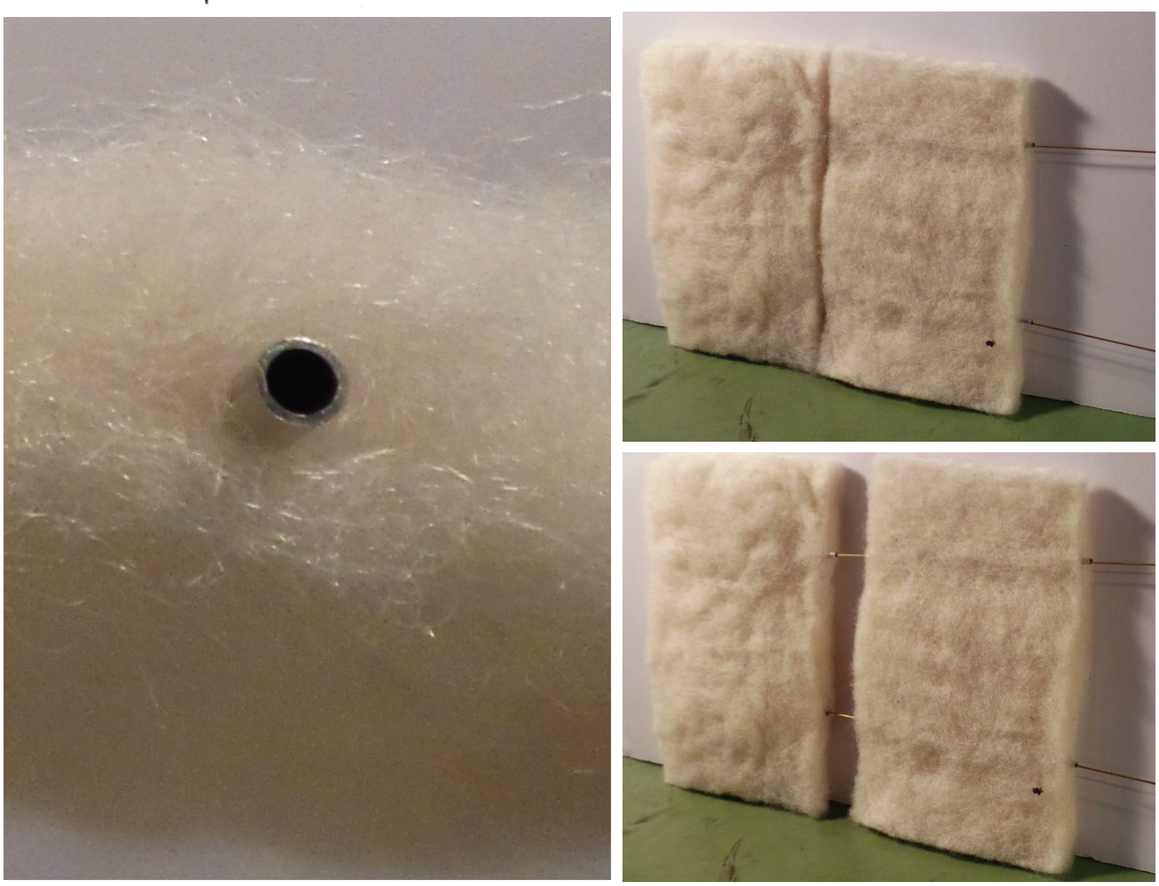
The next technique added to felt was the addition of rigid internal structure. Wood can be felted into the wool, which is able to be steamed and formed after the fabric is made. Although this was an interesting process, the wood is much easier to add after the wool is felted.



Bamboo skewers were added to the wool before felting, then steamed into shape after felting. A simpler method would be to put the wood into the wool after it has been felted. Another option would be to run the wood through a sleeve of a more abrasion resistant fabric to protect the wool, this sleeve could be added before felting.

Building on the idea of a rigid internal structure, metal tube were felted into the wool. Rods were then run through the tubes, turning the felt into sliding panel.





Like the wood, the tubes would be better to add after felting. The tubes could be made with a flexible material more like a garden hose, than the metal used in this experiment.

Coatings

Coating wool in other materials can help with waterproofing and windproofing, abrasion resistance, longevity and structural qualities. The way wool accepts the coating is necessary in determining its success.

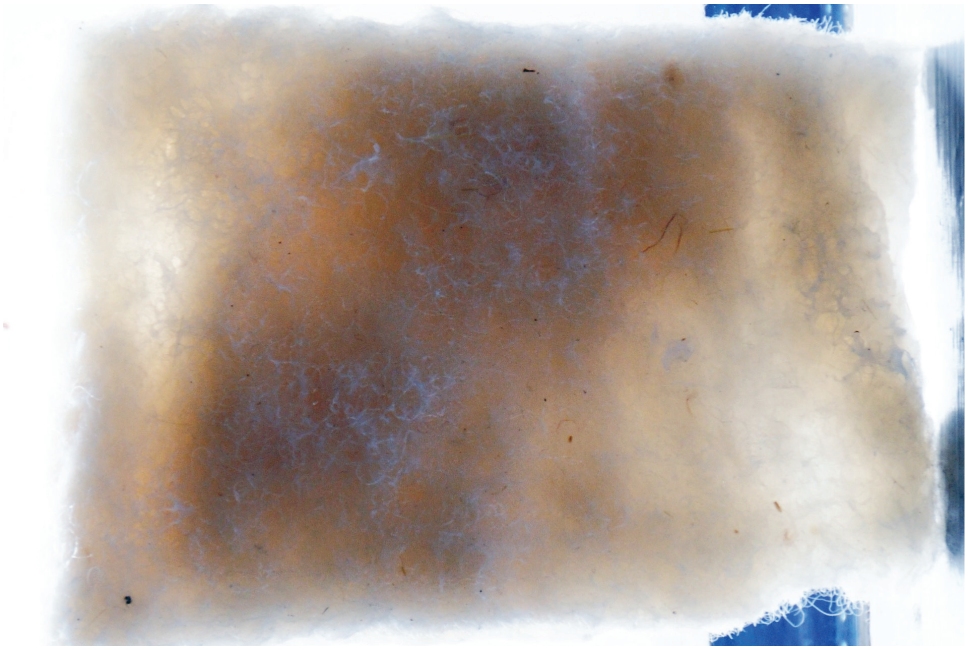
Wax

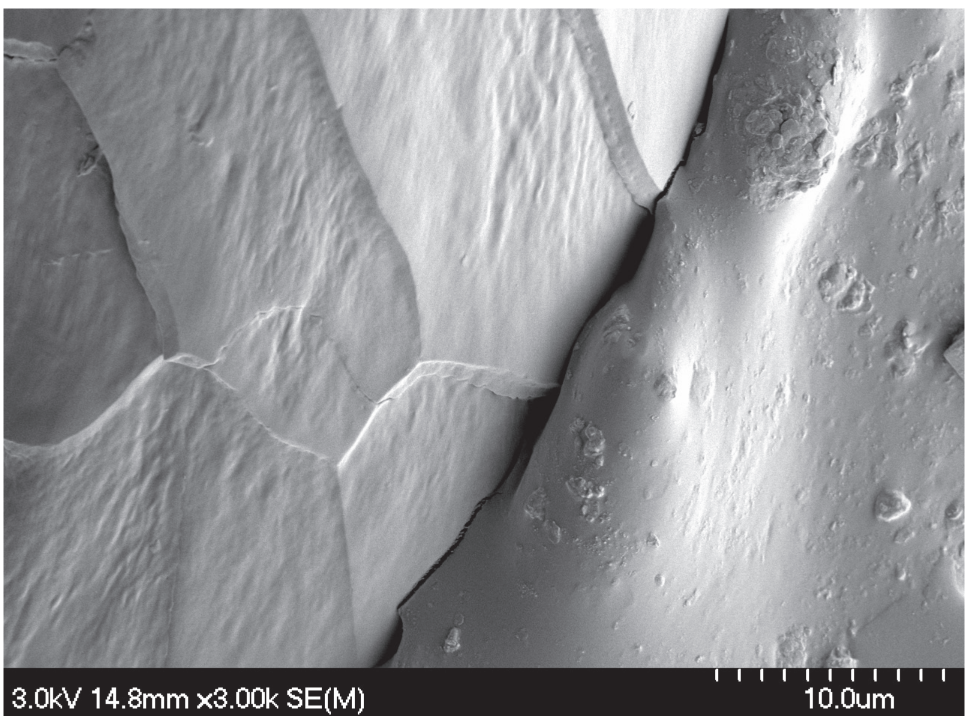
Wax was used before the invention of synthetics to waterproof and windproof fabrics. It needs to be reapplied once a year, it can be reapplied as a spray. It's a natural, renewable and healthy material. Exposure to direct sun is a concern.

Wax changes the aesthetics of the wool giving it a yellow and toned look.

Silicon

Silicon maintains the flexibility of wool and makes it waterproof and windproof. Many architectural fabrics are coated in silicon.

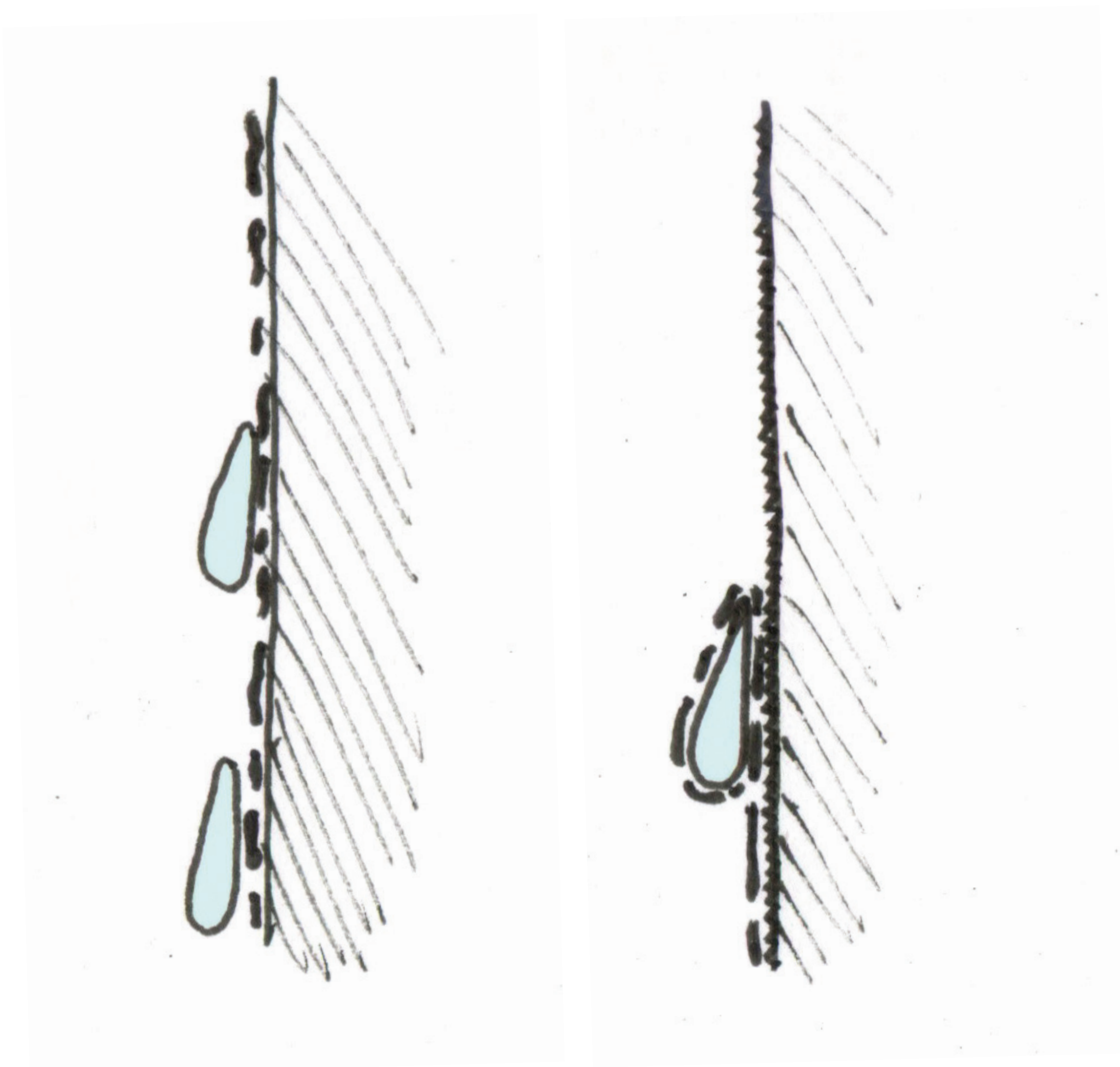




Top: This sample was coated in silicon.
Below: Under an electron scanning microscope, it can be seen that the silicon does not fully wet the wool fibres in the sample. A wetting agent should to be considered (photo by Patricia Scallion).

Teflon

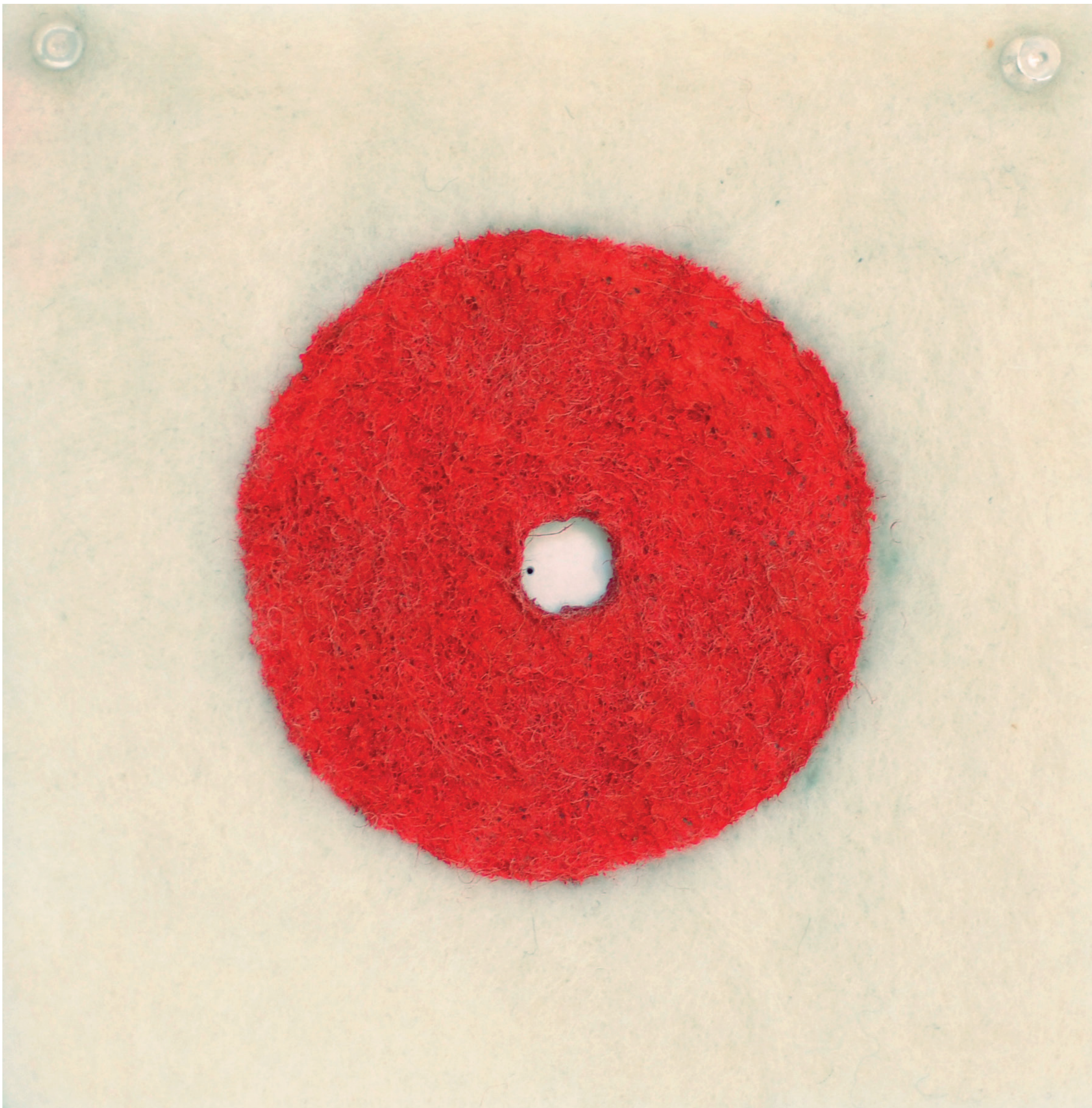
Teflon is a common coating for architectural fabrics. Teflon creates a water repellant surface that has minimal surface area for dirt to adhere to. Dirt that collects on the surface is easily washed away with rain. Its disadvantage is that it is not a natural material.



Left: Dirt bonds to the uncoated surface.
Right: Dirt is unable to bond with the teflon coated surface and is easily washed away.

Rubber

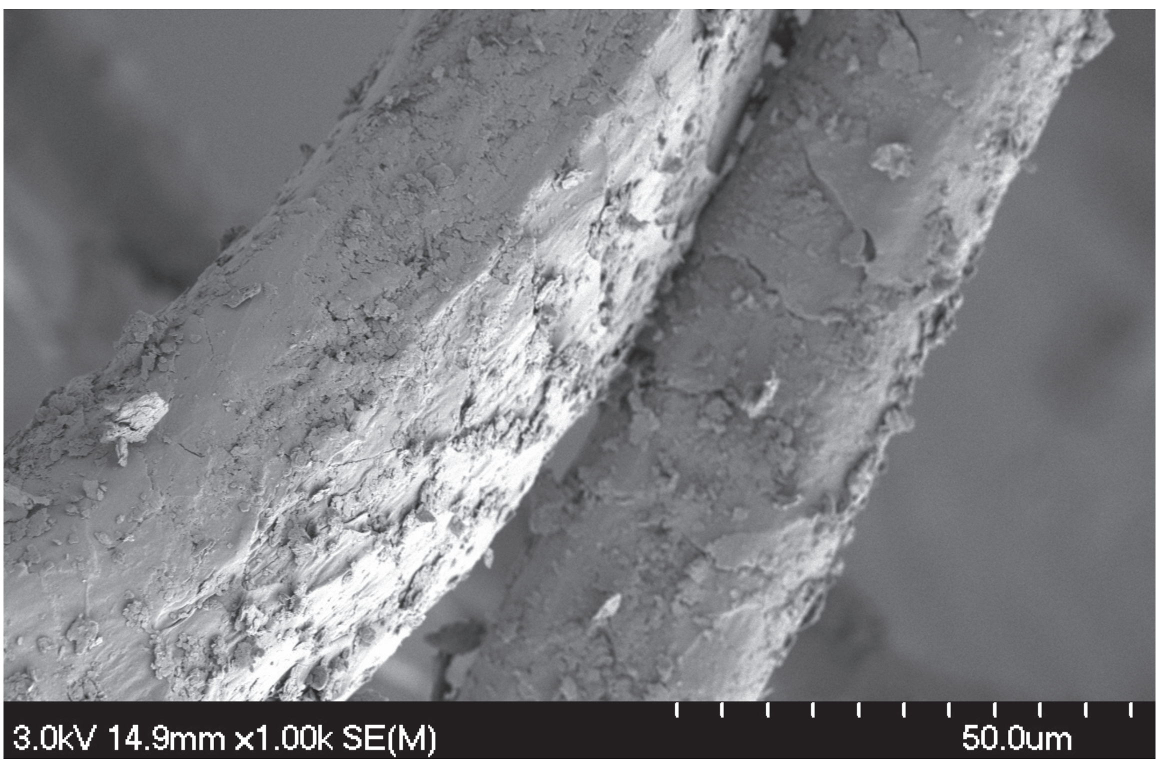
Rubber adds stiffness to the fabric and provides abrasion resistance. Rubber can be naturally, although not locally, sourced from trees. Rubber windproofs and waterproofs the fabric it is coating.



Synthetic latex with acrylic pigment was used to enforce felt.

Clay

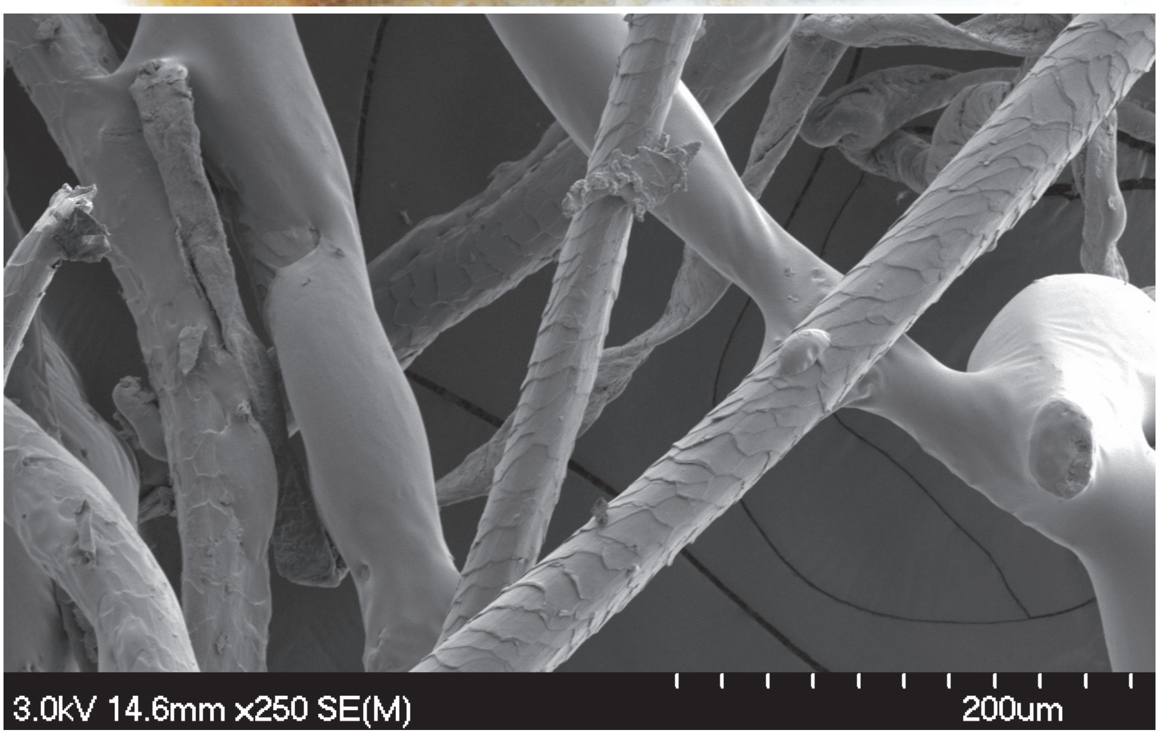
Wool can be used as a binding agent for muds and clays. Clay is found in the Bay of Fundy as a local and natural option. Rammed earth is a sterotomic use for wool.



Top: This sample was coated in an air dry clay.
Below: Under an electron scanning microscope, it can be seen that clay fully wets the wool fibres in the sample, making it a good pairing of materials (photo by Patricia Scallion).

Resin

Resin adds rigidity to the wool allowing it to hold a shape and become very strong. Resin is used in boat building and surfboard production; Nova Scotia has many skilled resin workers. Resin is a highly toxic material, because of its advantageous qualities, it will be used for experimentation in this thesis, but will not be proposed for use in a building material.



Top: This sample was coated in resin.
Below: Under an electron scanning microscope, it can be seen that resin has a difficult time wetting the wool. A wetting agent should be considered (photo by Patricia Scallion).

Cedar Resin

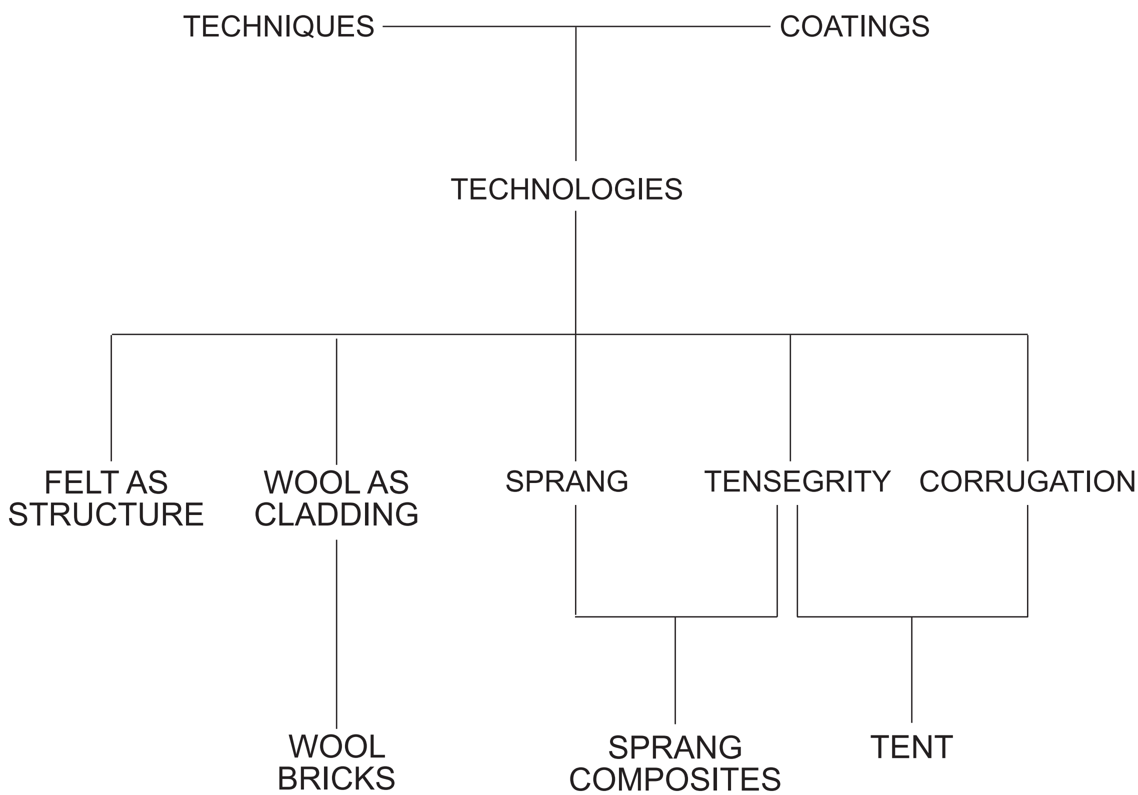
Cedar resin is not as strong as synthetic resins but maintains similar qualities. It's natural, and locally sourced from the cedar tree. Cedar is often used to make wardrobes and cedar balls are stored with woollen clothing because it repels moths and other insects. Unfortunately, cedar resin is highly flammable and negates wool's fire retardancy.

Although cedar resin is locally available, it is not on the market. Maple syrup was used to resemble the qualities of cedar, as seen in the above photo.

CHAPTER 6: ASSEMBLIES

Technologies

The material palette established in the study of techniques and coatings was a starting point for the studies of technologies. These technologies were considered architecturally and developed into products.



Felt as Structure

Felt itself is able to be structural. A dense enough felt will hold its shape. The Turkish kepenek is an example of this property.

Shepherds wear a kepenek when out with their flocks. They provide shelter from the elements and act as a coat, sleeping bag and claimer of space (photos clockwise from left: Joy Merron, Pinterest, Ankara University Photo Gallery, Cary Wolinsky).

These images show the process of making a kepenek by wet felting. The kepenek is made in two pieces which are felted together. The photos are from Milli Folklor.

Placing the embellishments.

Arranging the wool.

Wetting the edges.

Tidying the edges.

Wetting the rest of the wool.

Rolling the wool to put on the felting machine.

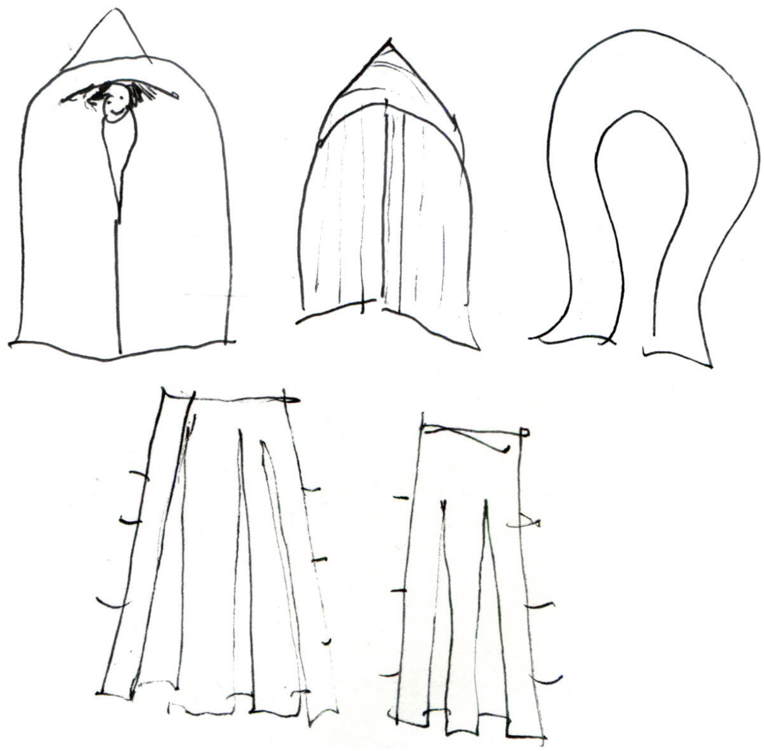
The felting machine agitates wool.

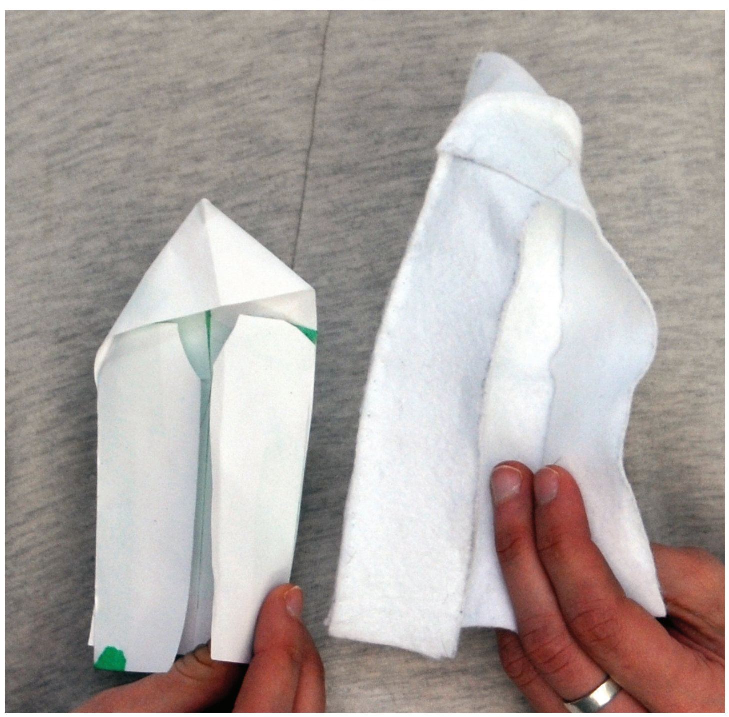
Edges are adjusted, and the front and back of the kepenek are attached with a seam running from the shoulders down the side.

The felt is returned to the felting machine.

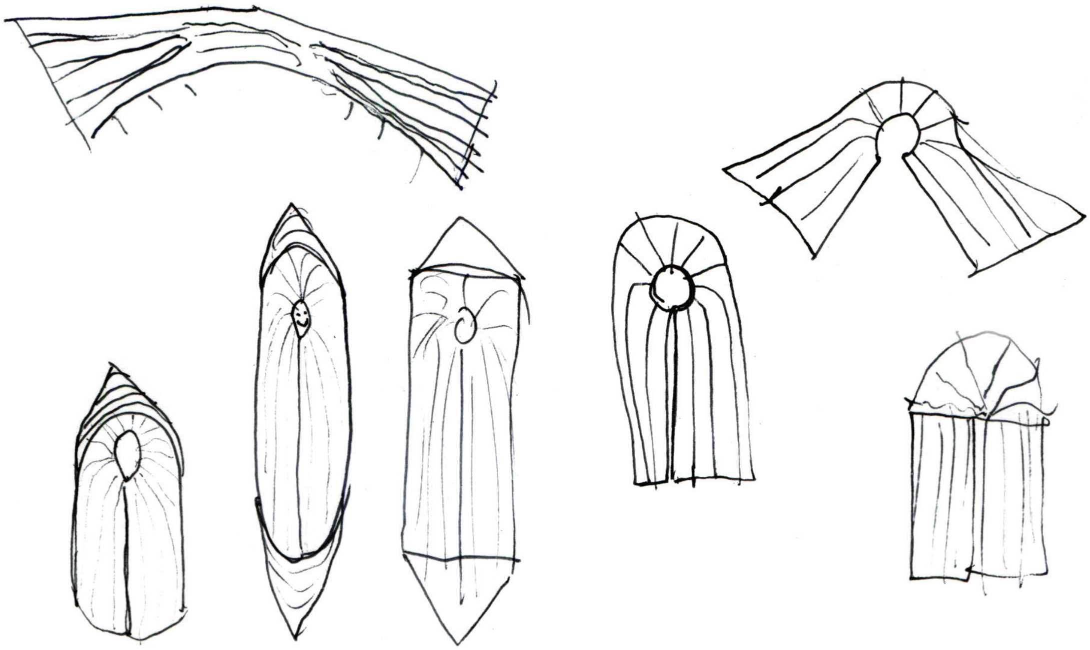
The front is cut in half with neck hole.

The kepenek is an interesting example of the similarities between fashion and architecture, this study designs a kepenek to learn from the process and adapt it for contemporary use. Enclosure is an important element in this kepenek, adding a foot compartment and zippers to the traditional design.

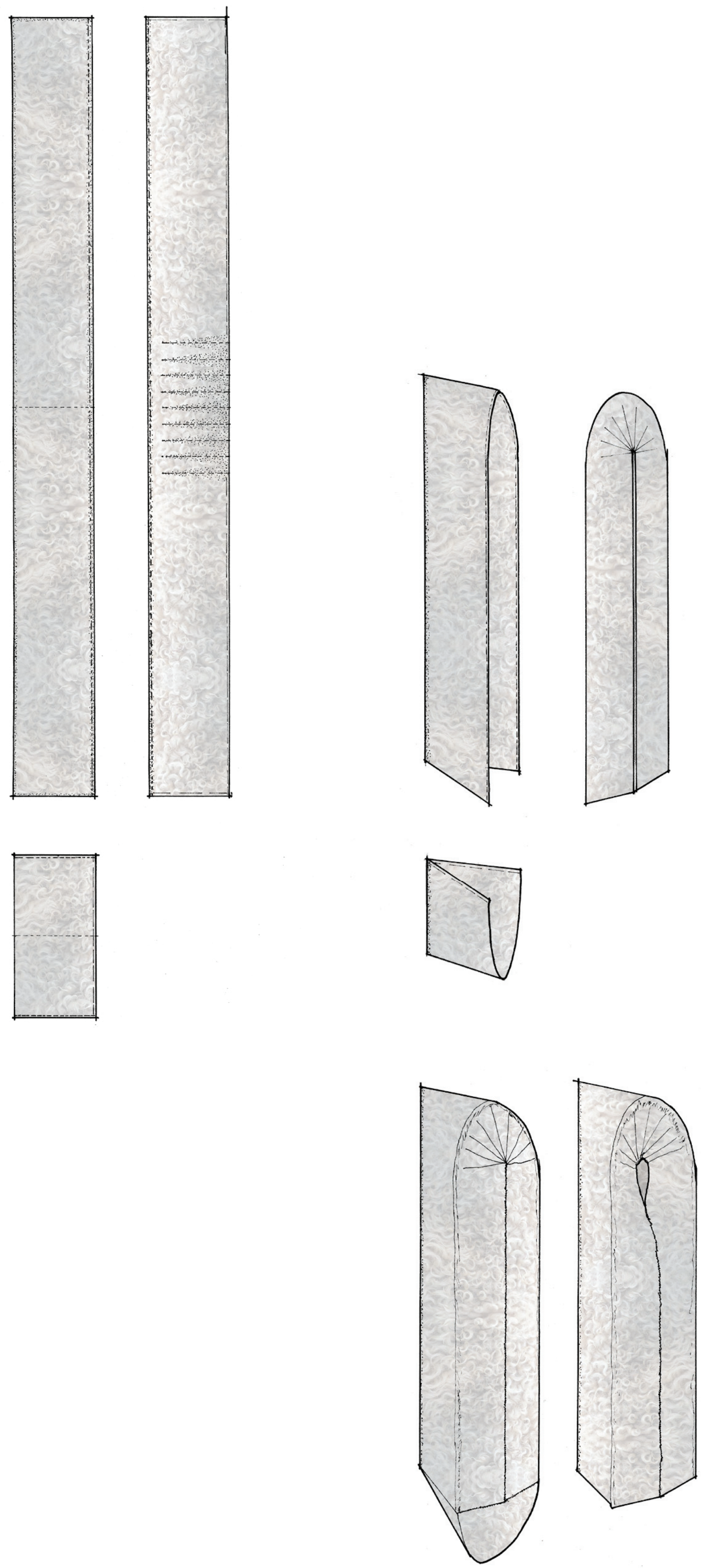




Traditional kepeneks are made from two pieces of fabric. This study played with ways of folding two pieces of fabric to start to form the hood.



Thoughts of pleating the fabric so the kepenek could stand up like a hut were modelled. A foot flap was added to the bottom of the kepenek, it is folded to the back when the kepenek is work as a cloak and unfolds to cover the feet like a sleeping bag.



In the final design, the kepenek is made from 3 pieces of fabric: a back, front and feet. The seams are all felted.

Top: the kepenek being worn as a cloak.
Bottom: the foot compartment being unfolded.

Top: zipping the foot compartment shut.
Bottom: the liner of the hood pops out over the head to enclose the occupant.

Top: the kepenek is fully enclosed when zipped shut.
Below: scraps from weaving and carpet manufacturing could be used to build up thickness. These srcaps add colour and are used in the inside of this kepenek.
Bottom: the feet of the kepenek fold into the coat and button to the back.

The kepenek is suited for people who are outside in the weather for extended periods of time. It gives a sense of interior space when in the outdoors, it could be a makeshift solution for homelessness, as well as a novelty camping abode.

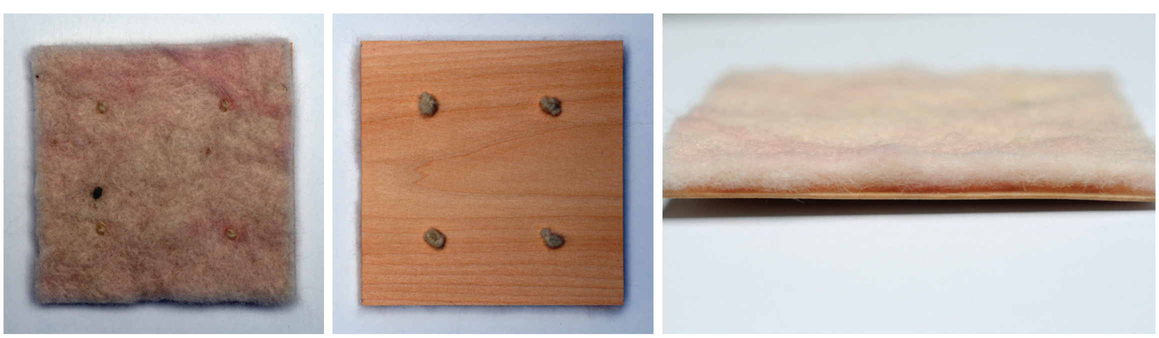
To continue working on the kepenek, coatings and the “mattress” condition would be further developed. The back of the kepenek becomes a sleeping surface, it would require a different coating where it hits the ground and could use extra padding for comfort.

This collage demonstrates the kepenek’s potential to be used by homeless people. A Turkish shepherd is seen next to the main character from Jason Eisener’s film *Hobo with a Shotgun* under MacKay Bridge in Halifax.

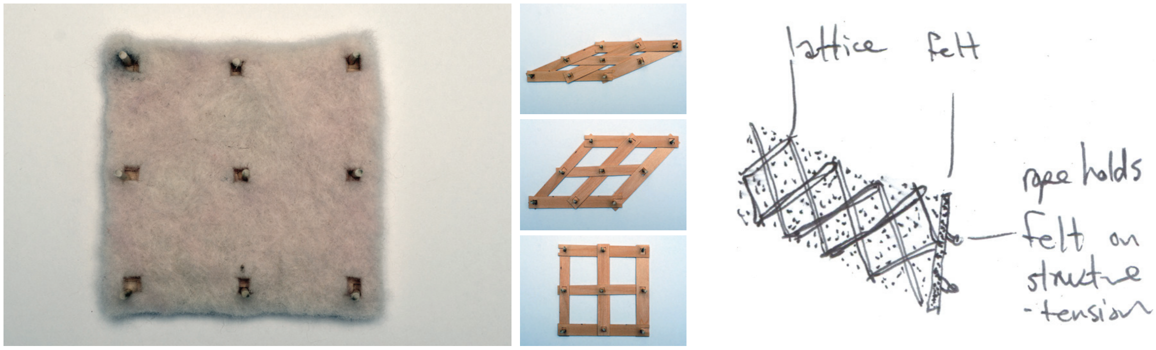
Wool as Cladding

This experiment looked at ways to fasten wool as though it's a skin to a structure. On the sheep, wool is rooted into the epidermis with a follicle, see page 16 for details. The skin acts as the structure supporting the insulating fibres. Wood was considered to act like the skin supporting a layer of wool cladding in this study. An inch of felt has an r-value between 1.7-25.4 depending on the density, the wool would act as both cladding and insulation. Coatings would be needed for the wool to withstand the weather.

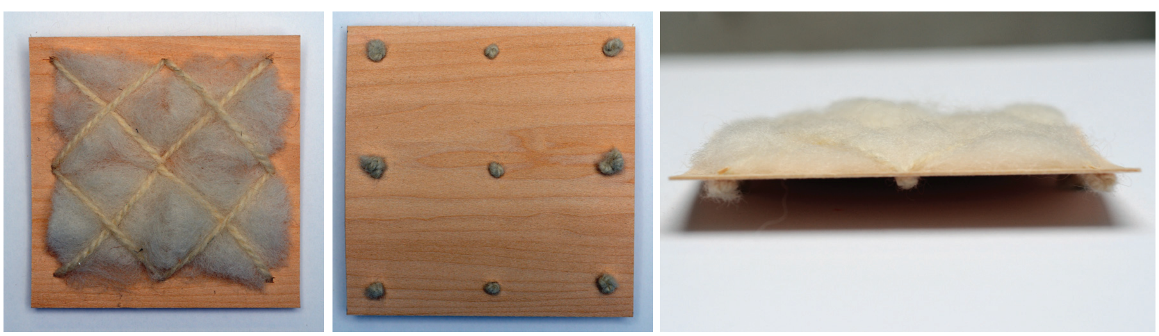
Wool is rooted to the epidermal layer by a follicle. When attaching felt to wood, the felt is sewn at evenly spaced connection points. When attaching batts to wood, they are sewn, with stitches holding down the corners of the batts.



The sewn points are held in place with knots on either side of the assembly.

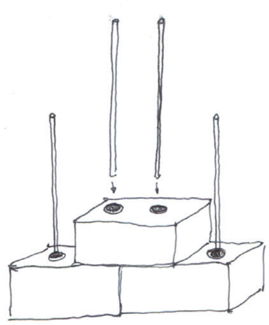


The same method of sewn points should be used on a wood lattice rather than a sheet of plywood. This sample used wood pegs as the connection which caused a break in insulation. This is a take on the lattice of a yurt. Wool is held to the lattice by a rope surrounding the circular structure. This sample allows the assembly to be a panel rather than depending on the circular structure.



Unlike the large sheet of felt, batts are smaller and need to be secured at the corners. These connections are knotted on one side of the assembly and stitches hold down the batts on the other side of the assembly.

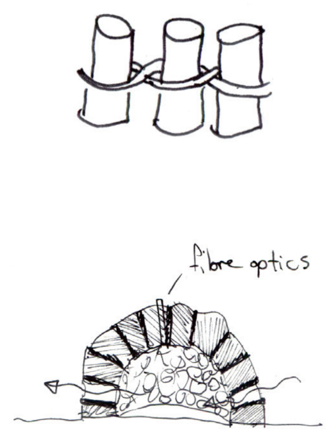
This study evolved into an idea of a “wool brick”. Sheets of felt are stacked and sewn together. The bricks would be assembled by running structure through them, using tension to compress them. The wool is dense in this assembly, lowering the r-value. The sample bricks made for this thesis have an r-value between 14.5-100.



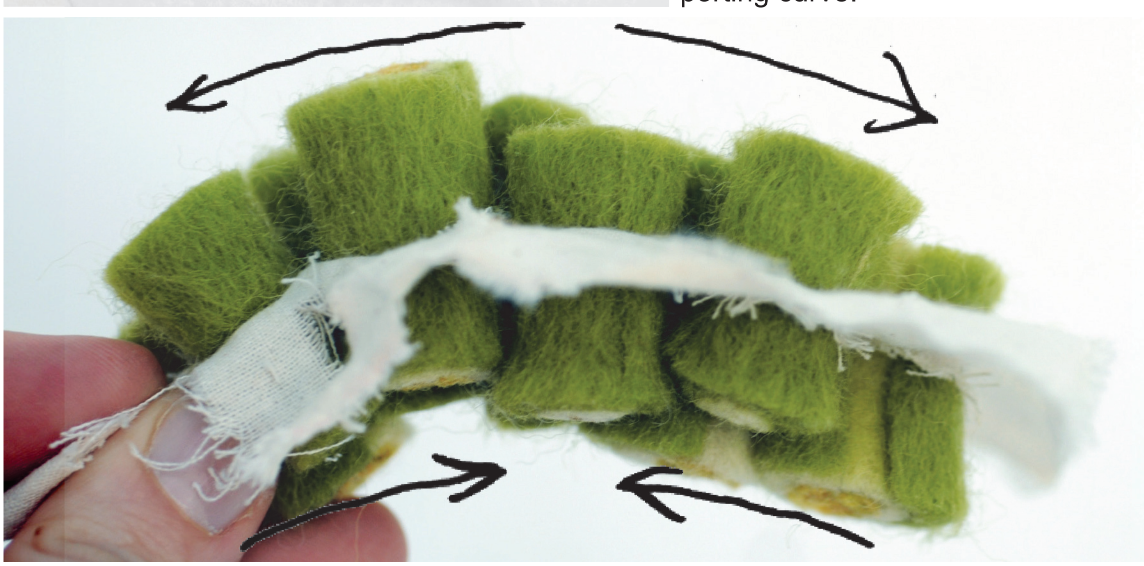
Structure running through “wool bricks”.

These sample bricks include colour.

Instead of stacking felt, this experiment looked at rolling it, making a cylindrical brick. The bricks are connected with a membrane, allowing them to remain flexible. They stack upon each other to hold a shape.



Top left: A cotton fabric was used as the membrane in this sample.
Top right: Taking this model further, I would use a net rather than a woven fabric, or use yarn to weave the bricks together. This system could be used to make arches and domes.
Below: The bricks form a self supporting curve.



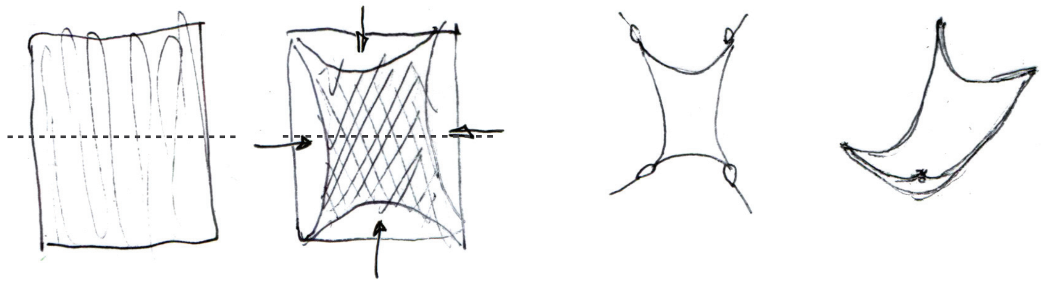
The “wool brick” could be used in a facade wall, or as a party wall because of its acoustic properties. The potential of this study will expand when design is taken further.

Designing the structural system used with the brick is an important next step. This system would vary depending on the building it is being used in. If the wall is a facade, the coatings on the exterior surface would need to be considered.

The study with the round bricks and the membrane could be taken much further. Different membrane materials and rolling sheets of felt rather that felting them into a cylinder would be the next step.

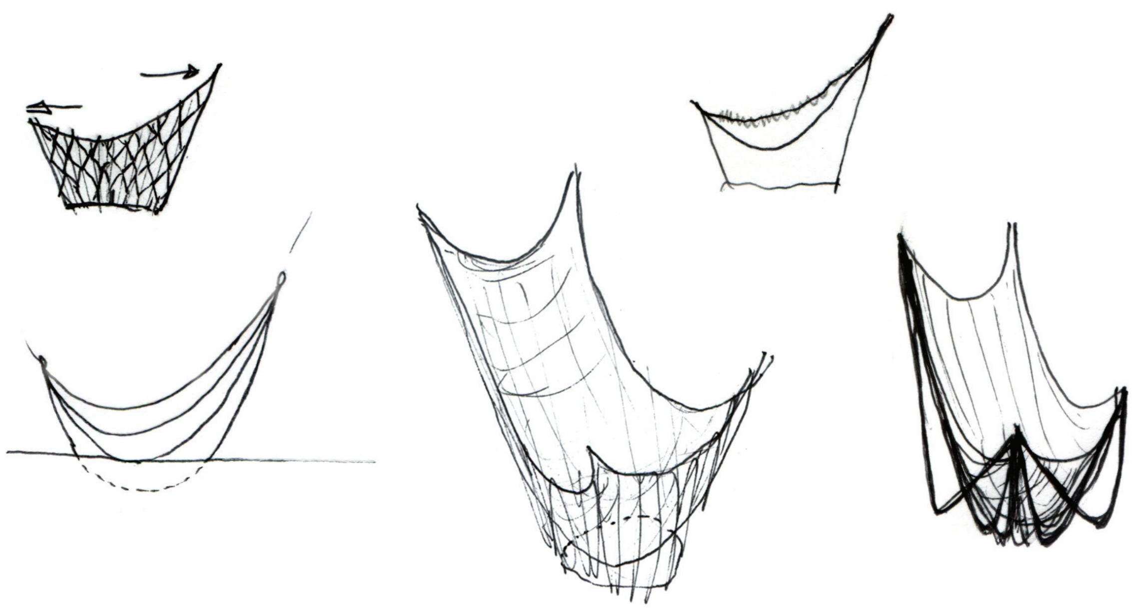
Sprang

When studying the sprang technique, the shape the fabric takes on was of interest. The fabric is symmetrical along a horizontal centre line and as the fabric tightens, the middle is pulled inwards. Sprang fabric is usually given form using a frame. Using resin, the fabric took form from its own weight.



Left: sprang fabric's natural form.
Right: suspended sprang.

This experiment resulted in a chair. The bottom of the chair is cast in resin and acts in compression while the top of the chair acts in tension. The four legs of the chair are holding the chair down rather than up.



Developing a chair design.

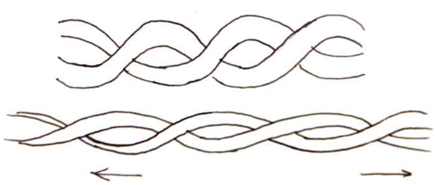
Precedents considered when designing the chair (photos of Mies van der Rohe chair and Grupo Austral chair from Vitra Design Museum, below photo from Marcel Wanders).

Model of chair.

The chair requires two types of yarn, one to perform in compression and the other in tension. Wool is not typically used in either compression or tension seeing as it is a weak fibre. The wool being compressed is being cast in resin and suspended. Felted yarn would perform better than a spun yarn because it acts like a sponge absorbing the resin.

Compression Yarn

Left: a single ply and double ply felted yarn were made by rolling out raw wool with hot water and soap.
Middle: the samples were soaked in resin.
Right: the samples were in half to see how deep the resin went.



Tension Yarn

After experimenting with braided yarns, an 8 ply yarn was decided to be the best option. This yarn repeats a spinning pattern to maximize strength and elasticity.

Photos from production process. Eleven litres of resin were used.

The chair as presented at the thesis defense. When sat it the resin cracks, it has not been tested to see if the cracking will stop and the chair will function.

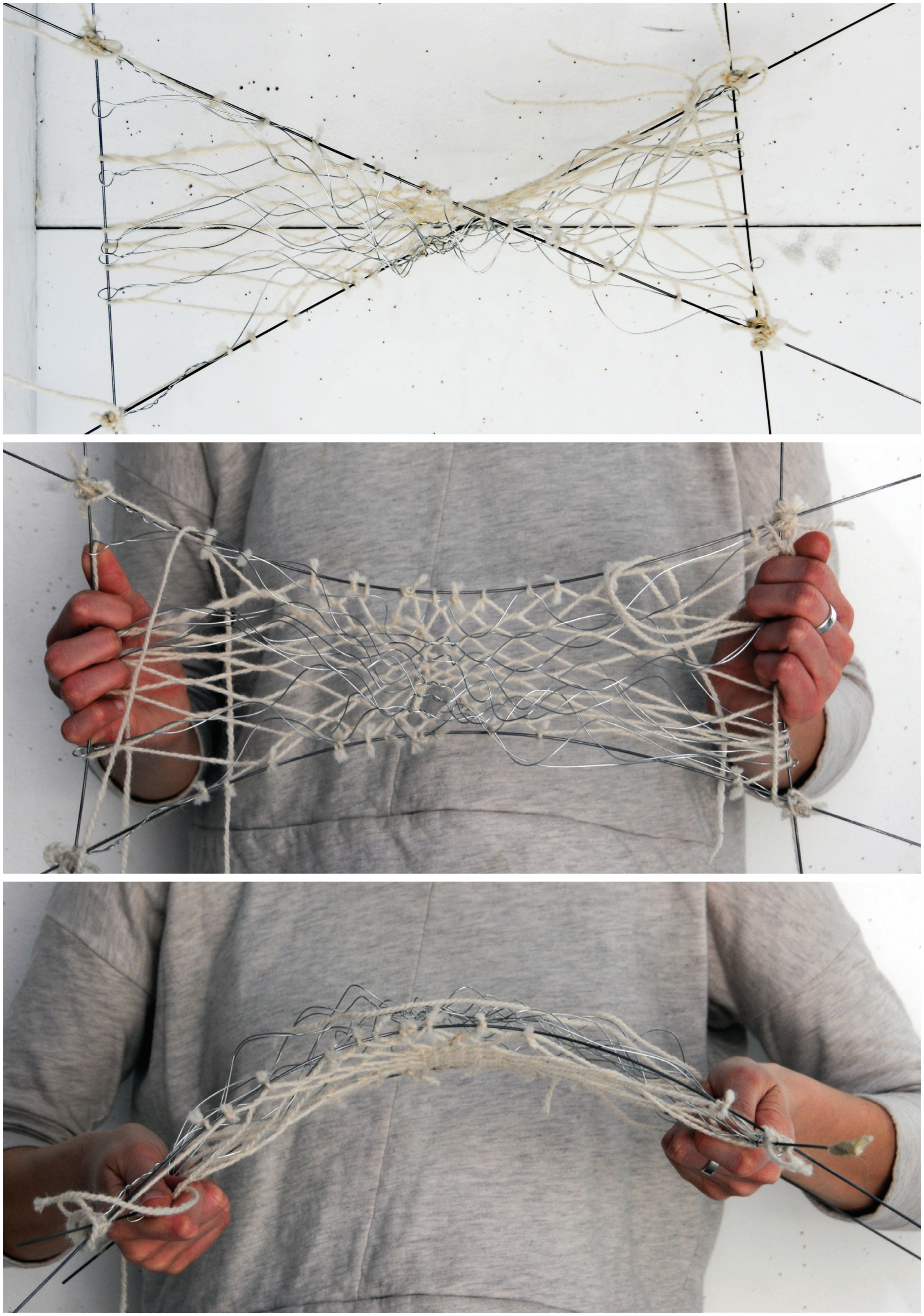
Out of the chair experiment came the study of how to use yarn in compression and tension. Continuing with the chair, natural resins would be used. Natural resins are not as strong as epoxy resins, this material change would require a geometry change as well. Making the chair replicable is important in determining its success.

The chair is a use for wool architecture that does not require a client who is building or renovating, it opens the use of wool up to a greater audience.

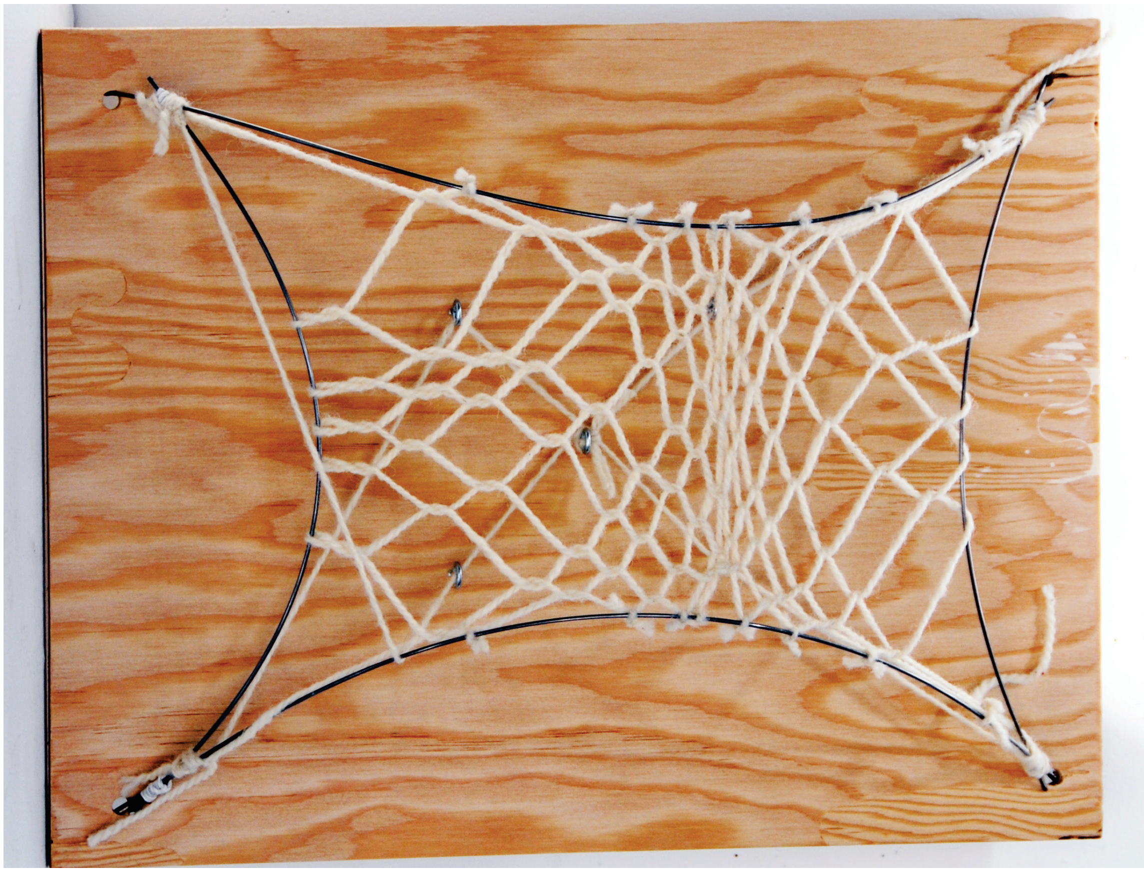
Sprang Composites

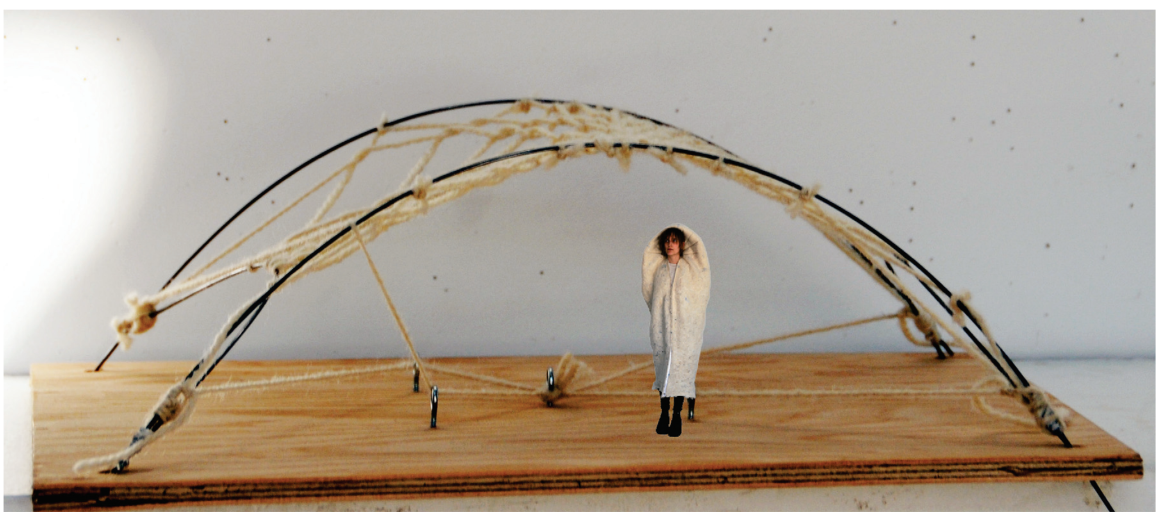
Continuing to explore the possibilities of the sprang technique without using resin, wood and metal elements are added to provide rigidity. Sprang fabric is made on a fixed frame which determines the fabric's form. Flexible frames were used to allow the yarn to give shape to the frame. As it made, it tightens and pulls the frame.

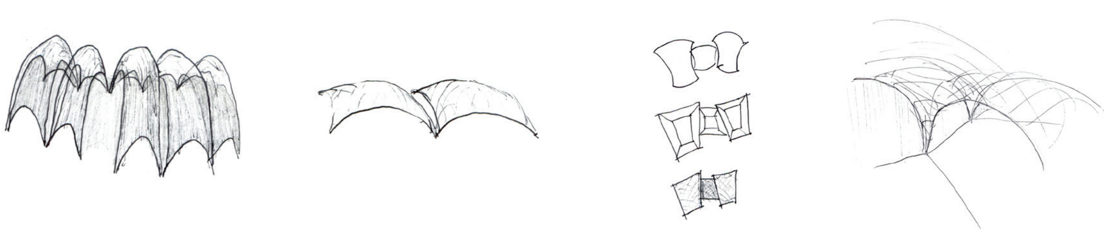
Samples showing flexible frames being distorted by the sprang technique.



The natural shape of the model is a hyperbolic paraboloid. This can become an extruded curve when stress is added.

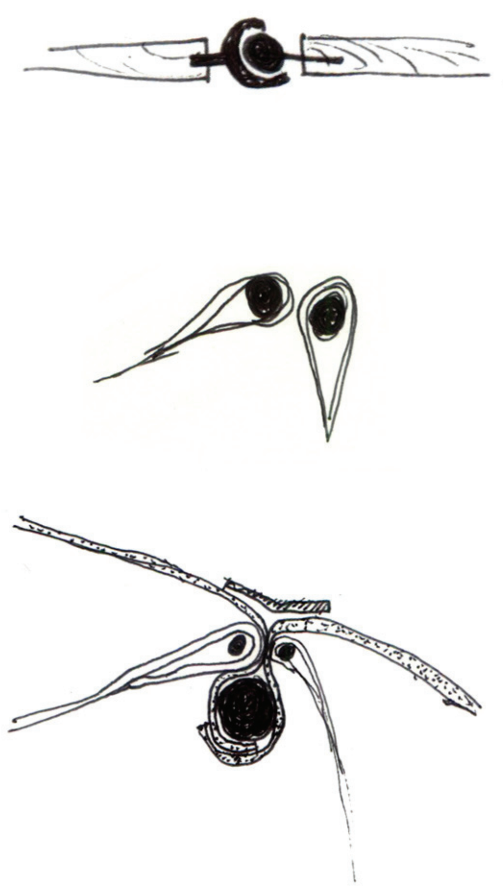




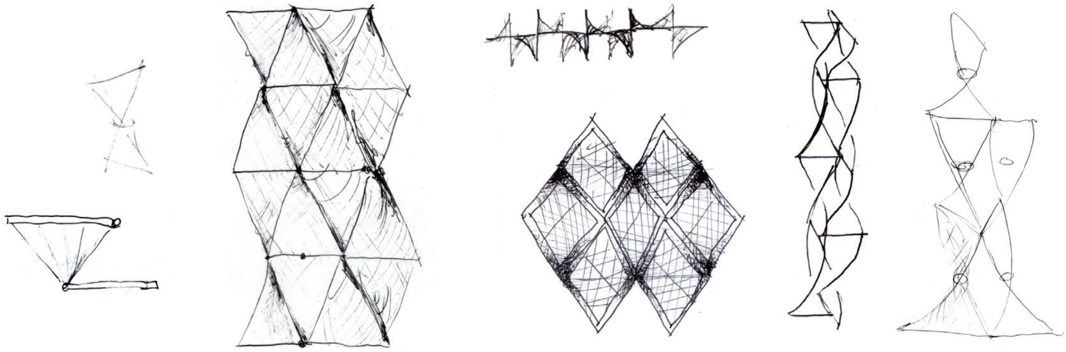


This idea was considered at the scale of a room. Connections between the rooms are like the disks between vertebrae.

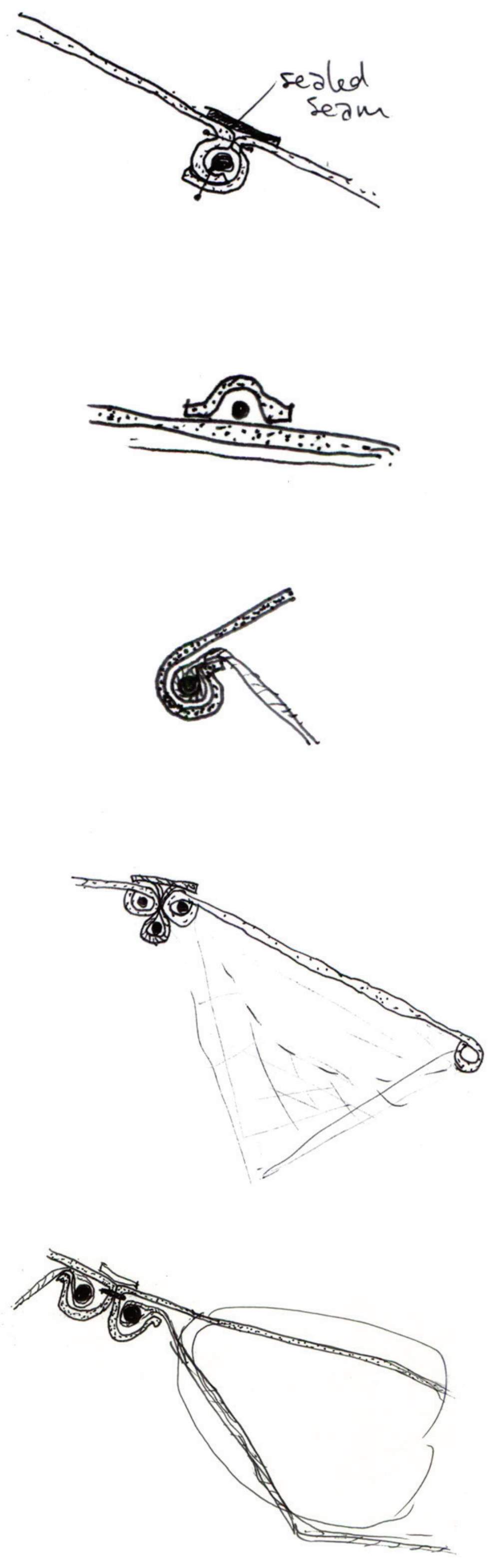
Connections are the most fundamental detail in this type of construction. Methods of connection are seen in gridshells (Siheru Ban), the use of ETFE panels (Sattler Global) and nature (photo from National Geographic).



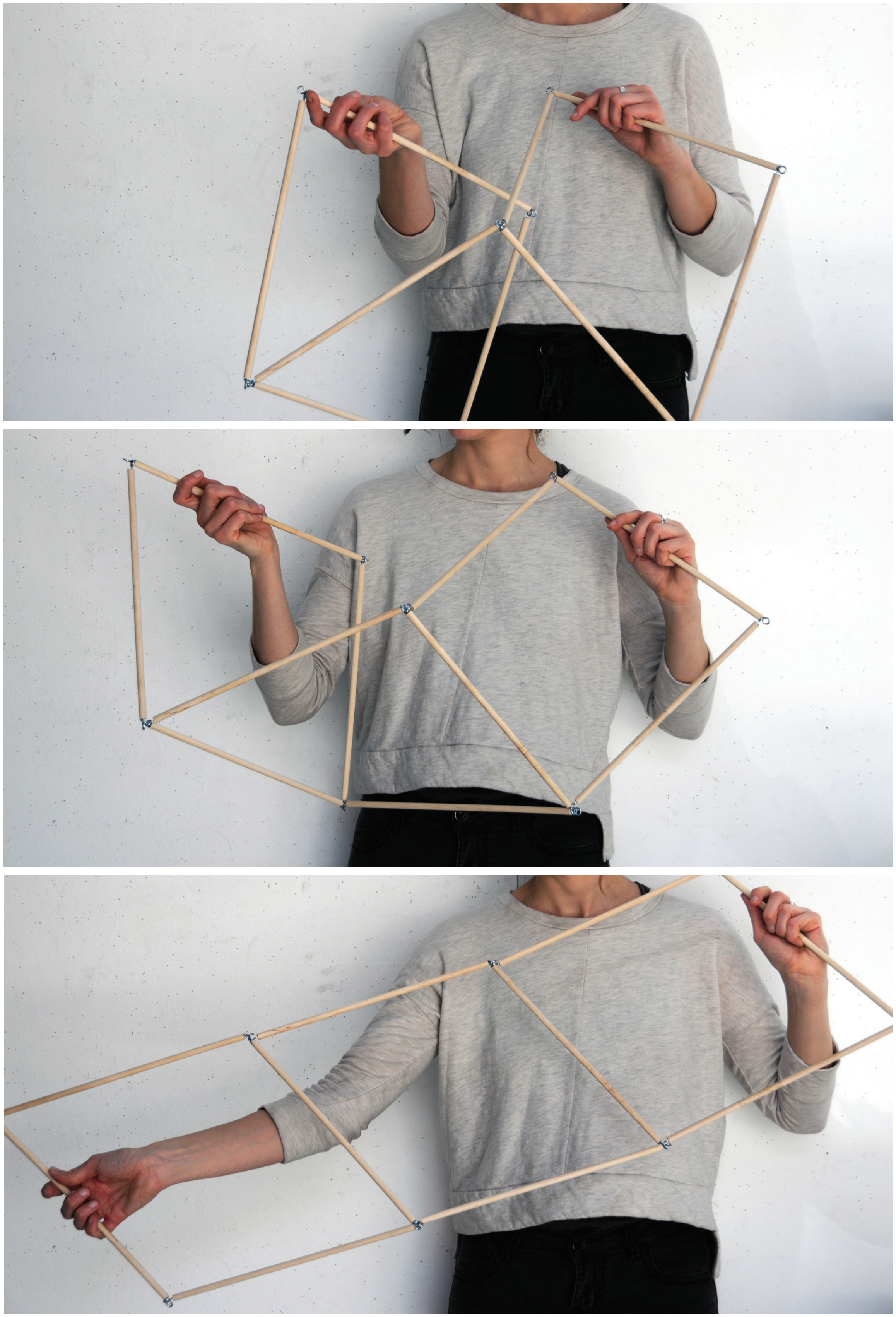
These sketches show detail development, connecting the panels to each other could be done before the sprang technique is applied or after.



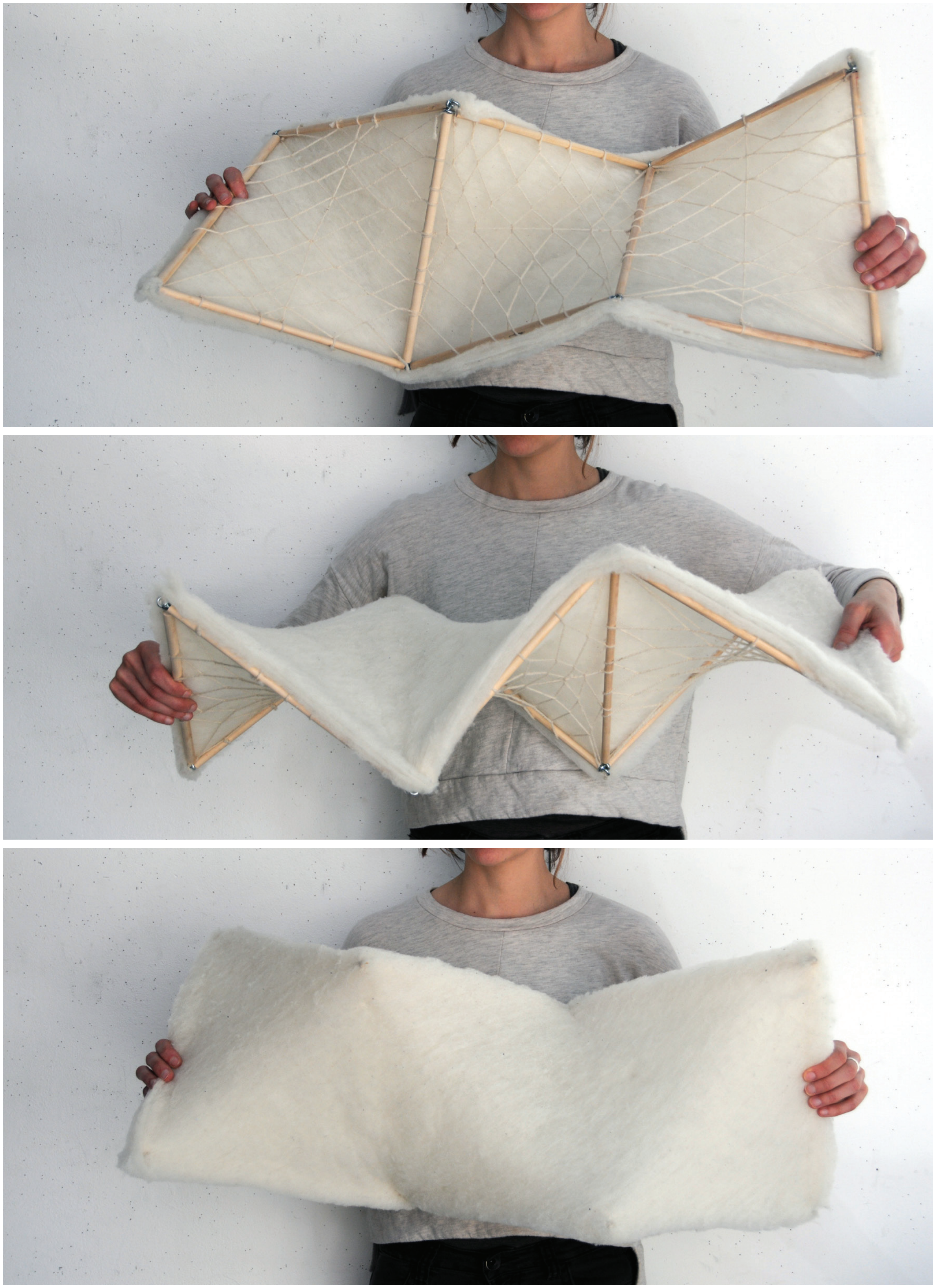
These frames are assembled with pin connections, although the wood is rigid, the frames are flexible at their joints. They were tested to find ways they could be assembled to become a structural system.



The exterior cladding could be rolled around the frame before the frames are connected or sewn on top of the already connected frames.



The frames are assembled first. They lack structural integrity.



Once the sprang technique is applied the frames become rigid. Batting is used for insulation, there would need to be another layer on top of the batting for weather proofing. This layer would be a much denser felt with a wax coating. The batting is only sewn at the necessary points to minimize water penetration.

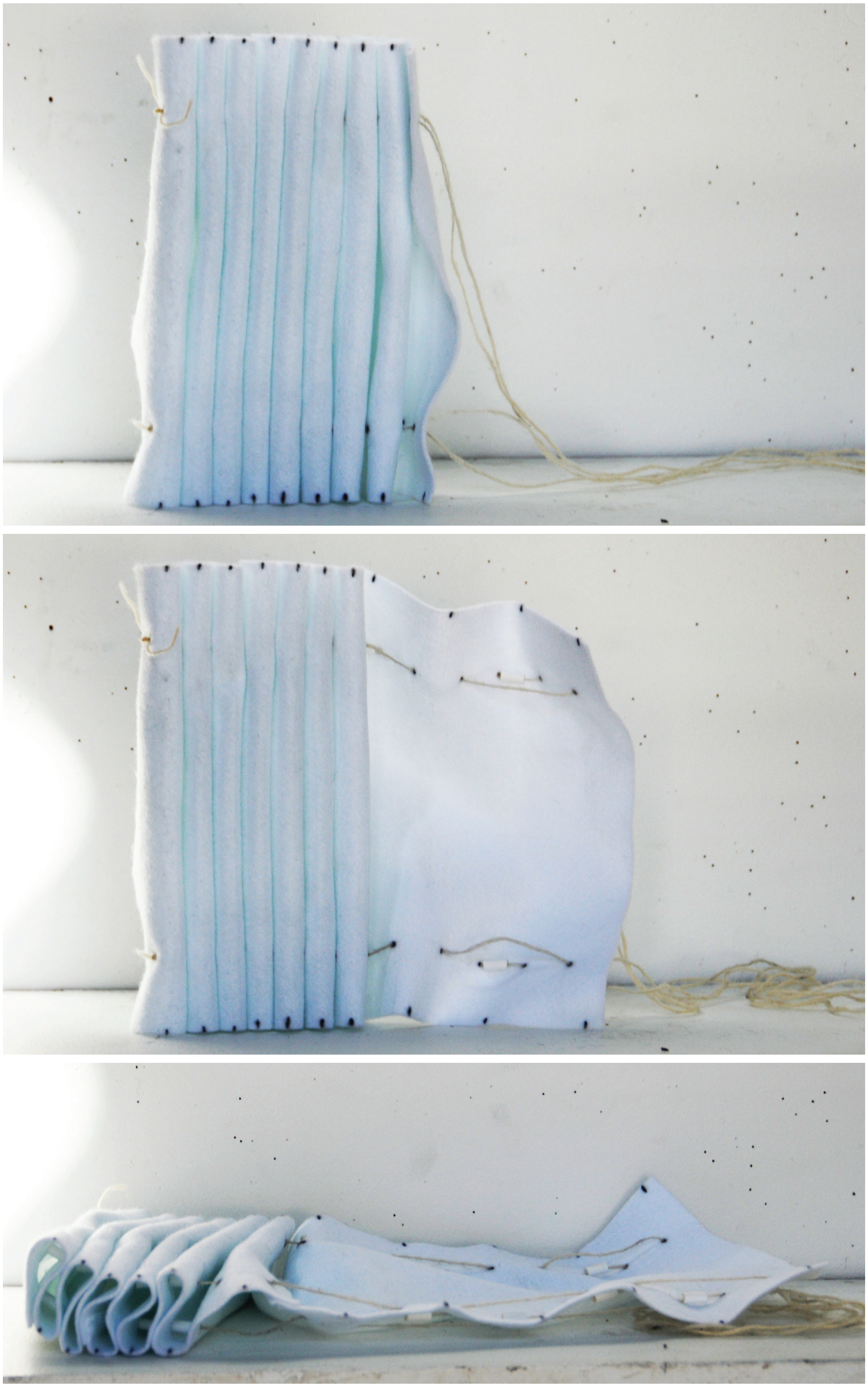
The wall created by these panels is intended for a niche market. These panels require a high level of craft and would likely be used for small buildings or small elements of large buidings.

The panels need to be integrated with a structural system, it could be a tensile or permanent system. Attaching the wool exterior to the frame is done with stitching, this punches holes into the fabric, eliminating the waterproofing. This can be solved by sealing the seams, or by exploring stitching alternatives. Inuit stitching does not fully penetrate the fabric, leaving one side waterproof, this technique should be explored.

Corrugation

Considering felt in a self supporting way, I used corrugation to give a flat sheet the ability to "stand up." This concept was used to design a wall.

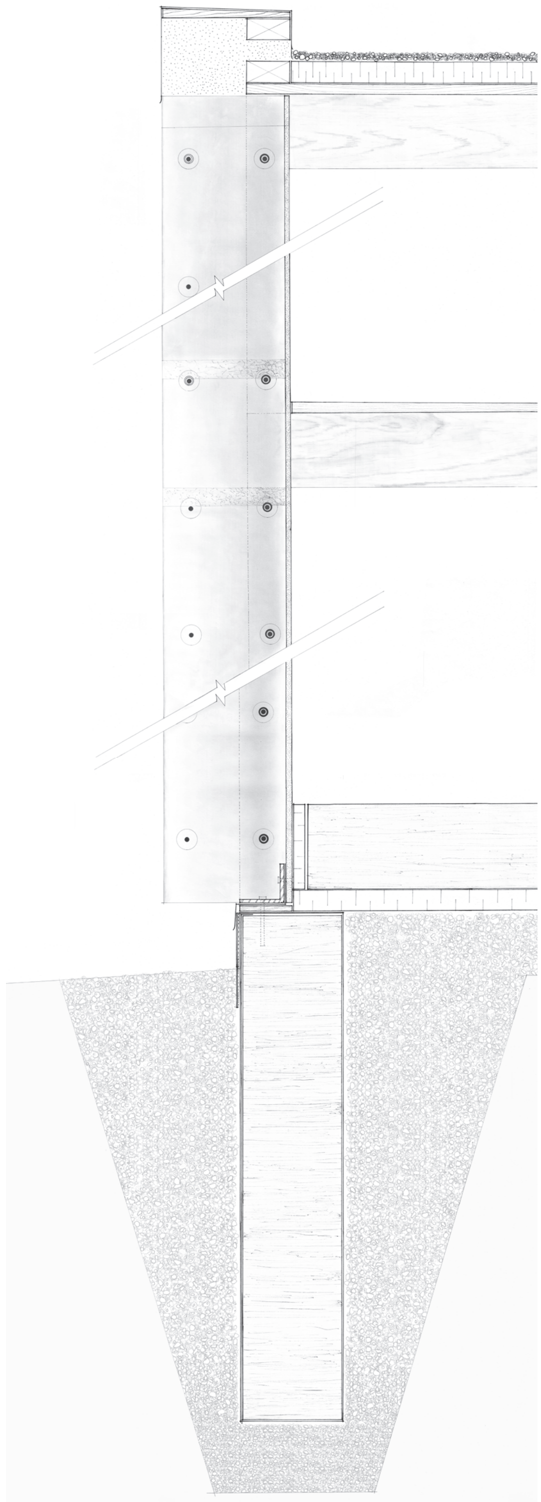
Nature is full of patterns that give strength to weak elements. The vertical structure of the celery was precedent for design of the wall (celery photo from Taylor Farms Foodservice, grass photo from Masterfile).



A flimsy piece of felt stands up when it is corrugated.

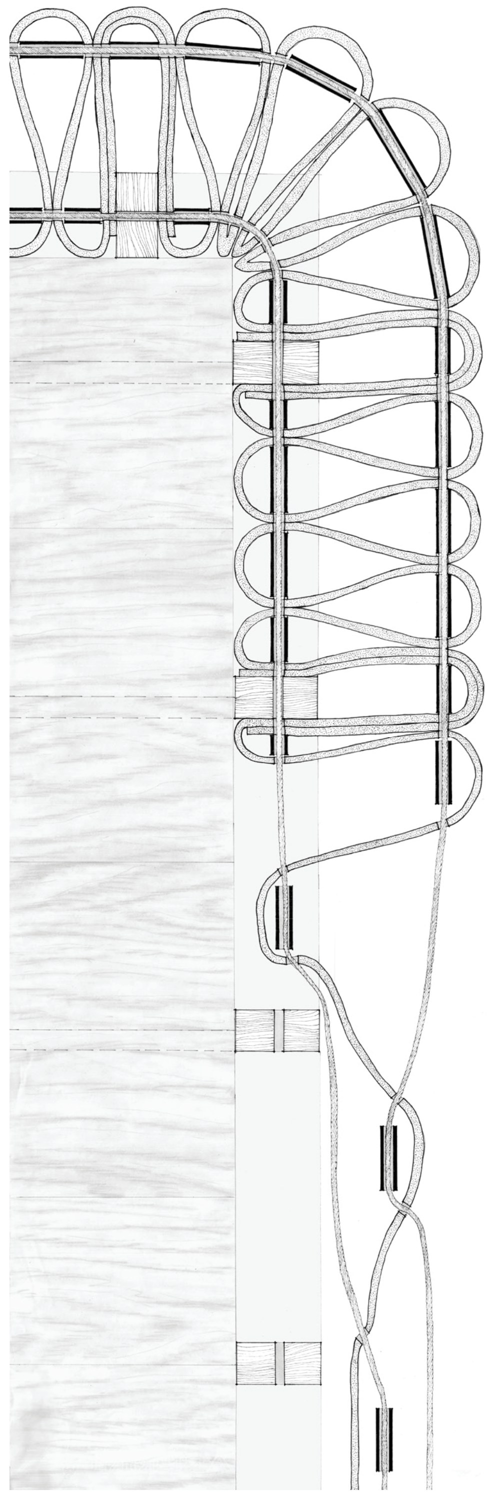
Top: this seam was sewn with thread.
Middle: a yarn seam adds stiffness.
Bottom: the seam is removed, folds are held inplace with tudes and yarn.

This design demonstrated how the wool wall would work with a balloon frame structure. A stereotomic foundation is used which contrasts the tectonic wall.



Batts are fit into the assembly above and below floor plates to act as fire stops. The foundation system is a mixture of wool, clay and concrete.

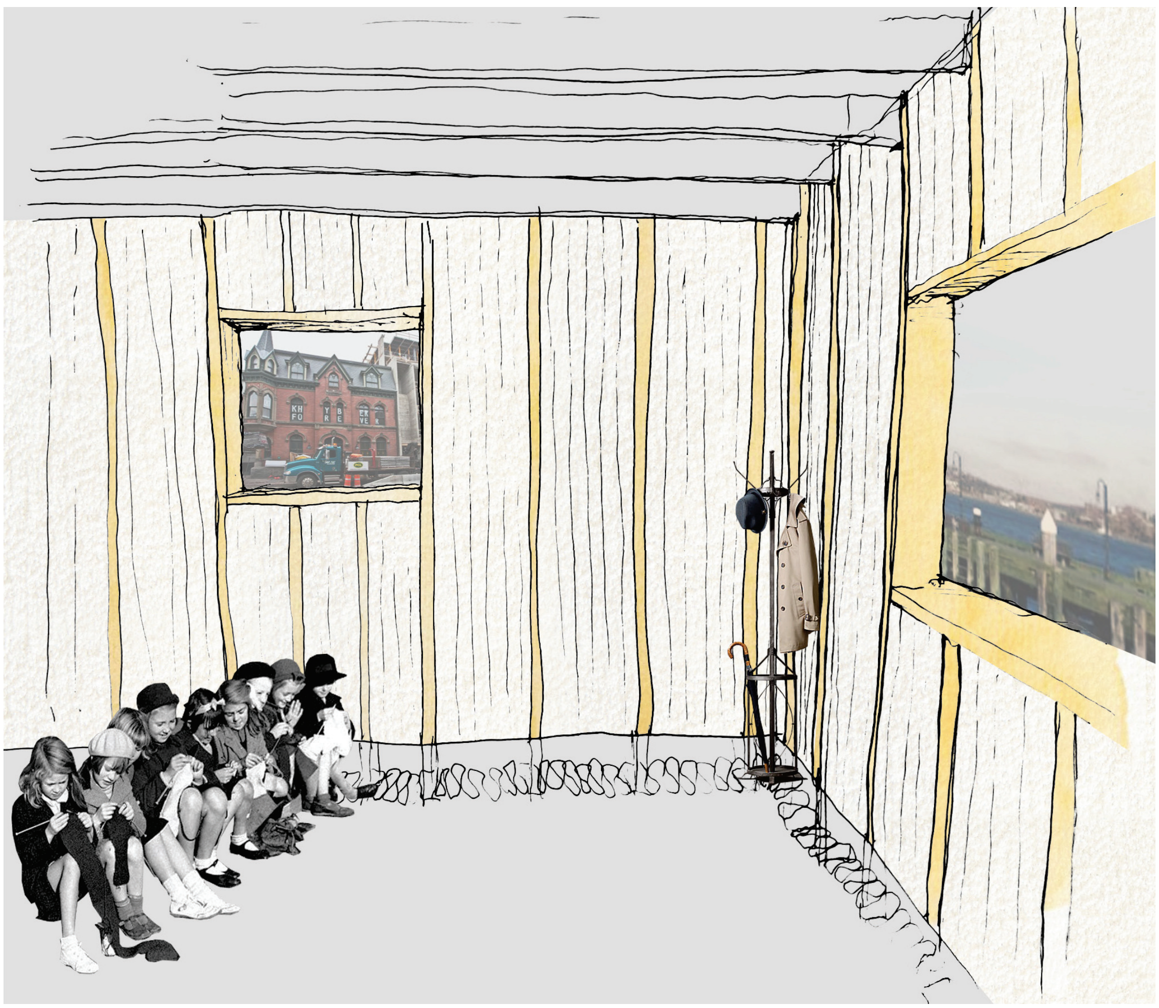
Scaling up this technique requires the use of rigid elements. Using cables and tubes inside the folds, the wall is given strength.



This plan detail shows how the wall is assembled on site.
The wall is split into panels which overlap at the studs.

This wall is intended to be a low-craft option. This brings down cost and opens the material up to a wider market. The wall combines insulation, fire proofing, interior and exterior finishes, acoustic control and aesthetic value which is considered when comparing the cost with a traditional wall assembly.

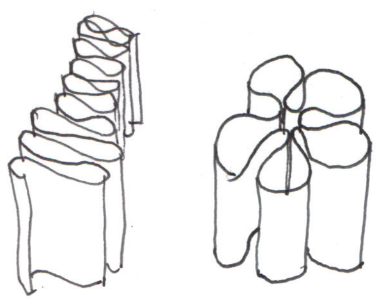
The next step with the wall is to test it in the outdoors. The way wool weathers and the strength of the cables running in side the wall are likely to determine design changes.



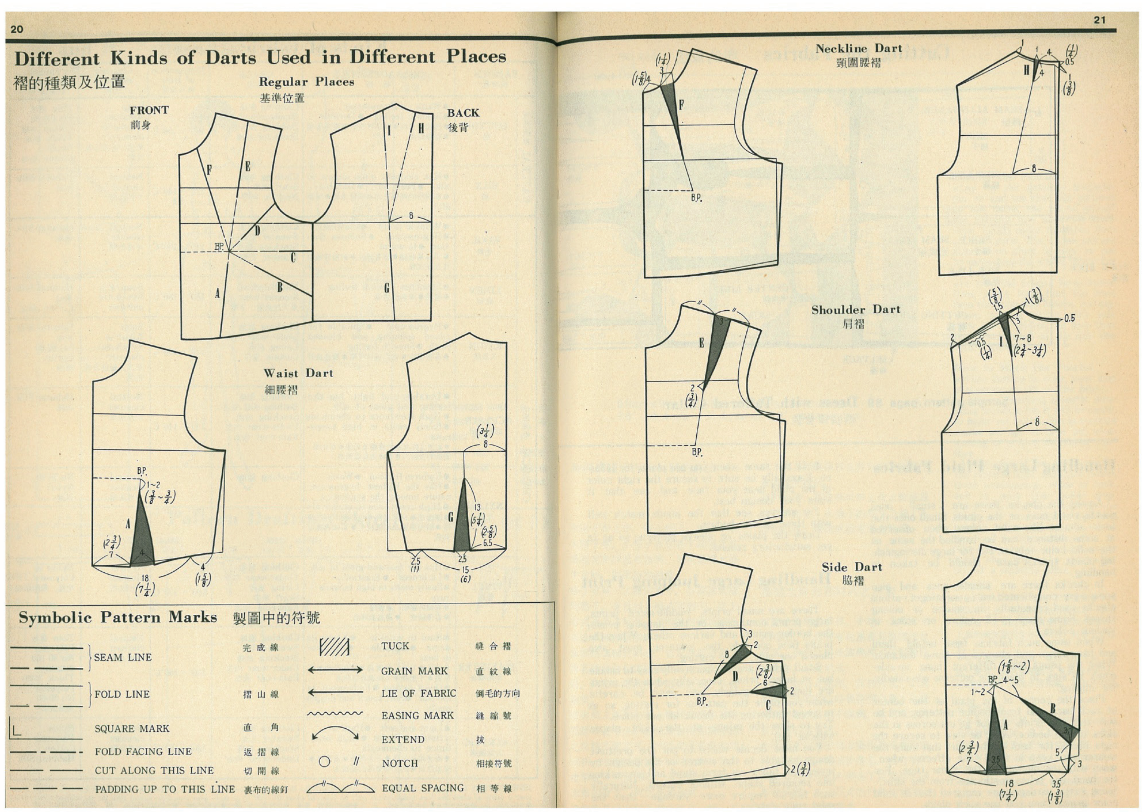
This collage demonstrated the wool wall being used as a facade in a small building in Halifax (photo used in collage from Judy Weightman).

The Tent

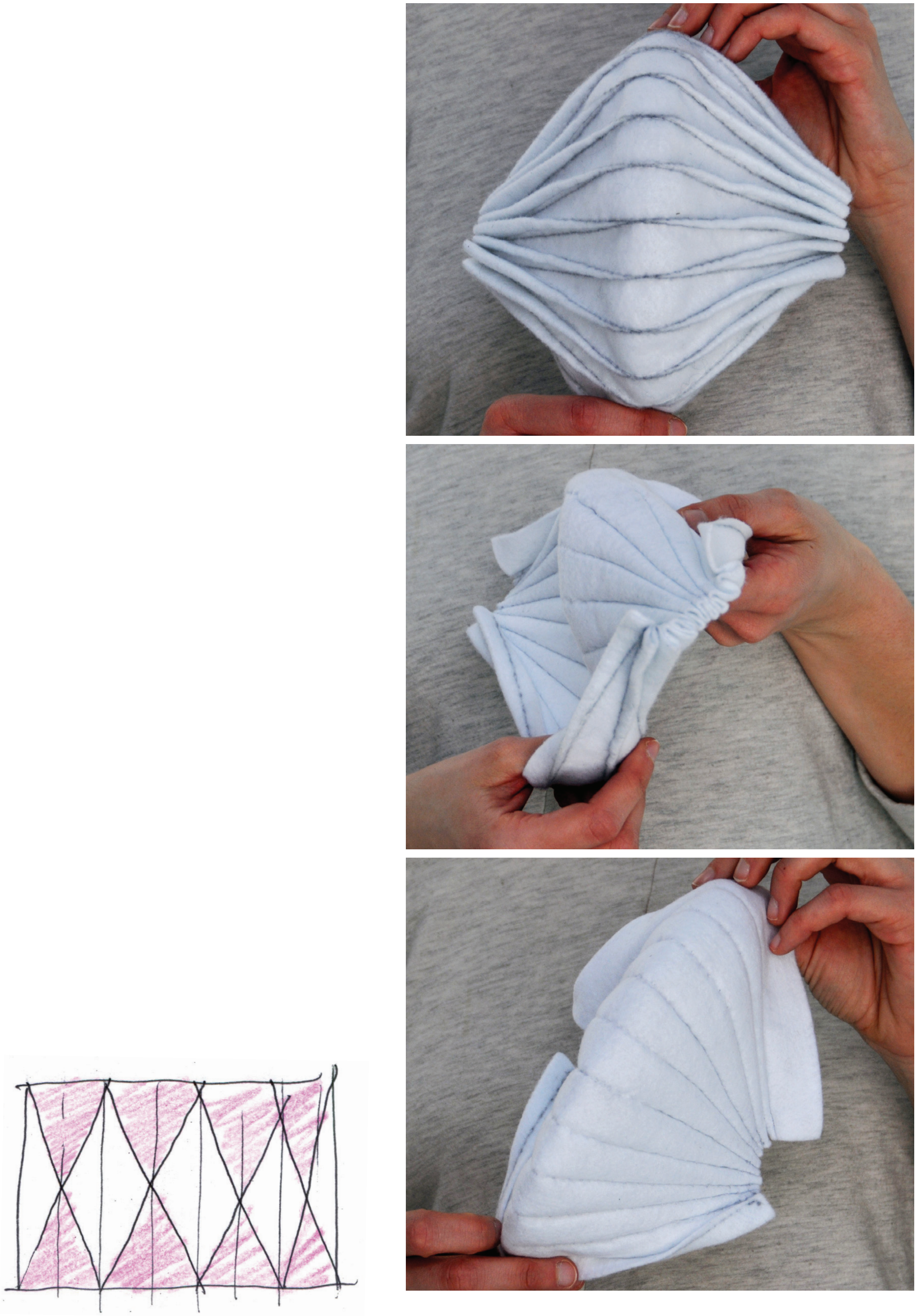
The system developed for the wall is flexible horizontally, but not vertically. I wanted to explore how the wall could become more adaptable. Using techniques of garment construction, I focused on the dart. The dart is used to give fabric 3 dimensional shape to fit the body.



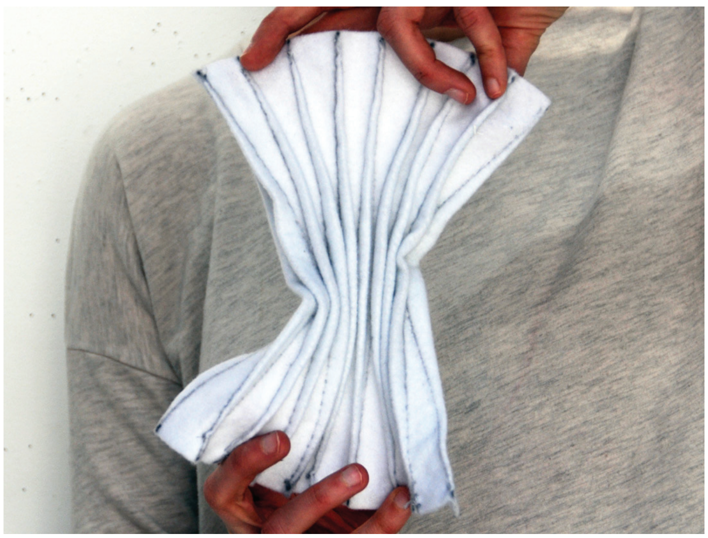
This system has a flexible footprint but not section.

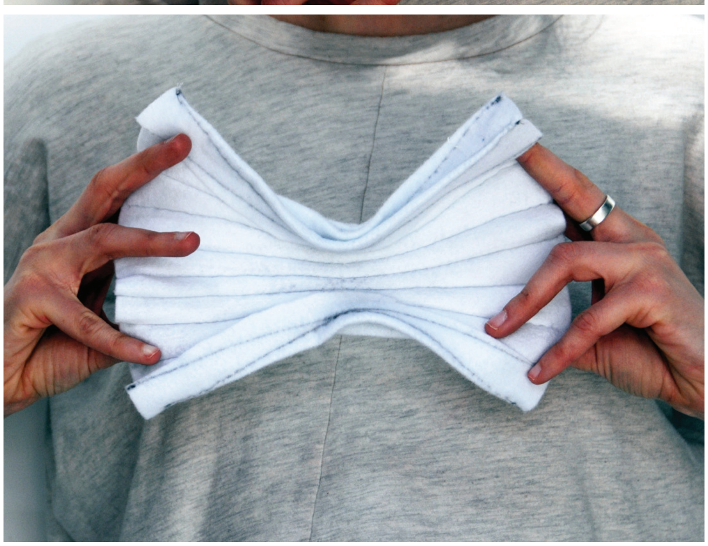


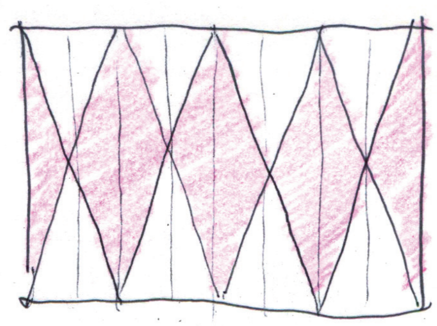
A shirt pattern using darts (Kamakura-Shobo 1969, 20-21).



This method folded the fabric at the ends, leaving the middle unfolded. It took the form of two cones joined at their base. The parts drawn in pink are folded.

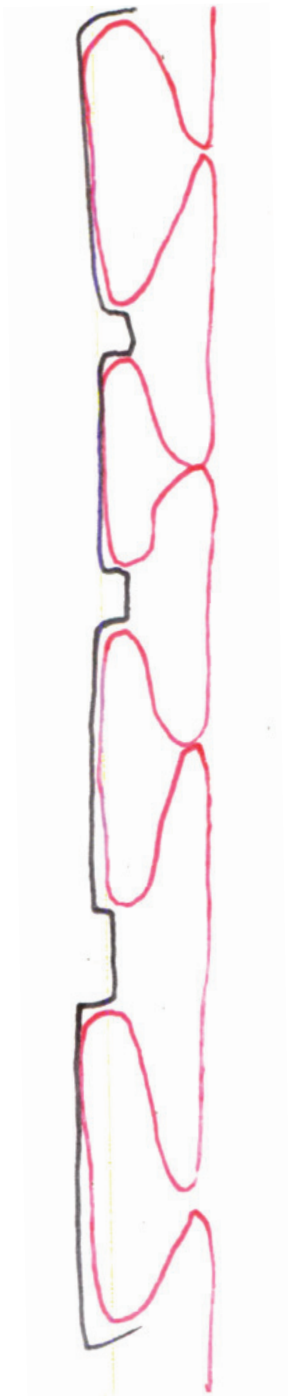


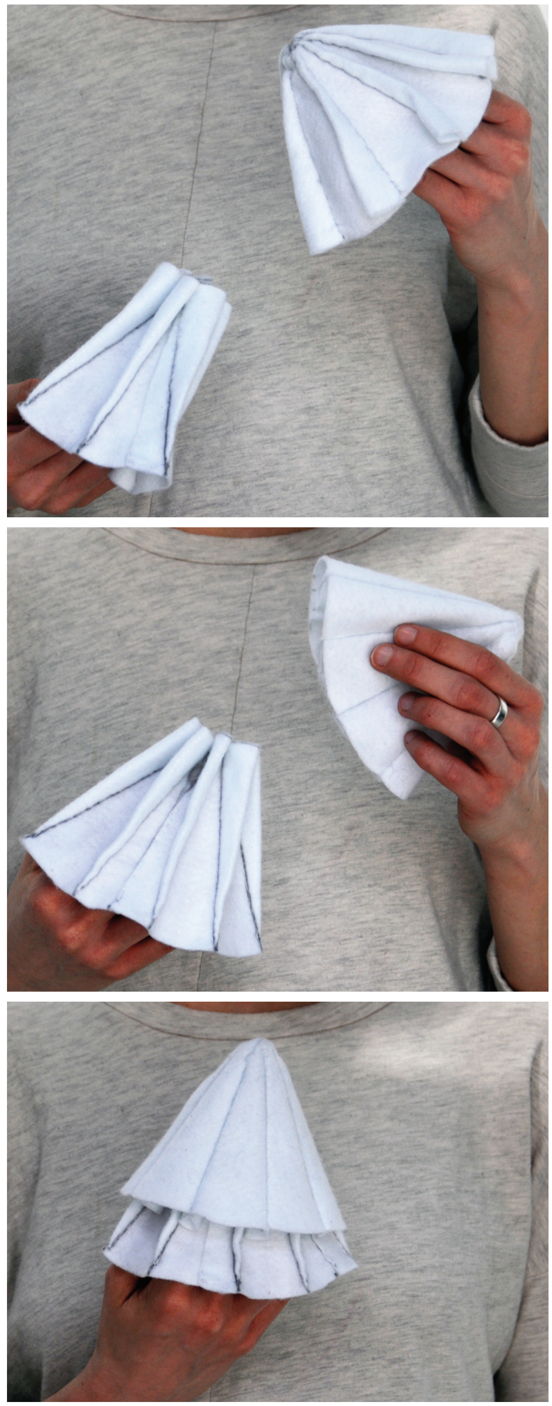




This method folded the fabric at the middle, leaving the ends unfolded. The fabric wants to take on the shape of a hyperbolic paraboloid. The parts drawn in pink are folded.

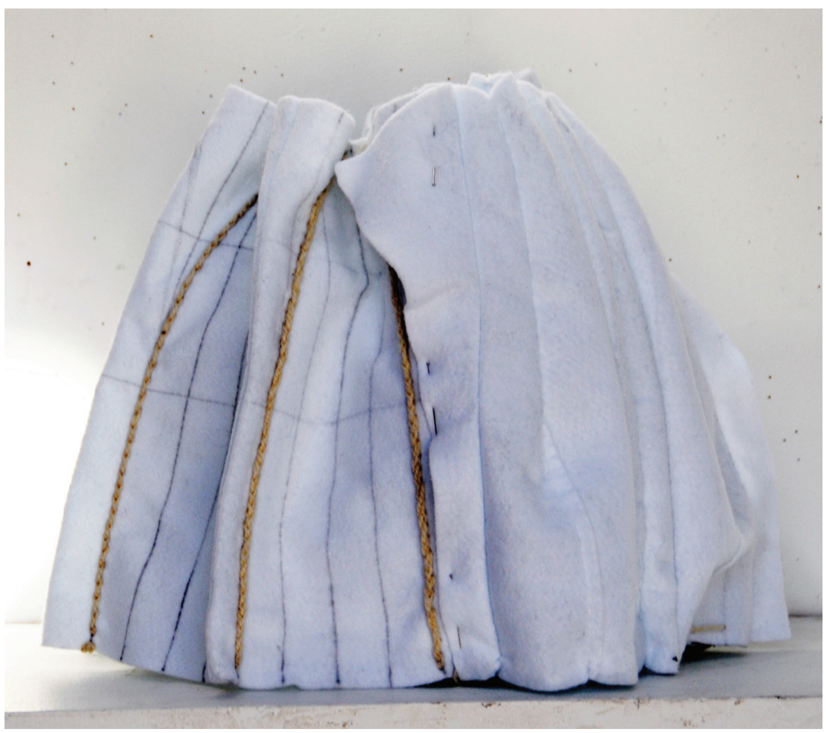
The darted samples would create uneven insulation, because the folds of the fab-ric concentrate in some areas, leaving other areas under-insulated. A double skin can solve this issue.





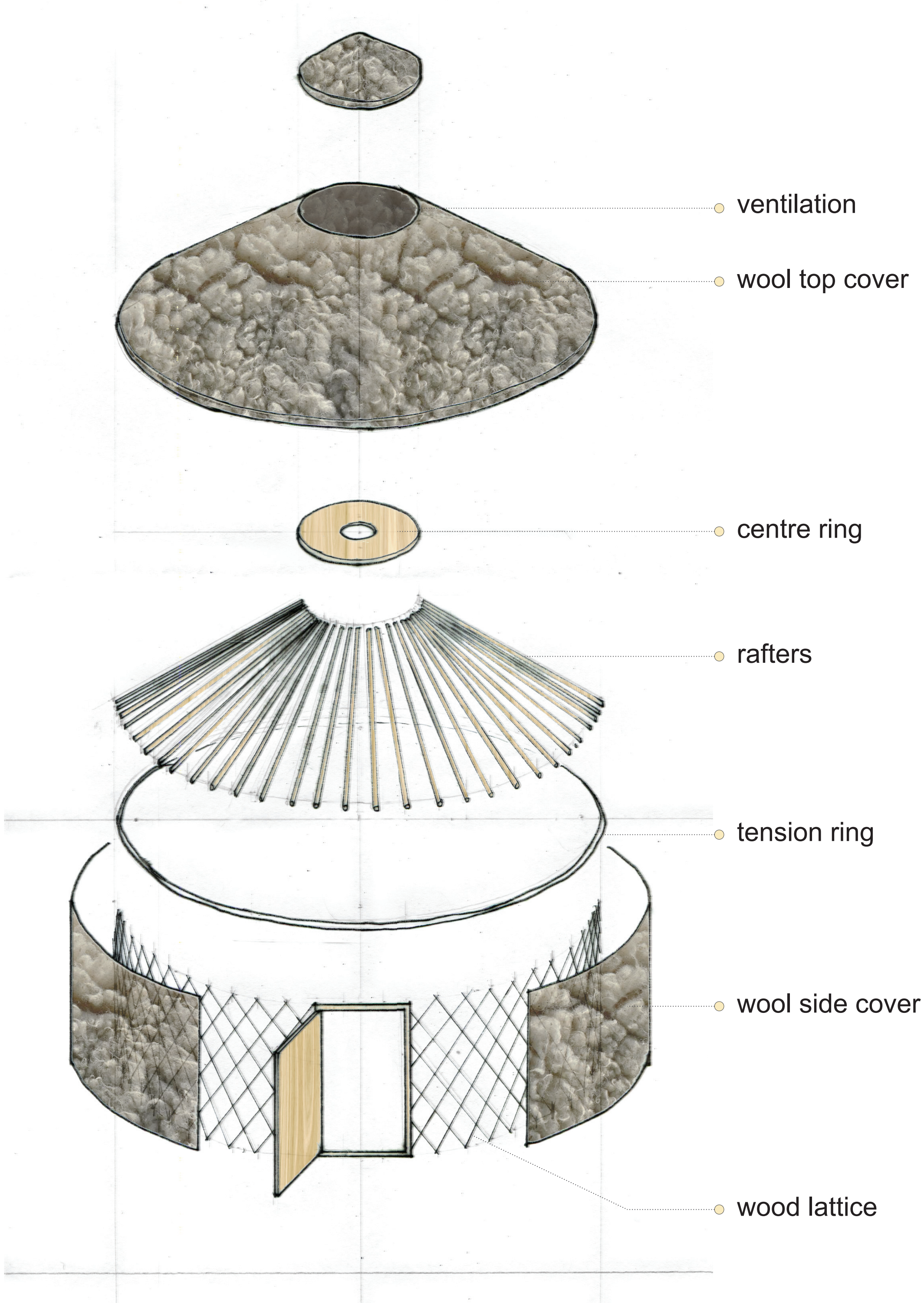
This cone is evenly insulated throughout because the folds of how the folds of the two skins fit into each other.

By curving the darts, this system can form a dome.



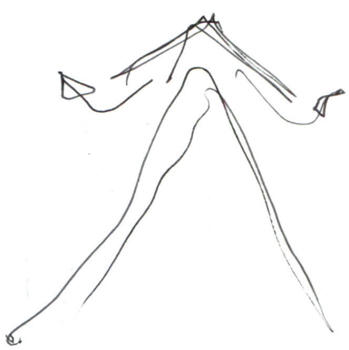
Top: The interior skin of the dome seen from above. The darts create air pockets.
Bottom: A side view of the dome with half showing the interior skin and the other half with the exterior skin in place. The exterior skin needs a wax coating and should be a denser felt than the interior skin which should be a loftier felt.

The yurt is precedent for turning the dome into a tent.



The yurt is assembled by setting up the lattices which fasten to the door, then the tension ring, rafters and layers of felt. The top is used for ventilation.

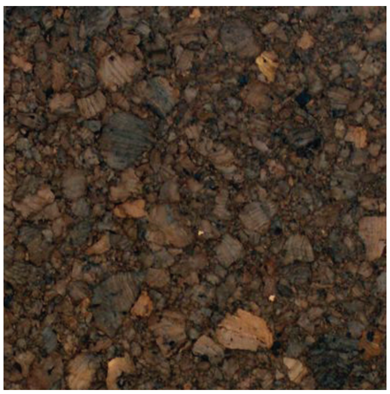
The top of the tent opens up, which is ideal for ventilation. To design an operable topper, the mechanics of an umbrella and vegetable steamers were pondered.

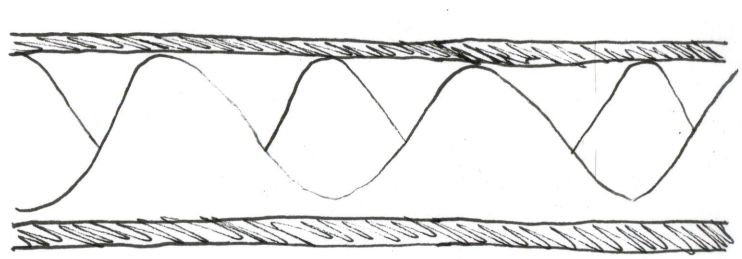


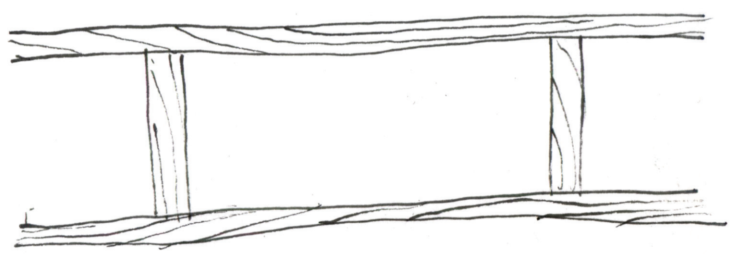
Air circulating from the bottom of the tent and out through the top is a traditional way of ventilating space, like yurt and the North American tipi. Umbrellas and vegetable steamers are examples of circular openings (unbrella photo from fanpop.com, steamer photo from wilco.com).

This twisting mechanism is a model of what would be used to open the top of the tent. The skewers are low lying in the top image, they lift open when twisted in the bottom image.

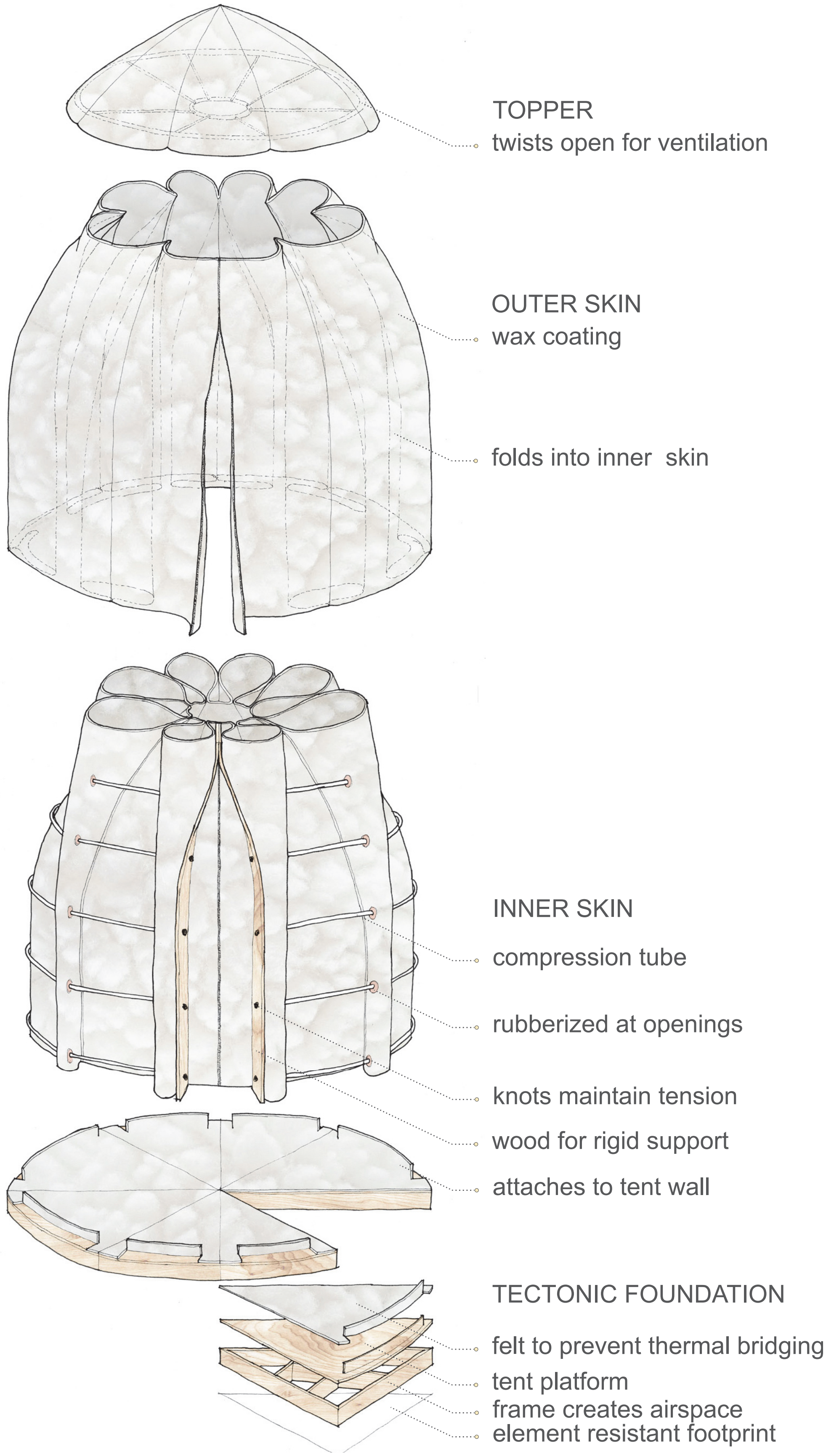
The floor should have air pockets for consistent insulation. A flexible floor can be rolled up when the tent is assembled, and a rigid floor can be divided into pieces.

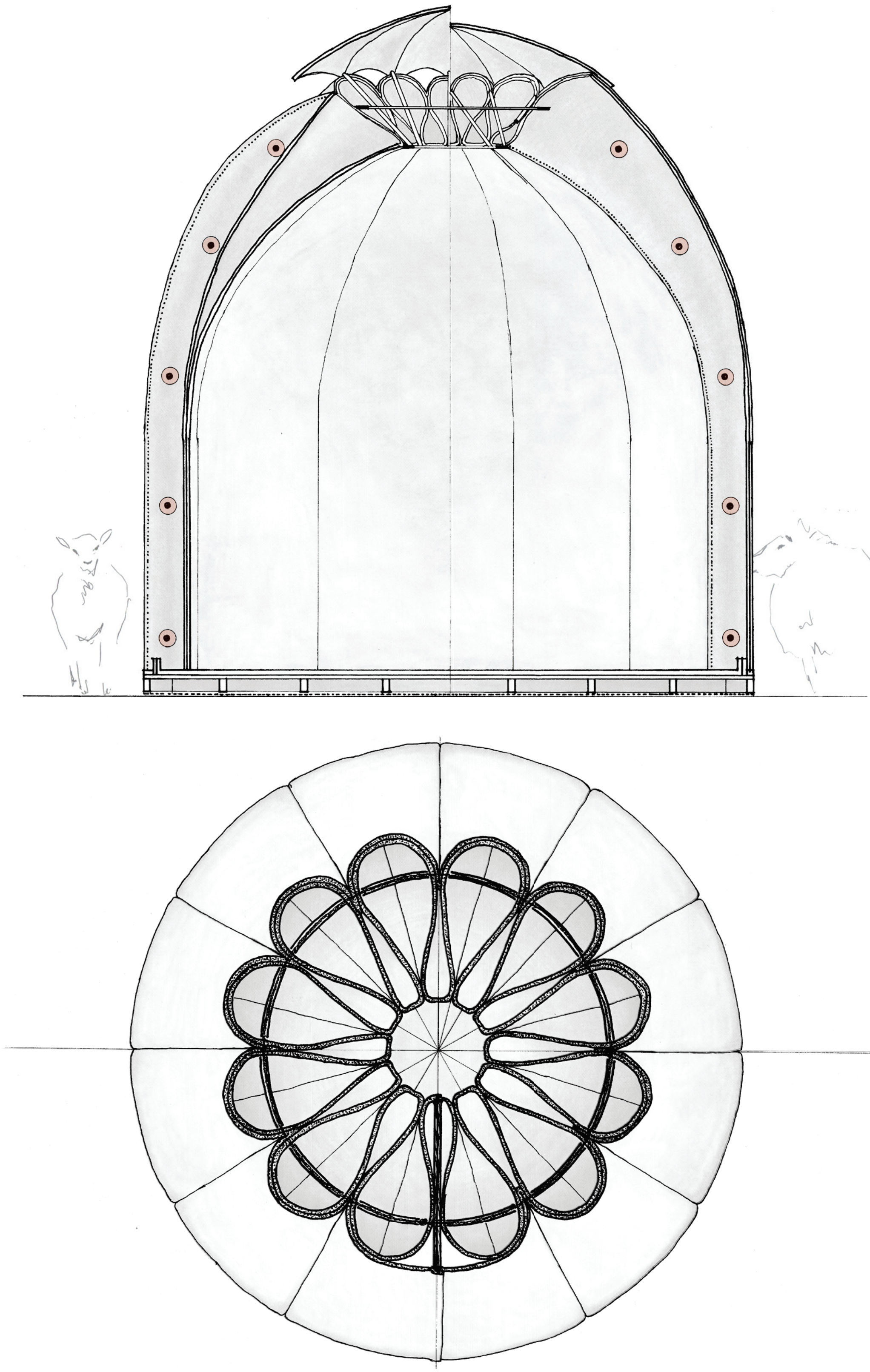




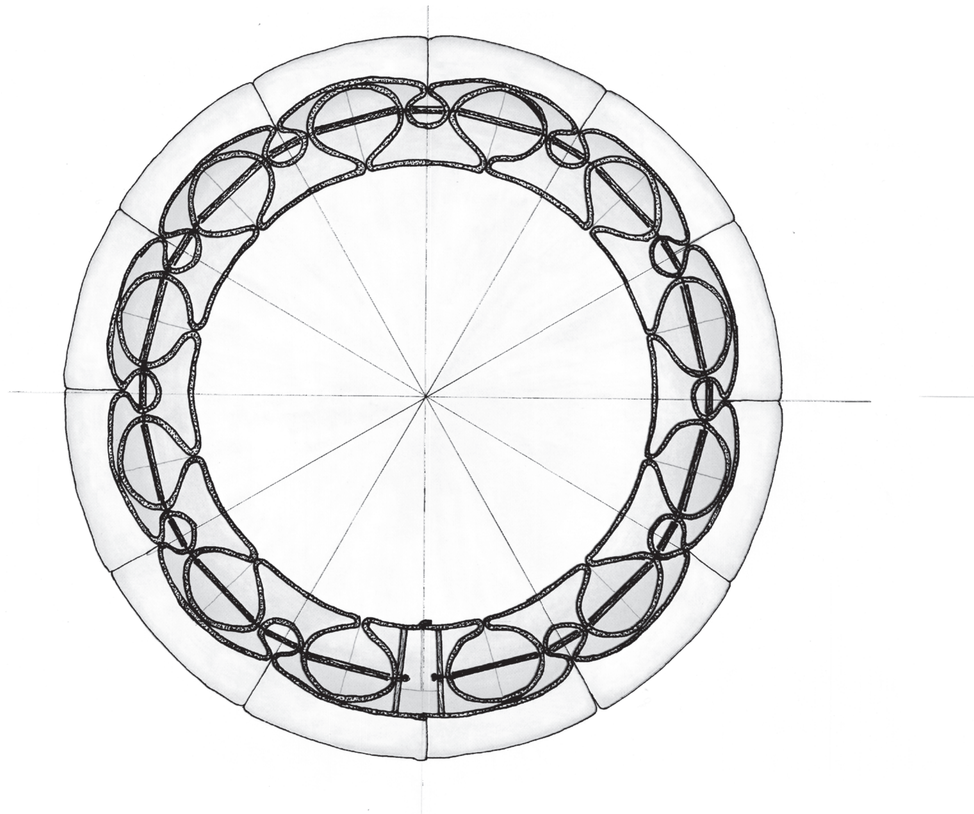


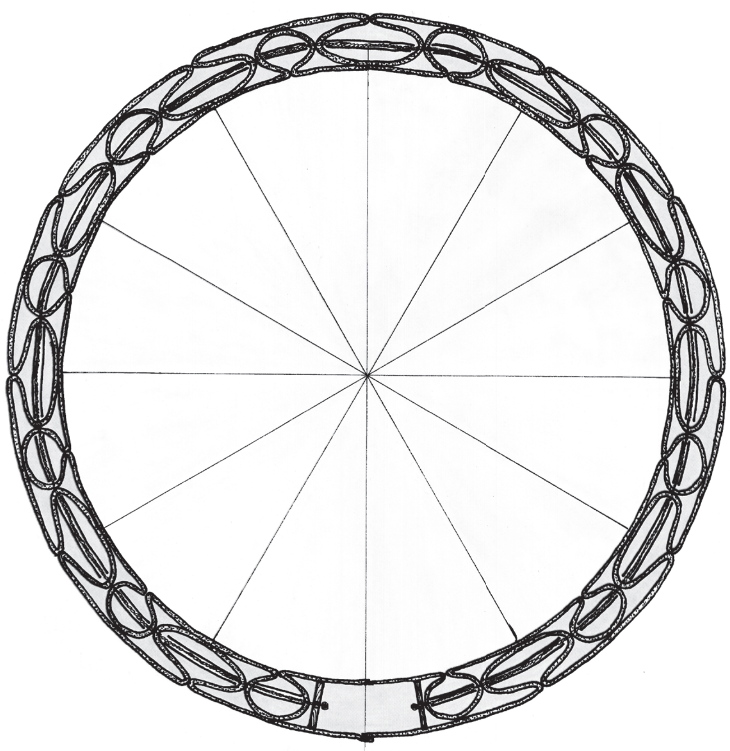
Top: Black cork is very versatile in form, it can be given an egg crate shape for air pockets.
Bottom: Plywood could be used as a more regional option.


TOPPER
twists open for ventilation
OUTER SKIN
wax coating
folds into inner skin
INNER SKIN
compression tube
rubberized at openings
knots maintain tension
wood for rigid support
attaches to tent wall
TECTONIC FOUNDATION
felt to prevent thermal bridging
tent platform
frame creates airspace
element resistant footprint



Top: the tent is seen in section. Half of the drawing is seen with the ventilation open and the other half it is closed.
Bottom: a plan through the top of the tent.





Top: a plan through the middle of the tent.
Bottom: a plan at the bottom of the tent.

These detail photos are from a half size model of the tent.
Top left: latex is used to rubberize parts of the tent needing reinforcement. This happens at the edges for stiffness and at the holes for abrasion resistance.
Top right: the matt used as the floor of this tent is folded and secured to the inside of the exterior wall to prevent moisture from the ground and wind getting in.
Bottom left: pockets along the seams hold wooden rods to provide extra support.
Bottom right: the double door system zips shut and has a wooden frame to hold the cables surrounding the circular structure.

The tent is suited for sites with easy access because of the bulkiness of the wool. Unlike a back country camping tent designed to be compactable, this is more of a nomadic living tent. The temporal nature of farm work makes fruit pickers and shearers potential users. There is also potential to work with the tourism industry, using tents as novelty accommodations.

The next step with the tent is to test it in the outdoors, testing would determine what design changes need to be made.

This collage shows the tent's potential to accommodate temporary foreign workers on farms. There are many workers that come to Nova Scotia seasonally to work on farms, accommodating these workers is a concern for many farmers.

CHAPTER 7: CONCLUSION

These explorations began with wool as the only material in mind, through exploring ways to make architecture out of wool, other materials were added. Wool's weaknesses are in its physical weakness making it difficult to use in tension, and the bulk required for it to work in compression. Introducing materials to compensate for these weaknesses means integrating with other industries. Nova Scotia has many resources that are compatible with wool, skilled labour comes along with raw material when pairing with an industry. The following pairings have been considered thus far.

Fish Nets

Fish nets were used as an internal structure for a new fabric in one of the studies of this thesis. There is a lot of potential to take this study further. Fish nets are made in Nova Scotia by Rainbow Net & Rigging in Dartmouth. Pairing with fish net manufacturers would be a mutually beneficial practice.

Clay

Clay allows wool to be used in rammed earth construction. Clay is found in the Bay of Fundy and has been used by Shaw Brick for over a hundred years. Pairing with Shaw Brick would contribute to a truly local building material.

Shipbuilding

Shipbuilding is a large source of jobs in Nova Scotia. The expertise involved in shipbuilding, particularly the use of fibreglass could be advantageous.

Wood

The lumber industry is prevalent in Nova Scotia. Like traditional architecture, local wood is very useful in wool architecture. Wood contributes rigidity and compressive strength that wool cannot provide.

Pairing with these place based industries contributes to a rise in Nova Scotian industry. As the wool industry intersects with these other industries, a network is built. As this network grows, infrastructural changes would need to be made, this would have to be done in phases.

The analysis of Nova Scotia's existing wool industry on page 23 serves as the starting point for considering potential growth. Nova Scotia has ample pasture land, and could easily support growth in sheep farming. Shearing is done on site, like farming, it would require an increase in skilled work but not infrastructure. The products proposed in this thesis can be made primarily using equipment at the three wool mills in Atlantic Canada: MacAusland's in PEI, Belfast Mini-Mills in PEI, and Legacy Lane in New Brunswick. The remainder of production could be run out of a rented facility while wool architecture is establishing itself. Once a larger facility is needed, production could move to the former textile mill in Windsor, NS. This building has not been divided and the whole site could be used, the entire production process could be run out of this facility. This iconic building is well positioned to be a hub for the community and wool industry. The Annapolis Valley receives many tourists, this site could draw people into visit the factory and help rejuvenate Windsor. This mill is conveniently situated in the middle of the highest sheep rearing counties and is a 40 minute drive to Halifax. Interior products such as carpets and upholstery could be shown in local stores, but the majority of sales would happen online. Products would be sent to Halifax to be shipped to the rest of Canada or to international buyers. There is a range of clientele these wool products are suited for.

This thesis developed architectures that are stereotomic (the wall), tectonic (the tent), informal (the kepenek), formal (the wool brick) and furniture (the chair). This wide ranging series includes designs for a high-value niche market and less expensive options for a greater audience. These woolly creations are meant to rejuvenate Nova Scotia's agricultural and industrial scene. Making this a reality would require testing, both of the products and of the market. Physical testing of the products would examine the way they wear when exposed to weather, how they handle loads, and other physical attributes. Once the products are considered ready for use, market testing would begin. Initially small quantities of products would be made to test their popularity. The limited amount of construction in Nova Scotia means the products would be promoted to an international audience. There are three types of users intended for these wool products:

- small scale wool - these customers are interested in wool products but are not building or renovating. The chair and kepenek reach this market.
- industrial manufacturing - these products are more attainable because of the lower cost of production. The corrugated wall is meant for this crowd.
- craft manufacturing - the skill required to make these products drives up the price, it is intended for a high-end, niche market. The "wool brick" and wall panels are suited for this crowd.

Initial sales will dictate which audience is the right one for future wool architectures to speak to.

This thesis contributes to rural communities' ability to evolve as Nova Scotia's rural identity and ideas of craft change. In encouraging the use of locally sourced, natural products communities are being supported, rather than left behind in the age of urbanization and globalization, increasing the sustainability of our society. With these ideals at its core, this thesis explores a middle ground between industry and craft, re-connecting it with agriculture.

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