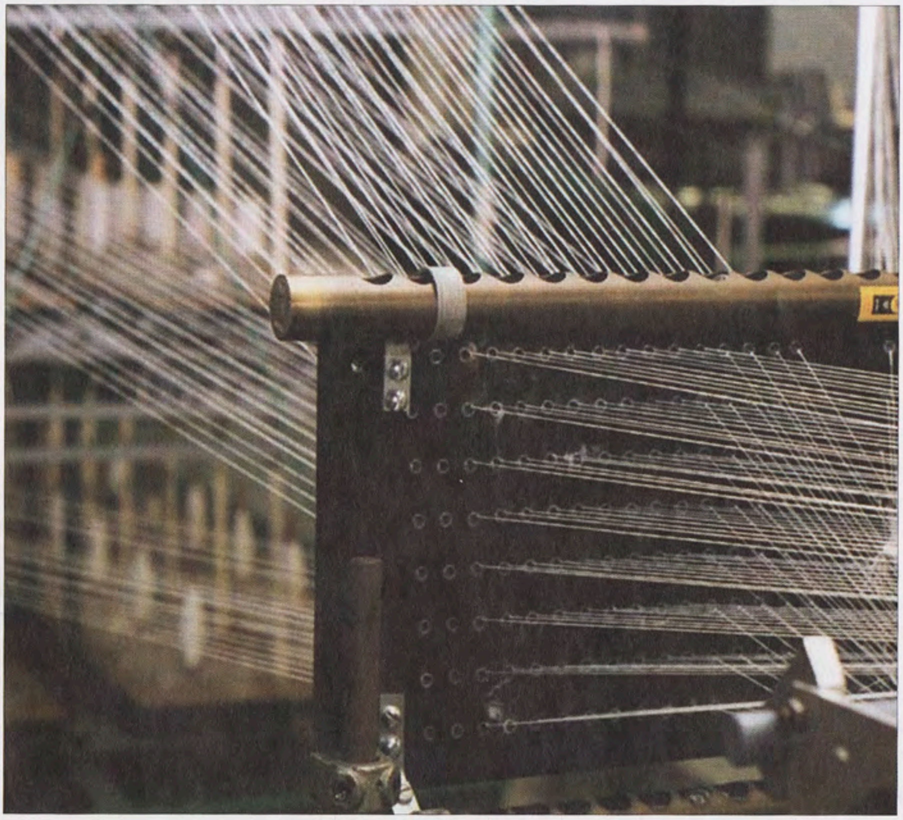
# Intimate Textiles



## Abstract

Textiles are one of the most intimate of materials. We wear them, sleep between them, carry our goods, and our often our memories, in them. Recent innovations in industrial textiles and in the growing field of bio-materials challenge this intimacy in interesting ways.

These developments provoke some interesting, and occasionally disturbing, observations of our understanding and conception of the body and our complex relationship to human, animal and machine life.



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*Textile*, Volume 3, Issue 1, pp. 88–99
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I approach the heavily barricaded gates, noting the numerous surveillance cameras and the imposing fence that surrounds the perimeter of the site. At the guardhouse I am asked to present identification, but before I am allowed to proceed, a call is forwarded to confirm my claim of a previously established appointment. Once inside the facility, I am asked to submit a piece of identification, which will be held until I return. I am told that no cameras or audio recording devices are allowed on site. At this point, my name is called and I am ushered from the reception area into the laboratories at DuPont Central Research and Development's Experimental Station in Wilmington, Delaware.

I was there to meet Kenn Gardner, a chief researcher at the Corporate Center for Analytical Sciences, who is in charge of DuPont's spider silk research, a prominent area of study at numerous private and public laboratories throughout the world.

The heavily guarded entrance and intense security around the experimental lab reveals the high stakes of this research. The potential of corporate and scientific espionage is taken very seriously. Once inside, the rather clinical corridors give way to a laboratory that in itself, is strikingly familiar: books, papers, machinery, tools a bound, not unlike the ordered chaos of many artists' studios.

In this article, I will present the results of a research trip I undertook in Spring 2001, to a number of leading scientific laboratories in the eastern United States that specialize in advanced textile technologies. This trip invoked science-fiction wonders and horrors, Greek myths, and Grimms' fairy tales; from Arachne's webs to Rumpelstilskin's spinning of yarn into gold, from spider's spinning silk to woven gold antennas and sutured pig parts. This trip raised some interesting speculations on the human/nature and more specifically human/animal divide.

Textiles are one of the most ancient and enduring technologies. As one of the earliest technological inventions they are part of every culture and every society, and they continue to be at the forefront of invention and innovation in the medical, aerospace, and defense industries. Current research includes the new field of bio-materials: a branch of biomechanics that investigates the mechanical function of biological materials and structures and includes hybrids between natural and synthetic materials.

## Natural and Unnatural

New developments in science and technology challenge our sense of being and our models for understanding the world. Long-held views about human nature, about the definition of life and of nature are being reexamined in what has been called the Biotech Century. (Rifkin 1998). Some have argued that the biotechnology



revolution will have as profound an impact on people's lives as that of the early Renaissance over 600 years ago. This paradigmatic shift with its accompanying breakdown of humanist dualities: nature/culture, public/private, machine/organism, has profound implications on how we come to terms with what is natural and, by extension, what is not natural. As post-structuralism and feminism have revealed, the word natural is a concept, and as such a product of discourse but with a very real referent. The challenge is how one is to define human nature and nature in discourse while the material perimeters of these are being continuously modified. What will future notions of the self be, given that the existing models are rooted in an essential relationship to the natural and material body, to its separation from both nature and machine, when new genetic and biomedical technologies threaten to radically disrupt this "natural" relation? The loss of a clear sense of boundaries, whether it is the proprioceptive boundary of our own bodies or the boundaries between the real and the artificial, the natural and the unnatural, leads to some interesting speculations and observations.

Contemporary science fiction and film have given us numerous images of the cyborg, a coupling of machine and organism, from Schwarzenegger's *Terminator* to Data of *Star Trek*. Inevitably, these cyborgs are hairless and seamless, dry, hard, and always slim, bodies.

But another boundary to be breached in addition to organism/machine, is the distinction between animal/human. Biotechnologies have made ambiguous the difference between natural and artificial, between self-developing and externally designed.

Unlike the critical models of the cyborg posited by cyberfeminists N. Katherine Hayles (1999) and Sadie Plant who see the cyborg as a prelude to a post-human future, current biomedical research suggests a more enduring biological base. Donna Haraway (1991) envisions the cyborg as uncoupled from organic reproduction where biology no longer constitutes destiny. But developments in current biotechnologies and bio-materials suggests that biology does matter and that the machine/human coupling is expanding into the machine/human/animal hybrid.

The cow and the pig are among the animals most compatible with human beings for transplants and gene transfer. In the same vein, a more humbling, less attractive, and definitely more frightening model of the cyborg is suggested. These new couplings raise serious ethical questions as well.

## Polymers: Natural and Unnatural

In 1928 the DuPont Chemical Company opened a laboratory solely devoted to research for the development of artificial materials, a rare decision for a company to make at that time. Wallace H. Carothers (1896–1937) began his pioneering research into the chemistry of giant polymers at the research laboratories at the DuPont Company. It was six years later that Carothers and his team developed the world's first totally synthetic textile fiber: nylon.

Patented in 1939, two years after Carothers' death, nylon was a huge success at the 1939 Worlds Fair in New York. Almost instantly, nylon became a replacement for silk in the hosiery industry. With the advent of World War II, nylon was commandeered for war purposes to make parachutes, canopies, etc. But the development of nylon marked the beginning of an expansive period of research into synthetics (synthetic polymer) such as polyester, acrylic, and spandex.

Material scientists have long been fascinated by the relationship of structure and function in biological materials and recently, natural polymers, rather than synthetic polymers, have become a major focus of contemporary research. A polymer is a substance made up of many repeating units (called monomer units). Polymerization is the chemical process that combines several monomers (smaller chemical units) to form a polymer or polymeric compound. Protein polymers produced by biological systems, e.g., spider silk, are attracting a great deal of attention as embodiments of new structural principles and as models for potential products of biotechnology. Compared to chemically synthesized polymers like nylon and neoprene, nature has a multitude of structural materials that have, through aeons of evolution, attained remarkable levels of strength and efficiency. Biopolymers are unsurpassed in their capacity to make complex multi-component composite structures. This capacity is even more striking when it is considered that all proteins are constructed from a comparatively small set of basic building blocks: the twenty naturally occurring amino acids. (O'Brien *et al.* 1998). Protein polymers can be thought of as nature's nylon. Their capacity to make complex structures has surpassed the capabilities of synthetic polymers.

The advent of recombinant DNA technology allows for the manipulation of elements in the biosynthetic process. This process produces small sophisticated molecules and polymers with a degree of precision that has not been possible using conventional synthetic technology. Some of the most dramatic progress has been made with research into protein polymers produced by biological systems. An example is the dragline silk of orb spiders, a material with nearly the strength of Kevlar[1] and even greater toughness.

## Spider Silk

Spider silk has been the object of research at many public and private laboratories around the world, attracting high-profile investors such as NASA, and the defense and aerospace industries globally. Potential applications include a kind of lightweight bio-steel with applications as an alternative to steel for use in everything from planes, cars, and armor, as well as uses in the medical field.

Silk filaments produced by orb weaving spiders and silk moths rank among nature's most highly engineered structural materials, achieving in some cases, combinations of strength and toughness not found in any of today's man-made materials. Because they are the strongest known protein fibers, the dragline filaments produced by orb weaving spiders have been the focus of recent research.

Of the various silk fibers produced by orb weaving spiders, that made by the major ampulate gland has the highest tensile strength. It is used as the main load-bearing member or dragline in the web and as a safety line with which the spider can control its movements in the wind or move from one elevation to the next. A broad range of silk is necessitated by the spider's demanding requirements for filaments. These include web construction, prey capture, reproduction and movement from one location to another.

At DuPont research, Kenn Gardner works with the silk of the golden orb spider, *Nephila clavipes* (Figure 1). The spiders are housed in individual but generously sized wire cages. At Gardner's lab a small custom extruding machine is used to gather the spider silk. Similar to a textile bobbin or skein winder used in traditional weaving, it collects the dragline from the spider. Dragline can be forcibly removed by placing the spider on its back but research has shown that dragline that is naturally extruded yields the strongest material. Spiders are unique self-producing systems. If they run out of dragline, in less than two days, by functioning normally, they are able to produce enough silk for their needs.

In spider silk research at the DuPont Experimental Research Facility, the molecular structure of the dragline was



**Figure 1**
Golden orb spider *Nephila clavipes.*

examined. Antisera, a serum containing antibodies used to test biological samples for antigens was used to stain the dragline silk fibers in cross section. Immunoelectronmicroscopy was then used to reveal the DNA sequence and molecular structure of the dragline. The focus of the research at DuPont was not to prepare an identical copy of the natural fiber but to capture its key structural and functional features. Their aim was to produce synthetic analogues to the dragline filaments. Artificial genes were designed, synthesized chemically, and established in bacterial and yeast hosts to induce the synthesis of large amount of silk-analagous proteins. Filaments of the analogous dragline were spun and were post-treated to provide highly lustrous fibers with mechanical strength in the range suitable for textile and apparel applications. As yet the synthetic fibers have not achieved their promise of becoming a bio-steel and DuPont is no longer concentrating on spider silk research at the Experimental Research Facility.

At Nexia Biotechnologies in rural Quebec, spider silk is also the focus of research. Housed in a former *cabane au sucre* (maple sugar farm), the incongruity between the pastoral setting and the level of technology is disconcerting. Similar to the DuPont Labs, Nexia Biotechnologies uses the silk of golden orb spiders but their approach is radically different. Nexia is involved in transgenics, simply defined as the transferring of genes from one animal to another. Nexia uses two spiders, the *Araneus diadematus*, a common garden spider, and *Nephila clavipes*, and also West African dwarf goats. In this process, a gene is taken from the golden orb spider and placed into a goat's egg. The genetically bred goat then secretes spider silk into its milk. The milk or silk–milk mixture is reduced and then spun in a custom extrusion machine that mimics the internal workings of the spider's abdomen. To date, bio-steel remains an unfulfilled promise but continues to be an ongoing research field.

## Medical Textiles

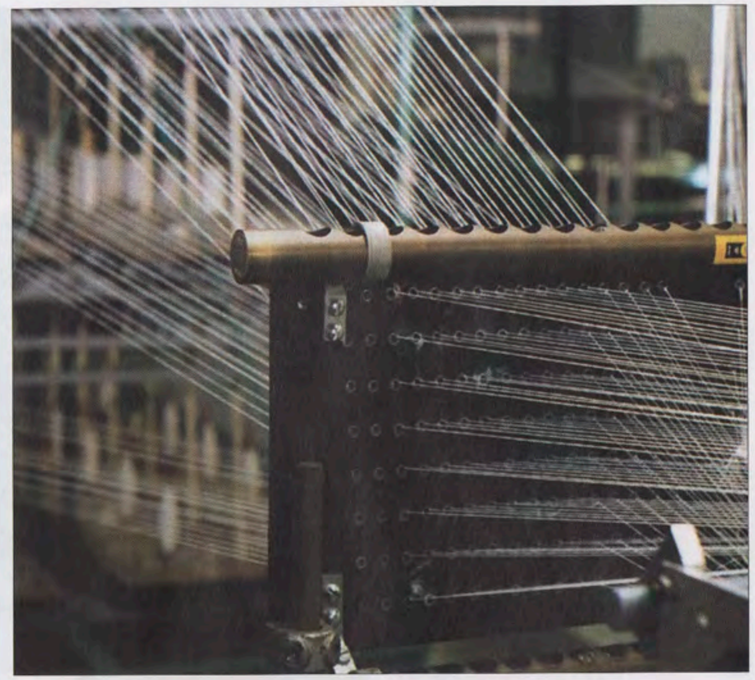
My next stop took me to Perkasie, Pennsylvania, to visit Prodesco. While this visit lacked the dramatic greeting I met with at DuPont's Research Facility, once inside, Prodesco produced its own excitement. Prodesco and its subsidiary, Secant Medical, designs, develops, and manufactures all types of custom-engineered fabrics and cloth structures for the medical, automotive, air, and space industries. It is a custom textile mill that offers a variety of textile processes, including warping, knitting, weaving, braiding, scouring, and heat setting (Figures 2–4). As a custom mill, they do not produce any of their own product lines but respond to client and customer needs based on request. Their role is essentially problem solving, based on an individual problem or project in direct collaboration with clients. In their medical textiles division, they produce vascular grafts, hernia mesh, biodegradable sutures, neurotubes, adhesion barriers, hemostatic dressings, replacement ligaments and tendons, and minimally invasive surgical implants.

In their industrial textile division, they produce Nomex, Kevlar, Spectra, PET, PTFE, PGA, PEEK, nylon, nitinol, stainless steel, eligiloy, gold-plated molybdeaum, and antenna mesh for the aerospace industry. I met with Robert J. Dougherty, Senior Knitting Engineer, and Anna Lietzke, Process Engineer, for Prodesco's Medical Products Division Subsidiary, Secant. I was impressed by their genuine enthusiasm for their work and their passion for textile structures.

**Figure 2**
Prosthetic tissue heart valves.



**Figure 3**
Warping, Secant Medical.



Textiles used in medical technology provide less invasive, lightweight solutions and structures that the human body is less likely to reject. One of Secant's most successful products is the bio-mechanical or tissue heart valve (Figure 2). Made from the animal tissue of specially bred pigs, the prosthetic valve is mounted on a sewing ring made of metal or plastic, sheathed in a knit fabric (usually Dacron or poly-tetr-fluor-ethylene) which is sewn into the orifice of the natural valve. Secant inserts a purple suture line into the woven structure to act as a guide for the surgeon in attaching the valve. A knit structure is used for the fabric because of its strength and flexibility. A woven or braided structure would be too rigid for this application. Sculpturally, the bio-prosthetic heart valve is quite beautiful. Although designed for maximum functionality and not for aesthetics, it looks like a miniature sculpture by Eva Hesse.

Secant also produces a mechanical heart valve, a ball and cage valve that is also sheathed in the same knit fabric. Mechanical valves tend to last longer but are said to create an audible ticking sound. Users of the mechanical valve also need to take anticoagulant medication for the rest of their lives because the materials used to make the mechanical heart valve—metal, plastic, ceramic coated graphite—can cause blood clots to form.

Another minimally invasive product that is manufactured is the human aorta. A woven tube, it is inserted via catheter into the existing aorta. It does not replace entirely the ailing part but supports it. In this instance, a woven structure is used due to weaving's strength and rigidity as opposed to the flexibility of a knit structure.

Other medical products Secant produces include synthetic veins—a braided structure used for its strength and flexibility. In this case, if a vein is severed, the braid is inserted between the damaged parts. Once it has healed, the synthetic vein disintegrates.

The textiles are produced in laboratories that are eerily reminiscent of textile studios, except these laboratories are antiseptic and clinically sterilized. I was able to enter only the antechamber of one of them. In order to enter the room, I would have needed to be gowned, hooded, gloved, and worn covered shoes, the standard garb for

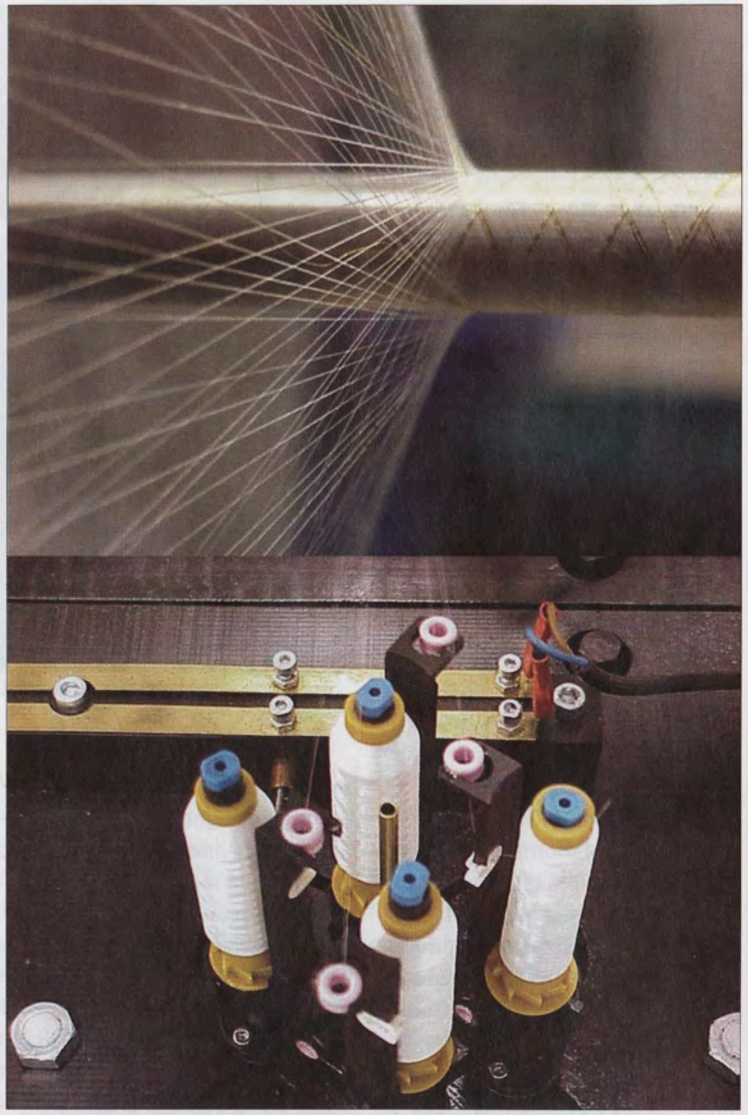


**Figure 4**
Braiding, Secant Medical.

surgical procedures where the utmost hygiene is required. The textile laboratories are designated as Safe Rooms, a rating and approval designation that is granted by the US government ensuring that the room holds 100 or less 5.5 micron particles per cubic foot of air. In other words, when a door is opened, the force of air pressure in the room ensures that no new air is allowed in to ensure the highest level of hygiene and sterility. Before entering the Safe Rooms, which house the looms, knitting, and braiding machines, the textile engineers are gowned to look like surgeons preparing to enter an operating theater.

Bio-prosthetics and bio-materials raise many ethical



questions regarding the use of animals. Pigs have been bred as farm animals for centuries and generally speaking, there are few ethical objections to rearing pigs for meat. Pig heart valves, which are inert pickled tissues, but nonetheless derive from the pig heart, have been used for thirty years in heart operations. Even those religions that forbid the consumption of pork as meat, Hindus, Moslems, Jews, do not object to the use of pig heart valves for transplantation. There is a cultural acceptance for the use of pigs and cows. Chimpanzees, although most compatible with standard selection criteria (compatibility of size and blood types) are unacceptable socially as a source of xenotransplantation.[2] Even scientists involved in xenotransplantation recognize the procedure as unethical with apes.

In Prodesco's industrial division, gold is knitted into textile surfaces for use in the space program to produce lightweight and portable antenna mesh for satellites. This gold-plated molybdeaum was so expensive to produce that the engineers who worked on this project were searched every night as they left the mill.

My last visit was to the Philadelphia College of Textile and Science, Textile Engineering Department, whose experiments crossed a range of applications including textiles for medical applications and for the car and aerospace industries. As a university, its main aim is to prepare future engineers for the textile industry while conducting some commissioned research from a variety of industries.

The Textile Engineering Department (Figure 5) is a wonderfully eclectic research laboratory, as different from the necessary sterility of the medical textile labs as possible. Here vintage jacquard looms and nineteenth-century braiding machines share space with computer and state-of-the-art textile machinery, old parts, and an odd collection of materials. It is the embodiment of the mad

**Figure 5**
Textile Engineering Department, Philadelphia College of Textile and Science.

scientist's laboratory and the spirit of experimentation and curiosity (that I met with throughout my trip) were palpable.

Here knee replacement prosthetics are being developed using textile procedures and materials. A form is first carved in Styrofoam or other building material. The finished form is inserted onto the central shaft of a braiding machine. Each thread intertwines the diagonal threads it crosses, one from above and one from below. The braider braids multiple strands around the form, creating a very stable, strong structure. The load bearing capacity of braided structures is greater than that of products made with other techniques, which is why they are used in, among other applications, mountaineering ropes, yachting ropes, and parachute lines. After the braiding is complete, the form is removed (if Styrofoam is used, it can be dissolved using acetone), and the form is coated with a resin to provide a lightweight yet structurally strong substance. This same process is being explored at the Department of Textile Engineering to produce lightweight parts for the car and aerospace industries in an attempt to replace steel.

## Conclusion

Contemporary industrial textiles provide a fascinating field that touches on many of the pressing questions of our age. Questions of boundaries between humans/animals, machines/organisms, and ethical questions on what constitutes natural and unnatural. All of these questions have the potential to challenge the humanist litany of dualities and the view of a technological telos—technological research as an inevitable, evolutionary march forward. The French philosopher Michel Serres (1990) suggests that humanity should make a new nature contract to replace the old outdated social contract. Perhaps this contract could be one of integration rather than subjugation. As many scientists are increasingly becoming farmers and bio-materials and reproductive technologies are creating new hybrids, perhaps now is the time to suggest a new model. This model could be more akin with medieval agrarian societies; a relationship to nature in which there is no radical separation of nature and society rather than the current situation of nature as an exploitable resource for the benefit of human life alone.

## Acknowledgments

My thanks to Kenn Gardner, Robert J. Dougherty, Anna Lietske, and Mary Anne Friel.

## Notes

1. Kevlar, patented by DuPont, is a man-made organic or para-aramid fiber that has five times the strength of steel yet is lightweight, flexible, and comfortable. Because of its unique combination of properties, Kevlar is used today in a wide variety of industrial applications including bullet-resistant vests, shrapnel-resistant shielding used in jetcraft air engines, as well as kayaks, skis, helmets, and racquets.



2. Xenotransplantation is the transfer of living cells, tissues, and/or organs from one species to another.

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