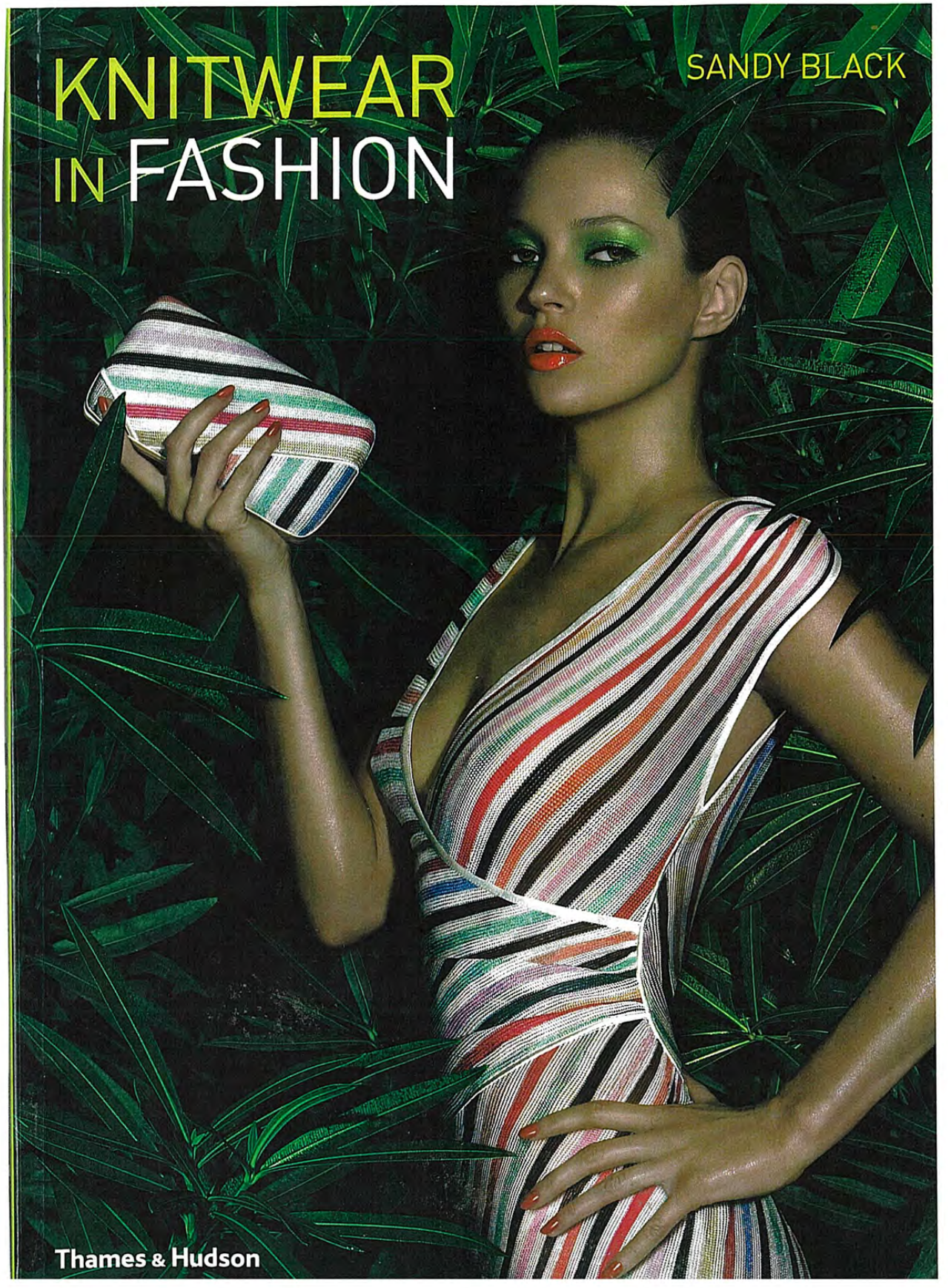
KNITWEAR IN FASHION

SANDY BLACK



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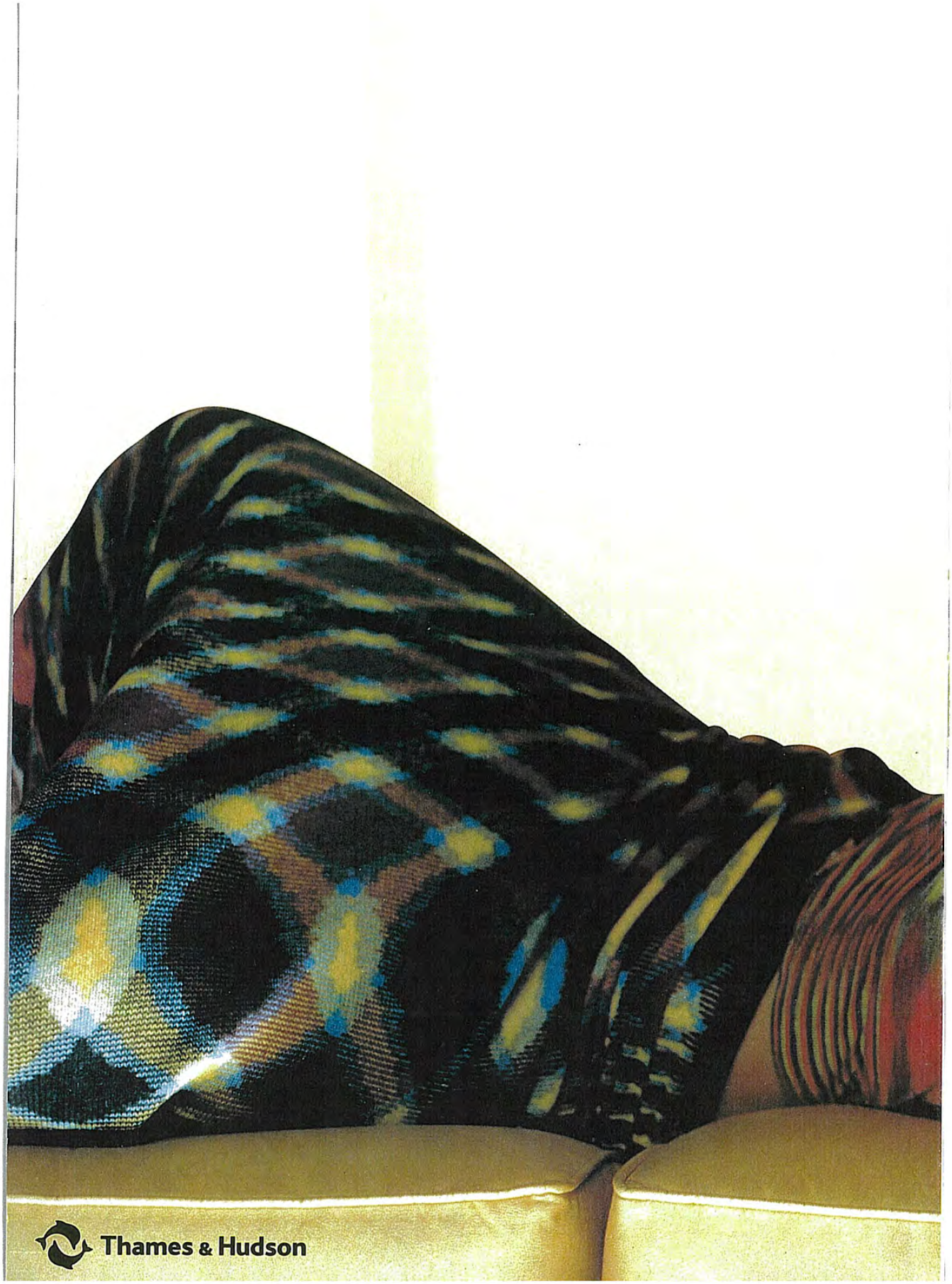
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300 illustrations, 285 in color

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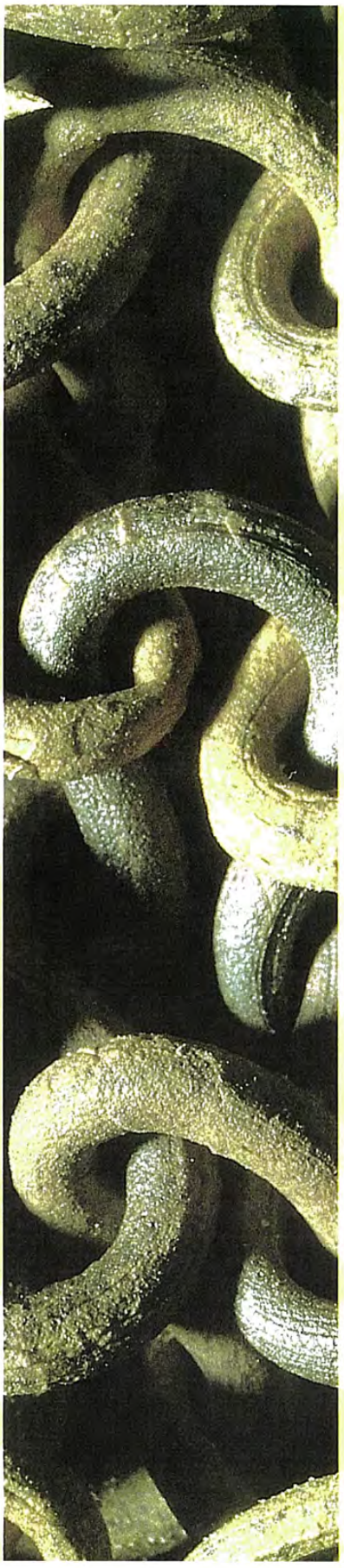
p. 1 Mie Iwatsubo, knitted fabric, 2001

pp. 2-3 Missoni, sweater and skirt, autumn/winter 1997/98

pp. 4-5 Georgina Naish, flexible clay knit, 1998



CONTENTS

INTRODUCTION
– REINVENTING THE ART 6

1 KNITWEAR IN FASHION
– FASHION IN KNITWEAR
Reinventing the Classics 10
Decades of Change 28
Creative Fashion Accessories 52

2 INNOVATION AND EXPERIMENT
– MAKING THE FUTURE
Materials, Structures and Processes 66
Radical Knitwear 90
The Seamless Revolution 118

3 BLURRING THE BOUNDARIES
– CONTEMPORARY ART AND DESIGN
Artworks and Sculptural Form 132
Knitwear in Performance 152
Design for Interiors 162

INFORMATION
The Technology of Knitting 174
Developments in Design 178
Yarns and Fibres 179
Designer Biographies 181
Glossary of Technical Terms 189
Further Reading and Resources 190
Picture Credits and Acknowledgments 191
Index 192

Opposite Marcia Windebank, panel, 1999. Utilizing the filigree effect of lace knitting, Windebank creates abstract textural compositions that are dyed and treated with paper pulp to stiffen and fix them in striking shapes for interior decoration.

In the climate of accelerated technological change which has prevailed over the past twenty-five years, new technologies and new fibres have transformed knitting from a homely discipline into the most innovative and exciting textile medium, and knitwear has gained a place at the forefront of contemporary fashion. Never before have so many designers and artists experimented with knit as a basis for their work, exploring structures and finishes, materials and meaning, and exploiting the unique sculptural qualities of knitted construction. A new generation of fashion designers who are pushing the boundaries have reinvented the art. By presenting a wide spectrum of hand-knitting, hand-frame knitting and industrial production, *Knitwear in Fashion* offers a fresh look at this 'common art' in the context of current creative fashion and design.

Fashion has emerged during recent years as a discipline worthy of study in its own right; as a socio-cultural, economic and high-profile design phenomenon, expressive and reflective of constant change, and open to multiple readings and interpretations. This fashion discourse has been conducted through a growing range of publications, both popular and academic, and increasingly through exhibitions. Given that the attention of the academy to fashion as a discipline is so relatively recent, knitwear as an element of fashion has received even less attention, perhaps due to its specialist nature and its hybrid position as both clothing and textile.

Knitwear is universal – everyone wears it in some form, either as underwear, hosiery or outerwear – but its domestic and mass-market connotations have until recently consigned it to a minor role in fashion and textile study. Museum collections have tended to overlook knitwear items and many historical pieces of everyday wear have simply worn out. However, the last few years have seen a change in attitude and knitwear has at last begun to be featured in fashion exhibitions, which now occur more frequently. As the introduction to the knit section of the 'Jouer la Lumière' textiles exhibition at the Louvre in 2001 confirms: '... often little understood in museums, and also badly understood by textile historians, knitting today plays a major role and reveals itself to be capable of a stunning diversity.' It is this diversity that has led me to present this anthology of knitwear and knitting, together with a love of materials and construction, and a desire to celebrate this 'little understood' technique for its unique capabilities: the way in which it can engineer both two- and three-dimensional shape; its affinity with the body through innate characteristics of stretch-to-fit; and its infinite structural and patterning potential.

Skechers EX1054-p. 7
Skechers v Nike

Right Simone Memel, 'Hard Rope', 1994/95. Memel branched out from her fine arts and three-dimensional studies into the craft of shoemaking in order to express dichotomies and perceptions associated with male and female roles. Her first shoe project was a sock boot, combining sock and shoe, and she has since created many versions of one-off shoes using a range of knitted and other materials. Here hand-knitted string is used to simulate the toughness of rope in a classic wearable style outlined by the knit and purl stitches and the plaited edging.

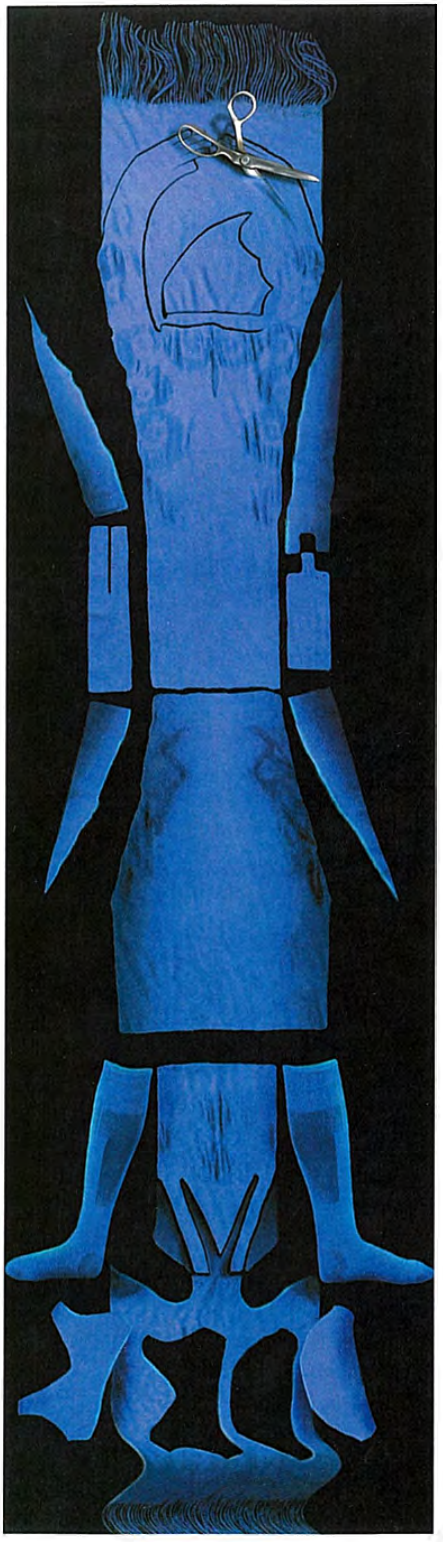
Below Ann-Louise Roswald, autumn/winter 1998/99. Capitalizing on her father's traditional clog-making business, Roswald was inspired to create matching clogs for her stylized floral printed knitwear. These were quickly taken up by Italian fashion house Marni for their winter 1999 collection, patterned to look like cowskin, and are now manufactured on a larger scale in Sweden.

Above Shelley Fox, summer 1996. Felted wool, which was also embossed and used for co-ordinated shoes, formed the fabric for Fox's graduation collection, showing her attention to detail and the importance of unique fabrics to her work. Each outfit had matching fabric shoes – a total-look theme that Fox has pursued through the use of co-ordinated knitted, printed and felted fabrics.

Right Vivienne Westwood, 'On Liberty' collection, autumn/winter 1994/95. Hand-knitted wool stockings with intricate lace and embossed leaf design and appliquéd flowers, finished with knitted tassels, were made to accessorize elaborate corseted and bustled hand-knitted outfits based on historical costume. Note how the knitted decoration extends to the shoes. Bags and jewelry were also created to accessorize.

Opposite Simone Memel, 'Homage à Monroe', 1995. The material defines the shoe in Memel's work – in this case a statuesque homage to womanhood, symbolized by an unwearable shoe in fluffy mohair with a quilted satin lining. In Memel's world Monroe and women stand precariously on their pedestal. Another creation – 'On the Road' – also used a mohair fabric, contrasted with tyre tread-patterned rubber for the sole and heel.

Skechers EX1054-p. 9
Skechers v Nike



Two of the most significant developments in knitwear manufacturing, which could have a major impact on the fashions we wear and on clothing production, are seamless (or integral) construction – currently seen in socks, gloves, underwear, lingerie and more recently in some sweaters – and the revolutionary clothing concept A-POC from Issey Miyake, in which a knitted tube of patterned cloth ingeniously separates into a whole wardrobe of garments, breaking new ground aesthetically, technologically and in its retail concept. Both developments use totally different technologies – integral knitting is based on weft knitting, A-POC on warp – but each depends on the computer control and design capabilities working at the interface of machine innovations and advanced yarns.

The concept of seamless knitting is as old as knitting itself, as shown by fragments of Egyptian socks dating from the fifth and sixth centuries held in museums. In medieval times, Britain and Spain were two of the foremost producers of hand-knitted seamless stockings. Since the Industrial Revolution, when knitting was mechanized, industrially knitted garments have been produced either in shaped sections on flat-bed machines or cut from fabric produced on flat or circular machines, both of which require a finishing process. The seamless, garment-by-garment, industrial manufacture of knitwear, requiring little or no making up, has long been something of a mission for machine builders. In 1965 the Japanese company Shima Seiki invented the first machine for manufacturing seamless knitted gloves to meet the demand for work gloves used daily by taxi drivers, construction and factory workers throughout Japan. The company has since remained at the forefront of integral knitting technology. Though the ability to knit in the round without seams is the oldest form of knitting by hand, it took until the later twentieth century to replicate by machine the gansey, sock, glove and cap – all perfect examples of seamless, three-dimensional knitting.

The hosiery industry has recently led developments in machinery and adapted their expertise in fine gauge production with synthetic yarns to create new engineered and sculpted lingerie, swimwear and underwear which have quietly infiltrated the mass market via companies such as Wolford, Benetton and Marks & Spencer. Much lingerie is now without side seams and increasingly features differential structures to add support and define shape in one-piece underwear.

Machine builders, such as Santoni, and manufacturers are now turning their attention to outerwear formed from basic body-sized tubes, which have tremendous potential for new forms of clothing. Philippe Starck and Wolford created the versatile

Opposite and right A-POC Queen, from 'King and Queen', spring/summer 1999. Seeing A-POC for the first time we are not quite sure what to make of the vague patterns and occasional gaps discernible in the cloth. Fortunately there is a computer animation to explain it. We are shown the fringed roll of cloth, the application of the scissors and one by one a wardrobe is released: dress, skirt, underwear, hat, gloves, socks and bag. They are put on by an invisible model who walks away delighted.

Below A-POC Alien, autumn/winter 1999/2000. Alien is possibly the most complex design to visualize. It contains the body in double layers of mesh fabric – dress over trousers, and face initially masked. In the fashion show presentation, two assistants cut away and opened up the fabric into a more wearable form, and the model emerged.

tubular dress 'Starck Naked' in 1998. Testu, a new design company, have created ranges of unisex pieces made from fine knitted tubes but deliberately shaped and distorted in the knitting process to create bizarre, two-dimensional forms which fall into folds when worn on the body. As with most innovations in technology, early use has tended to merely replicate the basic existing knitwear constructions. However, new design research is beginning to take place; for example, the work of Caterina Radvan focuses on unconventional shapes that create volume and drape in seamless garments.

Technological advances in knitting have at present outstripped the market's ability to absorb and utilize it, and the customer has to be educated to recognize the benefits. The role of technicians and designers must inevitably merge closer together to create a dialogue from which design innovation can spring.

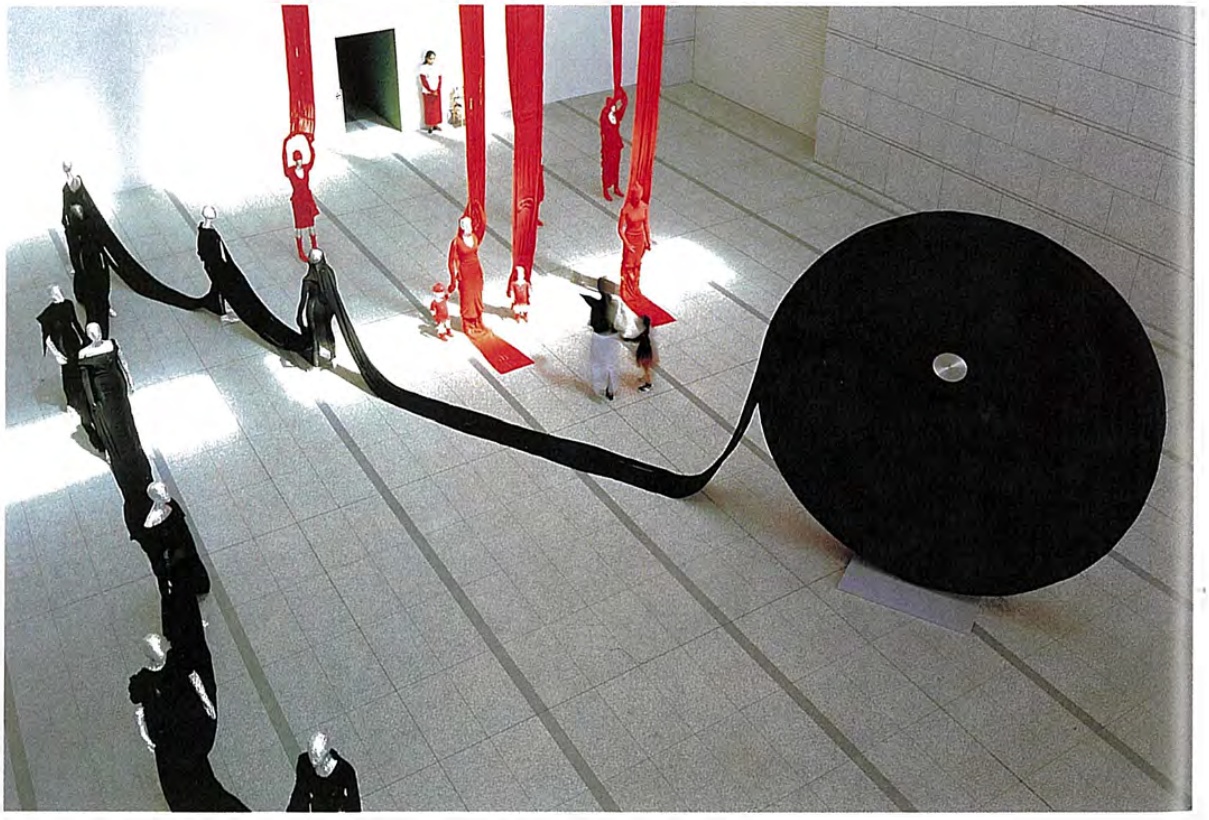
Issey Miyake remains unsurpassed in his commitment to the development of new forms of textiles and clothing which cross both international and fashion boundaries to have universal appeal. With his integration of old and new technologies, experimentation with processes and questioning of assumptions whilst resolutely looking to the future, Miyake has revolutionized our perceptions of clothing the body. The A-POC concept represents a simultaneous leap of the imagination and application of technology. A-POC (an acronym for 'A Piece of Cloth' and play on the word 'epoch') was first shown in 1997 and is a collaboration between Issey Miyake and Dai Fujiwara, one of the Miyake Studio design team who originally trained as a weaver. The whole process is an experiment designed in four stages – a continuing work-in-progress – in which the customer also participates. These stages are conjugated like Latin – APOC, APOS, APOM, APOE. As the technology of the cloth is perfected, they will turn their attention to the yarn (A Piece of String), then design the machinery to have complete control, and then hire A Person of Education and Dedication to create a fully integrated company. They see no boundaries or limits to what might be achieved – just technical problems to be overcome and refined. As Fujiwara says, 'Design is functionality and function is beauty.'

The fundamental philosophy is one within which Miyake has operated since he set up his studio in 1970 – to create the maximum with one piece of cloth; no waste, minimum cutting and seaming and, in the case of A-POC, no after-knitting processes at all. This has similarities to the classic construction of the kimono from one long roll of narrow cloth, and Miyake has applied it in many ways, with knitwear, woven garments and also moulded pieces. Indeed the first garment entitled 'A Piece of Cloth' was knitted and shown as early as 1976. The A-POC application may be the concept's most perfect realization as it involves no seaming or finishing processes except the cutting out of the chosen variation from the tubular roll of cloth which is presented to the customer. As such, it also represents a unique mix of customization and mass production.

Opposite A-POC Eskimo, autumn/winter 1999/2000. Another highly experimental design incorporating innovative new features. Eskimo introduced colour contrasts in graphic lines and areas padded with high-bulk cotton to define contours around the body and give it an almost protective layer – like packaging normally discarded.

Above A-POC collection, spring/summer 2001. Simple, plain top and trousers from the Baguette design (which can be cut anywhere, like the loaf), showing narrow, cut-out 'seam' lines, with ties made from cut-away fabric. The comfort and stretchiness of the fabric – wool or cotton with nylon and elastane – are demonstrated in the model's acrobatic pose.

Left A-POC collection, spring/summer 2001. The use in avant-garde designer collections of raw edges, fringes and frills of cloth at first appeared uncompromising and difficult to understand. This aesthetic, however, gained prominence in fashion in the 1990s, and now has widespread acceptance. Seen in this context, and presented on young streetwise models, this A-POC collection does not need to explain itself – it just presents modern fashion. He is wearing a simple top from the plain Baguette design; she is wearing a one-piece dress with distinctive fringing.



Above Issey Miyake, 'Making Things' exhibition, Tokyo, summer 2000. First presented in Paris in autumn 1998, the exhibition also travelled to New York. The A-POC section received more prominence in Miyake's home country, spectacularly filling the space with continuous lengths of cloth worn on mannequins and making the point of mass production by the presence of the huge roll of knitted fabric.

Opposite above A-POC Le Feu, spring/summer 1999. The A-POC concept was at first shown as part of the Miyake fashion show presentations, before becoming a collection in its own right. This dramatic display demonstrated the revolutionary concept by a series of models wearing a T-shirt and skirt, based on a square shape, each one connected to the next.

Opposite below Close-up of the 'Making Things' installation, showing the warp knit partially cut away, leaving the fringe effect and spaces in the knit, which create larger fringes.

Skechers EX1054-p. 14
Skechers v Nike

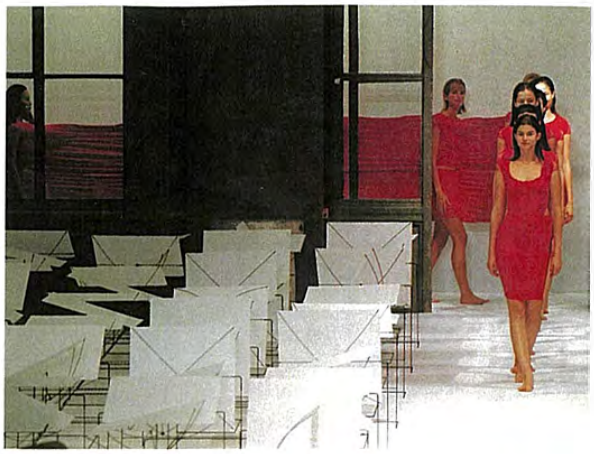
Attention has been given to the technical details, such as creating the right mesh fabric for appropriate stretch, and working out the different diameters of tube required for all the garment parts (the ideal body size was found to be 55 cm). With the right amount of stretch, however, these tubes can fit all sizes.

A-POC is manufactured using computer-controlled, warp-knitting technology, which creates fabric from a fine mesh of individual chain stitches flowing vertically, each linked together. A high level of stretch is derived from the cotton or wool/nylon (polyamide)/polyurethane mix. The innovation was to develop this technology in circular knit form and adapt it from socks to body-sized pieces, and then to design the contours of the garment shapes within the large tube, using graphic patterning on a computer interface and creating a subdivided tubular shape which, when released, opens to form three-dimensional garment pieces with internal patterns of mesh. The cutting lines are subtly delineated by gaps where the individual warp threads are not connected to each other. These create the signature fringing effect which demarcates all the outlines of the pieces within the flat fabric tubes, as well as the major sections such as tubes for arms and legs. As the experiment has developed, the garment shapes, internal designs and fabric patterning have evolved, each developed painstakingly on the computer screen.

One of the intrinsic qualities of A-POC in its first incarnation – 'Just Before' – was the unfinished, raw appearance derived from the fringed edges just released, the extra fabric from the sides of cloth remaining from cutting out (utilized as rough belts), and the raw-edged collars and necklines formed from removing the attached fabric. The effect was arresting and at first a little shocking: like any totally new concept it challenged our assumptions about clothing. The ragged edges have since undergone refinements and developments with each successive design until the simplest 'Baguette' sweater and its companion trousers show only the most discreet external 'seams'.

All the A-POC designs can be varied according to choice – round neck, V-neck or loose collar, short or long sleeves, short or long length, and so on. A computer-generated video shows the process of releasing the wardrobe from the cloth. The innovative retail concept of the A-POC shops is that they are to be seen as a laboratory in which the customer can view many examples of the variations on each theme and can cut their own garments from the piece or the roll, with help from the well-informed sales staff. In Tokyo Dai Fujiwara works with his assistants, all wearing white coats, in a laboratory at the back of the shop, separated from it by glass walls, so that they can feed customer reaction back into the design process. A live experiment indeed.

A-POC Eskimo and A-POC Alien were two designs from 1999, each incorporating new features such as areas padded with bulky yarn to define contours around the body and give it an almost protective layer. Further experiments have incorporated other features: the Millennium Pillow carries portable furnishings with the wearer, and Mobile is an anthropomorphic cross between clothing, furniture and plaything. Although sometimes a little difficult to understand, and not so universally wearable as Pleats Please, the A-POC concept will, according to Dai Fujiwara, eventually realize the merging of woven and knitted textile production to create new clothes for living in the twenty-first century.



Skechers EX1054-p. 15
Skechers v Nike

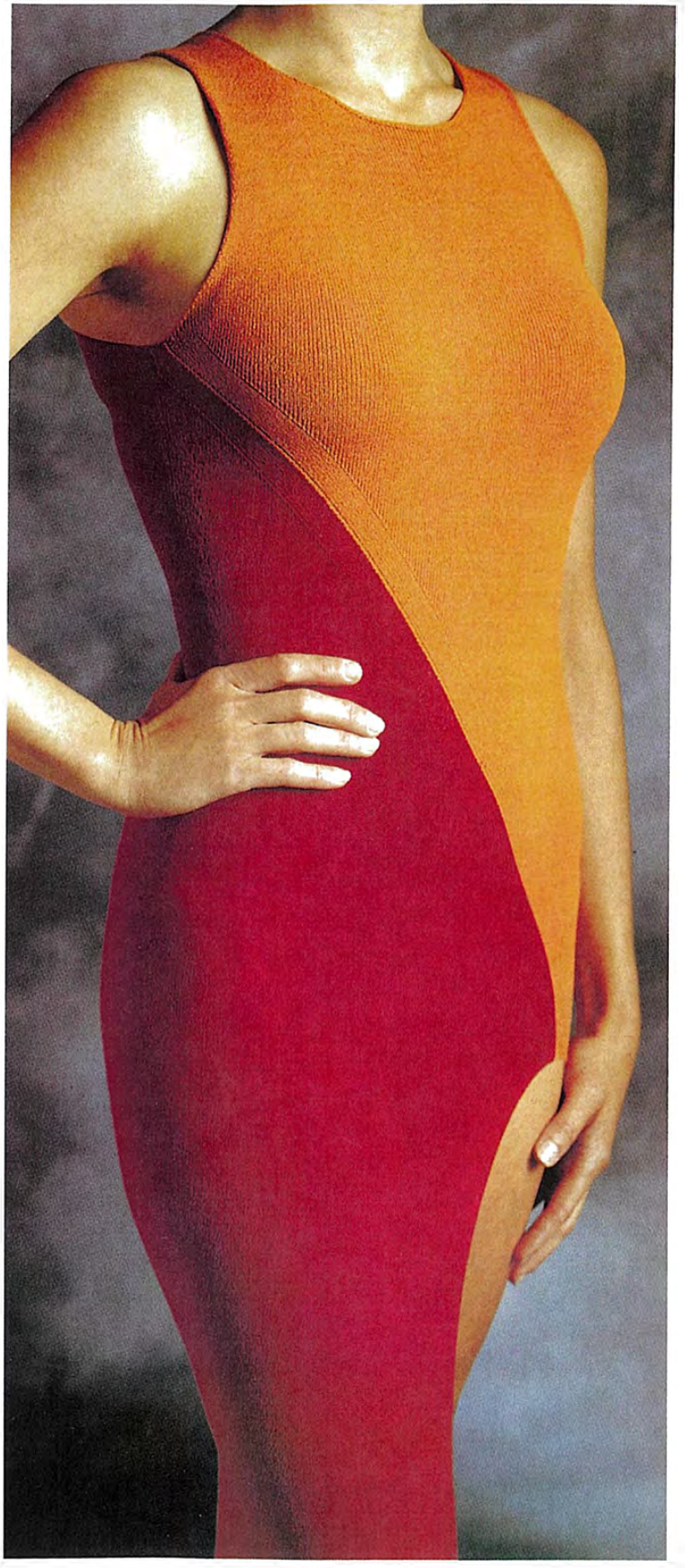
Left Caterina Radvan, 1998. Starting with geometric shapes applied to the body, Radvan has focused on creating seamless knitted garments to develop the unique potential of knitted construction. This seamless dress, made as part of her Masters graduate collection, is knitted in a giant blister stitch on a circular machine in a combination of lambswool and nylon monofilament, then washed to shrink and felt the wool, leaving a ruched layer of nylon attached loosely to the surface.

Opposite left Caterina Radvan, 2000. This seamless dress is knitted in linen, with raw-edged cuffs in rubber yarn. Continuing to develop the seamless theme, Radvan knitted dresses and tops with unconventional asymmetrical and greatly distorted two-dimensional shapes, subverting normal ideas of back, front, sleeves and left-right symmetry. When worn, this produces drape in parts of the garment, and lines of fashioning marks displace normal seams. Radvan is now applying her ideas to unconventional body shapes.

Opposite right Caterina Radvan, 1999. This seamless top is worked on a domestic knitting machine in tubular formation, with integral folds formed by short-row knitting, giving drape to the garment. The lambswool fabric has been felted.

Opposite 'Seamless for Kids', 2001. Machinery manufacturer Matec has developed revolutionary 6- to 10-inch-diameter machines with jacquard capability, which allow for the production of simple 'bodysized' children's garments with minimal seaming and patterned fabrics. The potential for the new technology is shown in this style concept by Emilio Cavallini, using stretch synthetic yarns. Partner company Santoni is at the forefront of 'bodysized' machinery development for adult seamless bodywear, including engineered stitch patterning to create form and structure.

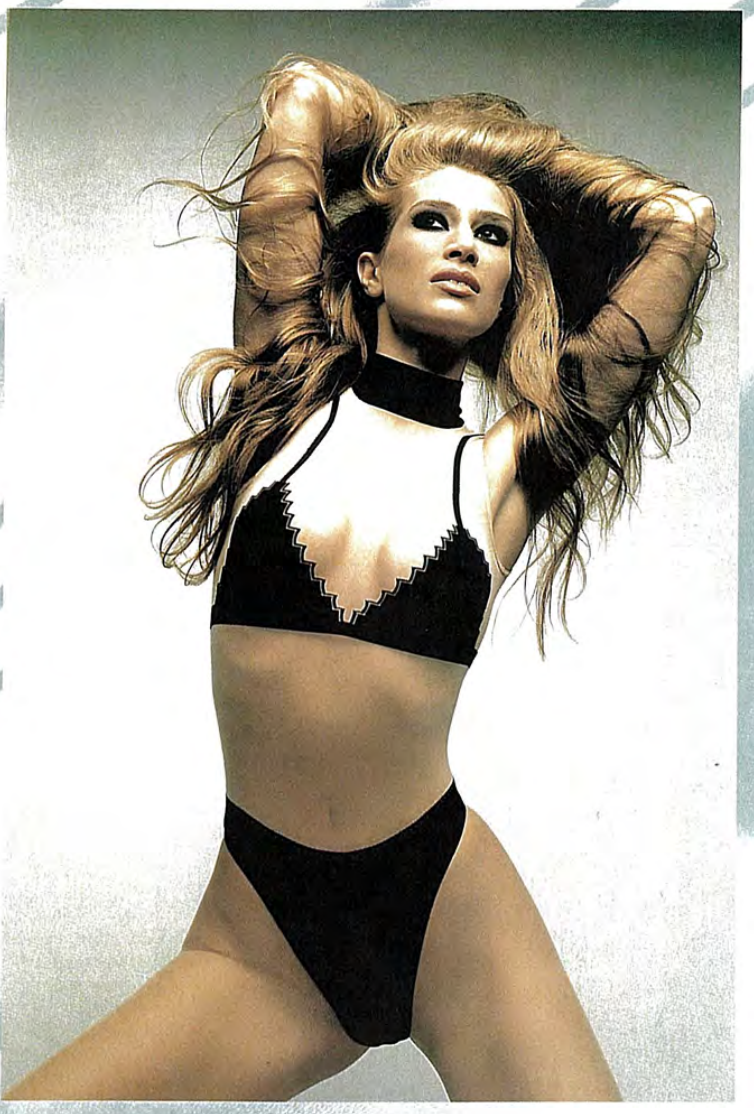
Right Stoll Knitting, seamless dress, 2001. Trend concepts are produced by the design department of this long-established machine builder, which is at the forefront of flat-knitting technology development. These concepts are used to inspire designers and manufacturers, and to promote the newest technologies. This dress combines two-colour knitting and integral knitting in one garment, requiring only neckline and armhole finishing. Note the fully fashioning around the colour divide.

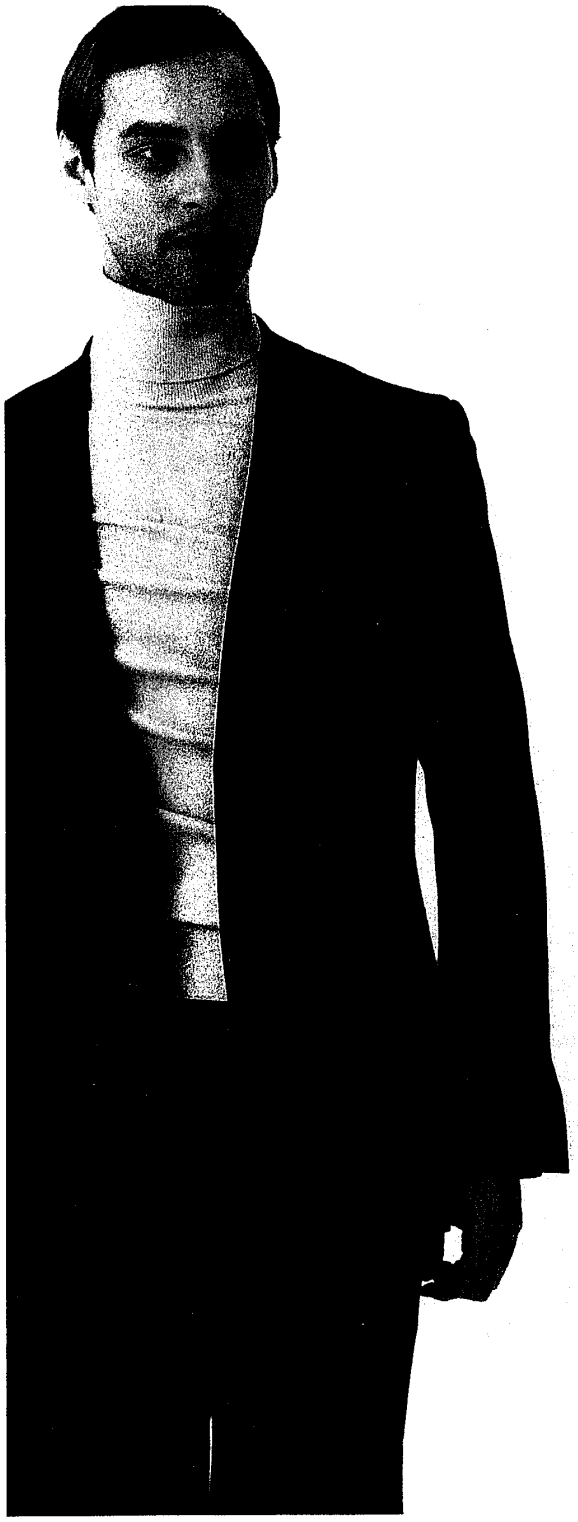


Opposite Wolford seamless dress, spring/summer 2000. Using seamless technology by Santoni, Wolford create bodywear ranges which cross over from intimate wear to outerwear, comprising complex jacquard patterning (such as the tiger-patterned 'Africa' dress) or simple stripes. Wolford have also collaborated with top designers, including Philippe Starck, Hervé Leger and Jean Paul Gaultier, to push the boundaries further.

Background Wolford 'System' tights, autumn/winter 2000/01. Seamlessness became the norm for women's hosiery after the advent of seamfree stockings, then tights, in the 1950s and '60s, although some seaming processes for the body-part and the toes are still generally necessary. Completely seamless tights can now be produced but are not yet widely commercially available. Most design development has taken place in the patterning capabilities applied to hosiery, which are now boundless.

Right Jean Paul Gaultier for Wolford, autumn/winter 2000/01. In this first collaboration, Gaultier designed a range of tights and all-in-one bodies which created the impression of separate pieces of underwear. Further irony was achieved in the seamless tights which were patterned to simulate seamed stockings, complete with suspenders. A second range of designs for summer 2001 featured the Eiffel tower patterned halfway up the leg and across the body.





Opposite left and right Testu, spring/summer 2002. Taking a philosophical stance based on a reading of Roland Barthes and the comparability of masculine and feminine clothes, Testu seeks to provide clothing which is gender-neutral but will adapt to either male or female form. The knitwear aspect is based on draping, achieved through a two-dimensional geometry which extends and displaces necklines and armholes as if the body has bent sideways and the clothes carry a memory of the movements. The knitwear is made from viscose with 25% Elité elastane and is side-seamless, forming draped folds on one side of the body. Knitwear items in the collection include sleeveless and long-sleeved sweaters, tops and tubes which can be worn around the neck as collars or around the body.

Below Testu, sleeveless top, illustrating the distorted shape used in the knitwear.

Above Lawrence Steele, autumn/winter 2000/01. The seamless sweater and sweater dress were one of the knitwear looks in this collection, creating a clean and sophisticated, body-hugging silhouette. Steele was one of the first to adopt this technology for designer fashion. The top yoke of the sweater is fashioned by internal wale shaping to give a smooth and three-dimensional shape, ending in an integrally knitted funnel collar. Note the knitted rosette corsage.

Skechers EX1054-p. 21
Skechers v Nike

3 Blurring the Boundaries – Contemporary Art and Design

Artworks and Sculptural Form Knitwear in Performance Design for Interiors

Opposite Freddie Robins, installation, Colchester, UK, 2000: 'Headroom', with 'Noway' and 'Headcase' in background. The play on the familiar, both visually and in words, is at the heart of Robins's current work. Her mutant bodies, sweaters and gloves comment on ability and disability. A combination of freak show and genetic engineering, they are at once humorous and disturbing. Utilizing the construction of knitted garments to great effect and taking it to illogical conclusions to create thought-provoking and unwearable pieces, Robins simultaneously puts knitted textiles into a new arena.

Since the Surrealists first adopted fashion as a powerful tool for the communication of their extraordinary concepts, fashion has continued to interpret Surrealism, and now appears within the context of art with increasing frequency. Elsa Schiaparelli believed that 'dress design ... is not a profession but an art', and made the first notable example of knitwear crossing into art with her 1928 trompe l'oeil hand-knitted sweaters. One, adopting the Surrealists' favourite visual trickery, was designed to resemble a tied bow. In the years since Schiaparelli, a number of artists and designers have been engaged in the creation of art objects that involve or interpret clothing, and sculptural or conceptual fashion that can transcend functional clothing to be viewed as art. Issey Miyake has been especially instrumental in bringing experimental textiles and clothing – a significant proportion knitted – into the art gallery and museum, setting standards that few others have met for the presentation of clothing and the body, and moving easily between the worlds of fashion, popular culture and art.

In recent years, the use of clothing – particularly the disembodied form of the dress – as a medium of expression in contemporary art has become a somewhat commonplace but powerful element within artistic vocabulary. Inspired by established artists such as Caroline Broadhead and Annette Messager, practitioners of both art and fashion have increasingly employed the dress, the corset and the shirt to explore the relationship between the body and its adornment and enclosure, the boundary between inner and outer worlds, themes of absence and presence, and temporal and corporeal ephemerality. The neutrality of colour and simplicity of material usually adopted by artists serve to emphasize impermanence and inspire contemplation.

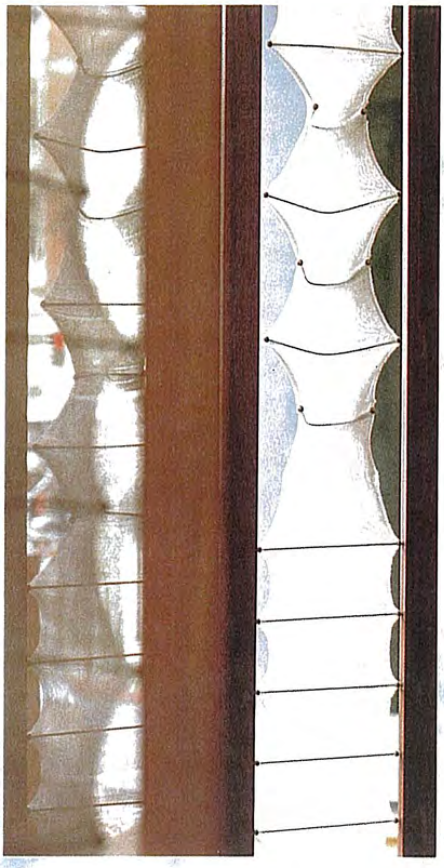
Given impetus originally by the feminist movement, female artists began to address issues of gendered perception associated with textiles and crafts, as noted in Rozsika Parker's book *The Subversive Stitch*. Knitting typifies this perception, with its strong associations of the feminine and the domestic.

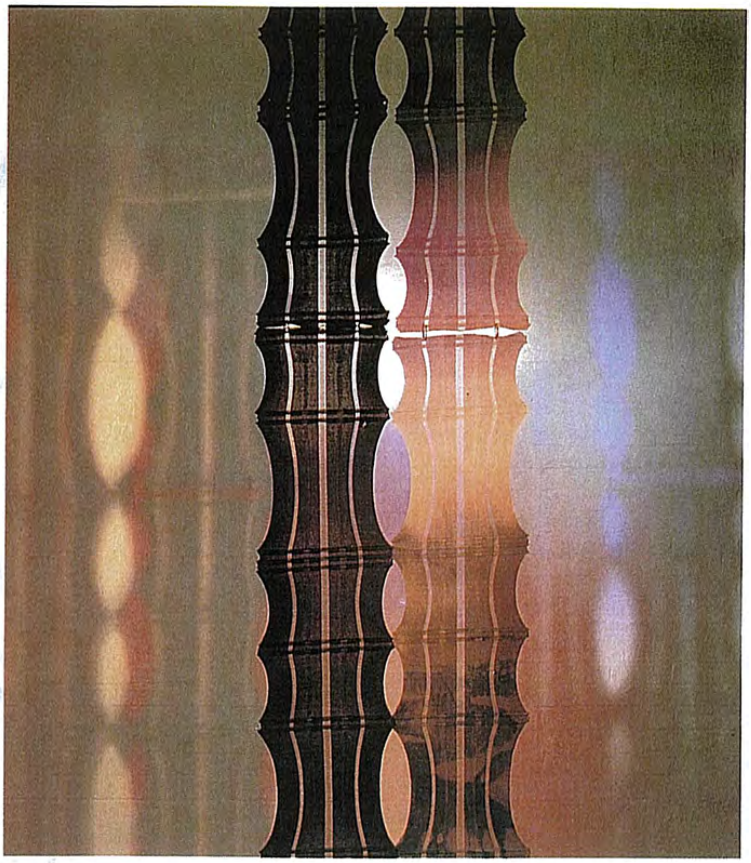
German artist Rosemarie Trockel brought knitting into the art gallery with industrially produced knitted 'pictures' and clothing such as balaclavas, leggings, dresses and sweaters, displaying repeating motifs and political logos – the Playboy bunny, the Woolmark, the hammer and sickle, and the swastika. The production of these items, using computer-controlled industrial knitting technology, was in itself a commentary on the familiar associations of knitting as a domestic activity. The shock of exhibiting knitted pictures and knitted clothing in 1986 has been compared in its impact to the Warhol multiples and Pop art of two decades earlier. By the act of being knitted, the logos became stripped of their political status. One art critic of the time was in no

Skechers EX1054-p. 22
Skechers v Nike

Above Karina Thomas of salt, 'Totem', 2000. This panel-glide blind is made of knitted cotton with a spaced rib structure. salt partners Karina Thomas and June Swindell studied knitted textiles and woven textiles respectively, and create bespoke fabric panels for windows and screens.

Background Karina Thomas of salt, 'Creased Totem', 2000. These cotton rib panels have bent metal rods inserted to create dimension. salt's textile solutions to light-filtering and control are both sculptural and innovative.





Above left Karina Thomas of salt, detail of knitted screen, 2000. salt's window treatments and screens have a minimal architectural aesthetic: a fusion of design, technology and technique, in tune with contemporary interior spaces. The panels shown here feature metal rods within a wooden frame screen.

Above right Karina Thomas of salt, 'Totem', 2000. These knitted panels can be combined to any width. 'Totem' modular knitted blinds are now available through a commercial collaboration. salt's recent work has included diversification into graded colours and surface textures.

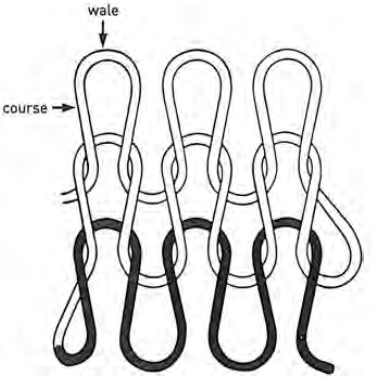
Skechers EX1054-p. 25
Skechers v Nike

Classes of knitted fabric and machinery
Knitting is formed from the intermeshing of individually made loops to create a fabric. This fabric is made either in tubular or flat form. Uniquely, it can be shaped whilst in construction. Industrial knitting technology can be divided into two main areas – weft knitting, which encompasses circular knitting, and warp knitting. Each has a different principle of construction. The majority of knitted fabrics for clothing are weft-knitted and this is therefore the main focus of this section.

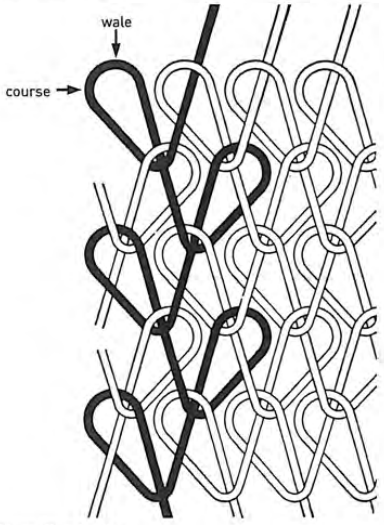
Weft knitting: comprised of loops formed in horizontal 'rows', technically referred to as 'courses', each loop linking to a loop or stitch below and to each side. The vertical lines of stitches are called 'wales'. The knitted loop is symmetrical, side to side and top to bottom. Basic fabric structures – such as plain knitting (stocking stitch) and ribs – are created from one thread. Weft knitting by machine was derived from hand-knitting and the structures are identical. The final courses of loops must be secured by binding off so that the loops do not disconnect from the stitches below, hence unravelling the fabric. A wale of loops which has unravelled is known as a 'ladder' – a term familiar from hosiery.

In hand-knitting, the two fundamental stitches are described as knit and purl, depending on the direction of the loop formation, front to back or back to front. In machine-knitting, the direction of loop formation is fixed, unless the stitch is mechanically transferred from front to back needle bed or vice versa. Weft knitting can be constructed as flat fabric with selvedges, created by knitting to and fro across a fixed number of stitches, or as circular fabric, formed in a continuous spiral. The basic properties of weft-knitted fabrics are extensibility and recovery, which can be accentuated by yarn choice and stitch structure, speed and versatility of production, and the ability to create shaped garment pieces or integral garments knitted and shaped at the same time.

There are three fundamental knitting actions undertaken by all weft-knitting machine needles: a) to knit, i.e. form a new loop and drop the previous loop to form a stitch; b) miss, i.e. hold the previous loop for that course of knitting, making a float appear on the back of the fabric (loops may be held for several courses, creating puckering effects and surface pattern: this action also forms the basis of float jacquard colour knitting sequences); c) tuck, i.e. take a new loop up but also hold the previous one, thereby holding two loops on the same needle until a subsequent knitting course (this action produces gathering and spreading of the fabric, but, depending on the gauge, loops may not be able to be built up for many courses).



Above Weft knitting



Above Warp knitting

Above Aberangel intarsia design by Ballantyne

Flat-bed machines can be fine gauge to heavy gauge (E14 to E3) and knit a wide range of garments, but mainly outerwear.

a) V-bed machines: two parallel needle beds with needles facing in opposite directions, inclined at an angle in inverted V-formation, for rib fabrics and variations. The majority of these machines are now electronically controlled (e.g. Stoll, Shima Seiki and Protti) but some are hand-operated (e.g. Dubied hand flat machines). There are also some domestic hand-operated or motorized versions (e.g. Passap and Pfaff). Many electronic V-bed machines can now knit geometric intarsia patterns (a specialist intarsia V-bed machine has been developed by Zamark).

b) Single-bed: machines with one horizontal needle bed, particularly hand intarsia machines (now almost obsolete) and domestic knitting machines (an additional needle bed can be attached for rib fabrics).

c) Cottons Patent machines: single-bed machines with bearded needles arranged vertically, specially adapted for automatic fully fashioned garment shaping.

d) purl machines, also known as links-links: specialist machines with two needle beds in a horizontal plane which share one set of double-ended latch needles, enabling plain and purl stitches to be created in the same wale and on the same face of the fabric. The needles slide between the two needle beds according to the programme. These machines were created to simulate hand-knitting effects and are slow in operation. They are gradually being replaced by the electronic V-bed machine.

Circular machines produce jersey fabric, normally in fine gauges from E18 to E30.

a) Single jersey: one set of needles arranged vertically around a cylinder (e.g. Bentley), capable of knitting plain fabric and variations such as stripes and tuck-stitch effects. The emphasis is on speed of production, using multiple yarn feeders to create efficiency. The resulting tubular fabric is slit vertically into flat fabric, finished, then used for cut-and-sew knitwear.

Skechers EX1054-p. 26
Skechers v Nike

b) Double jersey: two sets of needles at 90 degrees, one set aligned vertically – the cylinder needles – and the other radiating horizontally – the dial needles – for double-bed fabric production, particularly jacquard and interlock fabrics, or for specialist production (e.g. Moratronic and Wildt Mellor Bromley). Fabrics are stable and can be used for cut-and-sew outerwear or underwear.

c) Specialist circular machines (e.g. Santoni and Sangiacomo) are used to knit other fabrics, such as fleeces and plush or pile fabrics, or are used in smaller diameter to knit bodysized, seamless garments for swimwear, lingerie and underwear. Small-diameter, specialist, fine-gauge machines are also used for knitting stockings and tights.

Warp knitting: the principal direction of warp knitting is vertical. The fabric comprises wales of loops, each formed from a separate warp thread knitted vertically and interlinked to adjacent or other wale loops by the horizontal movement of the yarn feeders after each knitted course. The feeders underlap or overlap each needle to form the new stitch. If each thread continued to knit only in its own wale, the fabric would be split into separate chain lengths. Each needle has one or more yarn feeders, therefore different colours or textures can be knitted along the length of the fabric, parallel to the selvedge. Reels of warp threads are wound prior to knitting and form a warp beam, similar to woven fabric production. A wide range of fabrics, including mock crochet, and complex lace and embroidery effects can be produced, depending on the knitting sequence and number of warp beams and corresponding feeder guide bars employed. Warp-knitted fabrics are more stable than weft-knitted, and will not ladder or unravel. Fabrics produced by warp knitting are used for household textiles, such as sheets and net curtains; mesh fabrics, including string vests; and clothing, including scarves with integral fringes.

Two principal classes of warp machine are tricot and raschel, although there is now less distinction between the two and many fabrics can be produced on both.

Tricot: previously used bearded needles only, but now a compound needle is more common. Fabric is drawn away horizontally under very little tension, allowing high-speed production and soft-handle fabric to be produced that is suitable, for example, for lingerie. The simpler warp structure fabrics are generally produced on tricot machines, requiring only two beams and guide bars.

Above Uneven pleated fabric by Jürgen Lehl

Above Internal dart (wale shaping) by Azzedine Alaïa

Above Fully fashioned seaming by Alice Lee

Raschel: the knitting action, based on the latch needle, is different from that of the tricot machine. The raschel (e.g. Karl Mayer, leading manufacturer of warp machines) allows more versatility and commonly uses twelve beams and guide bars, though there can be up to 36. Fabrics are drawn away vertically under greater tension, allowing complex fabric structures, such as openwork laces, to be produced. The crochet machine is a specialist type of raschel machine. This works on a principle of warp chains linked by a separate weft inlay yarn. It is often used to produce decorative braids.

Developments are taking place in the warp-knitting industry, in particular adaptation to tubular knitting, and investigation of shaping possibilities.

Some types of knitted fabric

This section lists some of the fabrics commonly used in fashion (the majority weft-knitted) and featured in the book, but it is not a comprehensive list of knitted fabric structures (see Further Reading). It is included to facilitate fabric recognition within fashion garments and other end products.

Plain fabric, also known as stocking stitch, single jersey, stockinette: the basic weft-knitted structure is simple to knit by hand or on a single-bed machine, and has good elasticity. The fabric has a natural tendency to curl, the sides towards the back, the top and bottom towards the front. The two sides of the fabric appear different: the technical face appears as knit loops, the technical back as purl loops, though many designers use the back as the right side (see Yohji Yamamoto, p. 101).

Intarsia: plain fabric traditionally knitted manually on a single-bed knitting machine. Blocks of colour are laid over the horizontal needle bed according to a geometric, graphic or pictorial design, built up course by course. The technique is very labour-intensive as each colour is laid across the needles by hand. Each area of colour is worked only within its own boundary and does not cross any other colour area. Adjacent colours are linked together where they join by crossing threads or by knitting a stitch in both colours. The back and the front are almost identical. There is unlimited scope for patterning and intricate imagery using the manual technique, but finishing can be laborious.

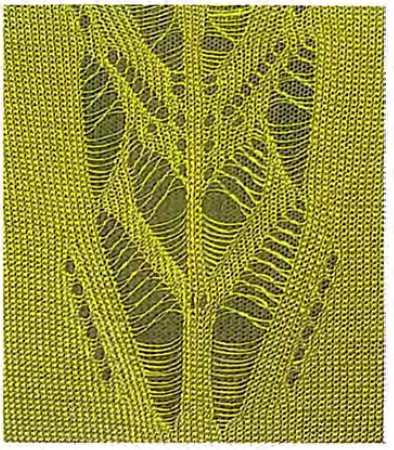
Skechers EX1054-p. 27
Skechers v Nike

Modern V-bed machines now have the facility to create true intarsia patterns using multiple yarn feeders and precision control to position the feeders to knit exactly where required, rather than across the entire needle bed. Geometric patterns such as the classic argyll diamond (called a Ballantyne in Italy) are simplest to knit. Mock intarsia is knitted with floats across the back of the motifs. Intricate patterns are still made by hand in a number of factories to meet a specialist demand.

Purl fabric, also known as links-links fabric: this structure is either hand-knitted or made on special purl machines. It has both knit loops and purl loops on each side of the fabric, both occurring in the same wale. The basic purl fabric (garter stitch in hand-knitting) shows as purl loop courses alternating with knit loop courses, which are slightly hidden. The fabric is the same on both sides, and stable, being particularly extensible in a vertical direction. Many variations of purl fabrics exist, including designs of textural purl stitches on a plain ground, which appear in reverse on the back of the fabric. Tensions within the knitted loops can give unexpected three-dimensional effects in some designs (see Nuala MacCulloch, p. 87).

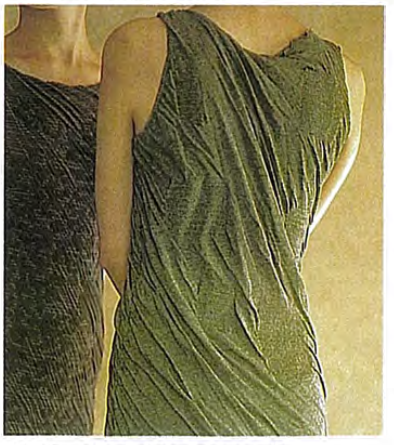
Rib fabric: comprises knit and purl stitches in the same course, arranged in alternating wales. The basic rib structure – an elastic, stable fabric that appears the same on both sides – is 1 x 1 rib (also known as English rib), consisting of one knit wale and one purl wale alternately. The fabric can be hand-knitted or made on a double-bed (V-bed) knitting machine or double jersey circular machine, with alternating needles selected to knit on each needle bed. Many variations are possible, the most common being 2 x 2 or 2 x 1 ribs. These have great elasticity and are used to give stability to knitwear in the form of welts at the lower edges of classic sweaters or cardigans, or to form entire garments which cling to the body. Many other wide rib variations can be devised, such as 5 x 5 or 3 x 6, with varying elasticity.

Tuck rib fabric, also known as half or full cardigan or fisherman's rib: one of the basic knit structures, this is a simple variation on 1 x 1 or 2 x 2 rib, in which either one needle bed (half cardigan) or both needle beds alternately (full cardigan) form tuck stitches. Half cardigan looks different on each side; full cardigan looks the same. The ribs are broadened and the fabric is wider than conventional rib. Cardigan stitch is often used for heavy knitwear.



Above Stitch transfer lace by Marina Spadafora

Above Four-colour jacquard by Kenzo



Above Twisted blister fabric by Jürgen Lehl

Pleated fabric: particular arrangements of needles can create clear pleated effects, particularly effective in fine natural wool or cotton yarns knitted in 1 x 1 rib structure, with single needles left out of knitting action on alternate needle beds at regular intervals. The removal of a needle creates a 'bend' in the fabric along the wale which has been removed.

Edge shaping and wale shaping: narrowing or widening of the fabric can be achieved at the edges or – on modern industrial machines (or by hand) – within the width of the knitted fabric piece. On the machine, to narrow the width of fabric, loops are transferred from one wale to an adjacent wale (creating one double loop and an empty needle) over a predetermined sequence, reducing the total number of wales in the fabric width. At the edge this creates shape but within the fabric it creates an internal dart and interesting visual effects where stitches have been moved and others fill their place. The effects are accentuated in rib-structured fabrics. Loops can be transferred for decorative effect without reducing the overall fabric width, giving rise to contour lines of wales which follow the fabric movement. If loops are transferred outwards onto an empty needle at the edge, this will have the effect of widening the fabric as the empty needle is knitted. Where edges are shaped by a movement of a constant group of two or three wales to widen or narrow the fabric, this is known as 'fully fashioning'.

Cable stitch fabric and 'aran' fabrics: traditionally made by hand-knitting, these three-dimensional effects can be produced on V-bed machines, with the cabled face loop wales being formed on one needle bed and the backing loops on the other. The cable cord is formed of two or three wales which twist around each other, achieved by physically changing the place of the two sets of stitches. On modern machines this is facilitated by additional transfer points to hold the loops (see Jean Paul Gaultier, pp. 17, 42). Similar procedures produce honeycomb and other textural stitch effects.

Stitch transfer lace: commonly created on single-bed machines or by hand-knitting on a base of plain fabric. The action of transferring a loop to an adjacent needle leaves an empty needle, which when filled in on the next knitting course creates an eyelet hole which is secure (i.e. it will not ladder). Geometric or more random design effects can be achieved (see John Rocha, p. 47). Shetland lace shawls are fine examples of the hand-knitted version.

Skechers EX1054-p. 28
Skechers v Nike

Colour effects: the simplest introduction of colour, in any technique, is through striping. Regular stripes in up to four colours pose no problems, whereas irregular stripes or single row stripes create more difficulties in aligning yarn feeders, and are usually avoided in commercial work. Colour can also be introduced by mixing different yarns together to create random marl effects. More systematic colour mixing is produced in machine-knitting by the use of a plating technique in which two different coloured yarns are held consistently in the same relative position to the front or back of the knitted loop. A bi-colour effect is produced dependent on structure: in a plain fabric, the back will appear mainly one colour, the front mainly the other; in rib fabric, when stretched, all the knit loops appear one colour and the purl loops another.

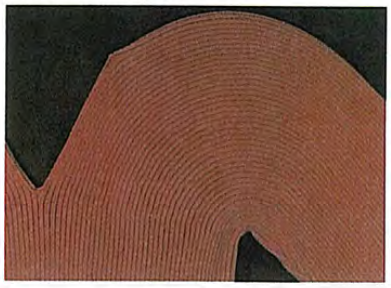
Jacquard fabric: colour patterning in geometric, floral or any other design can be created in jacquard fabrics, using two, three or four colours per course and individual needle selection. It is produced either as single jersey float jacquard, or double-bed or circular rib jacquard. Float jacquard is based on the principle of knit and miss: each colour is knitted according to a needle selection, and the remaining needles miss during that pass of the knitting carriage. During the next pass the second colour is knitted according to its needle selection, and so on. Two-colour jacquard takes two passes of the carriage to build up one knitted course, three-colour takes three passes, etc. The colour pattern is made up of face loops; the reverse of the fabric shows float threads. This limits the extensibility of the fabric.

Rib jacquard is composed of coloured face loops creating the design on one needle bed (or cylinder in circular machines), with the other needle bed forming a knitted backing. In three-colour jacquard with 'striper' backing, the knitting sequence creates six backing rows for two pattern design courses, which can be cumbersome. 'Birdseye' backing is more balanced, knitting alternate needles on each backing row to produce three backing rows for two design courses.

With clever design, jacquard can introduce many colours over the pattern design area (which, with advanced technology, can now extend to the width of the machine) whilst maintaining no more than three or four colours in each design row.

Blister or cloqué fabric: variations on jacquard fabric can result in relief stitch fabrics, either in self-colour or in two-colour. A ground yarn knits across both needle beds, then the blister yarn knits a selected pattern on one needle bed only, creating a separation between front and back. This results in more fabric build-up on the surface, giving a raised effect. Further dramatic effects can be created by working a quilt technique, in which groups of adjacent needles are knitted on the face needle bed only, and the fabric is joined only intermittently to the backing fabric (see Susie Freeman pocket fabric, pp. 150-1).

Above Short-row knitting by Alice Lee



Above Curved rib in short row knitting by Hiroaki Oya

Above Multiple patterning by Comme des Garçons

Three-dimensional effects using elastomeric fibres: the use of a stretch fibre under tension can create strongly sculpted surfaces when the fibre relaxes. Such effects are often achieved with jacquard techniques, one of the yarns being elastomeric (see Kate Carrick, p. 82).

Short row knitting, also known as flèchage, partial knitting, course shaping or wedge forming: this machine-knitting technique is usually worked on single jersey fabrics. It is highly versatile and can be applied to create three-dimensional structures, to introduce colour effects, or a combination of the two. It is also the principle under which sock heels and pouches are formed. It may be carried out at one side of a knitted fabric, across the entire width, or in a central section (as for a heel pouch). The number of loops knitted in each course is reduced or extended by regular steps, according to the angle required. When repeated, a spiral fabric formation occurs, from successive 'wedges' forming an angle with previously held courses (see Alice Lee, p. 97). No loops are lost during the process, which can be used to create additional fabric (frills) or to remove excess fabric (darts and spirals). Rib and other double-bed fabrics can be produced in a similar manner, but with greater attention to pressing or weighting the loops. The effect can also be produced in hand-knitting: one example is the entrelac technique, which gives a basketweave look.

Multiple patterning: with computer control and advanced pattern preparation systems, the scope for mixing techniques within one fabric has been exploited in high-level design (production of multiple techniques is slow and hence expensive). Shima Seiki machines first demonstrated this potential. They form the basis of the Australian company Coogi's products (see p. 21). Other multiple techniques, such as intarsia with stitch pattern effects, can be seen in Comme des Garçons menswear, produced on Stoll machinery.

Skechers EX1054-p. 29
Skechers v Nike

In the post-war years, knitting machine industries built up around the world, in particular in Germany, Italy and Japan, with Germany becoming dominant in warp-knitting. The transition from mechanically controlled machines to electronic control was the defining development of the modern industry. By the 1970s, most circular double jersey machines incorporated electronic patterning systems, linked with a computer-aided-design (CAD) unit. Electronic control, later applied to flat knitting machines, with individual needle selection, gave immense scope for patterning and opened up design potential beyond the mimicking of hand-knitting, through increasingly sophisticated CAD pattern preparation systems linked directly to machine production.

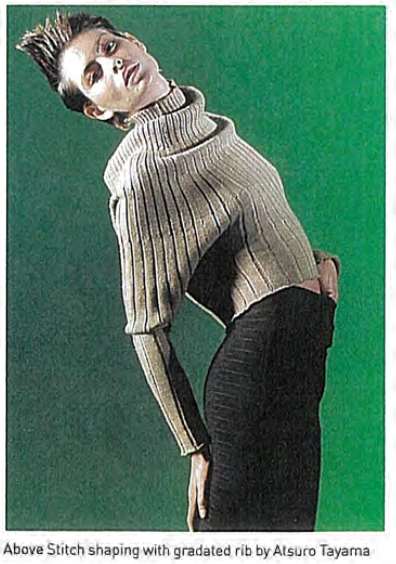
With electronic machine control, pattern preparation data from design systems can be transferred into machine language and knitting sequence data can be transmitted directly to the knitting machine. Global communication links mean, in addition, that information can be transmitted across the world so that design can function remotely from the site of production.

Flat knitting machines now predominate worldwide, due to their versatility. The two major players have emerged as Stoll of Germany and Shima Seiki of Japan. Both have recently developed machinery for integral garment knitting, based on similar principles. Shima Seiki's FIRST machine, for example, has four complete needle beds – two additional ones positioned just above the normal beds in exact alignment, to facilitate transferring of loops – and uses a newly developed slide compound needle. Such innovations represent the state-of-the-art of flat-bed knitting at present. Knitting sequences – key to design originality – are also increasingly being patented to protect competitive advantage.

Design developments can clearly be linked to technological developments: technology can lead design, or design and fashion can lead technology. For example, the early twentieth-century hosiery industry was predicated on fully fashioned – i.e. flat, shaped – stockings with a sewn seam at the back. With the advent in the 1950s of the bare-legged fashion, a new seamless production method was adopted – knitted circular tubes of nylon, heat-set to the leg shape. The fully fashioned hosiery industry had totally declined when the mini-skirt came in, but was replaced by the development of tights, which stimulated machine innovations in seamless construction.

Above Integrally knitted pocket by Stoll

Above Warp knitting, A-POC design, by Issey Miyake



Above Stitch shaping with gradated rib by Atsuro Tayama

Knitwear is constructed in one of three ways: 1) from knitted-to-shape (fully fashioned) flat pieces, requiring seaming and some trims; 2) from cut-and-sew fabric, requiring overlocking, trims and seaming; 3) by integral knitting with integrated trims, requiring little or no seaming.

Integral garments are based on tubular knitting. A basic sweater knitted on either Stoll or Shima Seiki patented systems is made of three tubes – two for the sleeves and one for the body. Each is positioned in the correct relationship on the needle beds, and the three are knitted simultaneously from three feeder carriages, with gradual widening of the sleeves until they meet the body tube. Narrowing occurs to create a raglan or circular yoke, finishing usually with a funnel collar which is automatically cast off on the machine (another recent innovation). The fabric may be plain or ribbed and can include intarsia patterns, stitch effects and complex details, such as pockets. Intricate styling details for collars and necklines within traditional production can also be achieved. Unique to knitwear production is a subtle variation of integral knitting, which comprises stitch-shaped items. These use variations in stitch structure and size to develop shape and form. The focus for integral garment research has now moved from lingerie and swimwear to outerwear.

New research in warp knitting has centred on creating seamless items from warp-knitted circular construction. Mesh fabrics and nets have been adapted to circular form to create fishnet tights and net bags. Tubular warp knitting is based, in a similar way to flat V-bed weft knitting, on two sets of needles, aligned vertically and knitting in tubular formation. Each tube requires four guide bars and sets of feeders, one for the back bed, one for the front bed, and one each to form the join between front and back at each side, enabling the tube to be formed. In order to create a sweater, two tubes are required for sleeves and a third for the body, using separate but simultaneous knitting actions, in a similar manner to weft knitting. Mesh patterning can be programmed into the fabric, as in Issey Miyake's A-POC tubular clothing. This is a unique process and has also been patented.

The potential, in design terms, resulting from new knitting technology is enormous.

Skechers EX1054-p. 30
Skechers v Nike

This section gives a brief introductory look at the fundamental material of knitwear – yarns and fibres. Fibres fall into two distinct categories – natural and manmade/synthetic – and two distinct forms – staple fibres (short lengths) and filament fibres (continuous length).

Natural fibres have remained consistently popular for high-quality classic knitwear and are classified in three main types: 1) animal staple fibres, including wool and hairs such as mohair, angora, alpaca, cashmere, and so on, either alone or blended with other fibres; 2) plant staple fibres, such as cotton (a seed fibre), which can be fine to coarse, or flax (stem fibre), a strong fibre from which linen is made; and 3) the only natural continuous filament fibre, silk, which is either cultivated or wild, and can be spun to a matt or lustrous finish.

Cotton and wool are most commonly used for knitwear. Yarns such as fine combed cotton or worsted spun wools have proved highly suitable for underwear and fine gauge knitwear, which ideally requires smooth, strong but fairly elastic yarns. Thicker, coarser woollen yarns are knitted on coarser gauge machines or by hand for outerwear of all types, from heavy, slightly oily, aran-style sweaters to tweed-effect coats knitted from multicoloured 'fancy' yarns, for example those pioneered by Bernat Klein in the 1950s. Hair fibres are classed as luxury fibres due to their high cost of production, and are often blended with wool. Hand-knitting in mohair became popular in the 1960s and again in the '80s, when prices fell and it was widely available. Silk is less commonly used for knitwear, except in fine gauge fabric. Jersey fabrics are made in a wide range of yarns, from basic cotton to silk and viscose blends for wonderful fluid drape characteristics.

The transition from natural fibres to synthetic fibres has taken place over the relatively short period since the end of the nineteenth century, when the first synthetic fibre – rayon – was invented. Nylon (polyamide) was the next to emerge in 1938. The purpose of the first generation of synthetics was very much to simulate the qualities of natural fibres – rayon was known as artificial silk, and acrylic yarns were designed to mimic wool. The continued development of rayon has produced a range of fibres, structures and finishes, dependent on the chemical processes used in their manufacture.

Rayon is a cellulose fibre, produced from wood pulp, and is therefore made from renewable resources, unlike oil-based polymer fibres. The cellulose is made into a liquid and extruded through holes (spinarets) into continuous filaments. Depending on the chemicals and the production process, the result is viscose rayon, acetate rayon, cupramonium rayon (used in a popular woven fabric, 'cupro') or solvent spun rayon, which is the latest development. Viscose rayon (commonly just called viscose) accounts for the vast majority of production. Its drape and lustre have made it a popular choice for knitwear.

Since the 1980s, great technological developments have taken place in the design of manmade yarns, pioneered above all in Japan, and a second generation of synthetics has evolved, focused on very fine polyester, polyamide and viscose, made into yarns which have highly attractive handle and finishes. Many of the newest synthetics are designed to have high performance qualities, giving rise to 'high-tech' fibres with very specific characteristics, such as high tensile strength, bulk without weight and moisture absorption. They may insulate from or conduct electricity; be biodegradable, resistant to odour or ultraviolet rays; they may change in response to heat. These fibres have applications in clothing for extreme conditions; automotive, aerospace and geotextiles industries; and, increasingly, in architecture and medicine.

Both the historical importance (the Silk Road) and the desirable properties of silk – such as lustre, drape, ability to take dye, softness of touch and attractive handle, together with its unique rustling and 'scrooping' sounds – have driven the development of synthetic fibres. One of the fundamental aspects of manmade fibres is the ability to create specific textures during the manufacture. Firstly, the cross-section of the individual filament fibres can be controlled by the shape of the spinarets (silk has a triangular cross-section filament, hence this was the first to be reproduced). Early synthetic fibres had circular cross-sections and were therefore smooth, but texturizing processes to provide bulk and surface interest were applied, such as crimping (as in Crimplene by Courtaulds) or knit-de-knit (knitting, heat-setting and unravelling).

The development of extremely fine microfibres has created more opportunities. Synthetics can be given textures – a soft, silk-like touch, for example, or a 'peach-skin' feel – to provide the comfort increasingly demanded by the market.

A new variation of cellulose fibre – lyocell, made by Courtaulds in 1988 under the name Tencel – is a yarn in which all the solvent used can be reprocessed: it is therefore more environmentally friendly. Tencel has a circular cross-section and cotton-like properties, and is particularly suitable for texturing treatments. Many companies, such as Kanebo and Toray in Japan, have produced 'high-touch' fabrics from combinations of fibre structures and yarn finishing treatments which create totally new aspects, not achievable with natural fibres – a new category, given the name *shin-gosen*, to denote a new aesthetic quality.

Fine microfibre and stretch yarns are finding increasing applications in the new seamless lingerie and bodywear markets. Brand names, such as DuPont's Lycra elastane and Tactel polyamide, Nylstar's Meryl polyamide and Elité elastane, promote qualities of comfort, fit and softness. The use of elastomeric stretch yarns in knitwear and bodywear has continued to grow since their development in the 1950s. DuPont were the first to invent an elastomeric fibre made from polyurethane (also known as spandex). Branded Lycra, it was at first used as a replacement for rubber in corsets, in knitted collars and cuffs, and later in stockings, but was slow to be taken up in knitwear. The fibre has a molecular structure similar to coiled springs, giving it the ability to expand greatly in length and then return to its relaxed state. It is usually combined in a small proportion with other yarns, or is covered with another yarn, such as cotton, and used as a yarn itself.

All fibres have their own intrinsic properties and, increasingly, sophisticated fibre blends are being spun together in order to best achieve desired effects. It is increasingly hard to distinguish individual components, and accurate textiles labelling is crucial. Many companies produce yarns from similar raw materials and of similar types, and the consumer may not differentiate between a generic name and a particular brand name. Indeed, some brand names, such as Lycra, have almost become generic.

Yarns are formed in two main ways: from relatively short lengths (staples) of fibres spun together, or from continuous lengths (filaments)

Skechers EX1054-p. 31
Skechers v Nike

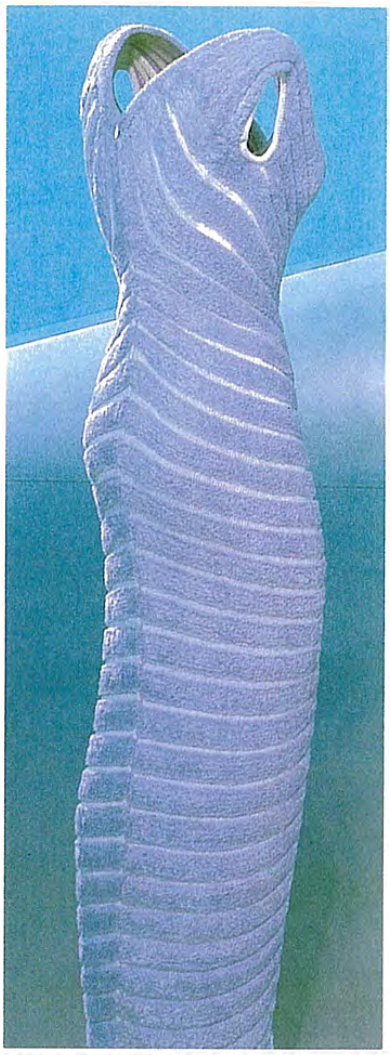
of fibres. All manmade yarns are of the filament type, extruded from chemical bases, but these can be processed in many ways, including chopping into staple lengths. Staple yarns usually appear more hairy and coarse than filament yarns. Most yarns contain many fine filaments, except in the case of monofilament yarns, which consist of one filament only. Continuous filament yarns tend to be smooth and lustrous, unless a texturizing process is applied to introduce crimps, snarls and crinkles into the filaments.

The basic twisted fibres form a single strand or 'ply' of yarns, but this is rarely used alone. Strands of yarns are folded together to make two-fold, three-fold and so on yarns (called two-ply, three-ply, etc. in hand-knitting), which are much more balanced. Yarn or thread thickness (count) is designated either by weight per unit length (direct system) or length per unit weight (indirect). Many different systems have evolved over time but these are now more streamlined. Examples are the tex system, which measures grams per kilometre (direct – the coarser the yarn, the higher the count) or the metric count, which is the number of metres per kilogram weight (indirect – the coarser the yarn, the lower the count).

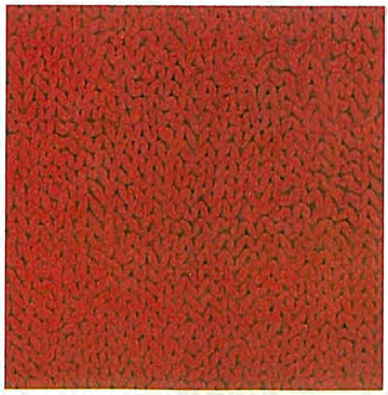
Combined with fibre content and thickness (count) of yarn, a further variable is yarn structure created during the spinning. Common structures are slub yarns which are of uneven thickness, bouclé yarns which have a loop structure, and knop yarns which incorporate tight coils of thread at intervals. Further highly specialized 'fancy' or 'novelty' yarns have interesting effects: chenille, for example, has a furry pile which results from cutting a special woven fabric along its warp threads.

Metallic yarns, for example the brand Lurex, are an example of a different yarn technology. They are produced from metal sheet, often aluminium, which is laminated by applying plastic film on both sides and bonding the layers together. This is then cut into strips and wound as a yarn. The flat surface gives great light reflection. A recent development – split film technology – can create yarns from strips of polyethylene or polypropylene film: under certain conditions, such as extreme tension, the film is induced to 'fibrillate', that is, break into fibres naturally.

Colour in design can be of major importance, as in the space-dyed effect which became popular in the 1970s . To achieve these results, yarn is



Above Dress in alternate bands of chenille and elastomeric yarn by Azzedine Alaïa



Above Ruched Maxxam fabric in single jersey float jacquard with Lycra by Rosemary Moore

wound into hanks and sections are immersed in different coloured dye-baths according to a predetermined sequence, until the hanks are all dyed. This is a laborious process but creates unique effects in two or more colours. When knitted simply in a straight piece without shaping, a distinctive pattern, reminiscent of ikat in weaving, appears – broad, broken, diagonal lines or 'flame' effects moving over the piece. When shaping occurs or when a new batch of yarn is introduced, the sequence is broken and changes constantly. This effect has become a signature of Missoni knitwear, either on its own or mixed with plain stripes (see pp. 2-3, 23, 30).

All the variables – yarn, machine gauge and stitch structure – must work in harmony before any real design development can begin. Machine gauges commonly used range from 3 (coarse) to 30 (fine jersey), and yarn thickness has to be compatible for successful fabrics.

Although extensibility is a benefit in knitting, it can make fabric prone to distortion when knitted too loosely – an effect capitalized upon in punk and grunge knitwear. Unwanted effects are sometimes turned to advantage in designer-level knitwear: for example, highly spun and twisted yarns can create spirality in single jersey structures, and this produces an angular twist of the seams – an effect regularly utilized in Yohji Yamamoto knitwear (see p. 98). Spirality can be avoided by using the yarns in a balanced structure, such as a rib fabric or double jersey. Jürgen Lehl, however, deliberately uses high twist yarns to create particularly 'lively' fabrics, which may have unpredictable results (see p. 45).

Successful combination of yarn and structure is paramount to the success of a knitted garment. For example, early rayon yarns proved to be very heavy, and tended to sag and grow in length. Stitch structure and stitch density (tightness or looseness of construction) play a major role, and several prototypes may be prepared to test out whole garment effects, making design development a costly process.

Skechers EX1054-p. 32
Skechers v Nike