6
Frontier of health and comfort fibers

6.1 Fibers for health

6.1.1 Health is on the balance of physical/mental/social well-being

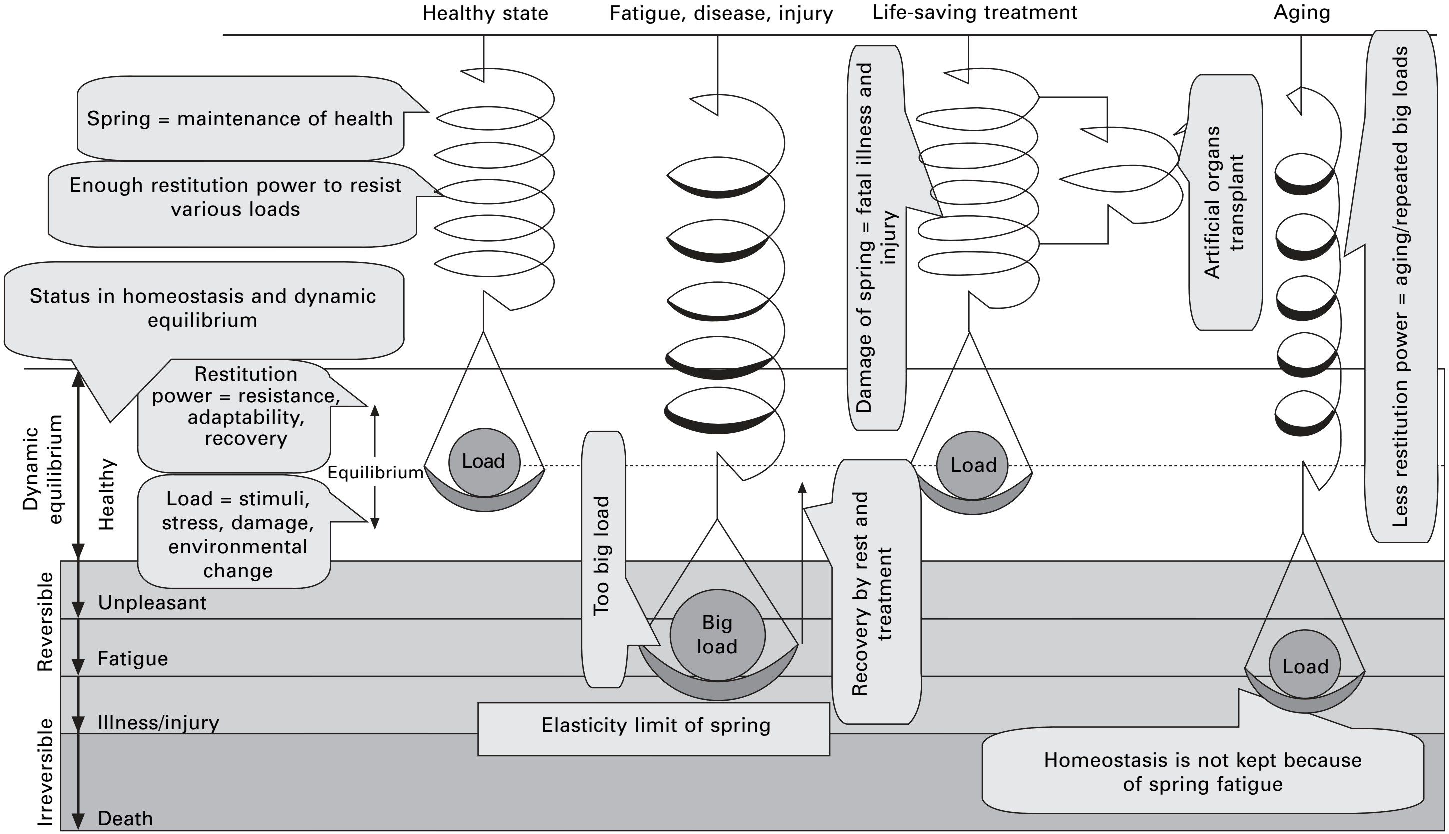
Definition of health

The World Health Organization (WHO), defined health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'. It is said that mental health, in particular, has a key control over physical, mental and social well-being. The WHO aimed at the maintenance and increase of mental health by positively preventing not only physical but also mental illness. Western medicine finds it difficult to deal with long-term recession syndrome, when a hard worker may lose motivation, or a new employee refuses to attend work.

Homeostasis

Figure 6.1 illustrates the extension of a healthy lifetime. The internal environment of a healthy human requires keeping a balance (equilibrium) in the face of various loads (stimulus). The reversible spring, which is within the limit of dynamic balance, stands for healthy conditions. In other words healthy condition means the condition of homeostasis (dynamic balance). If a bigger load than the limit of recovery is added to the spring maintaining homeostasis, the dynamic balance of the spring moves to the reversible area. One might say, then, that it is in a state of disease. If the spring is within resilience, the spring can return to the normal dynamic balance area by having rest or treatment. Young people can recover quickly and elderly people recover more slowly.

Suppose that a healthy spring encounters a traffic accident and is broken. If a spring is damaged badly, it is difficult for the spring to be repaired. It reaches an irreversible area, meaning death. If the damage is small, it can be



6.1 Extension of life and healthy life.

repaired by life-saving treatment. An organ transplant law was approved for the first time in October 1997 in Japan. Since then, some patients could recover by internal organ transplant donated by a human donor.

Repair by artificial organ

Use of an artificial internal organ is another life-saving treatment which can restore the spring that does not function, and a dynamic balance can be obtained by organ transplant to recover health again. An example of an artificial organ is the artificial dialyzer using a 'hollow fiber'.

Japan is the world leader in fiber technology to make hollow fibers for the artificial kidney. Hemodialysis now saves the lives of more than 170 000 patients every year in all Japan.

6.1.2 Healthy Japanese in the twenty-first century

Healthy Nippon 21

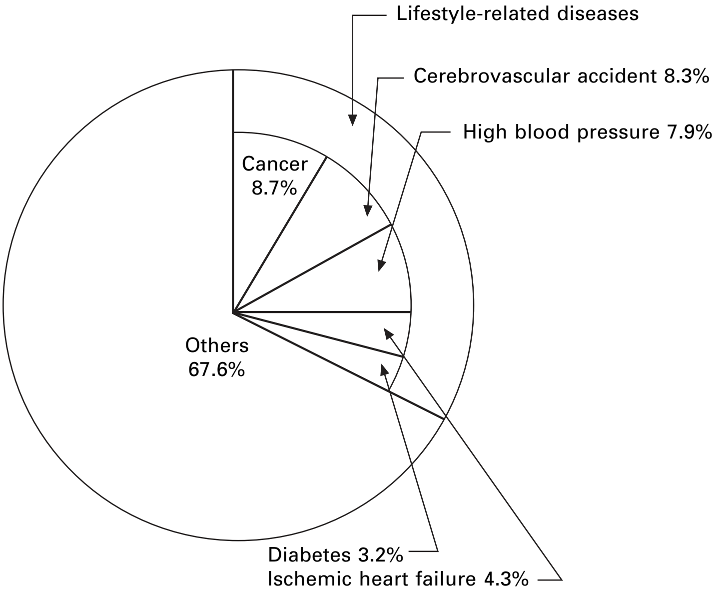
The Ministry of Health, Labor and Welfare in Japan recently announced the 'Healthy Nippon 21 Plan' (to extend from 2000 to 2010) aimed at improving general health in Japan. Health measures of the Ministry of Health, Labor and Welfare have evolved from the primary nation health measures (1978–1988), secondary nation health measures, the so-called 'active 80 health plan' (1988 to 1999) and now, as noted, the third plan. Until now, the measures have concentrated on nourishment and health promotion by increased exercise (Table 6.1).

'Healthy Nippon 21' aims to improve health and prevent disease. The plan was conceived because of the changing social background due to:

- smaller numbers of children and larger numbers of elderly people
- lifestyle-related diseases (see Fig. 6.2)

Table 6.1 Change of measures to promote health

	National measures	Tertiary prevention	Secondary prevention	Primary prevention
Healthy, life time	content	Treatment, life-saving, recovery and maintenance of functions	Early discovery and treatment	Promotion of health Prevention of disease
Change of measure	correspondence		Active 80 health plan	Healthy Nippon 21 plan
	term	1978–1988	1988–1999	2000–2010



6.2 General medical examination and treatment costs in Japan (1997).

- increase in private care of senior citizens (see Table 6.2)
- increasing medical costs.

In order to keep medical costs at a reasonable level and to maintain the quality of life, primary prevention is important. This plan was created by a study group of heads of medical care insurance. The 'Healthy Nippon 21 study meeting' consisted of 34 people of learning and experience in the field of diseases, habit diseases, medical insurance services, health insurance societies and local government.

6.1.3 The clothes which intercept stimuli from the natural world

The environment surrounding health

In Europe and the United States, the thesis that 'the thing which is bad for the environment is also bad for health' is commonly accepted. Here, the

Table 6.2 Change of population composition in Japan (%)

Age	1950	1994	2025
Older than 65	4.9	14.1	25.8
15–64	59.7	69.6	59.7
0–14	35.4	16.3	14.5

words environment and health are used together. The close relationship of environment, health and clothes needs study.

From the standpoint of protection of the body by clothing, external and internali environmental stimuli must be considered. In Japan, external stimuli include sweating in summer, pressure by layering of clothes in winter, changes of temperature and humidity caused by the Japanese four seasons, such as strong UV rays in May and abnormally hot temperatures in August. Furthermore, there are stimuli such as radioactivity, high temperature, ultra-low temperature, and extreme situation of high tension and high vacuum. In recent years the stimulus from the internal environment has attracted attention. The physical environment, such as illness, allergic trouble, and injuries, and mental environment, such as stress or neurosis, are examples of such stimuli.

Extreme environments

Generally clothes are the barrier between the body and the outside natural world. In the natural world there are ground, sky, and sea. Normal everyday clothes need to be different from clothes for climbing Mount Everest, with a height of 8000 m, or those for climbing Mt. Fuji, with a height of 3000 m. In other words, the higher the mountain, the more advanced must be the clothing. Furthermore, space developments require completely different suits for the surface of the Moon and Mars than those worn on Earth.

There are special environments where a person cannot live even on Earth. In order to work under such conditions, special clothes are necessary. For example, clothing to protect from radiation, nuclear radiation and heat or to wear in clean rooms for manufacturing semi-conductors. Clothes used in such extreme environments put priority on functions.

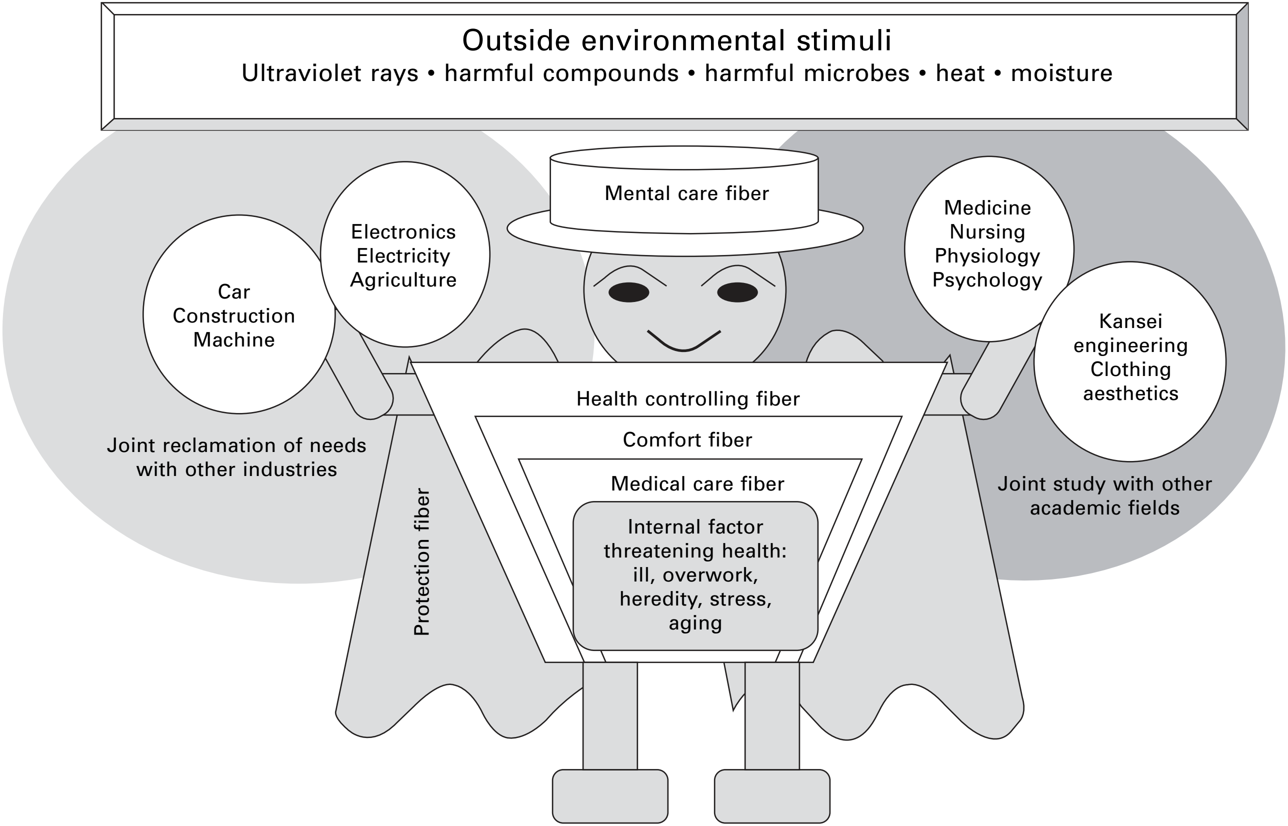
The sea is an extreme environment. Ships have a duty to carry life-jackets to aid survival in the sea. Such clothing must float with constant buoyancy, and support life even at sub-zero temperatures.

Coexistence with artificial environments

Clothes cannot intercept all hazards: temperature (heat), light (electromagnetic waves such as UV rays, infrared rays), air (wind), etc.

Life has been helped by the spread of mobile telephones, promotion of computerization, the development of information and communication technology. However, electromagnetic waves are emitted by such electronic equipment, which can change day by day. The effects on the health of the human body are not yet certain.

Turning off mobile phones in Tokyo Station began in April 2000 to protect people with cardiac pace-makers. Development of various fibers for protection, comfort, healthcare, medical care, and mental care is shown in Fig. 6.3.



6.3 Pursuit of fiber to keep physical and mental health.

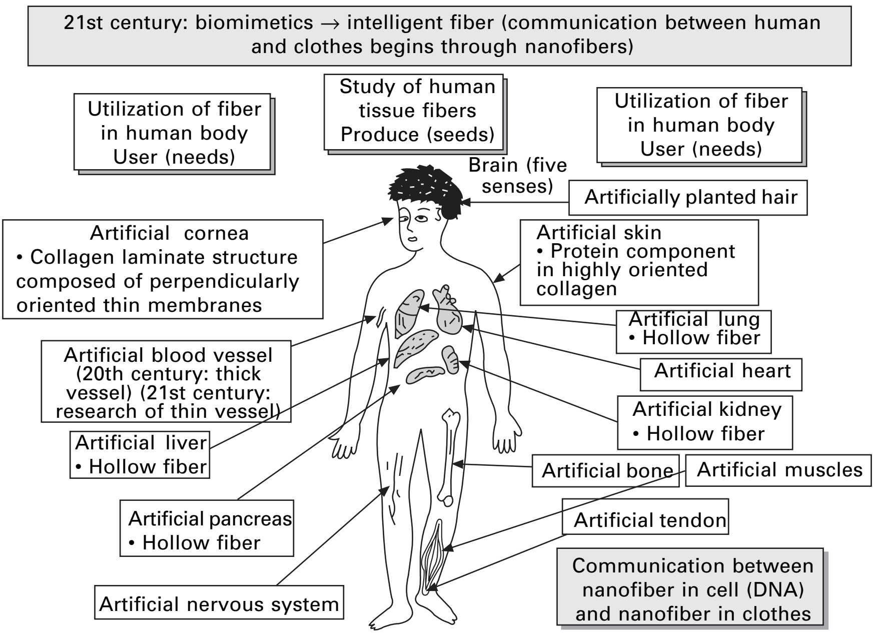
6.2 Development of medical care materials to learn from 'smart fiber'

6.2.1 Learn from fiber of the living body

Fiber material design by copying fibers within the living body is very important in order to protect human health in an ever aging society. Varieties of artificial internal organs are used as shown in Fig. 6.4. The human body is a large user of fiber materials such as artificial kidney and artificial blood vessels. Of course, the human body is itself a fiber manufacturer and produces various kinds of fiber to protect our health. The communication between nanofibers in a cell (DNA) and nanofibers in clothes will be possible by the middle of the century.

A good example is the artificial kidney used for hemodialysis. About 170 000 patients use an artificial kidney and the number increases about 5000–8000 per year. Including potential patients, 400 000 people need the artificial kidney per year. The average age of the patient becomes younger year by year. The greatest factor is complication of diabetes, and there are many chronic diseases of nephritis.

The glomeruli in human kidney are a bulk material of special parallel capillaries. The artificial kidney imitates the glomeruli using hollow fiber.



6.4 Various artificial organs.

The original aim of treatment was only life extension. However, the emphasis now is not only the prolongation of human life but also rehabilitation. Since the artificial kidney is not perfect compared to the kidney itself, the development of new dialysis membranes with continuity of high performance remains a priority.

Hollow fiber is also used in an artificial lung and in artificial blood vessels. Furthermore, active study progresses toward production of artificial liver and an artificial pancreas. Study for an artificial skin, artificial muscle, and the artificial nervous system is also being carried out. Development of such smart fiber, which can learn from the functioning of the fiber of the living body is a great need for an aging society.

Achilles' tendon

The Achilles' tendon is an ultra super fiber composed of collagen fibers which have become a development objective of the next generation fibers. Muscle and bone are tied by collagen fibril at the Achilles' tendon. The components of the tendon close to the muscle and bone are different and show the necessary specific characteristics of each protein. Moreover, the tendon is a flexible and soft ultra superfiber and has the possibility of being used as an absorbent surgical suture which does not need to be removed. Other types of collagen fiber are used in the cornea, blood vessel, and liver.

Fibrin

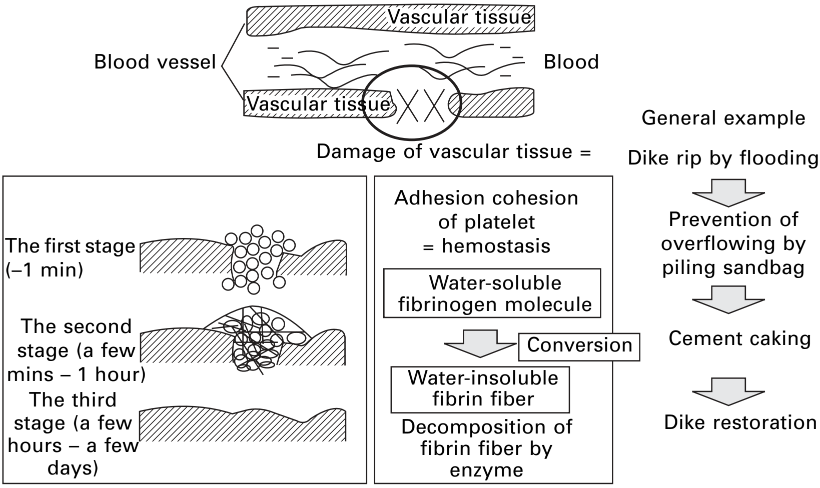
Another smart fiber is fibrin. Water-soluble protein fiber of fibrinogen is usually dissolved in blood. When injured, bleeding occurs. Then blood coagulates naturally in about 1–2 minutes. This depends on the defense reaction which a body possesses when the fibrinogen changes to fibrin fiber network. When the wound recovers, the blood which hardens is degraded by an enzyme. Fibrinogen is an intelligent fiber which recognizes the environmental change, changes its physical properties and repairs itself. The role of the intelligent fiber is shown in Fig. 6.5.

Bio-fibers are soft and have no incongruity; they are completely different from metal embedded in the human body. Biomimetic fibers which are soft to humans are now being pursued to support an aging society.

6.2.2 Care products demand rises in aging society

Care articles for senior citizens

Development of care fiber for an ever aging society will become more and more important in the future. These are textiles for patients undergoing



6.5 Role of intelligent fiber (fibrin fiber).

medical care. Patients are different from people with normal and healthy bodies in that they are in hospitals or welfare facilities. Some might be immobile or incontinent and others, such as those suffering from dementia, can be very active. Their needs are very different. Accordingly it is important to collaborate with other fields of industry for the development of new fibers. This is, in effect, a new frontier for fiber development. The target can be very specific. For example, there are new fibers with the function of antimicrobial and deodorization to protect the target person whose immunity resistance becomes weak from infection. Furthermore, there are textiles for MRSA (methicillin resistant *Staphylococcus aureus*). Fiber manufacturers develop the textile and sell it in the market place.

Many companies enter the care fiber market using their own fiber materials. ‘Full-scale expansion to health care products’ by Toray, ‘Well life plan’ by Teijin, and ‘the healthy cheering party series’ (Toyobo) are good examples. These have grown to be big business in the United States. They will be big business in Japan too in the near future.

An example of an active clothes study interchange meeting the needs of handicapped people and senior citizens is shown in Fig. 6.6.

6.2.3 Clothes which are useful for health maintenance

Three elements to keep health

Three elements to maintain health are nourishment, exercise, and rest. Moderate exercise is most suitable for a healthy life and stamina reinforcement. It is

6.6 Clothes study meeting the needs of handicapped people and senior citizens.

utilized broadly without distinction of sex and age because of the ability to reduce stress and change feeling.

The first functions required for sports clothes are lightness and fitting well to the body. Furthermore, durability is important. With intense exercise, there are occasions when people fall. It is thus necessary to be friction and abrasion resistant and durable to repeated washing. In addition, it should be safe and comfortable, and absorb sweat immediately and evaporate to keep the body in a consistently dry state. In winter sports, clothes which keep the body warm are important.

Wearing clothes helps protect the body from various external stimuli and to give distinction to the wearer. This identifies the direction of new fiber material development.

Sweat absorbent and easy dry material

Natural fiber has water absorbency, but polyester itself does not have water absorbency. By changing the textile structure, polyester can absorb sweat using a capillary action and allow the sweat to pass outside. MOISTY® (Toray), WELLKEY RMA® (Teijin), [eks]® (Toyobo), TECHNOSTAR® (Asahi Kasei), and AQUASTERUS® (Kanebo) are examples.

Moisture-permeable and waterproof material

This is the material which keeps the body comfortable in various kinds of bad weather. Mycroft R Rectus R® (Teijin), Goretex® (Goretex Japan) are examples.

Lightweight material

People feel more comfortable wearing lighter clothes. To get lighter clothes, the hollow part of fiber is increased, and as a result, the air in the hollow part contributes to lightness and heat-retention because of small heat conduction of air. Microart (Unitika), Aircube™ (Toyobo), LIGHTRON (Kanebo), Aerocapsule R (Teijin) are examples.

Low friction materials

To get a low friction material, various methods are available. It is better to have as flat a plane as possible, for example, making a dense plain weave with superfine thread, or making the surface water-repellent by modifying the surface with Teflon laminate. Another way is to make the surface uneven like a golf ball dimple to reduce resistance. Linplex (Descente) for skiwear and Aquabrade II (Mizuno) for swimming wear are examples.

Heat-retention and heat storage material

The passive heating material which does not allow heat to go out from the human body to the outside and positive material which takes in heat from the outside are typical of heat-retention and heat storage materials. The idea of the latter is to keep heat storage material in the hollow part of hollow fiber. Solar α (Unitika/Descente), Mobilethermo (Descente, Matsushita Denko), and Kerbinthermo (Toray) are examples.

The super strong material

An increasing tendency to use strong fiber, particularly for sports use, will continue in the future. T fiber in the shoes which Carl Lewis wears in a sports stadium is light and uses a strong polyethylene fiber, 'Dyneema' (Toyobo).

6.2.4 Development of a guard vest for jockeys in flat horse racing and steeplechases

Descente developed a guard vest for jockeys at the request of the Japan Racing Association (JRA). Since a fall from a horse in a steeplechase is more frequent than racing on the flat, the Japanese horse racing society requires a jockey to wear a guard vest. The purpose is two-fold. First, to reduce the shock to the jockey caused by the collision relaxation effect during a fall, and second, to reduce the damage to the jockey who might be stepped on by a horse after a fall. The vest is filled with polyethylene foam materials, so that it is stuffy when worn in summer, even though it has some holes for ventilation. A steeplechase is held only once a day, but flat races could take place several times a day. One jockey could ride several horses in a day. For this reason it is difficult to use the polyethylene foam vest for several flat races, and there was a request for a guard vest that includes heat control. The new vest must fulfill the following functions:

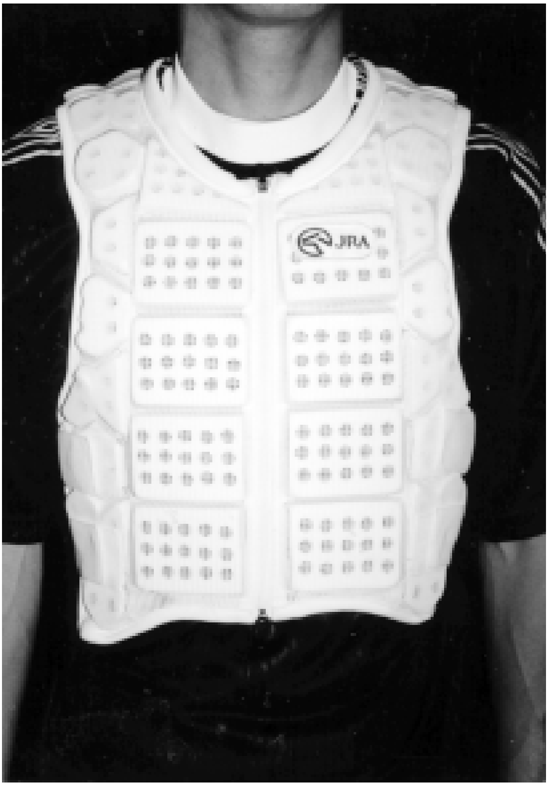
- not be stuffy and uncomfortable when worn
- more impact resistant than the existing available vests
- lightweight
- easier to move when worn than the existing vest
- price of the vest to be less than the existing vest.

To achieve these aims, an approach to introduce air into the vest was tried. The improvement of moisture permeability is possible by introducing many holes into the shock absorber, but then however, the strength of the material is reduced.

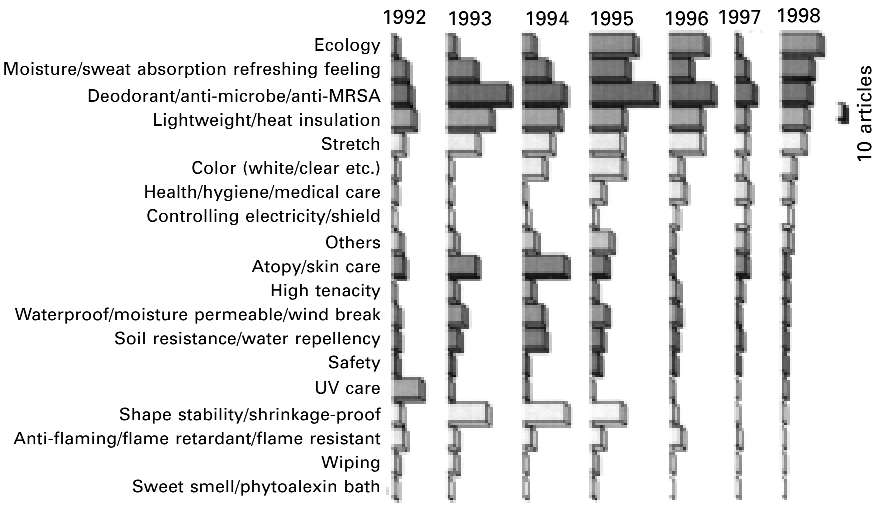
To solve the problem a honeycomb structure made of aramid was used by sandwiching the structure with foamed polyethylene of thickness 3 to 7 mm. The strength of the vest was then satisfactory. To improve the moisture permeability, apertures of 10 mm diameter were made by introducing 15mm apertures into the foam, with polyester mesh used for outer and lining materials. Elastic Velcro is used in the side adjuster to improve handling and fitness. The hips section is pushed into the pants usually. Accordingly mixed woven textile polyester/polyurethane was used for the side piece in order not to obstruct the movement of a jockey when riding a horse. The vest gross weight was 430 g, although the aim was initially 400 g. As shown in Fig. 6.7, the shock absorber is made of a rectangular block for the central part and equivalent hexagon for the shoulder and side parts not to disturb the movement of the jockey when using a whip. The honeycomb structure has more shock absorbency if the thickness of the structure is increased. The vest was provided to jockeys by the Japan Racing Association from June 1999.

6.3 Development trend of comfortable fiber for health

The trend of development of fiber for health is shown in Fig. 6.8. From the data, each manufacturer develops items which consumers demand. For example, the top five considerations required for clothes were:



6.7 Improved guard vest for jockey (Descente).



6.8 Development trend of functionality fiber (number of articles).

(1) ecology
(2) moisture absorption/sweat absorption/refreshing coolness
(3) deodorant/antibacterial/anti-MRSA (anti-hospital infection)
(4) lightweight/heat insulation
(5) stretch.

6.4 Trend to seek for cleanliness and comfortableness

The high temperature and high humidity in Japan are suitable for bacteria and fungi to grow. Thus people who pursue cleanliness and comfort demand goods with deodorant and antibacterial functions. The demand is not only for textiles but also for many kinds of goods such as socks, curtains, underwear, washing machine, telephone, floor material, waste basket, lunch box, insole of shoes, toothbrushes, mechanical pencils, interior materials in cars, etc.

‘Seiketsuhakusho of Toray’, ‘Toyobo’s Hygiene Revolution of Toyobo’, ‘Series of Comfortable and Hygiene products of Unitika’, ‘Esthetique salon series of Kanebo and Clean Declaration of Kuraray’ are examples of fibers designed for more healthy and comfortable life styles. A meeting to evaluate new functional needs of fiber products was convened by 177 manufacturers to unify the terms, evaluation method and standards of the evaluation. In this way consumer confusion is avoided, and the meeting is expected to contribute enhancement of antibacterial deodorization methods. There is no precedent for this kind of meeting in any other field of industry.

6.4.1 Evaluating new functions of fiber products

Background of the establishment of the meeting

In the high temperatures and humid climate of summer, microbes propagate very easily in the rainy season, particularly in June. Athlete’s foot, bedsores and uncomfortable odor caused by the propagation of microbes when wearing clothes became the target in the development of new products to control these problems. The first product with sanitized finishing was marketed in 1955. After that many products with deodorant function were marketed. However, then there was no standard to show antibacterial and deodorant functions. Consumers complained about such conditions. In 1983, a ‘textiles hygiene processing meeting’ was held by fiber material manufacturers, processing companies, and clothing companies including 35 companies in industry, university, and officials under the directive of the MITI, with the aim of consumer protection and sound development of the fiber industry. They settled on a standard of evaluation method for antibacterial and deodorant processing in 1989, and gave certificates to products which had a higher level of processing than the standard. The mark was named the ‘SEK mark’.

Inauguration of meeting

In April 1998, fiber products hygiene processing assembly changed its name to the Japanese Association for the Functional Evaluation of Textiles (JAFET) with the aim of international standardization. JAFET continued the authorization of 'antibacterial deodorization work' for more than 15 years, and started the certification mark of microbial control. The outbreak of pathogenic *E. coli* 'O157' in summer 1996 caused an antimicrobial boom not only in textiles, but also in kitchen utensils, toiletry (cosmetics) supply, and stationery (office supplies) manufacture.

Definition of microbial control

'Microbial control' means controlling microorganisms. 'Microbial control processing' means controlling specified microbes growing on fiber. The word 'antibacterial' is a wide-ranging term used within pasteurization, sterilization, antisepsis, disinfecting, preservation, mold proofing, and bacteriostasis. For this reason JAFET decided to use the term 'microbial control'. Furthermore, there was denotation to avoid consumer confusion by making a clear distinction between 'antibacterial goods' of different industries.

What is microbial control?

Microbial control means processing to restrain propagation of specific microorganisms on fiber such as *Staphylococcus aureus, Klebsiella pneumoniae,* a colon bacillus, *Pseudomonas,* methicillin-resistant *Staphylococcus Aureus* (MRSA). 'Propagation restraint' means to restrain propagation of microorganisms, not to make microorganisms extinct completely. If all microorganisms including skin normal bacteria are made extinct completely, it will cause other problems such as immune strength degradation and drug resistant fungus.

The difference between microbial control and antimicrobial deodorization processing

Antimicrobial deodorization processing is carried out for the purpose of 'deodorization', but 'microbial control processing' is classified into general and specific fields. The difference is shown in Table 6.3.

The SEK mark

SEK comes from the initials of Sen-i (fiber), Evaluation and Kinou (function). Granting the SEK mark is performed by a committee composed mainly of

Table 6.3 Comparison of deodorization and microbial control processing (Report of new fiber evaluation meeting)

Term	Deodorization processing	Microbial control processing General use	 Specific use
Purpose	Suppression of microbe growth on fiber and prevention of bad smell caused by microbe	Suppression of microbe growth to improve environment for life, healthcare and medical care	
Definition	To suppress growth of microbe on fiber and to show deodorant effect	To suppress growth of microbe on fiber	
Target product	All textiles	Textiles used in general family	Textiles used in medical and related institution
Target microbe	□ *Staphylococcus aureus*	■ *Staphylococcus aureus* ■ *Klebsiella pneumonia* □ *Pseudomonas aeruginosa* □ *Escherichia coli*	■ *Staphylococcus aureus* ■ *Klebsiella pneumonia* □ *Pseudomonas aeruginosa* □ *Escherichia coli* ■ MRSA
SEK mark	Blue (DIC 66) (Deodorant effect)	Orange (DIC 156) (Improvement of life and care environment in general family)	Red (DIC121) (Improvement of medical environment in medical institution)

■: Essential microbes to be examined
□: Optional microbes to be examined

experts. The SEK mark guarantees antimicrobial deodorant processing, microbial control for general purpose (orange SEK mark), and microbial control for specific purpose (red SEK mark).

Target products of SEK mark

Microbial control for general purpose and antimicrobial deodorant processing target almost all application fields such as clothing, bedding, room design product and personal effects. On the other hand, microbial control for specific purpose is applied to white robes, nursing clothes, care clothes, underwear, pajamas, apron, socks, a sheet, cover, a blanket, curtain, masking, cap, a towel, a cloth diaper and dust cloths, for the needs of medical institutions.

6.4.2 Fiber with water and moisture absorbency

Sportswear, in particular, needs to absorb water and moisture after intense exercise. Synthetic fiber without such function is not suitable for sportswear because of stuffiness and stickiness. For this reason, development of functional synthetic fiber with water absorption/hygroscopic properties was a major objective over a long period.

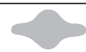
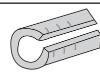
One of the principles used to give a water absorption property is the use of capillarity. Two representative examples are in the fiber industry. One depends on the application of capillary movement, a phenomenon at liquid boundaries resulting in the rise or fall of liquids in narrow tubes or in a slit between two leaves. The level becomes concave or convex, and the contact angle becomes an acute or obtuse angle depending on whether the surface of the capillary tube gets wet or not. The level of the liquid balances with surface tension and external pressure. Generally, the phenomena that control the wetting of a surface can be classified as:

- dispersion wetting caused by liquid diffusing on the surface of solid
- infiltration wetting observed in a cotton dry cloth and towel absorbing water
- and the so-called adhesion wetting as raindrop sticks to the surface of a solid.

Wetting occurs when the contact angle is 0°, less than 90°, and less than 180° in dispersion, infiltration, and adhesion wetting, respectively. For example, spacing of liquid to infiltrate into the apertures of porous material and a sieve tube of bamboo becomes very large for the liquid to get the wall wet. The fiber manufacturer produces sportswear with capillary structure to let sweat go outside as soon as possible. Hollow fiber and fiber with the heteromorphology in cross-section of fiber are examples. Examples of water absorption fibers from several companies are shown in Fig. 6.9. The ability of polyester or nylon fiber to absorb water can be improved by making the fiber gap just like a capillary. Furthermore, the decrease of contact angle can absorb water highly by alkali treatment of polyester fiber.

Porous water absorptive polyester fiber

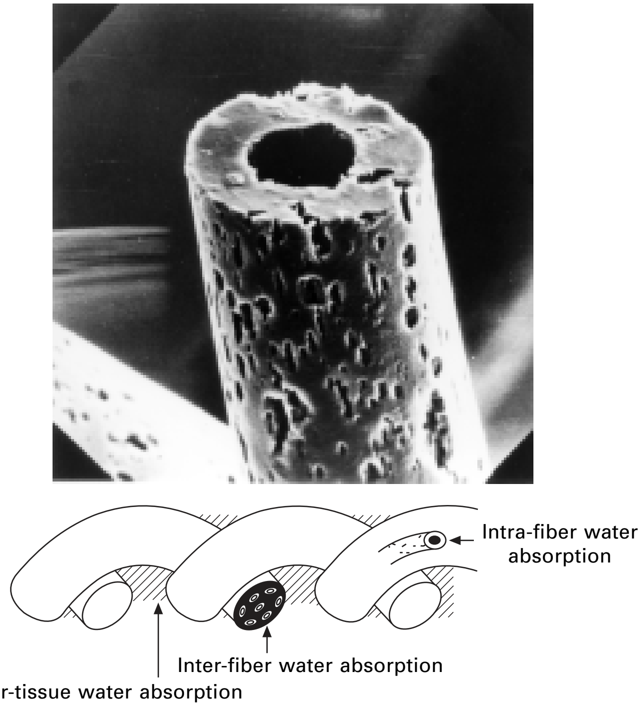
Teijin developed a porous water absorbing fiber 'WELLKEY' (Fig. 6.10) more than ten years ago. It was the first water absorbing fiber material and was awarded the Technical Prize of the Japan Fiber Science and Technology Society in 1990. The micropores of 0.01–0.03 μm in diameter on the surface run right through into the hollow part. The attached water on the side surface of fiber goes into the hollow part. The capillary phenomenon and rough surface make the fiber water absorbing. Textiles made of WELLKEY can

Trade name (Manufacturer)	Cross-section	Properties
WELLKEY (Teijin)		Hollow fiber with many pores (the first sweat absorbent Tetron in the world), no sticky touch, comfortable to wear, no cold touch
AREOCAPSULE DRY (Teijin)		The cool touch spun yarn material, special polymer, dry touch, UV shielding
Technofine (Asahi Kasei)		Capillary phenomenon, absorb and spread sweat, dry touch
CEO • α (Toray)		Water absorption by capillary
SPACEMASTER (Kuraray)		Unique cross shape polyester, water absorption, quick drying, dry touch
Kilatt-P (Kanebo Gohsen)		Lightweight, moisture keeping, water absorbent, suitable for training wear and inner wear
COOLMAX (Du Pont)		UFO shaped (four channels) fiber, spread sweat quickly, dry and comfortable
Aegean (Mitsubishi Rayon)		Hollow fiber composed of two hydrophilic polymer, tear in longitudinal direction and have cut in lateral direction, water absorbency, quick dispersion and dry, not sticky

Water absorption fits the following equation.
Water absorption rate (horizontal direction > $l^2 = (r\,\gamma \cos\theta/2\mu)t$
Introduction of capillary structure hollow fiber, different cross-section
Contact angle with water θ hydrophilic skin membrane

l: length of water absorption in horizontal direction (cm)
μ: viscosity of water (g/cm • sec)
r: radius of capillary (cm)
γ: surface tension of water (dyne/cm)
θ: contact angle of water and capillary surface wall (degree)
t: time

6.9 Examples of water absorption fiber by various manufacturers (modified from T. Suzuki, 1999 The society of fiber science and technology Japan, basic lecture).



6.10 Water absorbable polyester fiber 'WELLKEY' with many pores (Teijin).

absorb water and it is not sticky even after absorbing sweat. For this reason the uniform of the All Japan Women's Volleyball Team was made from WELLKEY.

Highly moisture absorbing and moisture releasing nylon

Recently, highly moisture absorptive and highly moisture releasing nylon was developed independently by Toray and Unitika. Originally nylon itself had many good characteristics, but it was inferior in moisture absorbency. When nylon was used for clothes the lack of moisture absorbency caused stuffiness, stickiness and was uncomfortable. Both companies solved the problems and developed materials by completely different approaches. Toray has developed QUUP and used it for pantyhose and an undershirt wear. Unitika developed HYGRA and used it for sportswear and geotextiles.

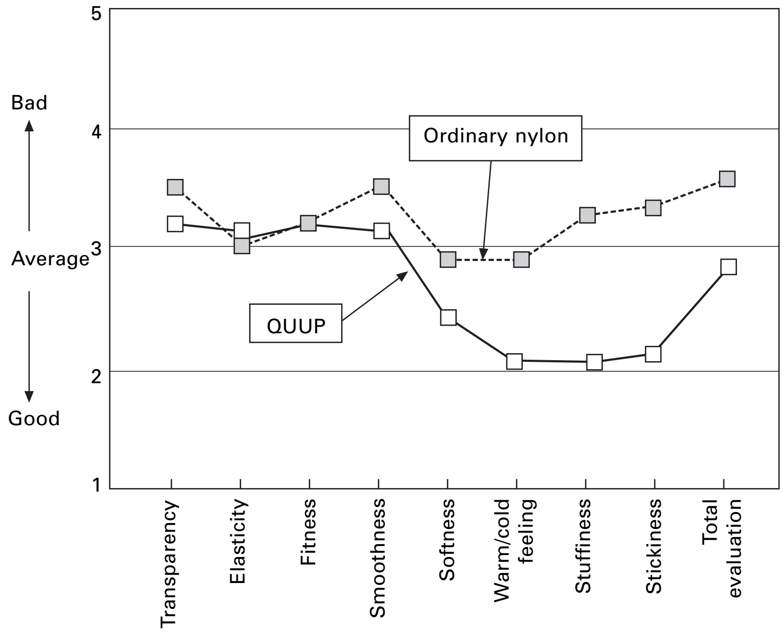
Highly moisture absorptive and moisture releasing nylon for pantyhose

Toray developed a new polymer material for nylon fiber, 'QUUP', with superior utility and highly moisture absorptive/releasing property, about double that of conventional yarn (see Fig. 6.11). It was achieved by a new polymer alloy technology development. A nitrogen-based special polymer was mixed with regular nylon molecules to give a fiber with high water absorptive and water releasing properties. The comfort of wearing QUUP used garments is very similar to that of cotton, and it has the added distinctive features of a soft and smooth touch and superior color intensity, while retaining the conventional functionality of nylon. QUUP is used for a wide range of applications, including pantyhose, underwear and sportswear. The price of the material is more expensive than ordinary nylon by about 20%. The evaluation result wearing pantyhose is shown in Fig. 6.12.

Moisture absorptive/releasing synthetic fiber with skin-core structure

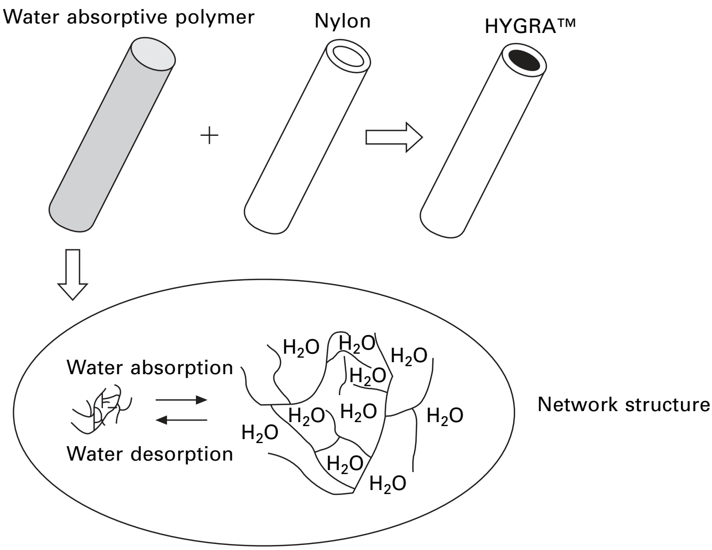
Unitika succeeded in making fiber from a highly water absorptive polymer, which can absorb water 35 times the polymer weight, and developed an epoch-making fiber HYGRA™. Conventional moisture absorptive fiber was made by modifying the surface of synthetic fiber to be hydrophilic or applying a hydrophilic polymer. Accordingly, no synthetic fiber could have superior moisture absorption to natural fiber. Many such water absorptive polymers were developed. However, they were applied only to disposable materials such as diapers and napkins because they do not have water releasing ability. Moreover, it was difficult to make such fiber by melt-spinning. Unitika

6.11 Pantyhose made of highly moisture absorbent and moisture releasing nylon fiber (Toray).

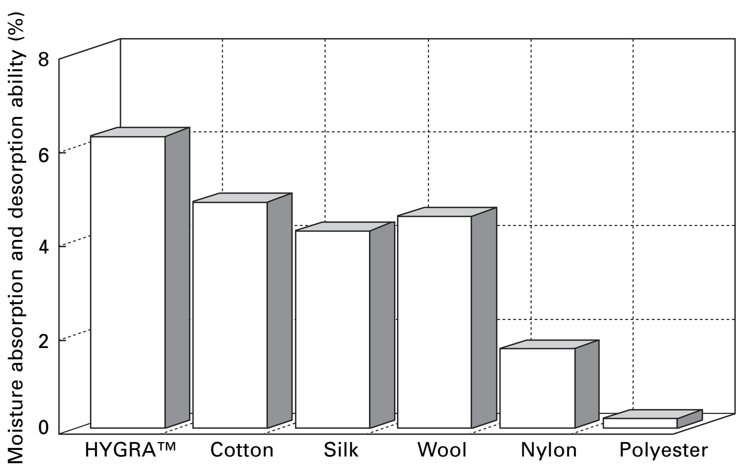


6.12 Wearing evaluation of pantyhose (Toray).

developed a highly water absorptive/releasing polymer which can be fibrilized by melt-spinning. It has a skin-core composite structure. The core part has a special network structure and the skin part is nylon as shown in Fig. 6.13. Conventional water absorptive polymers retain water by an ionic bond between functional ionic groups such as sulfone groups and water. Even if it showed high water absorbency, it did not have water releasing ability and ability to be melt-spun. HYGRA does not absorb water by an ionic bond. Hydrophilic groups retain moisture. The network structure of polymer used for HYGRA is controlled. HYGRA has the ability to release water even after absorbing water fully. The skin-core structure of HYGRA consists of a nylon skin part and hydrophilic core part, so that the moisture/water on the surface of the fiber is permeated into and absorbed by the hydrophilic core part when the temperature increases. Conversely, when the temperature decreases, the nylon part shrinks and moisture absorbed in the core part is squeezed out into the nylon part. The ability of HYGRA to absorb water and release water is higher than with natural fiber and HYGRA is stronger, has more dimension stability and is more comfortable when worn compared to natural fiber (see Fig. 6.14). The combination of the core and skin polymer will give many kinds of products. For example, the combination of polyester will give the same level of electric controlling character with natural fiber at low moisture content. Unitika will apply HYGRA not only to clothes such as underwear,



6.13 Technical concept of HYGRA™ (Unitika).



6.14 Comparison of various materials on absorption and desorption of moisture (Unitika)

sportswear, and socks, but also to non-clothes fields such as life materials, civil engineering, construction, industrial materials, interior, and living materials.

6.4.3 Antimicrobial fibers

The application demand for antibacterial products

These have a very great range:

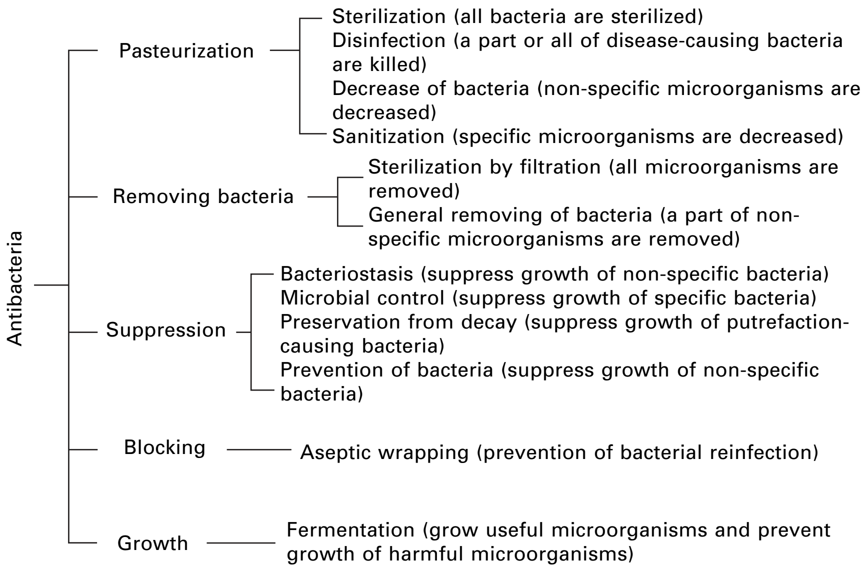
- Life materials: clothes, bedding, carpet, kitchen goods, kitchen mat, domestic electrical appliances, towel, toiletry (ceramics, mat), toy (stuffed animal)
- Environmental hygiene: antimicrobial sand in amusement park and sand box
- Food hygiene: kitchen utensils, wrapping material for food, tableware, clothes
- Labor hygiene: office supplies (stationery, telephone, facsimile, personal computer)
- Medical hygiene: bedding, white gown, surgical gown, curtains in hospital room
- Construction/public works: cement, building materials, woods with antimicrobial treatment
- Communication/transportation: coated electric wire, printed wiring, parts of car, hand straps
- Industry materials: clothes used in food and medical material factory, miscellaneous articles
- Agriculture/stock raising/fishery: wrapping material, container, working tools
- Sports: sportswear, accessories, tools for apparatus gymnastics
- Others: microphone for karaoke, cash card.

Antimicrobial goods are used not only in the field of food hygiene and medical hygiene, but also in everyday environmental hygiene fields including shirts and underwear, for which such treatment is not necessary if they are washed thoroughly. In addition, in the field of labor operation hygiene, as for the mechanical pencil, the ball-point pen, the telephone, antimicrobial treatment is applied. The microbial treatment for wood and leather is necessary to protect the material. Most of the treatment is done in one step.

The term antibacterial

'Sterilization' means that all microorganisms are sterilized. 'Disinfection' means decreasing some specific microorganisms. 'Repression' is used for textiles (see Fig. 6.15).

According to Professor N. Korai of the University of Tokushima, controlling microorganisms by antimicrobial reagents can be expressed by growth and growth inhibition curves, depending on the number of viable microorganisms and incubation time. There is an induction period, exponential phase, stationary



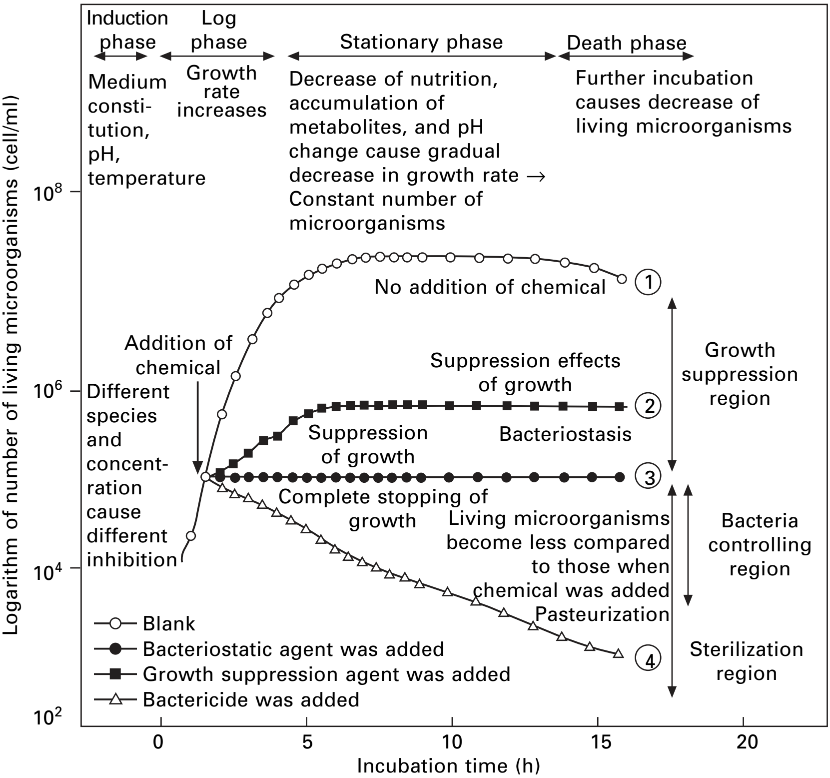
6.15 Definition of antimicrobial-related terms (K. Urabe, Japan Chemical Fibers Association, Report of Investigation, No. 4, p. 37 (1999)).

phase, and death phase. Such growth curves and inhibition curves of microorganisms are shown in Fig. 6.16.

During the induction period, microorganisms take time to get used to the components of the medium, the pH, and temperature, and increase gradually. In the exponential phase, microorganisms grow very quickly. In the stationary phase, the rate of growth decreases because of the lack of nutrition in the medium, accumulated metabolites in medium, and change of medium pH, and the number of viable microorganisms becomes constant. In death phase, the number of viable microorganisms decreases with incubation without addition of antimicrobial reagent. If some chemical is added in the exponential phase, different effects appear depending on the kind and concentration of chemical added. Figure 6.16 shows the following:

① Without chemical addition.
② In the growth suppression region, the increase of microorganisms is less than the ordinary case depending on the kind and concentration of chemical.
③ Microorganisms do not increase at all in bacteria controlling region.
④ Microorganisms decrease by addition of chemical in the sterilization region.

Chemical usage in the sterilization region has appeared only recently. However, most of the chemicals belong to the propagation restraint region. As there are many products treated with antimicrobials, consumers should select what they need. The conditions necessary for antibacterial agent use in textiles are as follows.



6.16 Growth and inhibition curves of microorganisms (modified from H. Korai, Senshoku (Dyeing), No. 61, p. 1).

First to guarantee the effect. To pass the technical standard of SEK, which includes deodorant processing and bacterial control processing, a bacteriostasis activity value of more than 2.2 is necessary by a unification test in the case of antibacterial deodorization processing.

The second is durability, particularly during washing. For disposable goods, the number of washing times is zero, whereas ten or more washes are applied for most goods. In fact, the effect of antimicrobial reagents must be maintained after 50–100 washings. Then there is the application limit. For the general purpose of controlling microbes by SEK from 1998, *Staphylococcus aureus* and pneumonia bacillus must be tested for, but pseudomonas and a colonic bacillus are optional. For specific purposes, MRSA becomes a required microbe, in addition to microbes for general purposes. A specific purpose would be chiefly for use in the medical field.

In addition, the safety of a medicine is important. Acute toxicity, mutagenic property, and skin acrimony are specified, and the security in disposal and burning must be addressed. For example, there must be no dioxin generation.

There must be security also in decomposition of a medicine and the chemicals should not be endocrine disrupting chemicals and also must be friendly to the ecosystem.

6.4.4 Antimicrobial treatment against MRSA

Many kinds of antibiotics are not effective against MRSA. When such hospital infection occurs, local infection causes blood poisoning of a patient, and the situation may be life-threatening, and family and the medical care persons may also become infected. Measures against MRSA infection are taken very seriously by the Ministry of Health and Welfare. Periodical hospital sterilization and hand washing by soap and running water are executed at each hospital for infection protection.

MRSA infection transmits, not only within a special environment, but also via doctors and nurses. For this reason the fiber manufacturer has developed MRSA propagation restraint textiles for prevention of infection. A white gown using antimicrobial material is shown in Fig. 6.17.

6.17 White robe made of microbe controlling material.

Tertiary ammonium and silver are the main chemicals for the treatment. ‘Hinokichi’ of Toho Textile uses a special microcapsule containing Cypress oil produced in Aomori Prefecture to treat the fiber. ‘Chytopoly’ of Fujibo uses chitosan from the shell of prawn and crab, mixed with rayon. In an investigation by the Ministry of Health and Welfare in 1992, MRSA was detected in about 90% of hospitals with more than 500 beds.

6.4.5 The causes and measures of unpleasant odors

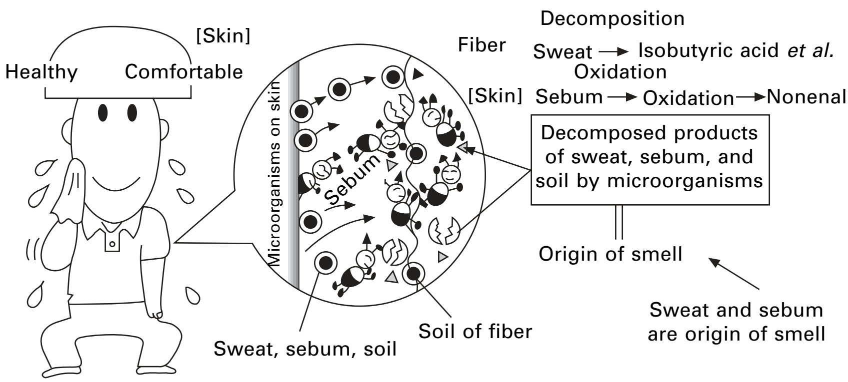
Good smell and bad smell

Unpleasant smells from a person’s sweat can be removed by taking a bath or shower. The microbe which lives in skin and clothes will multiply using sweat and soil as nutrition. The smelling component is isovaleric acid and comes from the decomposition of sweat and soil, and ‘nonenal’ which is peculiar to the old and middle aged. Possible causes of bad smells from a human body are shown in Fig. 6.18.

Unpleasant odors in living spaces

The Environmental Agency searched for the causes of ‘unpleasant odor in living spaces’ using 1200 private questionnaires. Top of the list is the smell of toilets, followed in order by decaying garbage, the smell of cooking, of drainage, musty odor (in winter dew condenses in a closet and mold grows), the smell of a shoe cupboard, from walls (due to formaldehyde and organic solvents used in the adhesives), cigarettes, a bad-smelling air-conditioner, and pet odor.

A mixed odor of volatile molecules comes from the living bodies due to protein, carbohydrate, and higher fatty acid being decomposed by microbes.



6.18 Cause of bad smells from human body (modified from JAFET data).

These number between 300 and 400 types. Among them the strongest are the following four offensive odors:

(1) Hydrogen sulfide, as from rotted eggs.
(2) Methyl mercaptan, as from a rotted onion.
(3) Trimethylamine, as from rotting fish.
(4) Strong irritating smell of ammonia.

An example of the four offensive odors from humans is given in Table 6.4.

Additionally, research and development has been carried out into the effects of deodorant on sulfur, oxides of nitrogen, indole and skatole from excrement, a smell of perspiration, a smell of a cigarette. Such offensive odor not only gives discomfort, but can affect the nerves, irritate, prevent peace of mind, give headache, and obstruct job performance. Furthermore, if the stimulus is strong, it also causes stress in the nervous system, increased pulse rate, elevated blood pressure and a bad influence on various internal organs. The minimum amount of material producing a sense of a smell is called the threshold value. Threshold values of the four offensive human body odors are given in Table 6.5. Clearly only very small amounts are needed to cause very offensive smells.

The mechanism by which we respond to smell

The chemical causing the smell volatilizes, enters into the nose, is absorbed in the upper part of the large chamber of the nasal cavity by the olfactory cells. Then a potential is generated in the membrane of the cell, a chemical stimulus causes an electrical impulse which is transferred to the nervous system, and the brain records the smell as unpleasant. If there is damage to the olfactory senses, it is debilitating and even dangerous since the taste of cooking can be affected and detection of gas leakage can be severely delayed.

Table 6.4 Bad smells from human body

Origin of bad smell	Main component of bad smell	Major cause
Bad breath	Methylmercaptan Hydrogen sulfide	Bad breath of leftover fermentation by bacteria
Body odor	Trimethylamine Acetic acid Valeric acid Caproic acid	Decomposition of sweat constituent by microbe
Excrement	Ammonia Skatole Indole Hydrogen sulfide	Smell of feces and urine, and decomposition of feces by microbe

Table 6.5 Threshold of four main offensive smells (Professor Y. Shirai, Shinshu University)

Chemical causing bad smell		Bad smell	Threshold (mg/l)
Hydrogen sulfide		Smell of rotted egg	4.1×10^{-4}
Methylmercaptan		Smell of garlic	7.0×10^{-5}
Trimethylamine		Smell of rotted fish	2.7×10^{-5}
Ammonia		Strong irritating odor	1.5
Reference	Skatole	Smell of feces and urine	5.6×10^{-6}
	Acetaldehyde	Irritating odor	1.5×10^{-3}
	Musk	Fragrance	5.0×10^{-6}–10^{-10}

Approach to eliminate or reduce offensive odours

Deodorization refers to removing odor in the atmosphere, and the word is used both for chemical and physical deodorization.

Using chemical deodorization the offensive odor is neutralized or immobilized by chemical reactions and is changed into material of low odor level. Fiber manufacturers immobilize such material on a fiber easily using blasting processing. However, the method is limited because chemical deodorization uses harmful chemical reactions. Photocatalysts such as titanium oxide have recently been developed which decompose offensive odors using UV light which initiates a redox reaction. The durability of the catalyst is theoretically semi-permanent. However, due to the energy of UV rays the fiber itself deteriorates.

By physical deodorization the chemical causing offensive odor is absorbed on to porous materials with a large surface area such as activated carbon, zeolites, and silica gel. These can absorb a large variety of chemicals. Such physical deodorizers also contain some chemical deodorizer.

Using biological deodorization, garbage can be decomposed in soil by microorganisms under aeration. Biomimetic deodorization was suggested by Professor Shirai of Shinshu University, utilizing an artificial enzyme which copies the way living organisms decomposes offensive odors. Deodorization can include masking of offensive odors with spice or oil of extracts of plant. Such deodorization can mask the odor immediately, but acute effect is high, and the smell itself is not removed.

6.4.6 The smell of cigarettes is very complicated

The smell of a cigarette is very complicated. From the cigarette, there is underflow smoke (very harmful) and mainstream smoke coming out from a point of a cigarette. When smoke comes out through a glass filter, some part of smoke like oil mist is trapped by the filter, and some like vapor is half trapped by the filter, and some like gas passes the filter. The components in the smoke have been studied and nicotine, acetaldehyde, acetic acid, catechol, hydrogen cyanide, phenol, ammonia, cresol, hydrogen sulfide, pyridine are included in high ratio. In reality, there are several tens of thousands of different kinds of chemicals in smoke from one cigarette. Among them, the biggest component is nicotine, which does not have a strong odor itself. It turns to pyridine or pyol and these smell.

There are deodorant fibers used with cigarettes. These include the strong deodorant material 'Cigernon' from Toray (Fig. 6.19), the highly durable deodorant polyester staple 'Freshcall™ II' by Teijin (Fig. 6.20). The deodorant fibers are shown in Figs 6.19, 6.20 and Fig. 6.21, respectively.

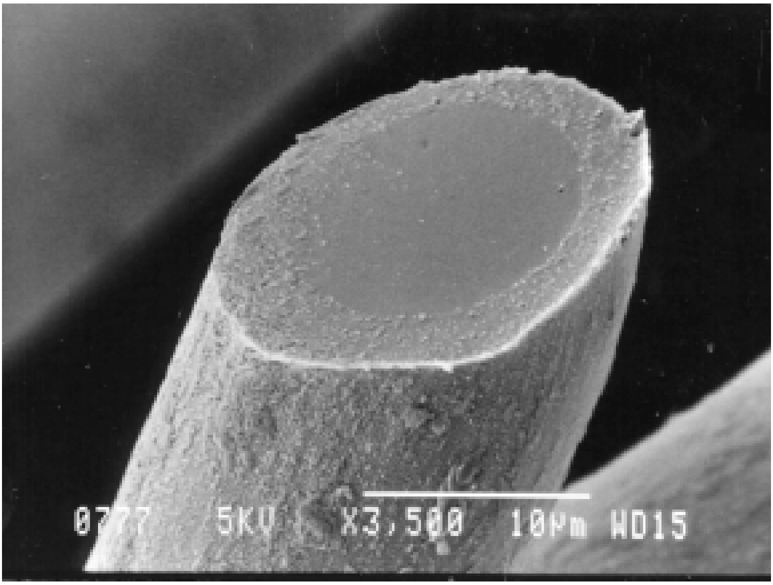
In reality, smells in everyday life do not come from a single source, but from many components mixed together.

6.4.7 Formaldehyde deodorant processing 'Deofor'

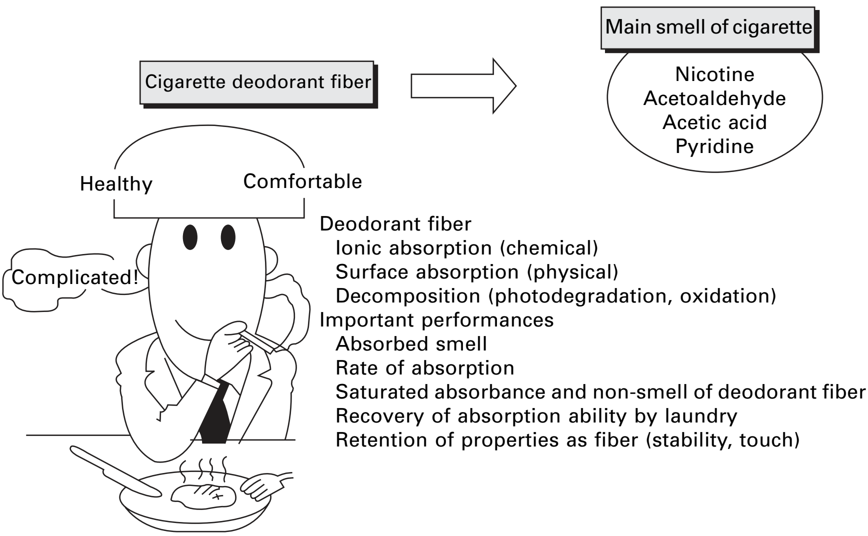
Indoor air pollution materials are classified by the World Health Organization into four categories: UV organic compounds, volatile organic compounds, non-volatile organic compounds, and particulate matter. Formaldehyde is a highly volatile organic compounds, and is used in building materials. No smell is sensed if the concentration of formaldehyde is less than 0.1 ppm.

As the concentration increases from 0.1 to 1 ppm, most people begin first to sense the smell, then become very aware, and later to feel a stimulus to nose, eye and throat and then discomfort. At concentrations greater than 1

6.19 Curtains made of high cigarette deodorant ability, 'Cigernon' (Toray).



6.20 Highly durable deodorant polyester staple 'Freshcall™ II' (Teijin).



6.21 Cigarette deodorant fiber.

ppm, tears are induced and a person may fall into dyspnea. At concentrations greater than 50 ppm, the experience could be fatal.

Daiwabo developed material to deodorize formaldehyde. An amine compound is coupled with formaldehyde by the Schiff's reaction which then deodorizes the formaldehyde. The deodorant effect of DEOFOR was evaluated by putting the test sample cloth (10 cm × 10 cm) in tedlar bag with formaldehyde. The concentration of formaldehyde was determined at various time intervals. Figure 6.22 shows the result when formaldehyde concentration was 4 ppm. The deodorant activity of a cloth having the DEOFOR processing improved compared to the untreated cloth. The curve of the cloth in the figure after washing three times showed same level of deodorant activity as the processed cloth before washing. Even after ten washes the result did not change.

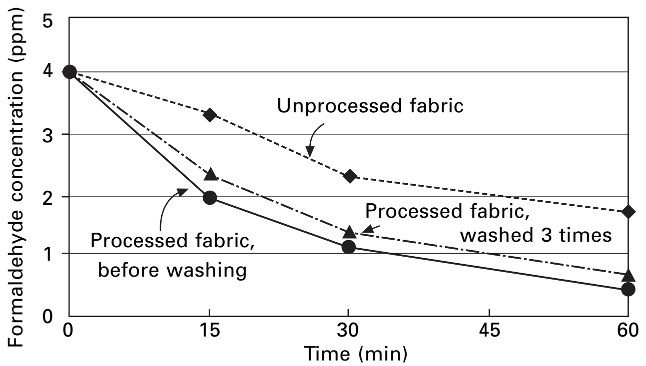
Furthermore, the evaluation of DEOFOR treatment was done using 7 m^2 curtain in a room where formaldehyde gas was released from three pieces of plywood at 30°C and 60% humidity for one week. After three days, the concentration of formaldehyde using untreated cloth rose after only one exposure. The cloth with DEOFOR treatment kept up deodorant activity for one week. In addition, material with DEOFOR treatment has the activity to deodorize ammonia, acetic acid, and acetaldehyde as the main components of cigarette smoke.

6.5 Fiber to guard environment and health

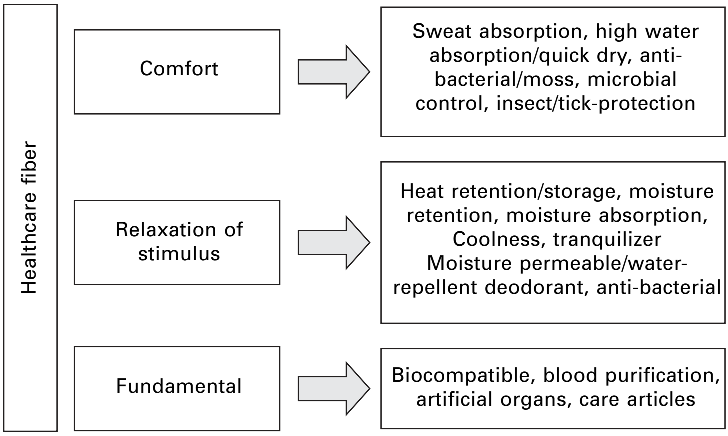
6.5.1 Various kinds of approach to maintain health

Fibers to maintain health are classified into four categories: healthcare fiber, comfort fiber, stimulus relaxation fiber, and environmental conservation fiber. In the classification, the relation among environment, health and fiber is readily understood.

Utilizing healthcare fiber has three objectives as shown in Fig. 6.23. 'Making life comfortable' and 'relaxation of outside stimulation' help to maintain health. The effects aimed at are sweat absorption, high water absorption,

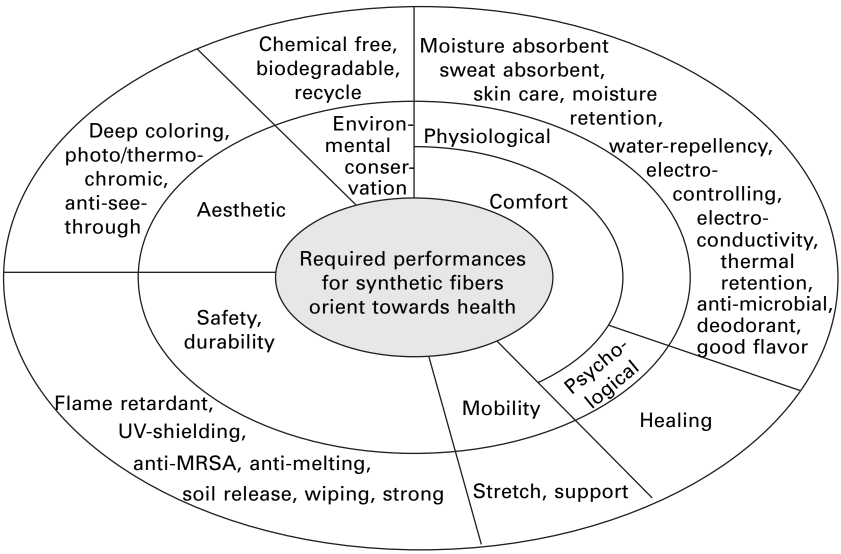


6.22 Remained formaldehyde concentration (Daiwabo).



6.23 Application of high functionality fiber to health.

fast-drying, anti-bacterial, mold-proofing, controlling bacterial growth, insect repellent, and acarid repellent, and the latter includes heat insulation, heat storage, moisture keeping, moisture absorption, refreshing coolness, moisture permeable, water repellent, deodorization, being antibacterial. Recently, fibers with complex antibacterial/deodorization functions have appeared. Functions required for fiber are shown in Fig. 6.24.



6.24 Main functions required for recent health keeping fiber.

6.5.2 High needs of fiber for medical applications

Fibers used in the medical field and their applications are shown in Table 6.6. Surgical suture used in operations is classified into two categories: non-absorbed and absorbed suture by human body depending on the place of operation.

6.5.3 Comfort fiber

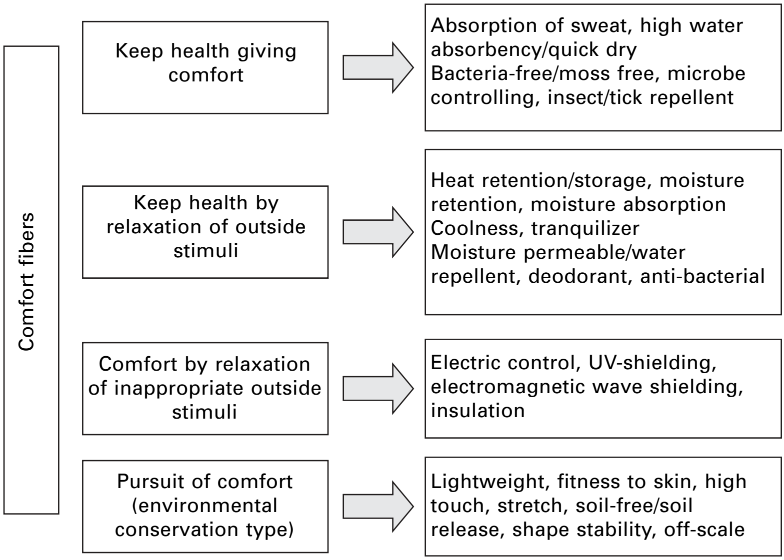
Application of high function fiber to become also a comfort fiber is shown in Fig. 6.25. Health can be kept by making people comfortable and able to relax to external stimuli. These two overlap within the definition of healthcare fiber. Furthermore, aims of comfort fiber include 'positive pursuit of comfort' and 'comfort by relaxing against uncomfortable external stimuli'. Such comfort fibers need to be lightweight and emphasize fitness and gentle feel.

6.5.4 Stimuli relaxation fiber

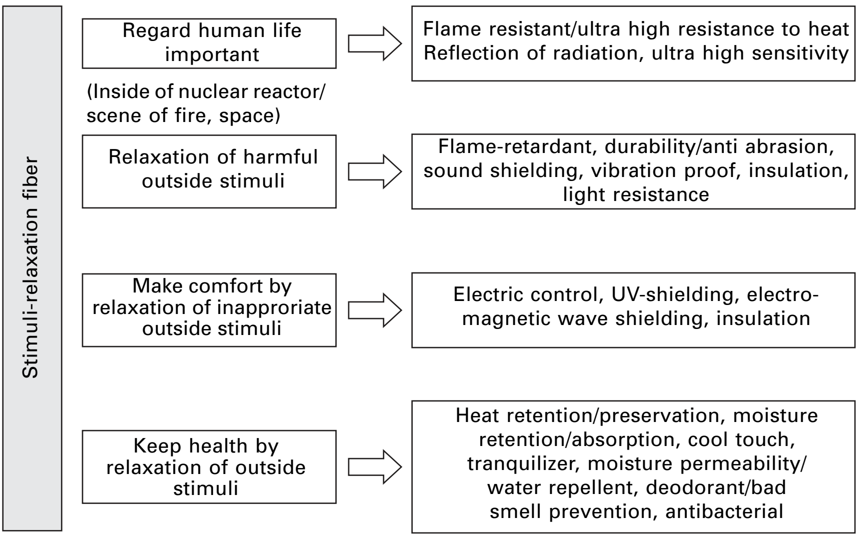
The application of high performance and high function fibers to stimuli relaxation fiber is shown in Fig. 6.26. Stimulus relaxation fiber, for example, are clothes worn in reactor accident, in fires and in outer space. They must be fireproof, extremely thermo-resistant, radioactive rays reflective, and of super high strength. In addition, they must be flame resistant, abrasion resistant, soundproof and vibration proof.

Table 6.6 Medical fiber and its application

Term	Material	Application
Short to middle	Hollow fiber	Dialysis, reverse osmosis, gas exchange, artificial organs, medicine industry
	Fiber absorbable by human body	Surgical suture, implanted artificial organs and blood vessel
	Anticoagulant fiber	Artificial blood vessel and organs
	Optical fiber	
	Polymer/fiber releasing chemical gradually	Autoscope Medicine
Middle to long	Anti-microbe fiber	Medical use
	ACM lightweight structural material	Bed, conveyance, artificial arm and leg
	Artificial muscle	Artificial arm, leg and heart



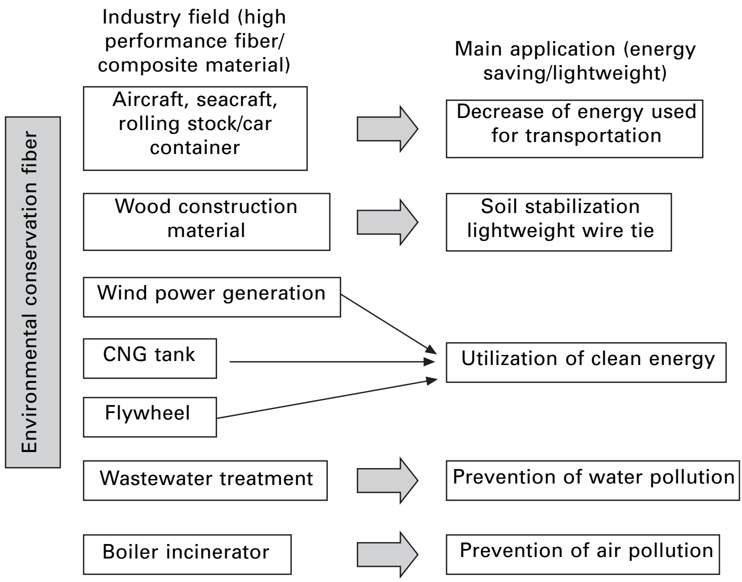
6.25 Utilization of high functional fibers for comfort.



6.26 Utilization of high performance/high functionality fibers for relaxation of stimuli.

6.5.5 Environmental conservation fiber

High performance fiber applied to environmental conservation is shown in Fig. 6.27 together with industrial fields of use. Protection from UV rays, radioactive rays, harmful matter, microorganisms, viruses, and moisture is



6.27 Application of high performance fibers to environmental conservation.

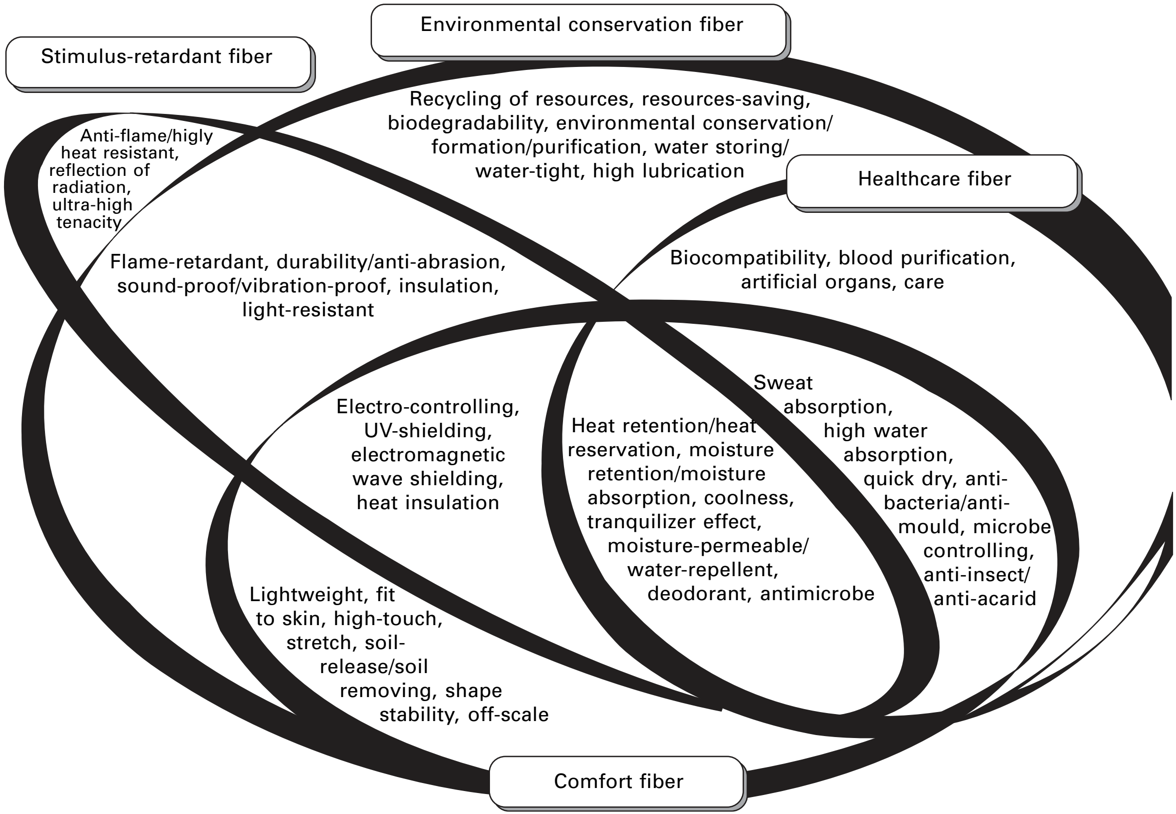
necessary because these can be harmful to health. It is necessary also to consider internal stimuli such as heredity, aging, stress, and deterioration of human health. Fiber directly concerned with environmental conservation includes recycling fiber, resources saving fiber, biodegradable fiber, environmental conservation/formation/purification fiber, storing water/ waterproof fiber, and high oil absorption fiber. Stimulus relaxation fiber from outside is also included within environmental conservation fibers. If indirectly concerned fiber is included, healthcare fiber and, comfort fiber also belong to environmental conservation fiber, as shown in Fig. 6.28.

6.5.6 Pursuit of fiber to maintain physical and mental health

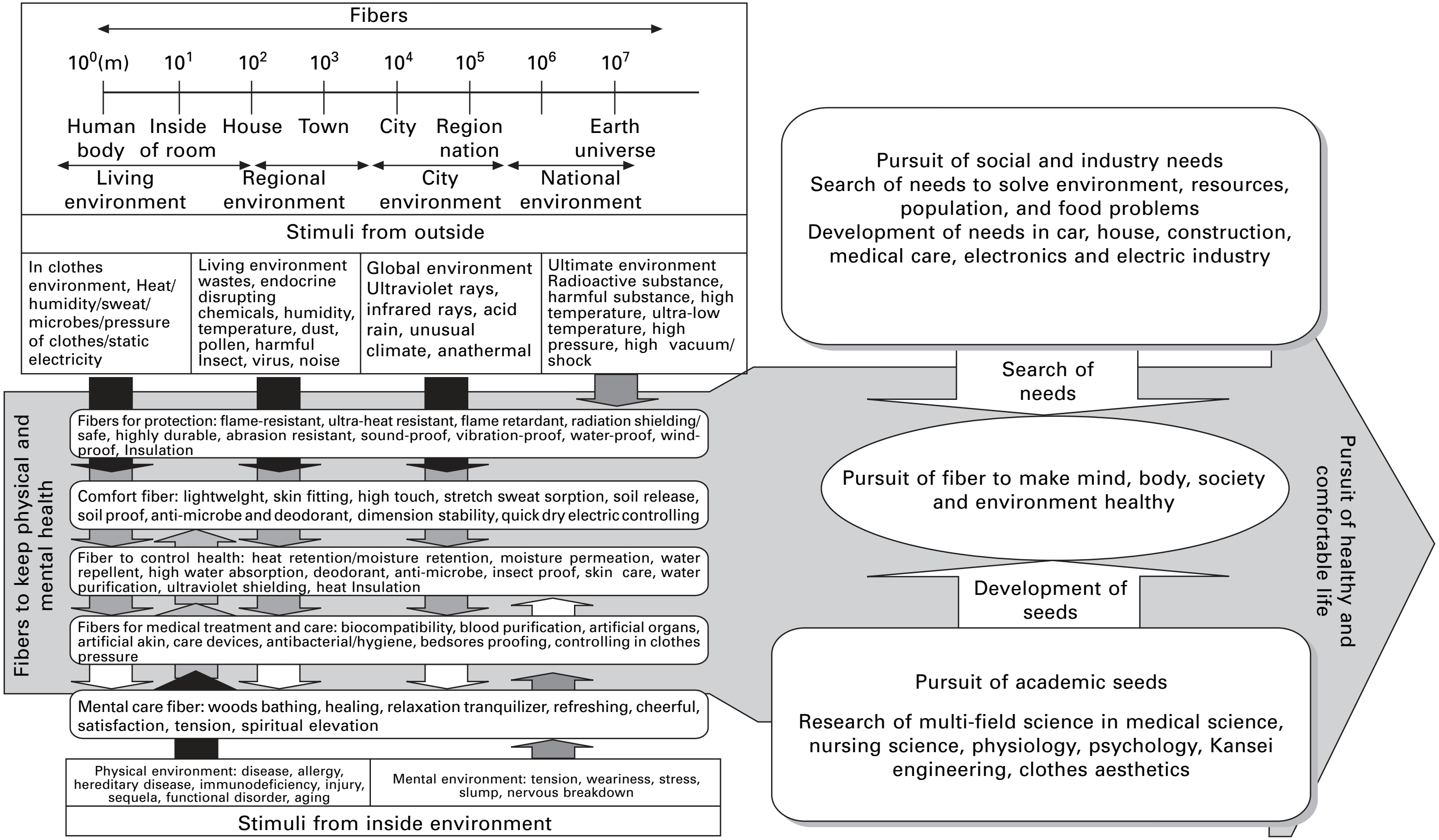
Figure 6.29 shows the relation of stimuli and fibers necessary to maintain physical and mental health.

Stimuli from internal environment

The internal environment introduces stimuli composed from physical and mental environments. The physical environment includes illness, allergies, genetic disease, immune disorder, injury, after-effect of disease, functional disorder, and aging. Then there is the ‘mental environment’ which indudes



6.28 Fiber to maintain environment and health.



6.29 Pursuit of healthy and comfortable life (T. Koyama, Shinshu University, modified).

tension, weariness, stress (stimulus added to the living body), slump (dull), and neurosis.

Fluctuations found in nature such as the murmur of a brook, or a breath of wind are called 1/f fluctuations. Honorary Professor of Tokyo Institute of Technology, T. Musha has studied 1/f fluctuation theory. Besides this aspect, there is geometry of a fractal of self similarity in natural form such as a cloud, a mountain or a river, and this is called fractal theory which has been studied by Professor Monday in the United States.

This kind of phenomenon and uniformity in nature gives a feeling of ease and comfort. This can be taken into textiles and each company develops and markets these products. This is a new way of thinking. An example of the healing materials applying 1/f fluctuations is shown in Fig. 6.30.

External stimulus

Various popular stimuli from the outside environment indude: 'clothes internal environment', 'living environment', 'global environment', 'ultimate environment'.

The 'clothes internal environment' includes heat, moisture, perspiration, various germs, pressure from clothes, and static electricity. The study of such factors on wearing clothes is the most advanced. In a company and a university, for example, Toyobo and Faculty of Domestic Science of Ochanomizu Women's University, they study these factors using mannequins. The result is reflected as 'climate in clothes' by manufacturer.

6.30 Material using 1/f fluctuation (Nisshinbo).

'Living environment' includes the effects of waste or endocrine disrupting chemicals, moisture, air temperature, dust, pollen, a harmful insect, microorganism, viruses, and undesired sounds.

'Global environment' includes UV rays, infrared rays, acid rain, abnormal weather, and a thermal problem.

6.6 Technical concentration to achieve comfort

Following the Kyoto International conference on global warming, to prevent an increase of carbon dioxide concentration the government proposed that the temperature of air-conditioning should be maintained at 28°C and 20°C for cooling and heating the office, respectively. A person who has adjusted to the environment with traditional cool air-conditioning feels considerably hot and humid when the temperature is set to 28°C. Thus suitable clothing had to be developed to adjust to these conditions.

6.6.1 Nisshinbo and Teijin were at the forefront

Nisshinbo and Teijin jointly developed 'Ecosys 28°C' for a shirt in which a businessman feels comfortable even at 28°C in the office, and it was first marketed in November 1998. This required the development of (1) the material, (2) the texture of fabric and (3) processing in order to get a comfortable cool feeling. The polyester included in this material is different from ordinary polyester since it is made with hollow fiber with triangular cross-section. By combination of the hollow fiber and high-quality Egypt cotton, the fabric is light and does not stick to the skin. They examined the texture and fabric density, and adopted Lawn, Oxford and a Panama cloth in order to improve breathability. In addition, by using voile fiber, the fabric is cool and feels better than the ordinary fabric. In finishing, they adopted new shape stable finishing SSP to improve water absorbency.

The functions of Ecosys 28°C were examined in artificial meteorological conditions by Teijin. The volunteer wore long-sleeved shirts made with Ecosys 28, walking at 5 km/h for 10 min and the result was compared with that examined wearing an ordinary shirt. The sweat decreased by 20%, feeling of stuffiness and stickiness decreased by 5–7%, and moisture in clothes decreased more than 20% after 40 min motion. They also carried out different evaluations wearing the shirt made of Ecosys 28°C at temperatures of 28°C and humidity of 60% as in an office in summer. The subject first rests quietly in bed under windless condition for 10 min. He then walks for 10 min in wind and then rests quietly in bed under windless condition for 20 min. According to the organoleptic test, the 'Ecosys 28°C' shirt is comfortable because it is cool, not sticky and not stuffy when worn.

6.6.2 Development of 'Toyobo's Science in Comfort™ shirt'

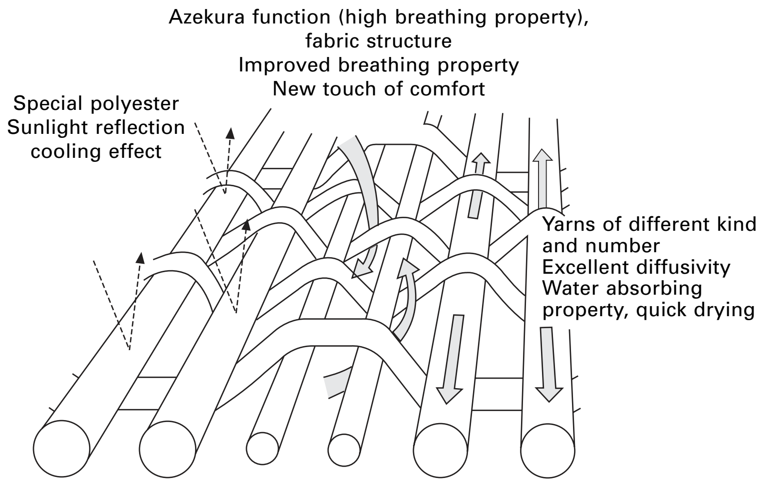
Toyobo carried out research under the key word of 'comfort shirt' 20 years ago. They commercialized the product under the brand 'Toyobo's Science in Comfort'. 'Climate in clothes' became core, and they provided sportswear first, and then uniform, undershirt and shirt. Toyobo's comfort science 'comfort shirt' is shown in Fig. 6.31.

Toyobo gave the shirts the name 'Toyobo's Science in Comfort™'. The fiber 'Alsace™' uses cotton and polyester in three layers. It is made of hollow polyester, and 'Ramiluck™' (polyester and ramie), and is used as the material for shirts. Lawn, Dobby cloth and voile with rough texture are used for the fabrics of the shirts in order to give breathability. Besides that, treatments named 'Eternally™' 'Miracle Care™', and 'Deodoran™' are given for moisture absorbing/soil repellent, wash and wear, and odor-eliminating, respectively. In Toyobo, they combine material, texture and treatment to follow the needs of consumers.

6.6.3 New comfort business shirt material 'Azek™'

'Azek™', after 'Azekura', a storehouse built of logs, was first announced in 1999 as a joint development between Shikibo and Toray. Azek structure and function image drawings are shown in Fig. 6.32.

6.31 Comfort shirt made of Toyobo's Science in Comfort (Toyobo).



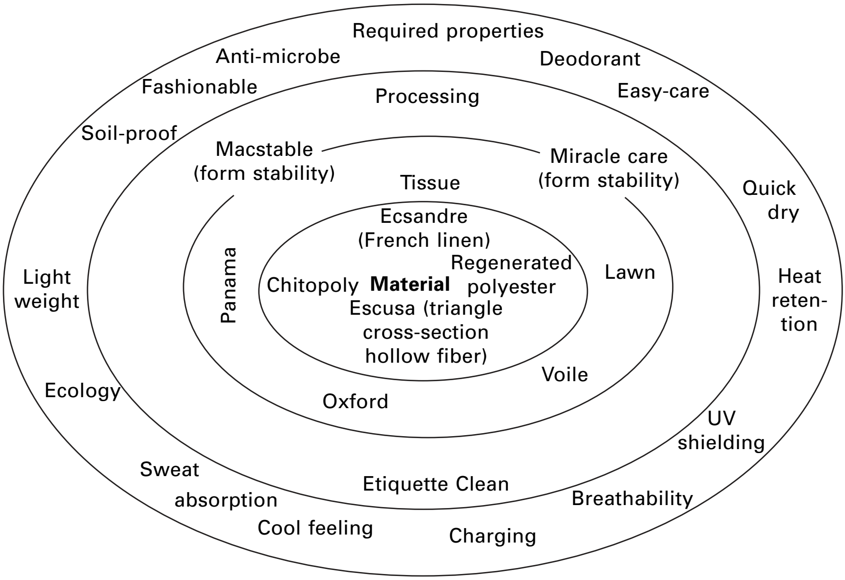
6.32 Structure of Azek (Shikibo).

It was the golf shirt that led to the development of ‘Azek™’. It was made of a high special ceramics/‘Alfix™’ composite material which can reflect sunlight, and has sold well using the catchphrase ‘cool & dry’ in 1999. Before then it was not thought that a business shirt could be made of 100% polyester, for previously they used natural fibers, such as cotton and ramie. Alfix was used to reflect heat by changing the thickness of the thread to realize the Azekura structure, square log architecture, within the fabric. As a result, the surface of the fabric becomes three-dimensional with wide space between thread to realize breathability. Moreover, it does not have the see-through nature which is disliked in men’s shirts, nor the fluffy nature used for ladies’ materials.

‘Ecosys 28°C’ and ‘Toyobo’s Science in Comfort’ were developed combining existing material, texture and treatment, but ‘Azek’ was a new texture in fabrics.

6.6.4 A new comfort business shirt from various companies

Fuji Spinning developed ‘BODY GUAR-°C’ under the concept of being friendly to the earth. The project to develop the comfort shirt is shown in Fig. 6.33. They aimed to develop comfort and fashionable shirts, suitable for air conditioning at 28°C and 20°C, in summer and winter, respectively. The material used in summer, ‘Escusa’, is made of hollow fibers with triangular cross-section, increasing breathability by a factor of four, and lighter by 20%. ‘Ecsandre’ is made of high-quality French linen, and the antibacterial fiber ‘Chitopoly’ made of the natural polymers chitin and chitosan from crab



6.33 Planning of comfortable shirt (Fuji Spinning).

and prawn shell. Lawn, voile, Panama, and Oxford are used as texture of the materials.

For winter shirts worn in a 20°C room, 'Incerared' is used. Here broadcloth, herringbone and Karsey are used as fabric texture, and functionalities such as shape stability finishing, moisture absorption/heat generation finishing and warm finishing are combined.

Kurabo developed, 'Feel More' and 'Charade' by mixed-spinning of hollow polyester and cotton, giving fine denier polyester covered with cotton in the 'Oasis project'.

Kanebo developed 'SPERANZA', 100% cotton, in the program 'Interface amenity material planning by Kanebo'.

Daiwabo developed polyester/cotton/rayon mixed-spinning material, 'Cooldry', so making rayon part anti-microbial.

6.6.5 Comfortable underwear

Gunze developed the underwear, 'YG28°C', for people to feel comfortable even in the 'hot' environment of air-conditioning at 28°C. It uses 'ACTICOT' made by blending 'Benberg' of Asahi Kasei, which is superior in moisture absorption, and 'Technofine', high water absorption polyester. It absorbs and diffuses sweat very quickly.

6.6.6 New warm shirts comfortable at temperatures of 20°C in autumn and winter

Three companies, Nisshinbo, Nippon Keori and Teijin, planned 'Ecosys 20°C' for autumn and winter together as a part of 'a triangle project' using distinct Tetron of Teijin, Egypt cotton of high quality by Nisshinbo, and spun wool of Nippon Keori.

Toyobo developed 'Toyobo comfort science 20°C'. The Toyobo 'comfort shirt' was 'warm, lightweight and tender'.

Shikibo developed the moisture absorbent and heat generative material, 'Thermo stock', for the use of a comfortable shirt to be worn in autumn and winter. When wearing the shirt, the temperature increases by 1 to 1.5°C and is made of modified cellulose, in which the hydrophilic groups of cellulose are bonded.

Kurabo developed 'warm process' using cotton for the core part and acrylic for the sheath part.

Fuji Spinning developed 'Incerared' and 'Escusa' made of cotton/polyester mixed with ceramics having an ultra-red radiation effect.

Kanebo used warm materials of cotton/wool 'RANA COTONNE', and hollow-type polyester/cotton 'Kilatt', together with insulating fiber 'ANGELUS FM'.

These shirts have contributed to a major boom for the industry and have been of great benefit and comfort to the user.

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