

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

# PROPERTIES AND FUNCTIONS OF THERMOACTIVE CLOTHING

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# INTRODUCTION

One of the basic functions of clothing is to protect human body from the effects of climate change and to support its own thermoregulatory functions in various combinations of environmental conditions and physical activity.

The microclimate around the body - it is an interaction of parameters, such as: skin temperature, humidity and air motion.

The values of these factors depend on the amount of heat produced by the body and the conditions of heat exchange with the environment.

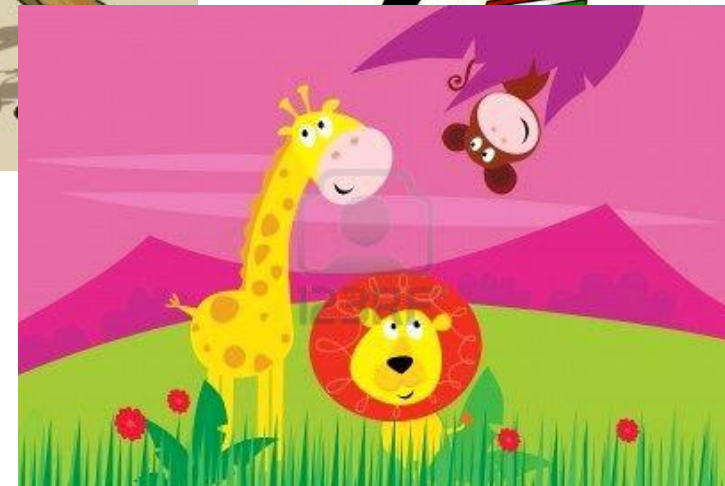
Clothing work as a barrier for the transport of heat and water vapour between the skin and the environment.

This barrier is created by:

- clothing layers,
- air contained between the layers,
- air inside of the materials.

# Thermoactive Clothing

is a garment which provides human maximum comfort in all weather conditions and different terrains.



# The Brief of History of the first Thermoactive Clothing.

The art of manufacturing thermal suits perfectly mastered the Eskimo (Inuit).

Due to the extreme climatic conditions of their garment primarily had to be the windproof , waterproof and heat protection.

They had just acquired, „primitive” intelligence and skill but they created a multi-layered clothing with **excellent performance!**

Good insulation properties :

- an interesting design construction,
- a very intelligent combination of connections of animal skins and furs.





# The First Thermoactive Clothing

Their clothing was quite large, which allowed free circulation of air and blood



A constrained body freezes and is vulnerable to frostbite.

Due to a special arrangement of the hairs of the used fur, respectively addressed to the some parts of the body



They made protection clothing which can absorb sweat and allow the skin to breathe.

From the outside, the clothing look like winter coat of caribou.

Caribou has in outer layer long, stiff hairs - it is a first insulating layer. Under it there are thick bedding, which holds air.

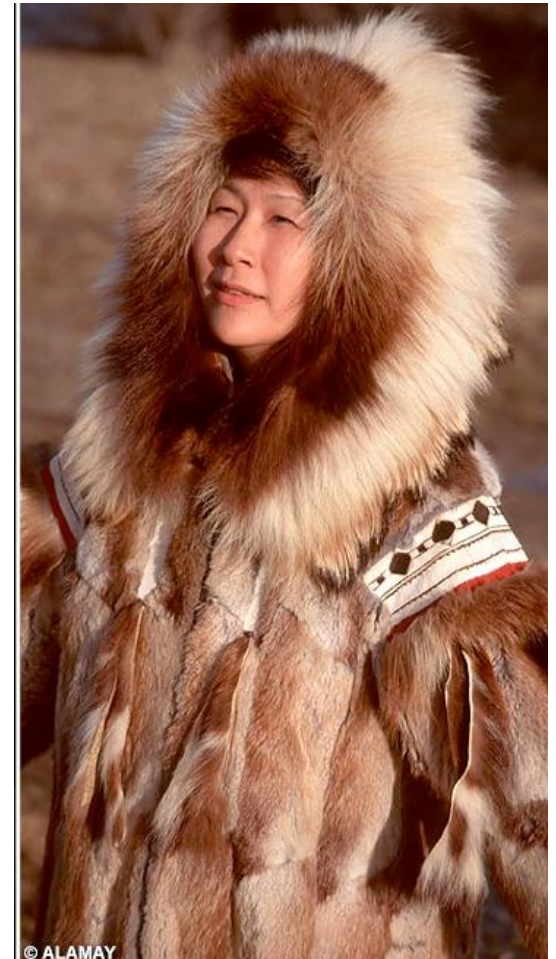


# The First Thermoactive Clothing

Furs were sewn so, that:

the outer hairs were arranged from the top to the bottom - it gave the opportunity to:

- freely sliding of the snow down,
- keeping the air inside fur as an insulating barrier,
- strong and soft animals skin (leather) created waterproof layer.



# The First Thermoactive Clothing

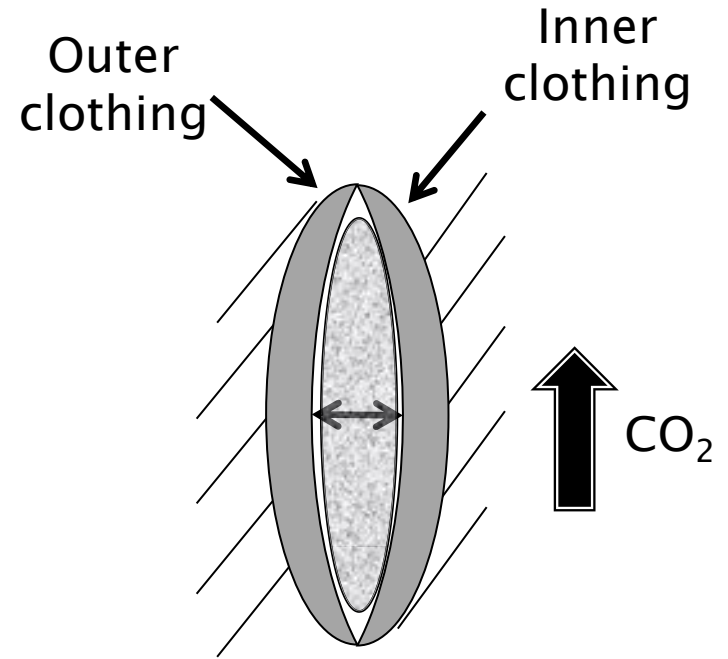
Clothing under outer garments, was cut in the same way, but the layers were putting inversly - hairs to body and skin to skin of outer clothing.

In this time, the hairs were going to the top, that the air exhaled by the skin together with the carbon dioxide could float in the direction of the collar and get out.

Between these two layers, hermetic closed from top to bottom, was the insulating layer of air, which formed some kinds of balloon.

This whole suit can be consider as a specific kind of first

**"THREE-DIMENSIONAL STRUCTURE".**



# The First Thermoactive Clothing

Coat called „anorak” were often sewn round by leather fringe, which in addition to decorative functions, gave possibility for melting snow slip down.

Down hem of jackets and hoods were also trimmed by wide belt of fur:

- protection against heat escaping outside,
- protection against the incursion of the cold to inside,
- an extra shield of face from falling snow or frost.





# Modern Thermoactive Clothing

## 1. PASSIVE CLOTHING.

Thermoactive Passive Clothing changes parameters of microclimate in the layers between clothing and human skin after the application of a special structure of the materials and by using some physical phenomena.



## 2. ACTIVE CLOTHING.

Thermoactive Active Clothing change parameters of microclimate as a result of additional technologies such as electrical or electronic equipments – smart clothing.



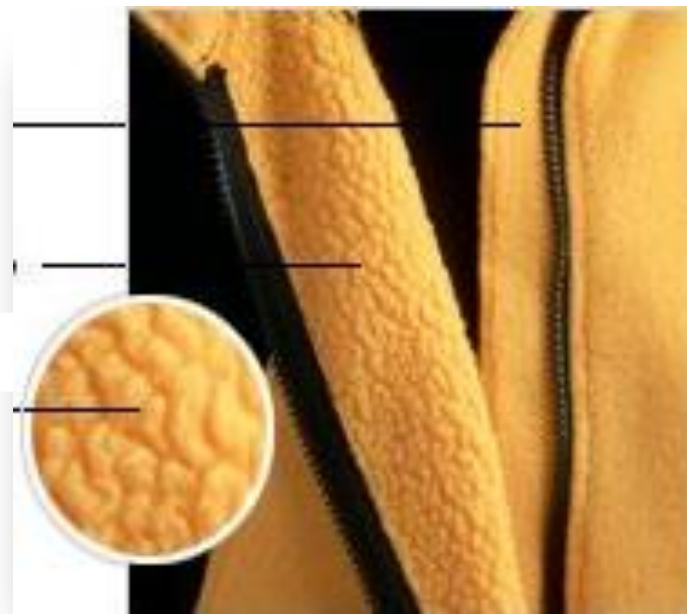
# PASSIVE CLOTHING

Focus of the passive thermoactive clothing is HYBRIDIZATION, which is giving clothing articles special features.

**Hybridization** - creative process of composing in the one textile product various raw materials, textile technology and properties.

The examples of passive thermoactive clothing designed by hybridization can be:

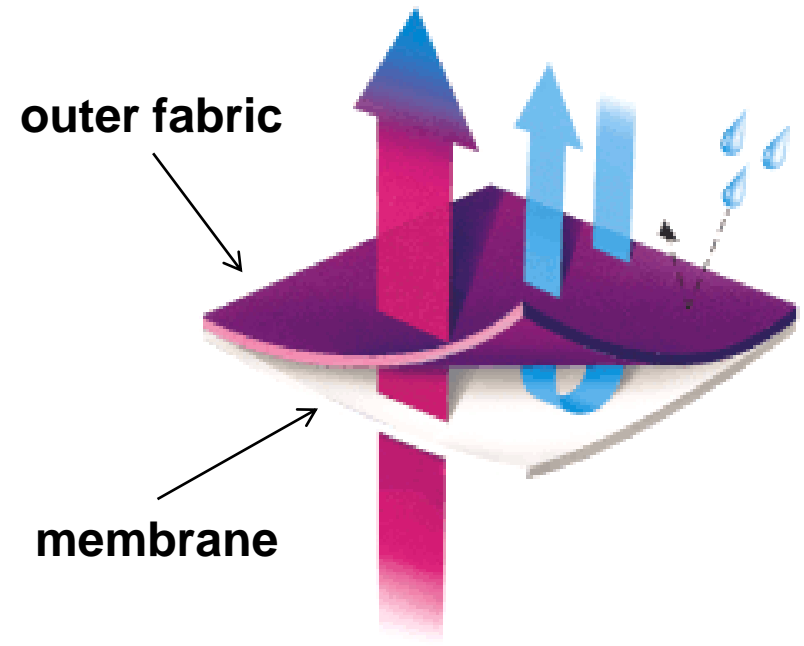
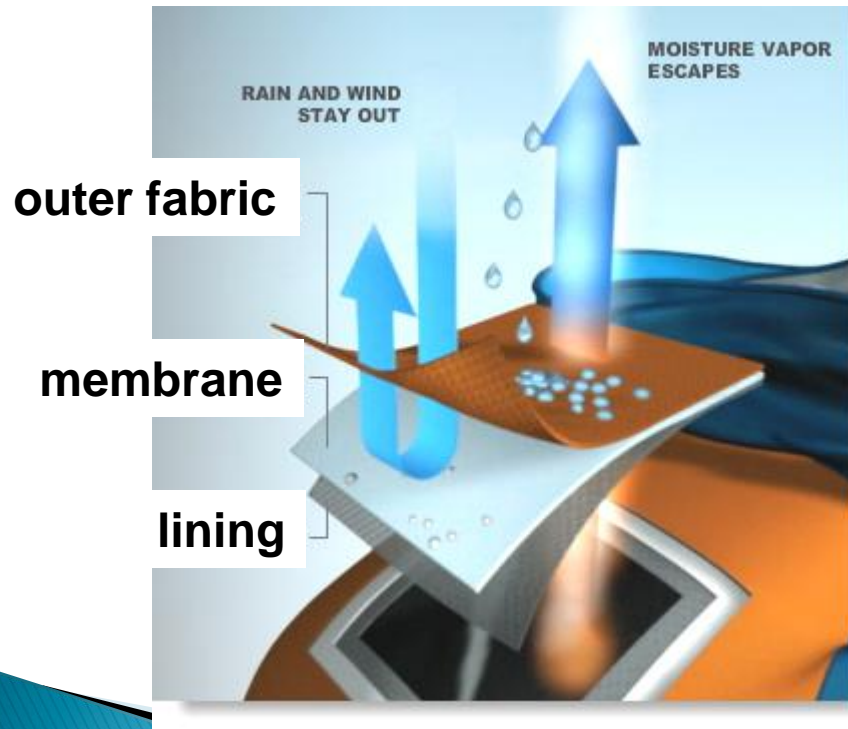
1. **MATERIALS WITH MEMBRANES**
2. **PHASE CHANGE MATERIALS**
3. **POLARTEC**



# MATERIALS WITH MEMBRANES

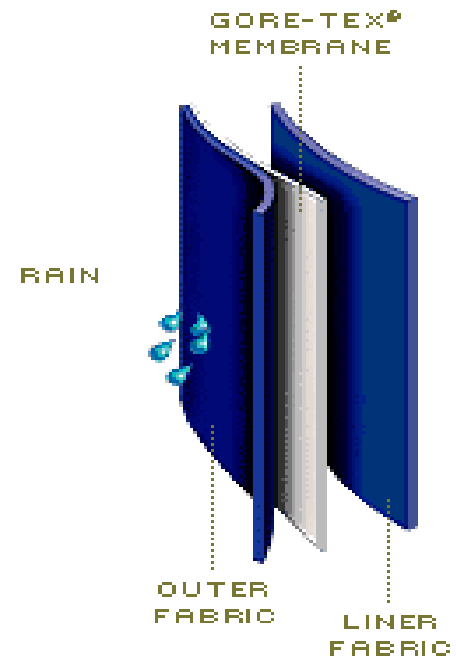
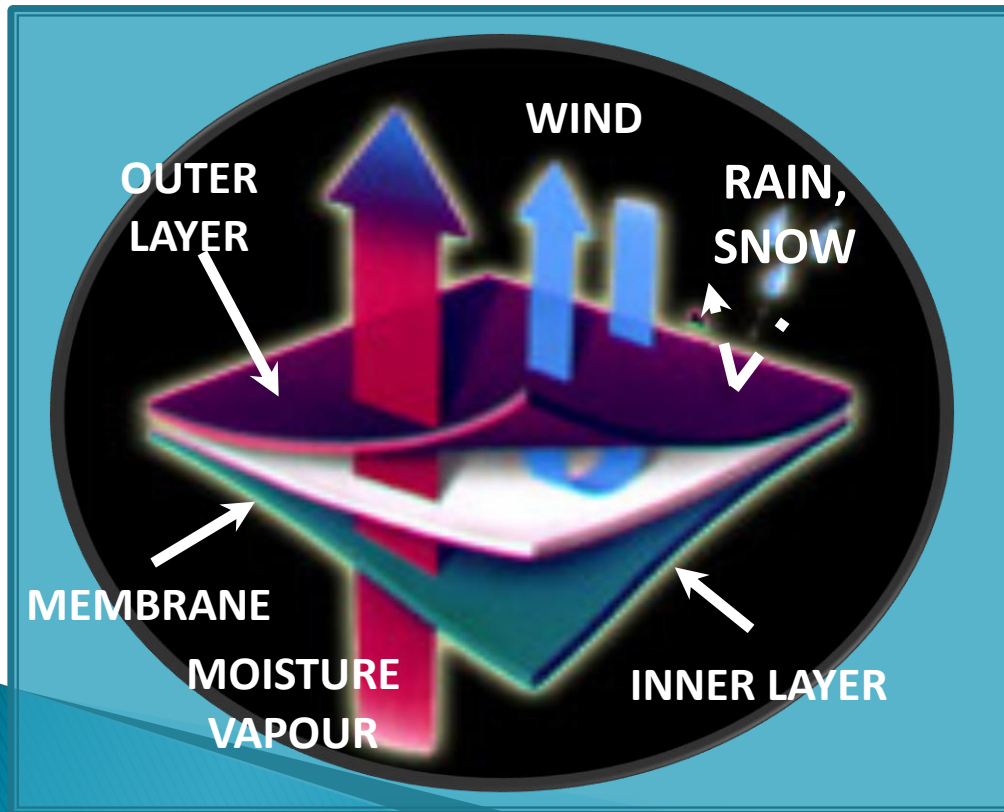
Membranes can be bonded with:

- ✓ the outer fabric and with the lining creating a three-layer laminate
- ✓ or only with the outer fabric - two layer laminate.



The membrane structure characterizes two, theoretical opposite factors:

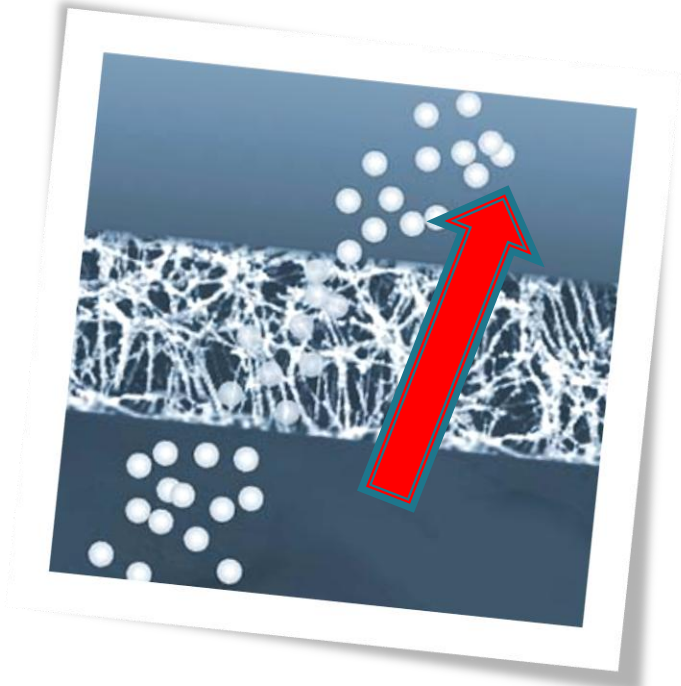
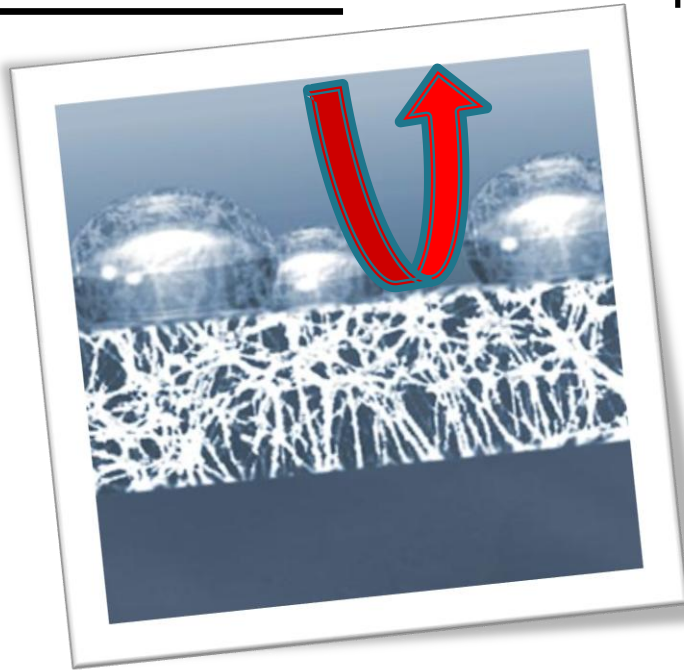
1. from the outside, the membranes are almost ideal barrier against wind, rain and snow;
2. from the inner - membranes are breathable, have a good ventilation and prevent proper transport of moisture outside.





Inside membrane there are micropores (for Gore-Tex ab. 1.4 billion per  $\text{cm}^2$ ), which dimension are 20 thousand smaller than drop of the water which usual falls as rain or snow on clothing.

In case of water vapour - their molecules are 700 times smaller than the dimensions of the micropores.



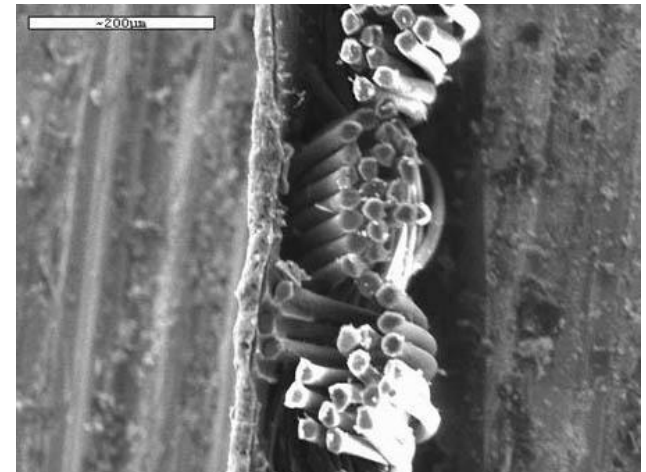
This allows water vapour can be transported freely outside the clothing - phenomenon called „breathing material”, and water from the outside does not penetrate into the garment - securing waterproof clothing.

This phenomenon is enforced by the basic physical laws of nature  
- **STRIVING TO A BALANCE**

Water vapour concentration difference on the two sides of the membrane creates an osmotic pressure, which allows the transport of water vapour with a higher concentration of medium to a medium with a lower concentration.

Water vapour molecules are moving, if there is a difference in pressure, temperature or humidity on both sides of the membrane.

The phenomenon of "active breathing" is intensified with a large temperature difference, and decreases when the difference decreases.



# BASIC INFORMATION ABOUT MEMBRANES

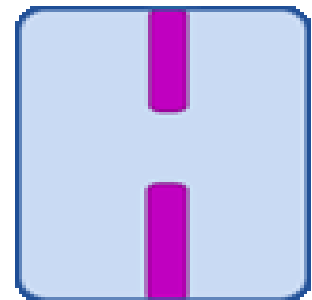
## Structures of pores in membrane:

### 1. **OPEN** - propagated by the climbers.

They are effective wherever run the sublimation phenomenon. The moisture is removal in the gas state.

Sublimation - transformation phase, which consists of a direct passing from the solid state to a gaseous state without the liquid. The vapour pressure of this material must be lower than the triple point pressure, and melting point must be higher than the temperature of sublimation.

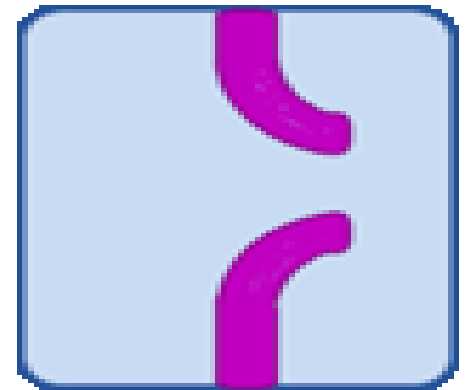
However, at the high pressure can appear the effect of moisture saturation in the inner layers of clothing and condensation.



# BASIC INFORMATION ABOUT MEMBRANES

## Structures of pores in membrane:

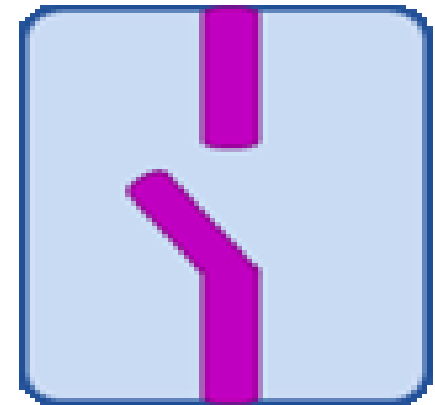
- 2. FUNNEL-SHAPED** - it works using the phenomenon of hydrophobicity. This type of membrane to work must be wet - wherever we are constantly exposed to rain. Their disadvantage is a large mass and that they don't apply in temperatures below zero.





# BASIC INFORMATION ABOUT MEMBRANES

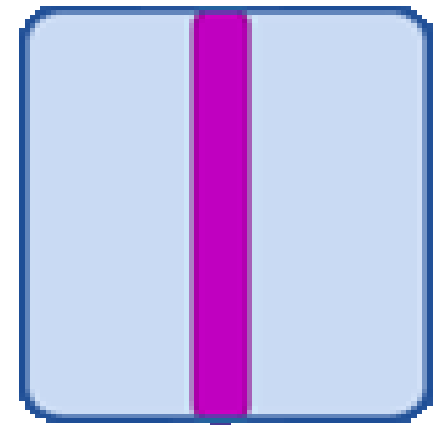
3. **MOVED** - a very complicated structure - water vapor molecules from the environment during penetration through the tortuous construction of the membrane cause the closure of micropores. This happens as a result of plugging pores so that the membrane acts as a valve, slightly increasing its weight. This type of membran is applicable wherever there is a a high partial pressure in the environment and the weather is variable for example at the sea, moderate zone or polar zone.



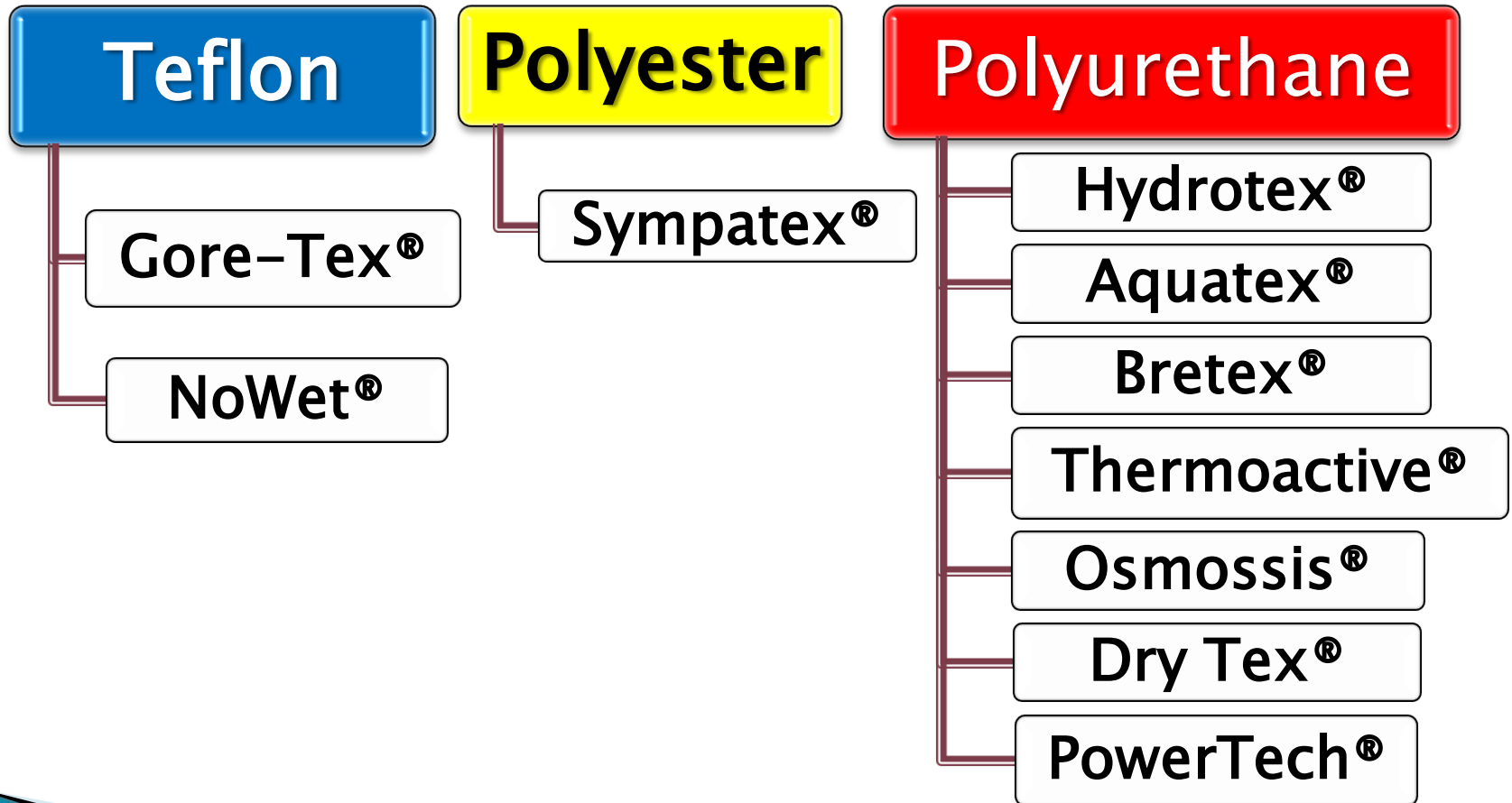
# BASIC INFORMATION ABOUT MEMBRANES

4. **CLOSED** – the membranes have no the microporous and work on the principle of chemical absorption, where the transport takes place on the basis of molecular chains.

The advantage is – membranes are still dry, because the moisture can't be stored inside pores – the best for shoes (no possibilities of development of fungus (mycosis) and bacteria).



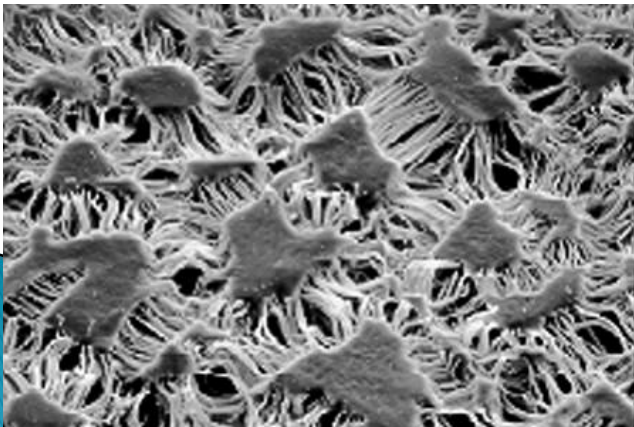
# THE TYPES OF MEMBRANES USED IN THERMOACTIVE CLOTHING



# CHARACTERISTIC OF SAME MEMBRANES

## I. Gore-Tex

– the technology of company **W.L.Gore & Associates Technologies**. Bob Gore first developed what is now called Gore-Tex in 1969 and the first products using the Gore-Tex brand were announced in 1978. It is a porous membrane made of polyfluoroethylene (PTFE - Teflon). Its **contains pores of about 1,4 billion/cm<sup>2</sup>** and a pores diameters are within the range of 0,05 - 0,5 microns. Gore-Tex is produced by controlled stretching in two directions at once thin Teflon film and immediately pressed into the outer fabric (dacron or nylon) with a loose interlacing. This allows the teflon formed spontaneously optimal pore sizes.





# CHARACTERISTIC OF SAME MEMBRANES

## I. Gore-Tex

The family of Gore-Tex product is not limited only to waterproof clothing materials.

Films and Gore-Tex membranes are also used as:

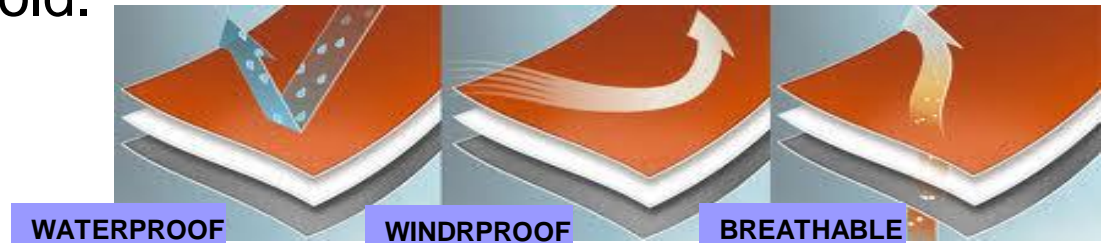
- transparent and airy membrane against insect, replacing the traditional mosquito net;
- cover for microwave radar;
- filters used in difficult weather conditions, or exposed to abrasive chemicals;
- coatings used for "temporary architecture" - in large tents suspended over the stands, spectacular halls, etc.
- films for protecting the organic waste during their biological utilization;
- GoreTex used for the construction Ericsson R310s - the material covers the microphone, ringer and speaker from water - it is permeable to sound waves, but not impermeable to water.



# Gore-Tex

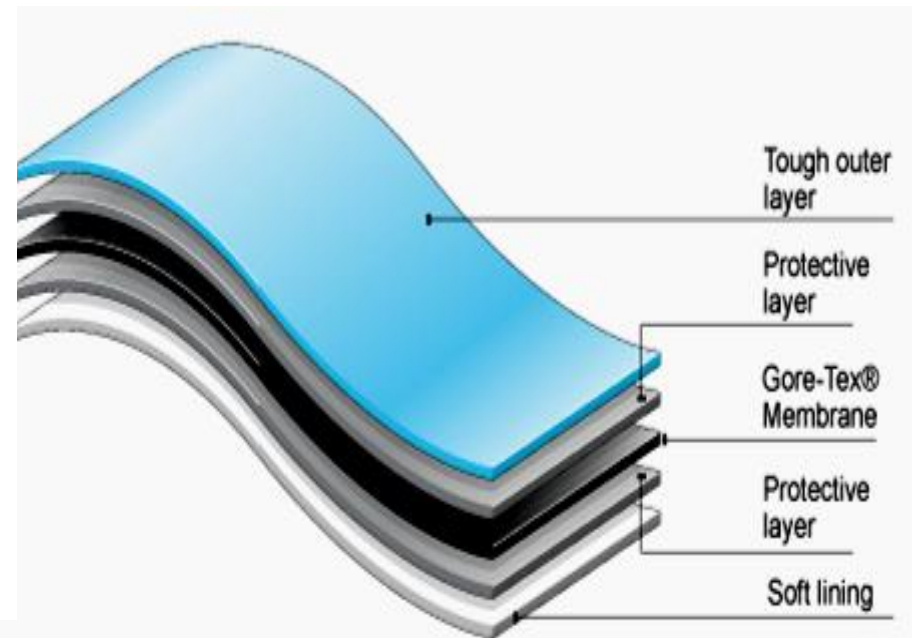
Material with the GoreTex membrane participation is:

- resistant to leaking (rain/snow),
- can transports moisture (sweat/vapour )
- provides protect against cold.



Modern materials of Gore-Tex consists of five parts:

- outer layer - the dense fabric,
- protective layer - which is the extra waterproof barrier,
- Gore-Tex membrane,
- functional layer - which is the extra thermal barrier
- soft inner lining



# Gore-Tex

## Major properties:

- waterproof - 4 to 8 meters of water,
- breathable -  $18000\text{g/m}^2 \cdot 24\text{h}$ ,
- it is a barrier against water, dust as well as bacteria.
- non-wettable - high hydrophobicity (waterproof),
- the membrane structure is a „prison for the wind” – windproof,
- resistance to ultraviolet radiation.

## Disadvantages:

- the membrane is not resistant to mechanical damage
- is not eternal (is crumbling) - enough for about 3 - 5 years,
- because it is a Teflon membrane, there is a problem with recycling.

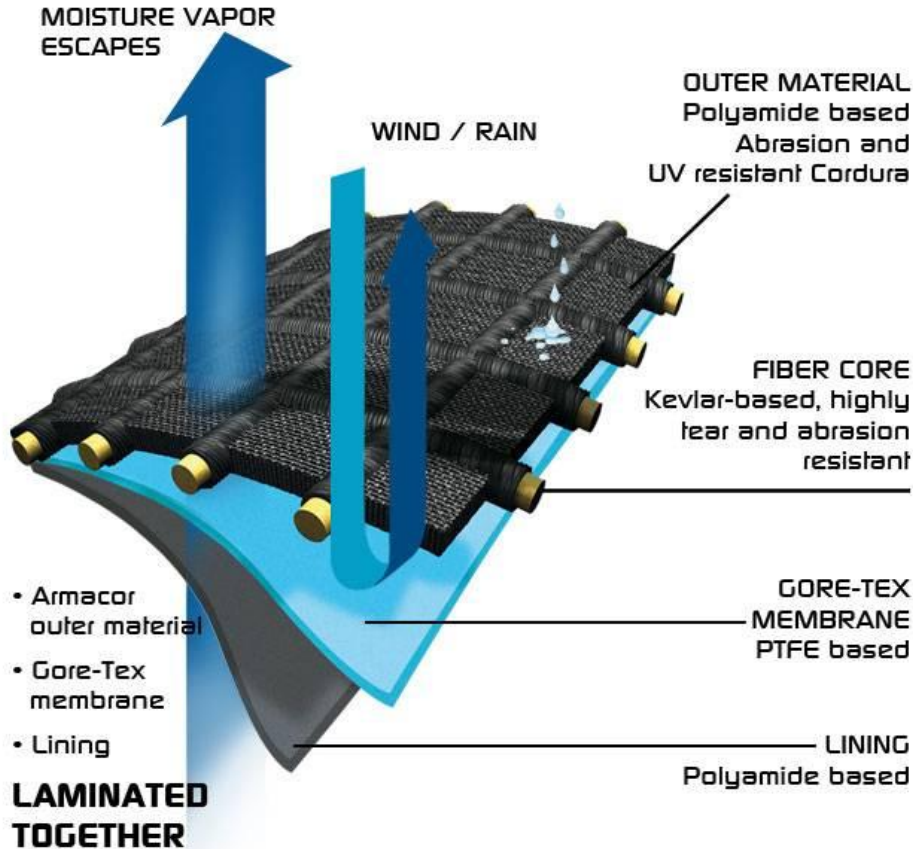
<http://www.gore-tex.co.uk/>



# INNOVATIONS:

## 1. Technology ARMACOR ®

Into the structure of outer fabric was built the net with  
This technology provides extreme resistance to tearing and abrasion - used in military or motorcycle clothing.





# INNOVATIONS:

## 2. Gore-Tex Pro Shell 3-Layer Leather

The leather has a "solar reflective outer shell" incorporated into the surface:

- reflect solar radiation,
- keeping the wearer cooler and more comfortable than leather without the treatment,
- the leather is perforated to allow the out gassing of body moisture (i.e., breathability),
- the new material has a high resistance to abrasion.

The leather is bonded to the Gore-Tex membrane from back side and to textile inner liner. The seams are sealed with breathable Gore-Tex material.



# II. SympaTex

- the technology of company **SympaTex Technologies GmbH**.

The company was founded in 1980 and is based in Germany. Hydrophilic membranes made from polyester (70%) with addition of modified polyether (30%).

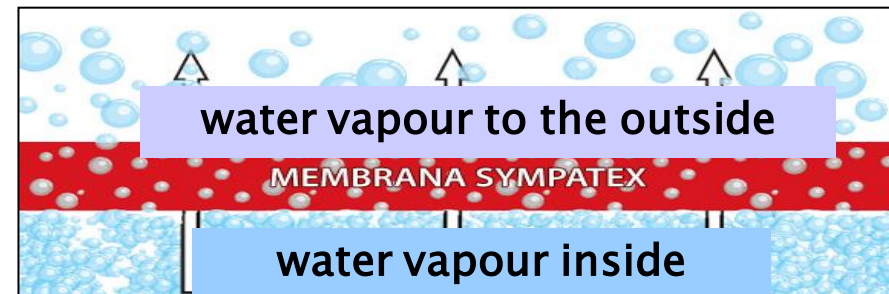
**SympaTex's** co-polymer consists of polyester for molecular strength, and polyether to transport water molecules.

The membrane is at least 5  $\mu\text{m}$  thick, translucent, and stretchable with good stretch recovery.

The **SympaTex** membrane is completely recyclable and relatively environmentally friendly.

The **SympaTex** membrane contains no channels or pores but the water vapour molecules are transported through the membrane from the inside to the outside by way of an absorption and evaporation process

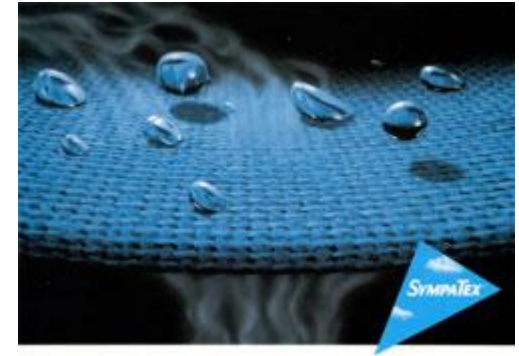
**Intelligent hydrophilic membrane**



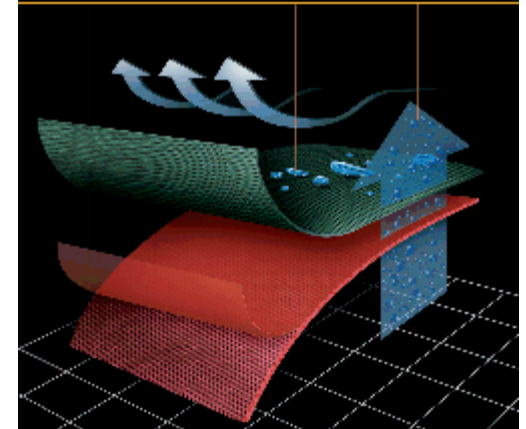
# SympaTex

Waterproof, windproof and breathable membrane is laminated to the fabric:

- from the inside – 2 layer laminate
- between two layers of materials (fabric and lining) - 3 layer laminate.



The 3 layer system offers good durability from abrasion and better protection of the SympaTex membrane.



# SympaTex

**SympaTex** membranes are characterized by:

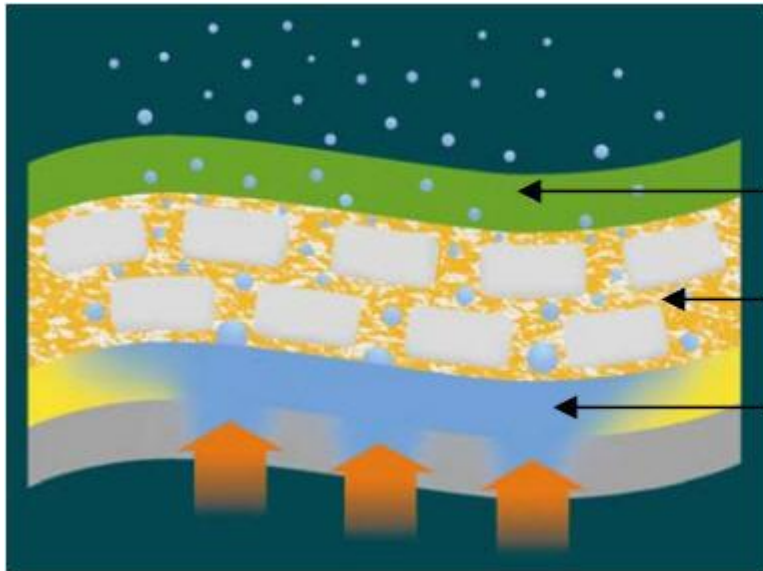
- water resistance - up to 2,5 m column of water,
- good windproof,
- transport of water vapour – good breathing,
- good transport of moisture away from skin,
- a very good resistance to mechanical damage,
- is environmentally friendly (Oko-Tex Standard),
- extraordinary lightness,
- long-term functionality - without pores in the membrane,
- high flexibility - up to 300%,
- resistant to pollution, clogging dirt, dust and oily substances,
- ease of conservation process
- **antibacterial and antifungal.**



<http://www.sympatex.com>

# INNOVATIONS:

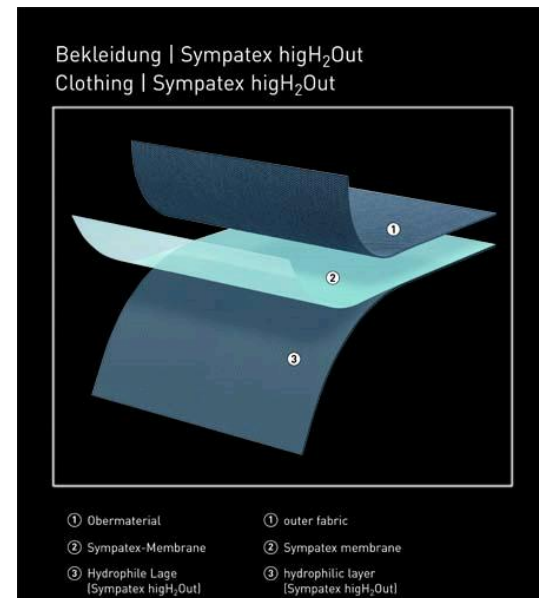
1. **HigH2Out** - has a more absorbent inner lining fabric - padding.



Outer Material

Non-porous Sympatex Membrane

Extremely Absorbent Layer

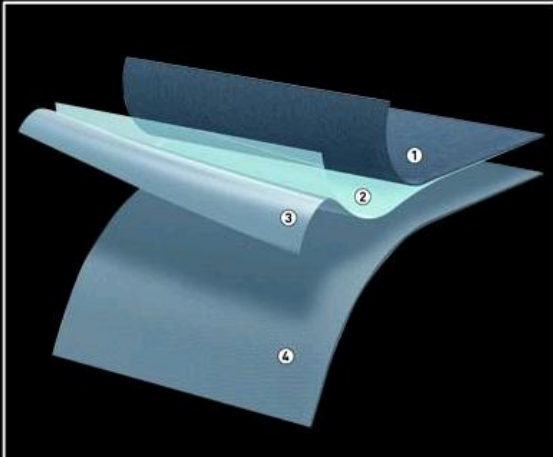




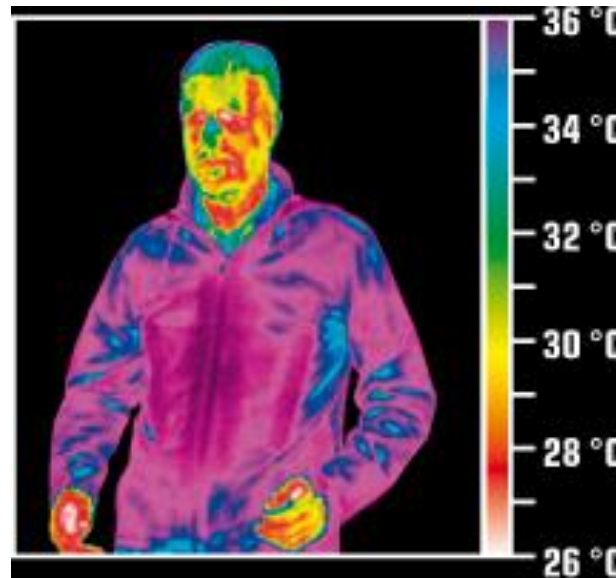
# INNOVATIONS:

**2. Reflexion** - contains a coating of aluminum a few nanometers thick - space technology - sandwiched between membrane and lining, This coating improves the excellent thermal insulation of clothing - to prevent dissipation of heat generated by the human body - to 3.6 C less heat loss.

Bekleidung | Reflexion Oberstofflaminat  
Clothing | Reflexion direct laminate

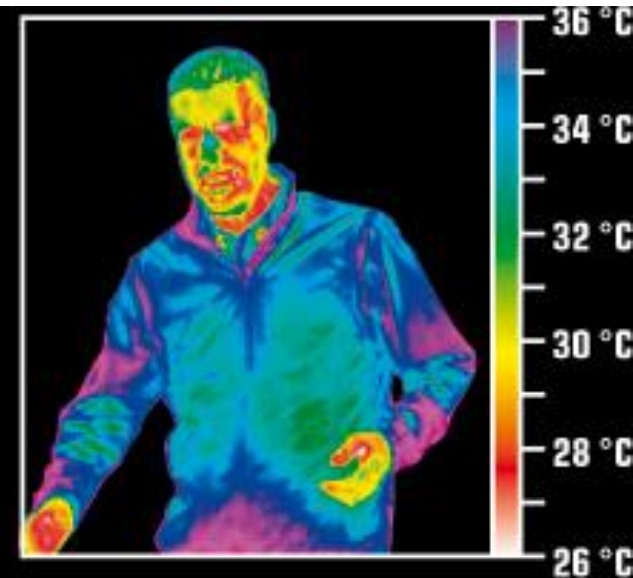


- |                     |                     |
|---------------------|---------------------|
| ① Obermaterial      | ① outer fabric      |
| ② Sympatex-Membrane | ② Sympatex membrane |
| ③ Aluminiumschicht  | ③ aluminium layer   |
| ④ Futterstoff       | ④ lining            |



Mit/With/Avec/Con/Con:

Sympatex Reflexion®



Dhne/Without/Sans/Sin/Senza:

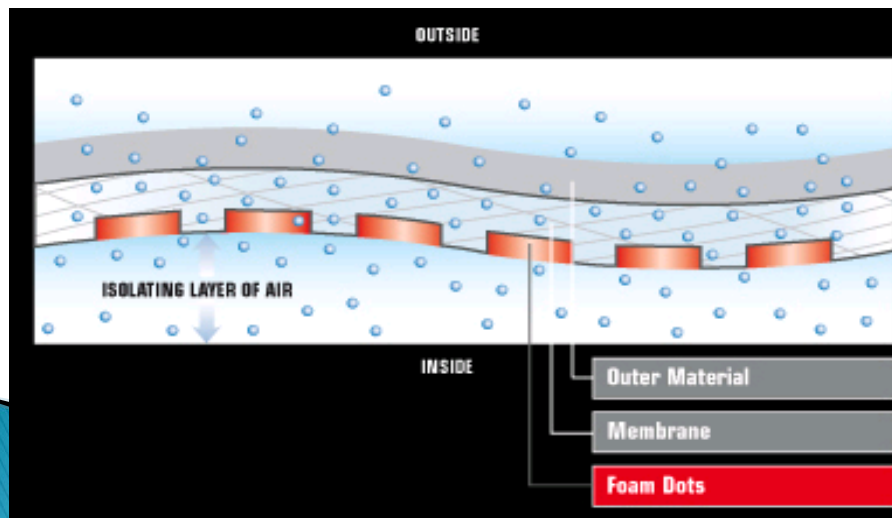
Sympatex Reflexion®

# INNOVATIONS:

**3. SympaTex Phaseable** - is described as 2,5 layers, without lining fabric.

Intelligent insulation actively adapts depending on the user's activity. When the temperature and humidity change, the membrane changes its structure:

- at low levels of activity - the body is protected by an insulating layer of air.
- with the increase in activity level - temperature and humidity around the skin increases, the membrane stretches and expands, causing enlargement of the holes and increase the empty space - reduce the thermal isolation and increases breathability.



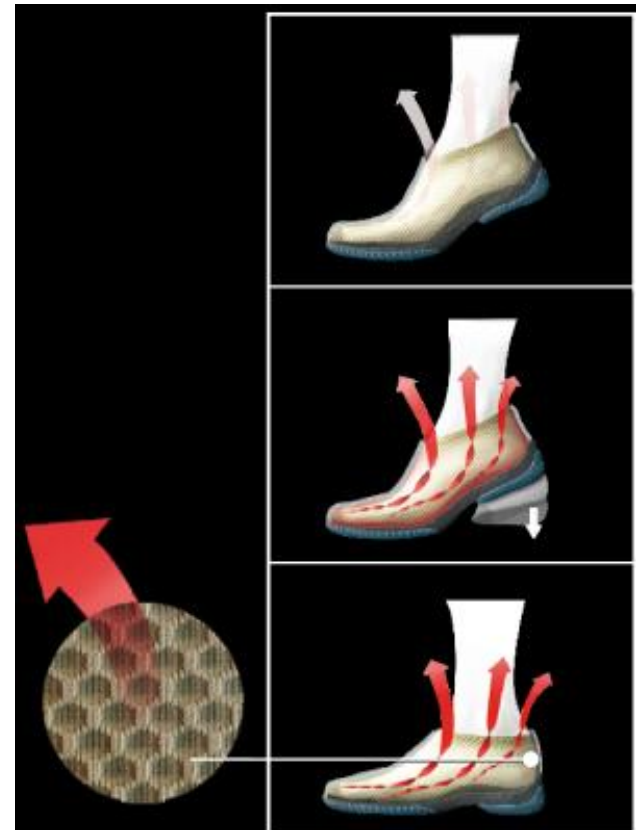
## INNOVATIONS:

4. **SympaTex Airflow** - is a membrane designed for footwear.

It consists of 4 laminated layers:

- outer layer - fabric resistant to water and wind
- membrane
- the inner layer - knit spacer fabric, allowing greater airflow and more moisture evaporated around the membrane;
- lining.

The structure of the material allows the removal of wet air from the shoe by rotating movements of feet during walking



# III. THERMOACTIVE®



The technology of **The Laboratory Equipment Mountaineering Adam Malachowski.**

The company was founded in 1977 and is based in Poland

The membrane made of polyurethane.

The main idea is that the human body is the source of the heat generated as a result of metabolic changes.

THERMOACTIVE concept is based on the existence of a **laminar layer of air surrounding the entire body surface.**

According to this concept clothing only helps to regulate the phenomena occurring in this layer.



# III. THERMOACTIVE®

THERMOACTIVE is membrane with **moved micropores**, which works **as valve** and prevents the penetration of moisture from the outside.

THERMOACTIVE membrane transports moisture to the outside in the similar like the skin.

Similar to the behavior of the skin, the membrane acts in a variety of weather conditions:

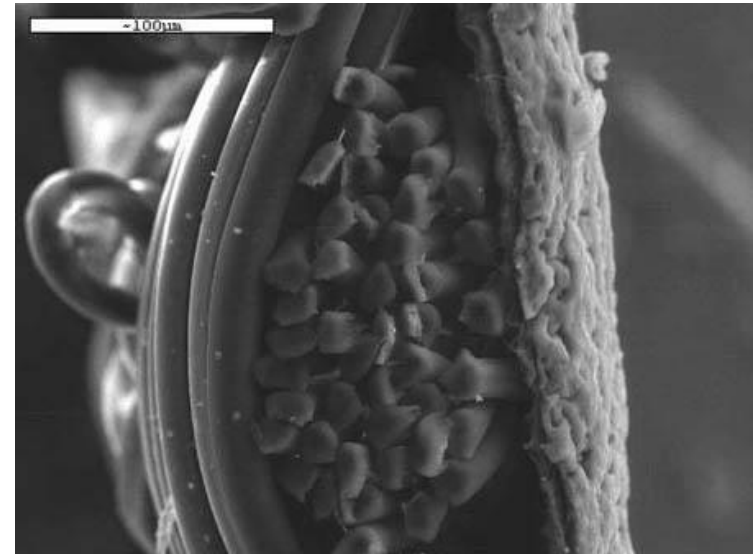
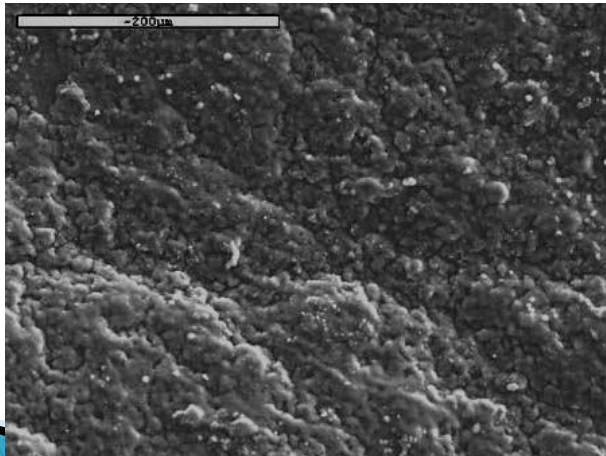
- at low temperatures the micropores of membrane are closed, such as skin pores,
- with increasing temperature the micropores opening up and discharge vapour molecules on the outside.



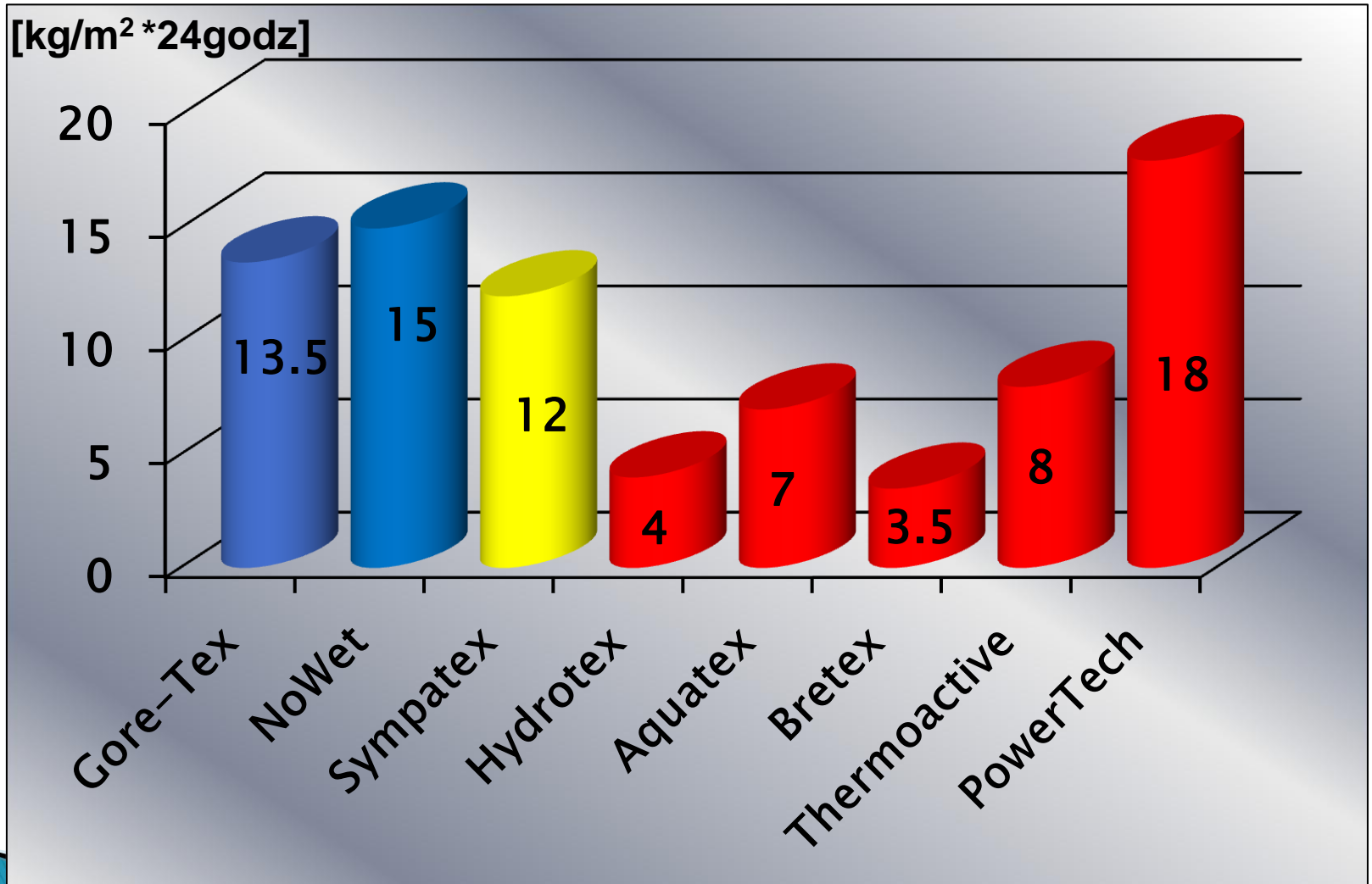


# III. THERMOACTIVE®

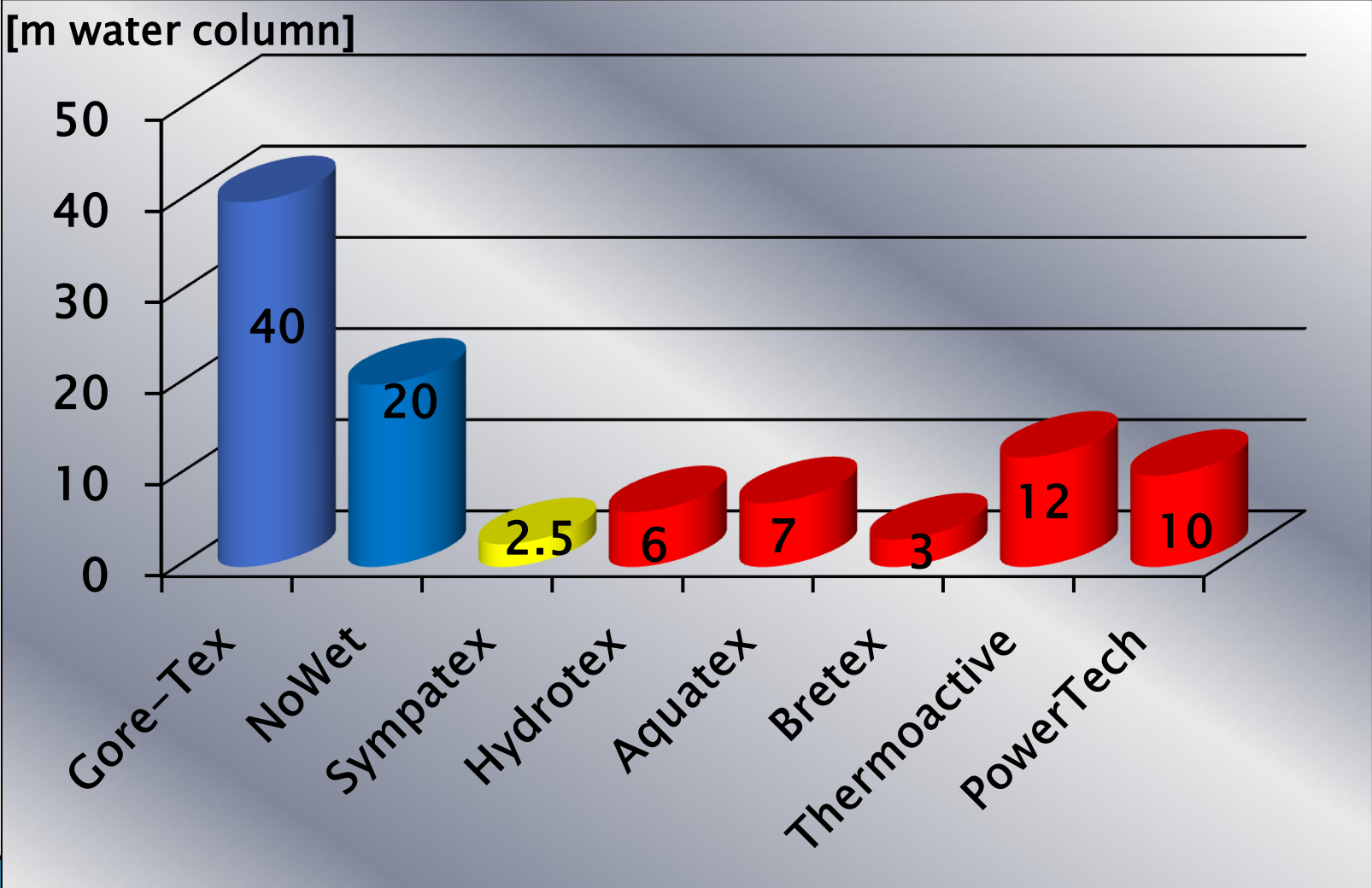
1. **Laminate type THERMOACTIVE 2L** – it is membrane bonded with the durable polyester fabric. Laminate has a very smooth surface - high resistance to heavy rain.
2. **Laminate type THERMOACTIVE 3L** – it is a combination of outer fabric, membrane and polyester lining with special construction. All these layers are permanently laminated together, characterize by better durability.



# Compare water vapour permeability of membrane's materials.



# Compare waterproof of membrane's materials.

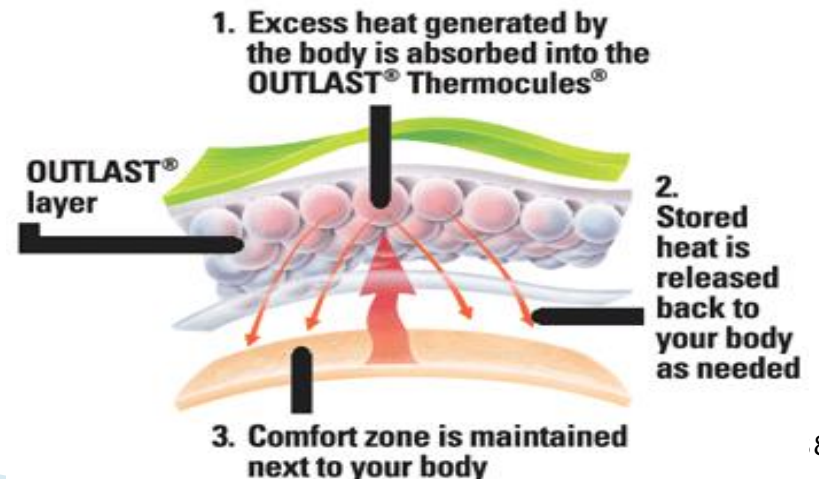


# PHASE CHANGE MATERIALS (PCM)

Phase change materials have the ability to absorb, store and release large amounts of energy as heat in a specific temperature range when the material changes phase or state (from solid to liquid or from liquid to solid).

Phase change materials are able theoretically to change state at nearly constant temperature and therefore to store large quantity of energy.

As a result of applying PCM to the textile structure can be achieved thermoregulatory properties - those which absorb or release heat depending on environmental change.



# PHASE CHANGE MATERIALS (PCM)

The required properties for a PCM for a high efficiency cooling system with thermal energy system for application in textile fields are as follow:

- melting point between 15 and 35 C;
- large heat of fusion;
- little temperature difference between the melting point and the solidification point;
- harmless to the environment;
- low toxicity;
- non-flammable;
- large thermal conductivity, for effective heat transfer;
- ease of availability;
- low price.

A classical example of PCM is the paraffin wax (size from 15 to 40  $\mu\text{m}$ ), which can be microencapsulated and then integrated into fiber or used as a coating.



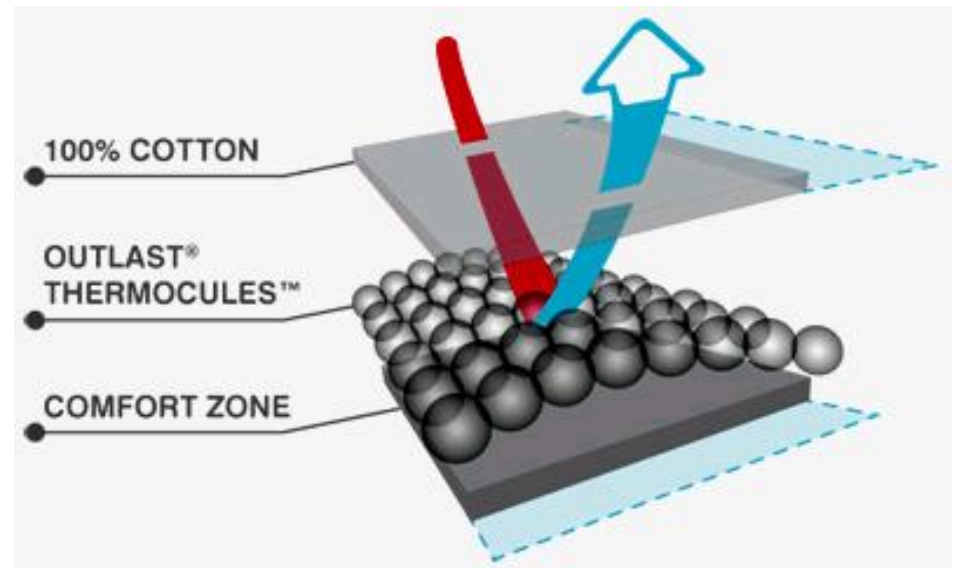
# PHASE CHANGE MATERIALS (PCM)

The technology for incorporating PCM microcapsules into textile structure to improve their thermal performance was developed in the early 1980s under NASA research programme.

To apply the PCM material to the textile structure should be subjected to microencapsulation.

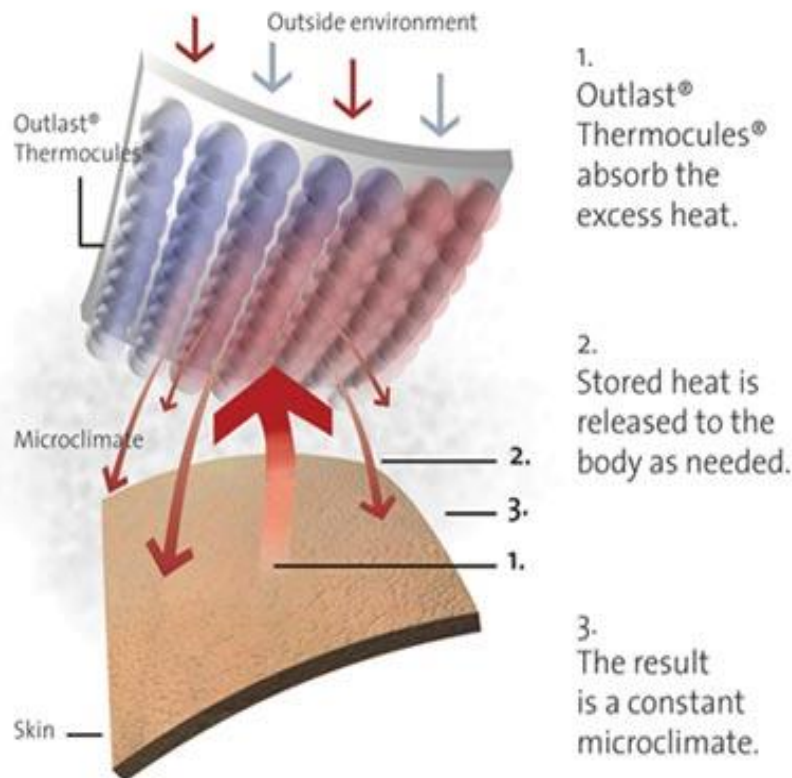
PCM microcapsules are used in textiles, such as:

- shoes,
- blankets,
- jackets,
- gloves,
- clothing, etc.



# PHASE CHANGE MATERIAL (PCM)

Currently on an industrial scale is produced acrylic fibre with the addition of PCM microcapsules with a trade name OUTLAST - Textile and Clothing Company „Teofilow”.



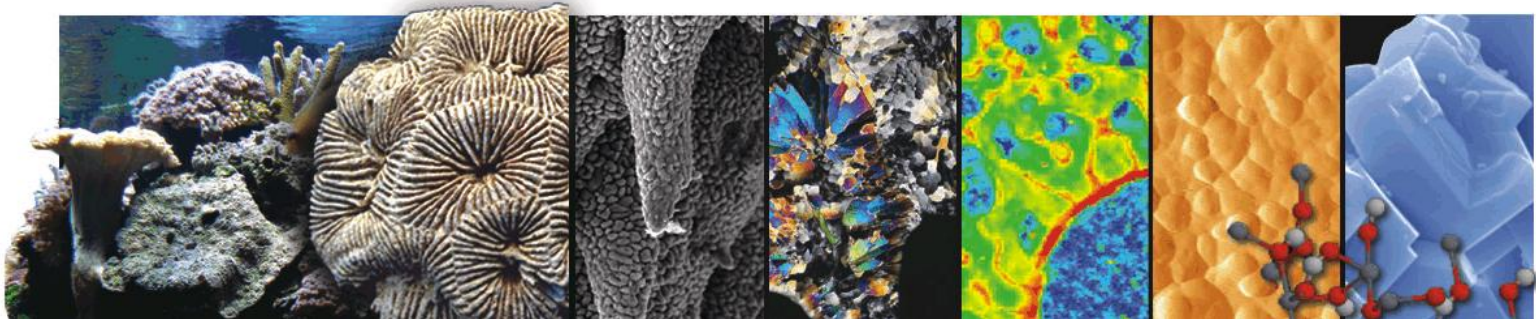
- Using this type of material is obtained clothing with the following characteristics:
- **cooling effect** - PCM microcapsules absorb excess heat produced by the body through absorption.
  - **isolation effect** - PCM microcapsules emit heat to the product, creating a thermal barrier, which limited the flow of heat from the human body to the environment
  - **thermoregulatory effect** - PCM microcapsules regulate the microclimate temperature - keep it on an almost constant level.

# Polartec

Polartec, commonly referred to as fleece fabric (Polar), is the most common example of the application of bionics science.

**Bionics** (also known as **biomimicry**, **biomimetics**, **bio-inspiration**), is the science based on observing nature and its practical application in human life.

**Polartec** is a material, which in 1979 was developed by the U.S. company Malden Mills.





# Polartec

The starting point for the creation of the Polartec material was tubular fur of polar bear.

Fur of polar bear is made up of thin tubes that retain the air and work as an excellent thermal insulator, and at the same time characterized by another very important advantage - do not keep the water.



# Polartec

Polar bear fur is white (single hairs are transparent as water droplets forming a cloud), which gives him a good camouflage in the surrounding environment as well as insulation from the cold. Fur acts as a miniature greenhouse - converts sunlight into heat needed to warm the body, absorbed by a black bear skin.

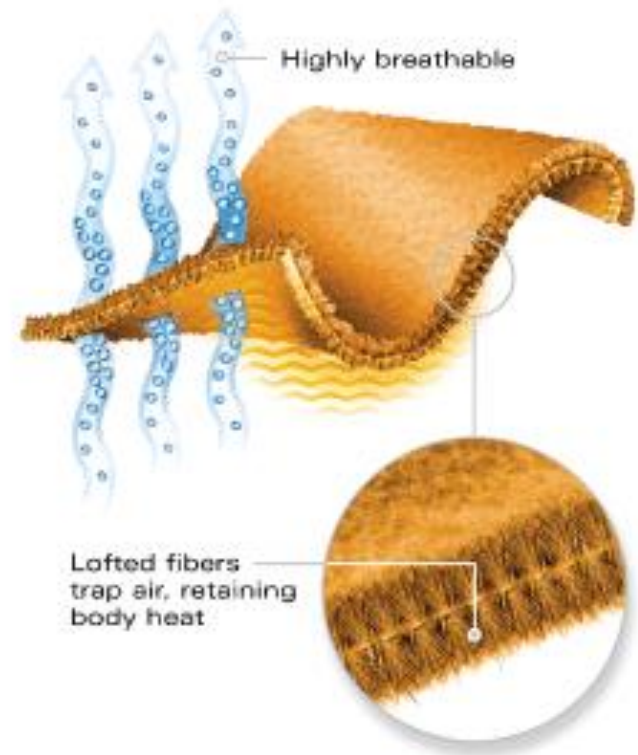




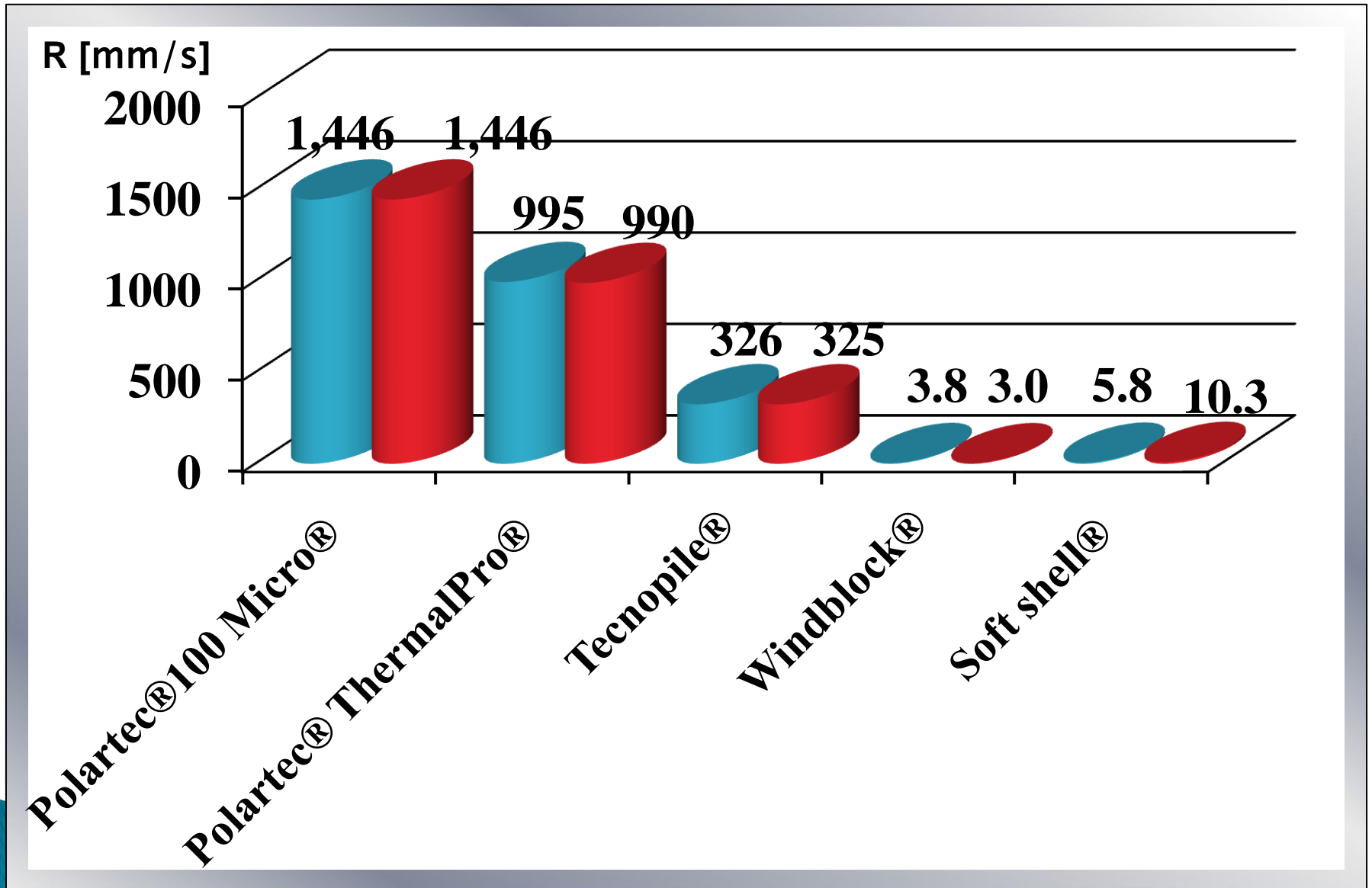
# Polartec

**Polartec** is constructed from thin polyester tubes. A single tube may have a length of 40 km, and weigh about 5 grams.

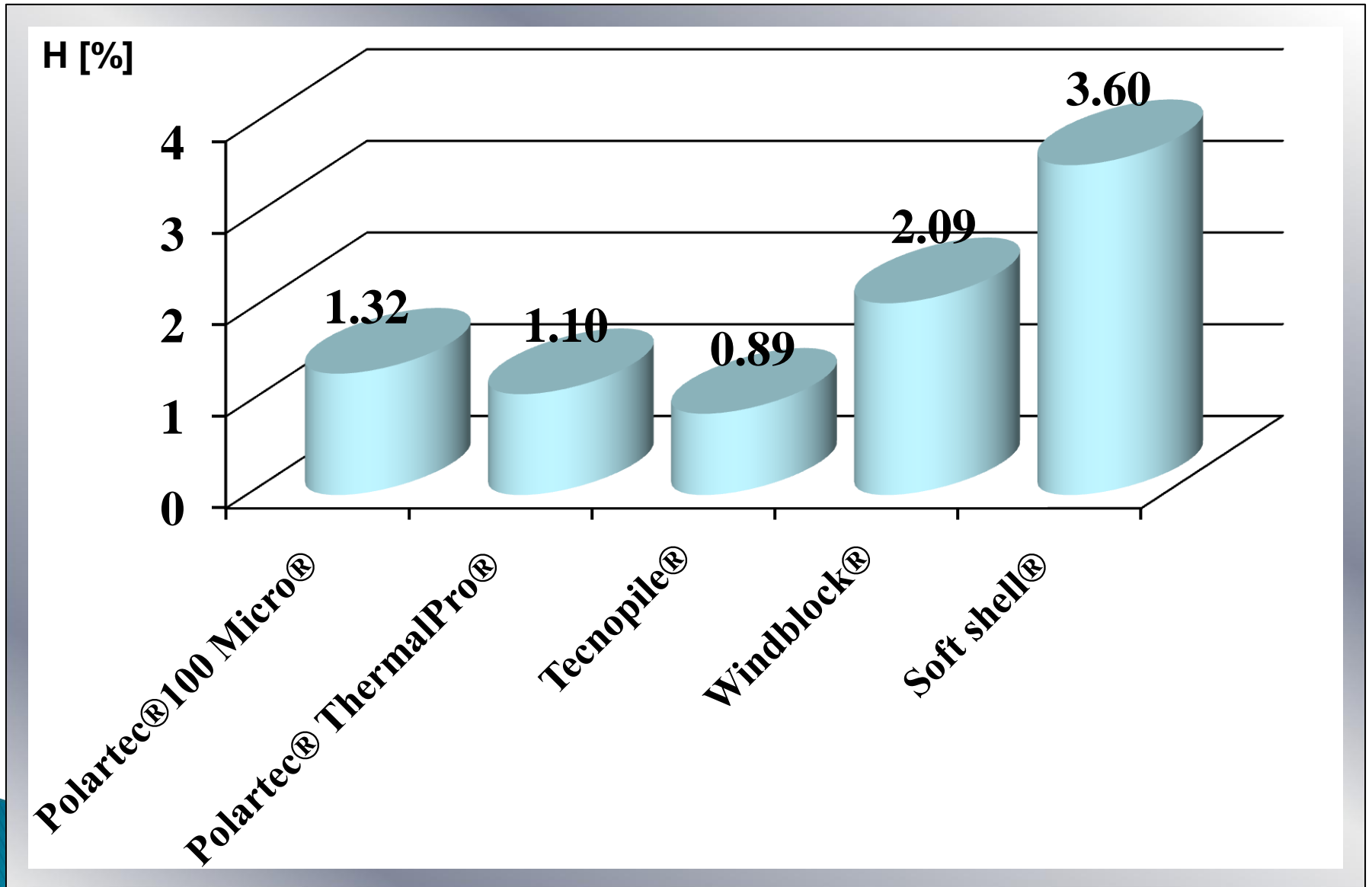
**Polartec** allows free evaporation of sweat without absorption of moisture, because the polyester is hydrophobic and even the remains dry after dipping. Water absorption may be less than 1% by weight of the material - so protect against fleece soaked, and after washing dries rapidly. The knitting Polartec has better thermal insulating properties than products made of natural fibers.



# Compare air permeability of Polartec fabrics.



# Compare hygroscopicity of Polartec fabrics.



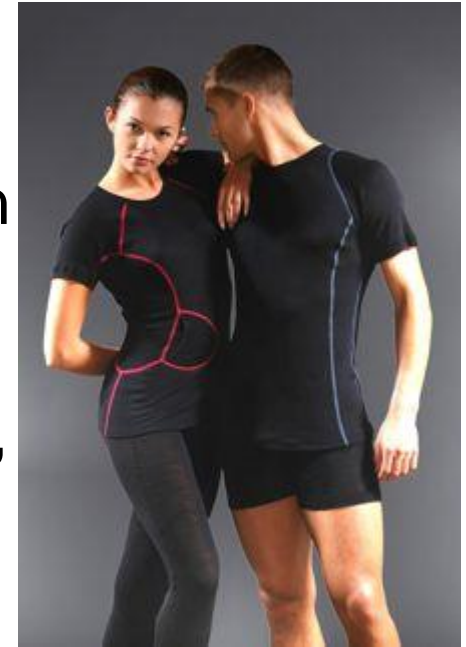
# Conclusion.

Contemporary clothing to be noticed at market and win in the "jungle" of competition must fulfil more and more complicated and sophisticated user requirements.

It is no longer enough just to be fashionable, must also be functional and physiologically friendly.

## **MODERN THERMOACTIVE CLOTHING**

characterized by such features, that regardless of the technology have the invaluable properties of self-regulation of thermal parameters of microclimate under clothing for comfort physiological regardless of weather conditions and the type of physical activity





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# PROPERTIES AND FUNCTIONS OF THERMOACTIVE CLOTHING

**Thank you for your attention!**

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