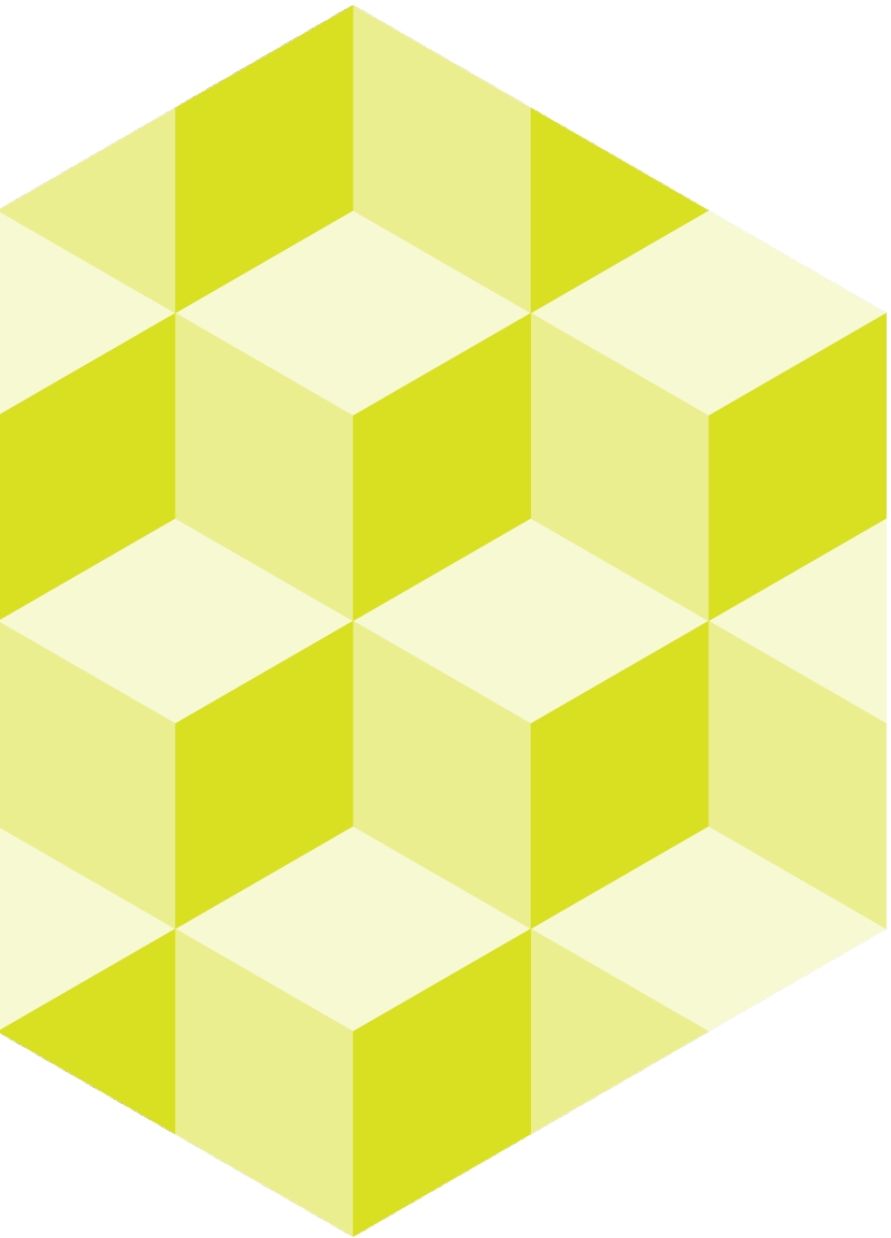
This open educational resource has been developed by Anikó Varga / Moholy-Nagy University of Art and Design Budapest

SusTexEdu

3.4 Textile printing, dying and pre-treatment

Funded by the Erasmus+ Programme of the European Union



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SusTexEdu | Erasmus+

This learning material was developed in the Erasmus+ funded project Education Partnership of Textile and Clothing Sector Materials & Sustainability (SusTexEdu)

The goal of the project is to research and develop education in the textile and clothing sector related to textile materials, sustainability and circular economy.

The learning material has been prepared for piloting, and students were asked for voluntary feedback after the course for the further development of the material. The material is translated from Hungarian by SusTexEdu team.

Project coordinator: Metropolia UAS

Partners: Hogent (BE), Mome (HU), Omnia (FI), TTHK (EE), TTK UAS (EE), University of Borås (SE)

Funding: Erasmus+

Project period: 2022-2024

About this learning unit

CONTENT DESCRIPTION

- Basic knowledge about textile pre-treatment processes, dyeing and printing methods and their technical and chemical demands.

LEARNING OUTCOMES

Student will be able to:

- identify appropriate materials and techniques for resource-efficient dyeing & printing
- identify the properties of a fabric after mechanical and/or thermal finishing

STUDENT WORKLOAD

1 ECTS, which is equal to 25-30 hours of work:
for example

- Lectures 12-16 h
- Group activities 4 h
- Independent study 9-14 h
- Learning diary 2 h

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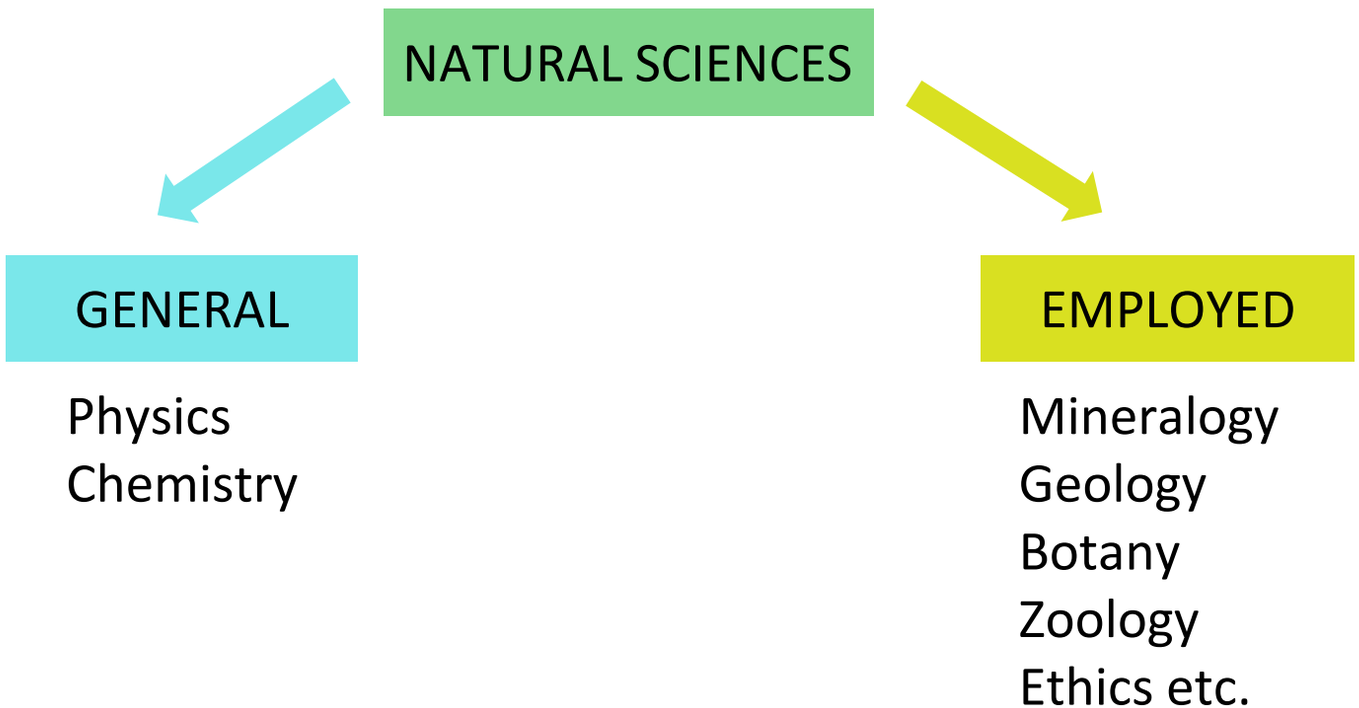
Content

Introduction



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Physics and chemistry

Physics and chemistry are called general natural sciences because they play a more or less essential role in the cultivation of the other natural sciences. (1.2.3.)

Both branches of the general natural sciences deal with the characteristics of materials and the phenomena that occur on materials.

Physical characteristics, phenomena which can be detected without profound changes in the properties of the materials.

e.g.:

- magnetism of iron
- dissolution of sulfur in carbon disulfide - if the carbon disulfide evaporates, the sulfur will be received back.

Chemical characteristics, phenomena

when detected, the properties of the materials undergo a profound change.

e.g.:

- *iron and sulfur combine to form ferric sulfide during heating - the resulting compound is neither iron nor it does not have the characteristics of sulfur.*

[1] A tanóra anyagának alapja: dr. Péter Ferenc Textilkémia I. Bp., 1963

[2] A tanóra ismereteit Kovács Leventéné, vegyészmérnökjegyzetei és oktatási anyaga alapján állítottam össze.

[3] PANYOVA; Színezék és vegyszerismeret (Jegyzet textilnyomó szakmunkásoknak) 1968-as könyvének ismereteit is felhasználom a jegyzetben.

Solutions

Most substances dissolve in a suitable solvent. Solubility is greatly affected by temperature. In general, we can dissolve more substances by raising the temperature.

Saturated solution: under given conditions (at a given temperature) it cannot dissolve more of the substance to be dissolved.

The concentration of the solutions: usually given in weight percentage or volume percentage.

Weight percentage: How many grams of solute are there in 100 g of solution.

E.g.:

- *A 10% solution means that 100 g of solution contains 10 g of solute and 90 g of water.*
- *Volume percentage: How many ml of solute there is in 100 ml of solution.*

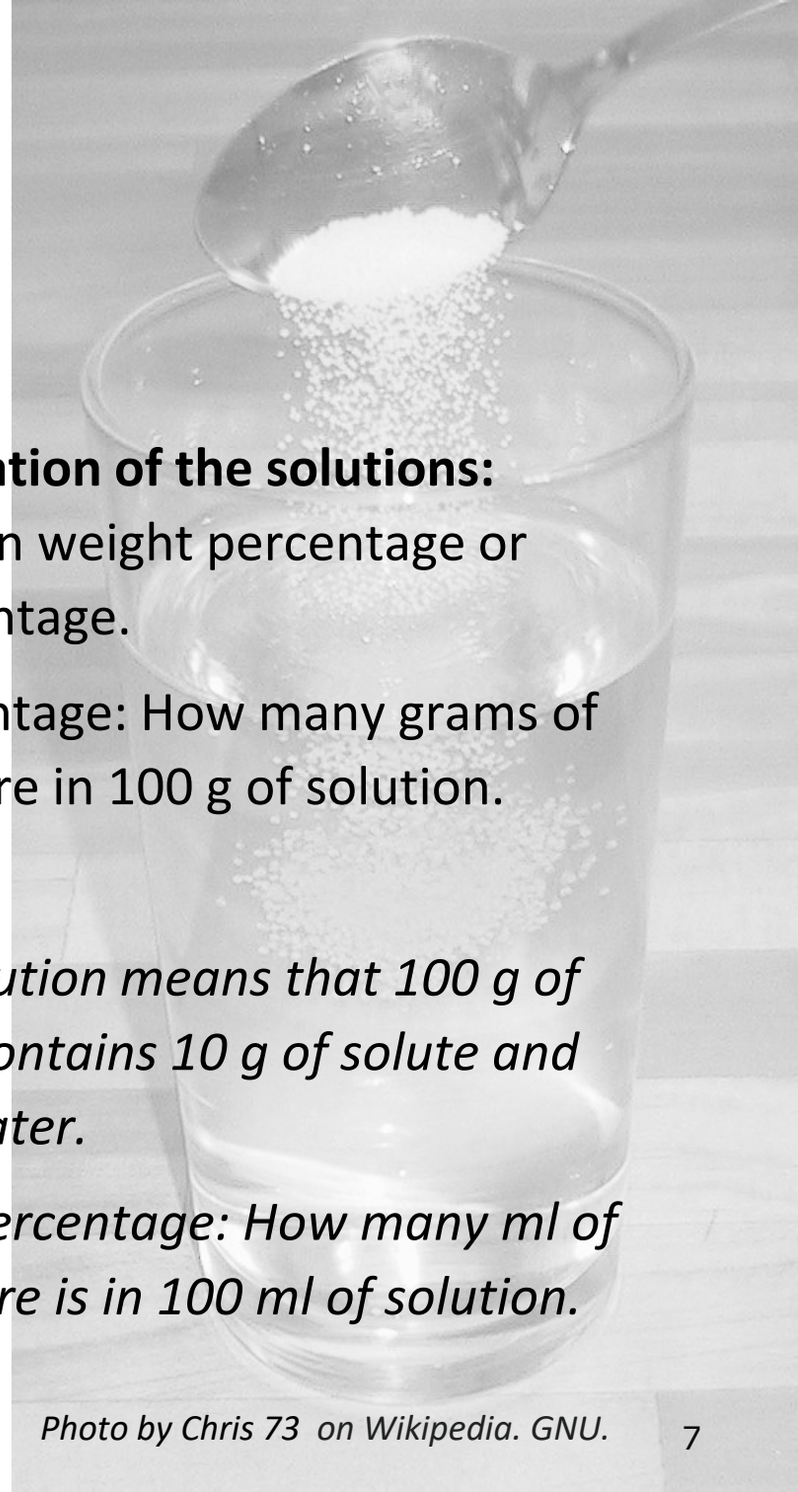

Photo by Chris 73 on Wikipedia. GNU.

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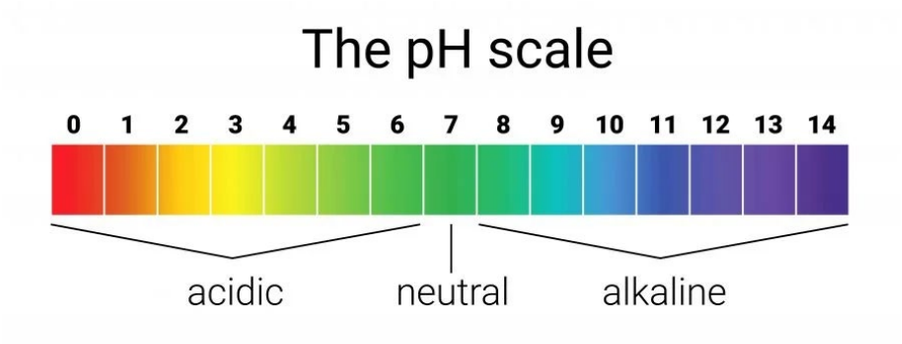
… solutions

Mixed %: grams of solute in 100 ml of solution.
Real solution: if the dissolved particles in the solution cannot be detected either with a microscope or with an ultra-microscope**.**
Suspension: if solid particles in the liquid medium are visible under a microscope. E.g.: a mixture of fine powder and water
Emulsion: if liquid particles are dispersed in the liquid medium. E.g.: oil-water mixture. Both the suspension and the emulsion break up easily.



E.g.: PH notation is used to characterize acid-alkaline solutions. The more acidic a solution, the lower, the more alkaline, the higher the pH value.

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Safety data sheets

- Data sheets provide users information about the physical, chemical and physiological effects of chemicals and hazardous substances, as well as about the safe use, storage and treatment of the resulting waste.
- The content requirements of safety data sheets are regulated by REACH.
- The global harmonization system (Globally Harmonized System - GHS) defines the formal requirements of the safety data sheet in 16 points concerning chemicals/hazardous substances:

1. General data (name, formula)
2. Risk identification
3. Composition
4. Classification according to hazard (R phrases and S phrases) - for the CLP system, H phrases and P phrases
5. First aid
6. Flammability
7. Precautions in the event of an accident
8. Conditions for work that does not endanger health
9. Physical and chemical properties
10. Stability and reactivity
11. Toxicological data
12. Ecotoxicity
13. Waste management and disposal
14. Shipping regulations
15. Regulatory requirements
16. Other

REACH

- Unlike before, REACH also prescribes safety data sheets for hazardous, persistent, bioaccumulative and toxic (PBT) or very persistent, very bioaccumulative (vPvB) substances.
- A safety data sheet must be provided to the customer even if the mixture contains more than 0.1% of the previously mentioned properties.

REACH Regulation

Example of a safety data sheet in Hungary:

Fertőtlenítő folyékony szappan 1/6
Verziószám: 1.0-HU
Készült: 2015. május 17.
Felülírja a 2012. október 14-én kiadott 1.0-HU változatot.

ESTREA

BIZTONSÁGI ADATLAP

készült a 1907/2006/EK, a 453/2010/EU és 1272/2008/EK rendelet szerint

1. szakasz: Az anyag/készítmény és a vállalat/vállalkozás azonosítása

1.1. Termékazonosító: Fertőtlenítő folyékony szappan

1.2. Azonosított felhasználás: fertőtlenítő hatású folyékony kéztisztítószer, biocid termék, I. főcsoport 1. termékfípus – lakossági és foglalkozásszerű felhasználásra

Ellenjavallt felhasználás: az azonosított felhasználástól eltérő

A termék hatóanyaga: poli(hexametilén-biguanid)-hidroklorid

1.3. A biztonsági adatlap szállítójának adatai: Estrea Termelő és Forgalmazó Kft.
Cím: 1106 Budapest, Fehér út 10.
Telefon: 06 30 241 6393
A biztonsági adatlapért felelős személy elérhetősége: estrea@estrea.hu

1.4. Sürgősségi telefon: Egészségügyi Toxikológiai Tájékoztató Szolgálat: napközben (36) 1 476 6464
éjjel-nappal hívható szám: (36) 80 20 11 99

2. A veszélyek meghatározása

2.1. Az keverék osztályozása: a vonatkozó uniós szabályozások (67/548/EGK (DSD[1]) és 1999/45/EK (DPD[2]) irányelvek szerint nem veszélyes, a 1272/2008/EK (CLP[3]) rendelet szerint **a termék veszélyes keverék.**

2.1.1. Osztályozás a DPD szerint: nincs
2.2.2. Osztályozás a CLP szerint: Eye Irrit 2, H319

A rövidítések magyarázatai a 16. szakaszban találhatók, illetve lásd még a következő 2.2. szakaszt.

2.2. Címkézési elemek:

A keverék veszélyeire/kockázataira figyelmeztető H-mondatok:
H319 Súlyos szemirritációt okoz.
EUH208: poli(hexametilén-biguanid)hidrokloridot tartalmaz. Allergiás reakciót válthat ki.

FIGYELEM

Óvintézkedésre vonatkozó P-mondatok:
P102 Gyermekektől elzárva tartandó.
P103 Használat előtt olvassa el a címkén közölt információkat.
P305 + P351 + P338 SZEMBE KERÜLÉS esetén: Több percig tartó óvatos öblítés vízzel. Adott esetben a kontaktlencsék eltávolítása, ha könnyen megoldható. Az öblítés folytatása.
P501 A tartalom/edény elhelyezése hulladékként: a helyi előírások szerint.

Összetevők a 648/2004/EK rendelet szerint: 5%-nál kevesebb amfoter tenzidet tartalmaz
Biocid hatóanyag: 0,4% poli(hexametilén-biguanid)hidroklorid

2.3. Egyéb veszélyek: Rendeltetésszerű használat és kezelés esetén nem várhatók.

A PBT, vPvB értékelés: nem alkalmazható

3. szakasz: Összetétel/vagy az összetevőkre vonatkozó adatok

Kémiai jelleg: többkomponensű keverék, vizes oldat

Veszélyes komponensek	Konc.	DSD: Veszélyjel, R-mondatok CLP: veszélyességi osztály, kategória, H-mondatok
Alkil(C_{12-14})-dimetil-amin-N-oxidok* CAS: 308062-28-4, EU: 931-292-6 REACH Reg: 01211949006147	1 – 5%	Xn, R 22; Xi, R 38-41; N, R50 Acute Tox. 4, H302; Skin Irrit. 2, H315; Eye Dam. 1, H318; Aquatic Acute 1, H400; Aquatic Chronic 2, H411
Alkil(C_{8-10})amido-propil-betain* CAS-szám: —, EU-szám: 931-296-8 REACH Reg: 01-2119488533-30	1 – 5%	Xi, R 41 Eye Dam. 1, H318; Aquatic Chronic 3, H412

[1] Dangerous Substance Directive: 67/548/EGK irányelv és módosításai
[2] Dangerous Product Directive, 1999/45/EK irányelv és módosításai
[3] Classification, Labelling and Packaging, 1272/2008/EK rendelet és módosításai

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Basic material determination methods

- Sensory examination: looking, touching, smelling
- Combustion test
- Wet and dry tear test (e.g. cotton and viscose are quite similar, but viscose tears very easily when wet)
- Solvent determination, chemical analysis
- Dyeing with Neocarmine dye mixture W, B, Ms
- Staining with dyes known to us
- Comparative stainings using multifibre ribbon
- Microscopic examination

Photo by Yakuzakorat from the lab working. Wikipedia, CC BY 4.0

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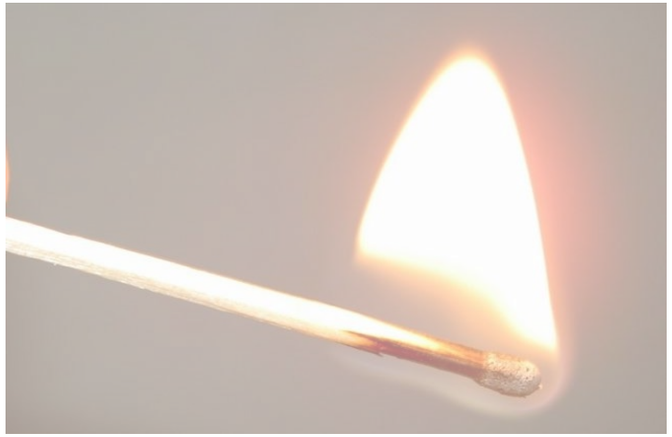
Fibre indicator test by burning



material	burning	flame	smoke	ash	smell
cotton	fast, clear, keeps glowing	orange	bluish gray	grey, light crumbly	burned paper
flax	fast, clear, keeps glowing	orange mauve	bluish gray	light gray, light crumbly	burned paper
hemp	fast, clear, keeps glowing	orange mauve	bluish	framed structure	burned paper
wool	ignites quickly and burns slowly, it sizzles and crackles	yellow orange	lump-like	black, hard nodules	burnt hair smell, horn smell
silk	ignites quickly and burns evenly	yellow orange	bluish gray	black hard crumbly lump	burnt hair smell, horn smell
viscose	ignites quickly, does not melt	orange sparks	dusty blue	gray black frame	burned paper
polyamide	hard to ignite, melts	bluish	bluish gray	dark melt	smell of celery
polyester	hard to ignite, shrinks and melts	yellow	black	pearly melt	odorless

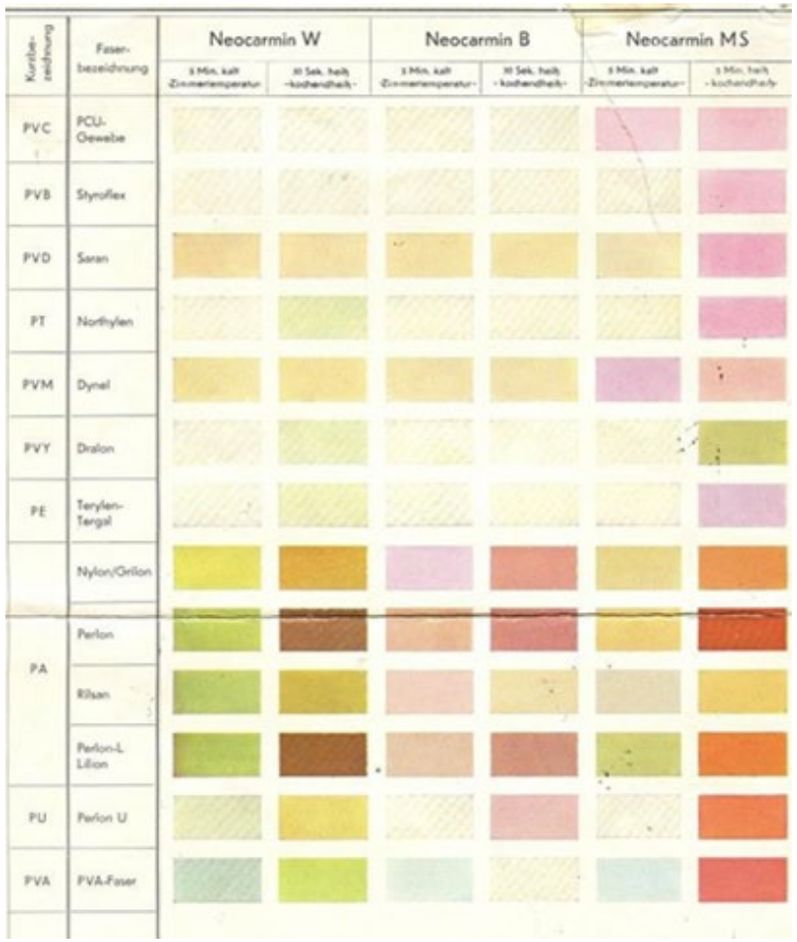
Fibre indicator test with neocarmine solution

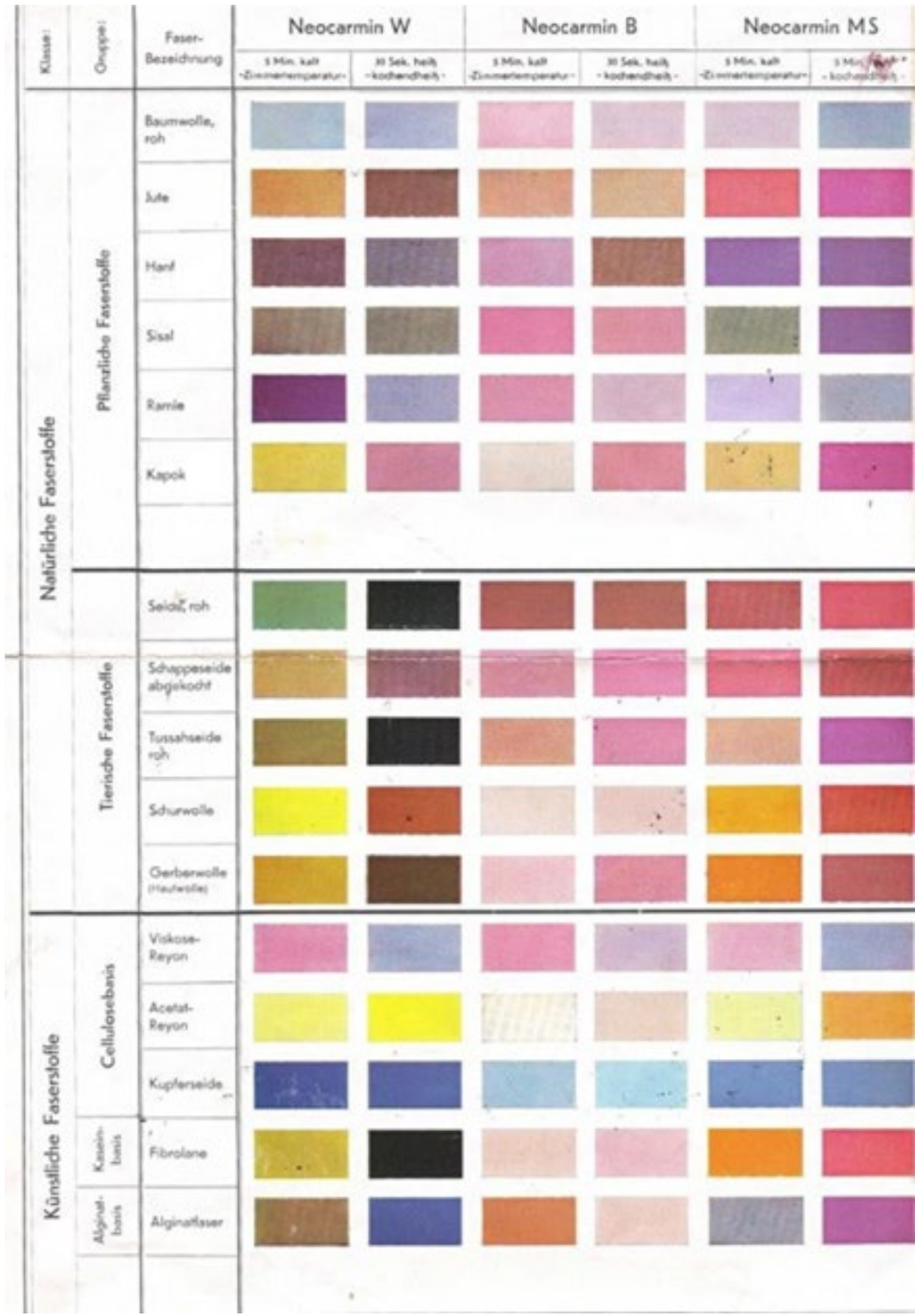
- The reagent is made in a composition in which individuals of different colors have been selected from the groups of dyes applied to the given fibre materials (e.g. blue direct dye, which colors cotton; green acid dye with yellow-blue content for protein fibres, red dispersion dye for synthetic fibres, etc. .),

  E.g. when placed in a dark brown solution, the fibres absorb only the dyes suitable for their "number", thus cotton becomes blue, wool yellow, silk dark green, polyamide green, polyester reddish, etc.

- By definition, only colorless fibres can be used for the test, the characteristic color effect is mainly formed by rinsing after 5 minutes of dyeing in a hot solution.

…fibre indicator test with neocarmine solution





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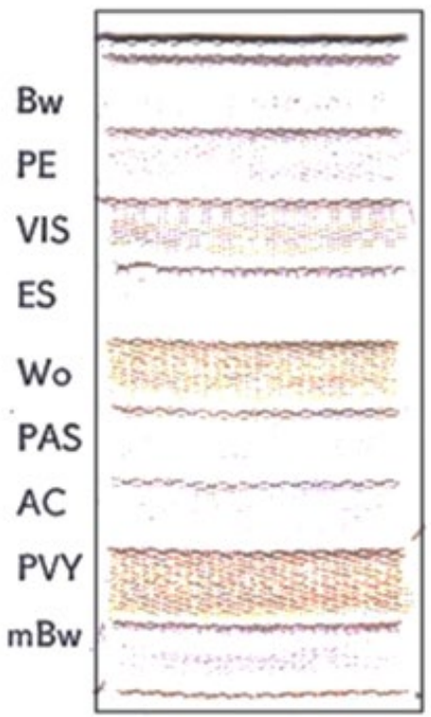
Fibre indicator test with multifibre ribbon

- The multifibre ribbon is a textile tape woven from several fibre materials, which can be used to identify either the raw material of the textile or the dye used.
- Along with the test material, also a piece of tape is painted. After painting, checking where the color matches on the tape and the textile, then reading the type of material from the table.



Mehrfaserband vor dem Färben
Multifibre Ribbon prior to dyeing
Ruban en matières différentes avant la teinture

/	= Baumwolle, gebleicht	Bleached Cotton	Coton blanchi
	= Polyester (Grisuten)	Polyester (Grisuten)	Polyester (Grisutene)
S	= Viskoseseide	Viscose Rayon	Rayonne viscose
	= Naturseide	Silk	Soie
o	= Wolle	Wool	Laine
AS	= Polyamidseide (Dederon)	Polyamide Rayon (Dederon)	Rayonne polyamide (Dédérone)
C	= Azetatseide, glänzend	Acetate Rayon, lustrous	Rayonne acétate, brillante
CY	= Polyacrylnitril (Wolpryla P 61)	Polyacrylnitrile (Wolpryla P 61)	Polyacrylnitrile (Wolpryla P 61)
mBw	= Baumwolle, merzerisiert	Mercerized Cotton	Coton mercérisé

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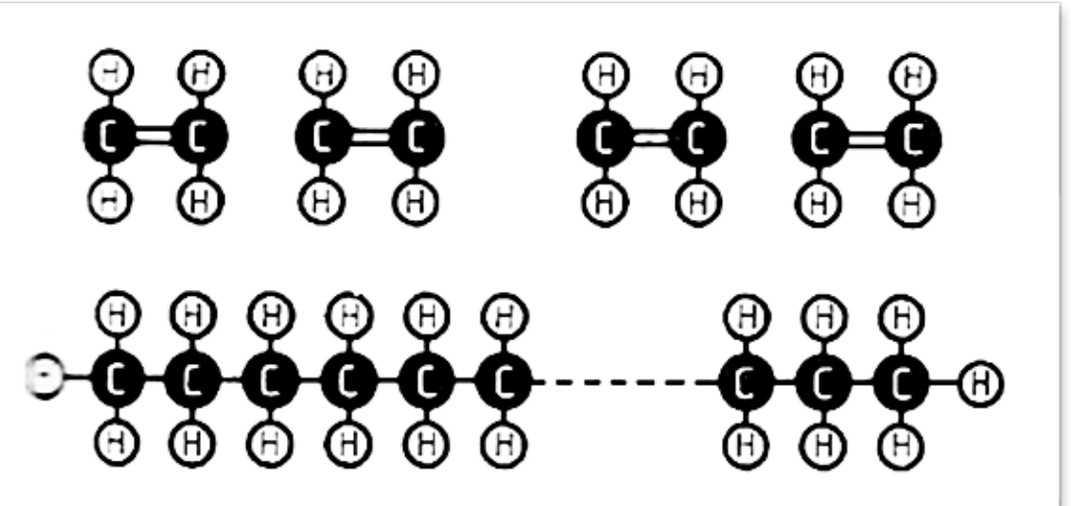
Staining with dyes known to us

- Different types of materials can be colored with different types of dyes. So, by doing a dyeing test with a dye that we know, the success or failure of the dyeing can bring us closer to determining the raw material.
- Molecule types: Small molecules (monomers) and giant or macromolecules (polymers).

In 1925, a German chemist, Standinger, discovered that the common property of all textile fibres is, that they are made up of macromolecules next to each other and connected to each other. Ever since its discovery, it has been consciously tried to create molecular chains synthetically.



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Forming and finishing the fibres

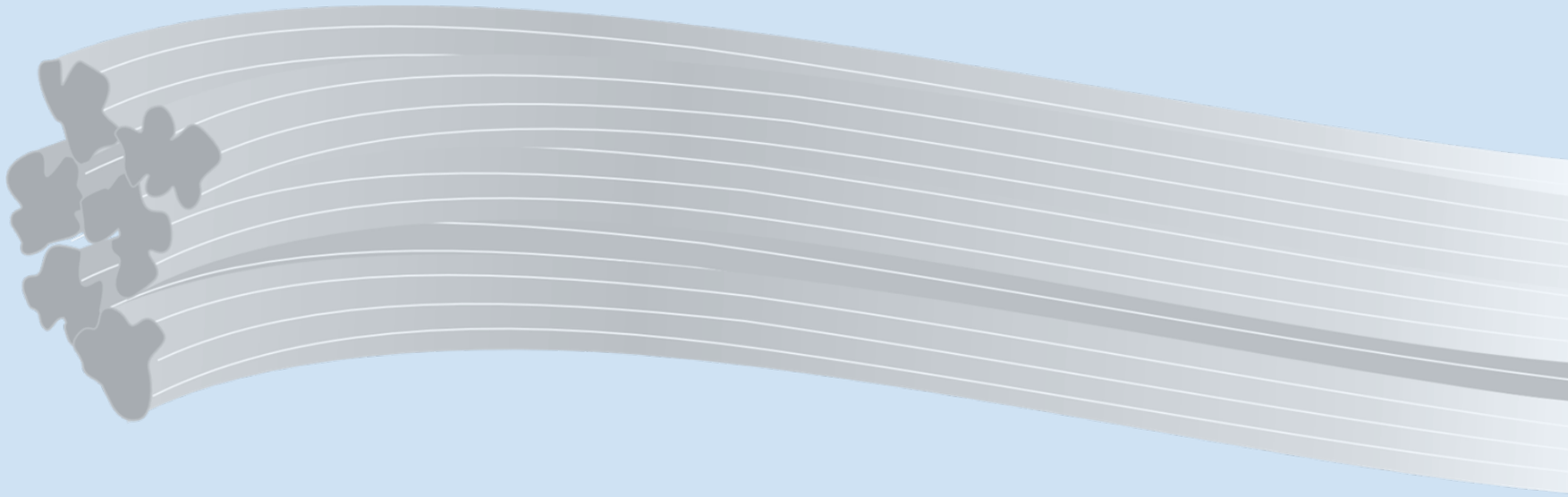

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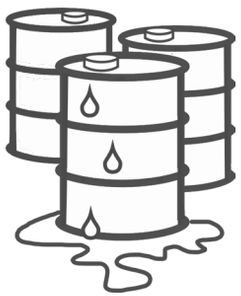
Image by SusTexEdu

… forming and finishing the fibres

Fibre-forming liquid for synthetic chemical fibres:



The main raw material is crude oil.

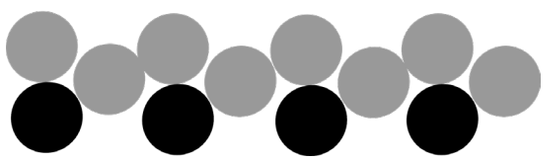
Synthetic fibres are produced in two stages:

1. synthesis of reactive substances made up of small molecules called monomers.
2. joining of thousands of small molecules into macromolecules also called polymers.

Reaction types:

- polymerization
- poly addition
- poly condensation

monomer



polymer

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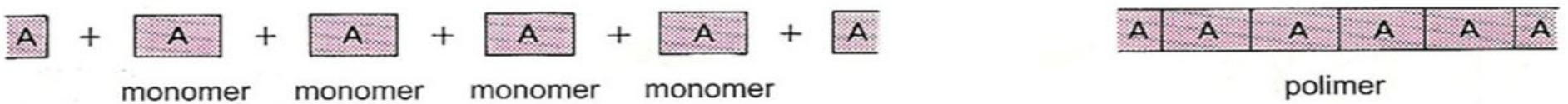
Forming and finishing the fibres

1. By **polymerization**, monomers are chemically combined to create larger molecules or a macromolecule / polymer.
2. **By polycondensation** reaction between two monomers leads to the elimination
   of a molecule of water. Emerging polymers: polyamides, polyesters, polyethers, silicones.
3. **By polyaddition** reaction of successive additions of monomers induces the creation of a polymer chain. Emerging polymers: polyolefins, rubbers, vinyl polymers, styrenic polymers, acrylic polymers.

… forming and finishing fibres

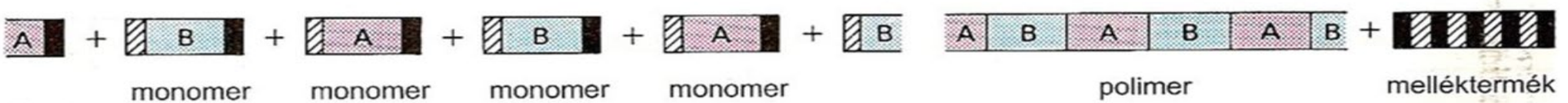
Polimerizáció

A polimerizációban azonos, reakióképes monomerek kapcsolódnak össze hosszú láncú polimerekké. Ezen eljárással állítják elő a poliamid (nylon 6), a poliakril, a poli-vinil-klorid és a polipropilén szálképző folyadékát.



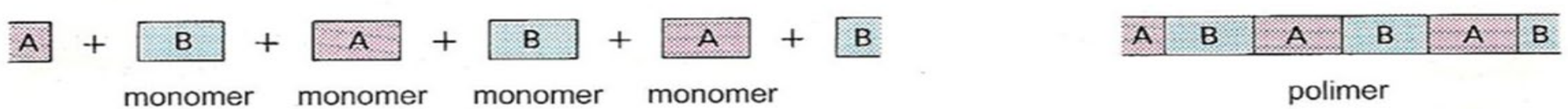
Polikondenzáció

A polikondenzációban különböző monomerek kapcsolódnak össze melléktermék (többnyire víz) kilépése mellett polimerekké. Ezt az elvet alkalmazzák a poliészter és poliamid (nylon6.6) szálképző folyadékának előállításakor.



Poliaddíció

A poliaddícióban két különböző fajta monomer kapcsolódik össze polimerré. A kiindulási anyagból poliaddícióval állítanak elő pl.: gumirugalmas szálakat.



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… forming and finishing fibres

Fibre-forming liquid for cellulose-based chemical fibres:

Natural polymers are used in the production of cellulose-based chemical fibres.

<u>Starting material:</u>

- cellulose

<u>Chemical processes:</u>

- viscous process
- copper oxide-ammonia process
- acetate process
- solvent process

Wood chips, photo by SusTexEdu

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… forming and finishing fibres

Stretching the fibres

- The fibre-forming liquid solidifies into a fibre where the molecular chains are disordered.
- As a result of stretching the fibres become more organized and firmer.

The cross section of a fibre can be round or other shaped as required. The shine and feel of the fibres depends on the cross-section.

Infinitely long threads are called filaments.

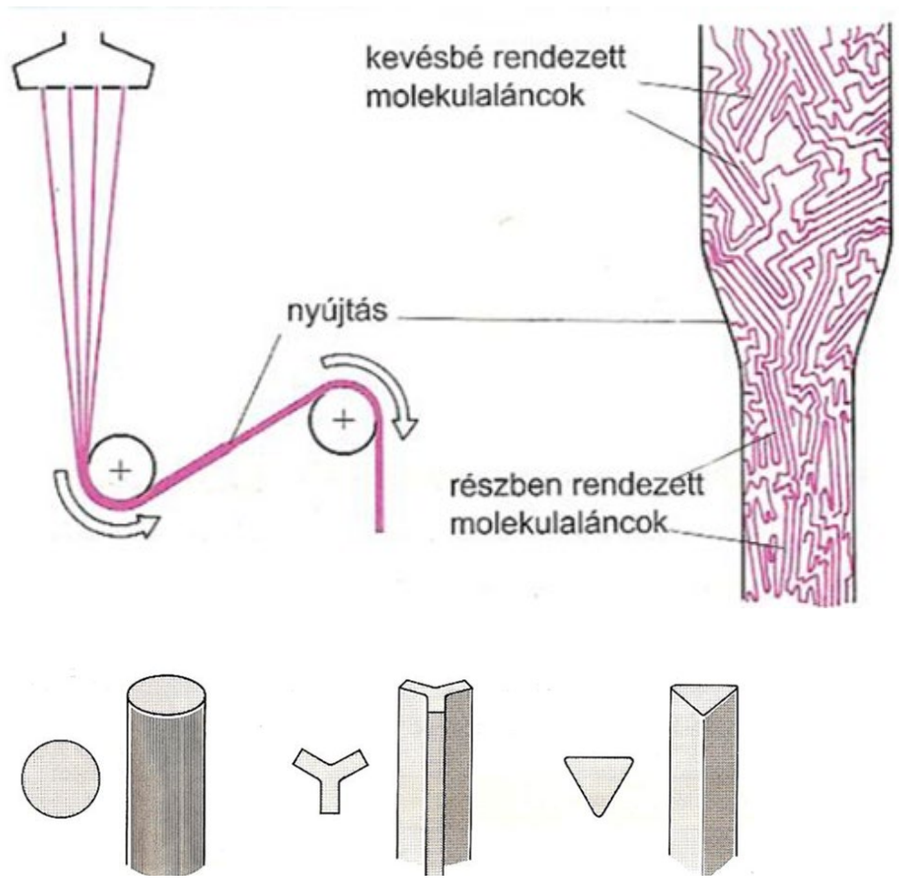

Image: different cross sections of fibres

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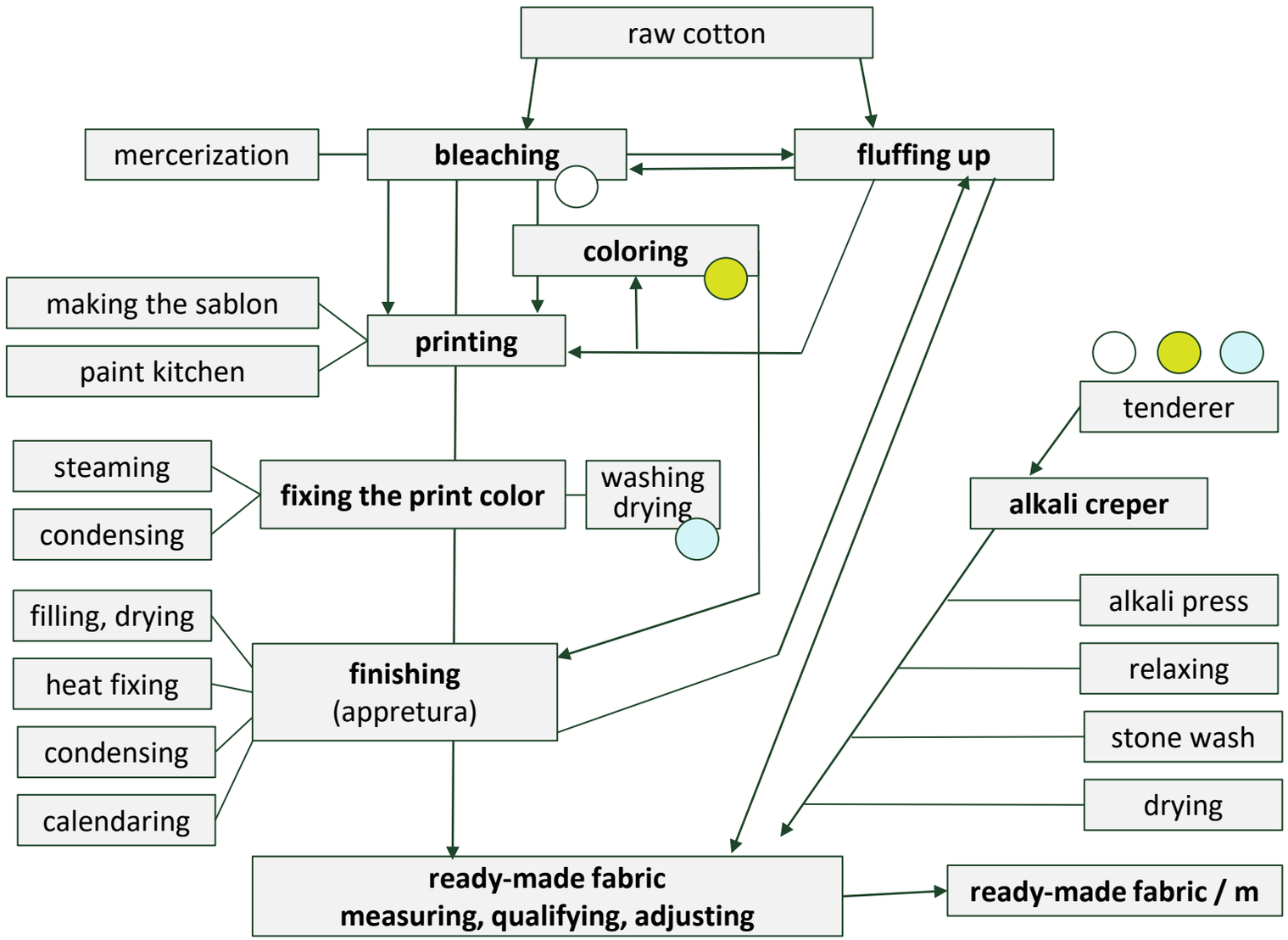
… forming and finishing fibres

Example of finishing processes of cotton



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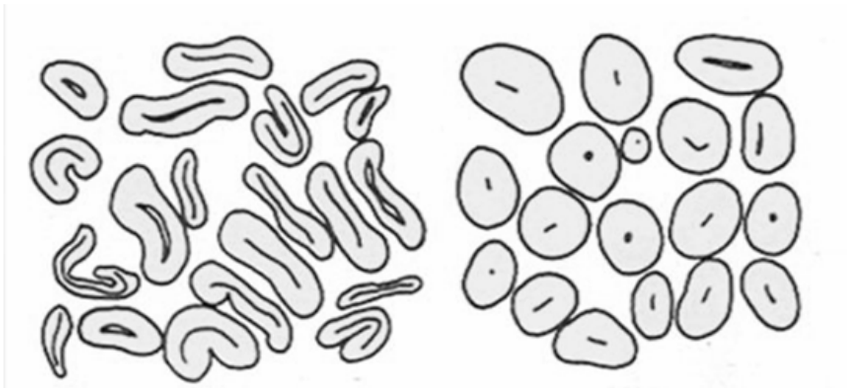
… forming and finishing the fibres

Mercerization

Mercerization: alkali effect performed during stretching. In 1850, John Mercer first observed the beneficial effect of concentrated, cold sodium hydroxide solutions on cotton. In 1890, Lowe discovered that the treatment during tension also provided a "silky light effect"..

Changes in physical properties: The cross-section of the cotton thread changes (the secondary wall swells, its volume increases, an almost circular cross-section is formed / the thread shrinks in the longitudinal direction/)



Raw cotton and mercerized cotton

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… forming and finishing the fibres

Contaminants of raw cotton fabrics

natural pollutants

- cotton accompanying materials
- mechanically bound dirt

contaminants during processing

- fabric colors
- iridescent auxiliary substances
- impurities (dust, etc.)

removal

Cotton thread % composition

94,1% cellulose
1,3% protein
0,9% pectin
0,6% wax
0,9% color substances
1,2% ash
1,0% other

- alkaline cooking
- alkaline cooking
- oxidative bleaching

Photo fr. Wikipedia by Suyash.dwivedi CC BY-SA 4.0

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… forming and finishing the fibres

Bleaching cotton fabric

- Scorching: achieving a clean fabric surface by burning off the protruding fibre ends.
- Degreasing: removal of dyes and auxiliary materials from the warp yarns (usually chemical decomposition makes the main material of the protective layer applied to the warp yarns before weaving soluble in water), followed by washing.
- Alkaline cooking: saponification of the cotton wax that prevents wetting from among the natural contaminants of cotton, destruction of any seed shells, breakdown of protein accompanying materials (hot caustic soda / NaOH / treatment), hot and then cold rinsing.
- Oxidation treatment: coloring agents causing yellowish-brown discoloration
- Decolorization by oxidative damage, e.g. cold with sodium hypochlorite ("hypó").

NaOCl with hot hydrogen peroxide ("peroxide" / H2O2) is harmful to the environment. It is advisable to replace it with sodium chlorite (NaClO2) in a closed device made of special material.

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… forming and finishing the fibres

- Finishing operations: e.g. after hypochlorite bleaching: dechlorination (eliminating the activity of hypochlorite that is no longer needed, etc.)
- Acidification: neutralization of the tissue, possible calcium and magnesium salts into solution.
- Carrying

Photos of a sample washing cylinder and sack of salt by SusTexEdu

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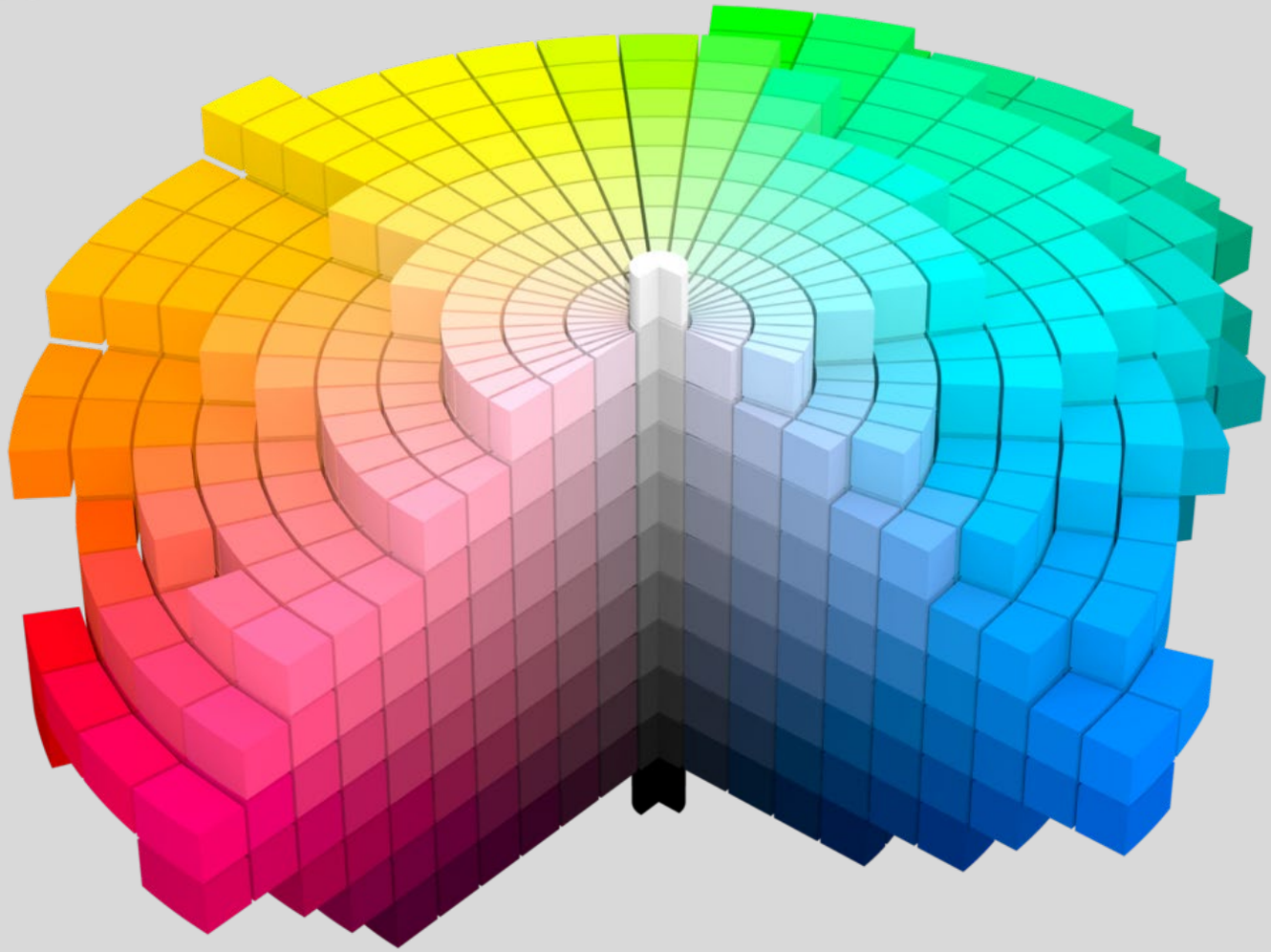
Color models



Munsell 1943 color solid cylindrical coordinates.

Wikipedia. SharkD. CC BY-SA 3.0

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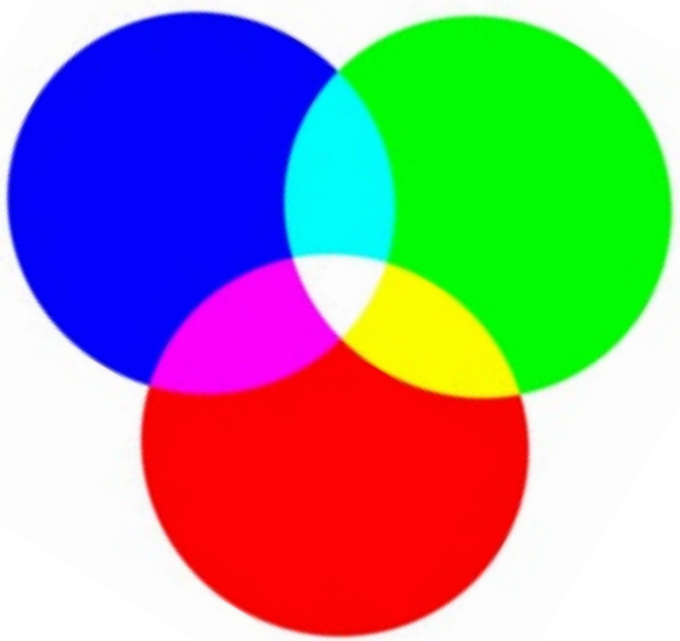
Additive color mixing

- In additive color mixing, light rays of different colors are mixed with each other so that they reach our eyes at the same time.
- If the colored rays are combined using a prism, white color is obtained (RGB).
  TVs and monitors also work on this principle, or color raster images smaller than the resolution of the eye, e.g. four color printing (quadrichromie).



RGB

Photo on top from Wikipedia by Bb3cxv. CC BY-SA 3.0

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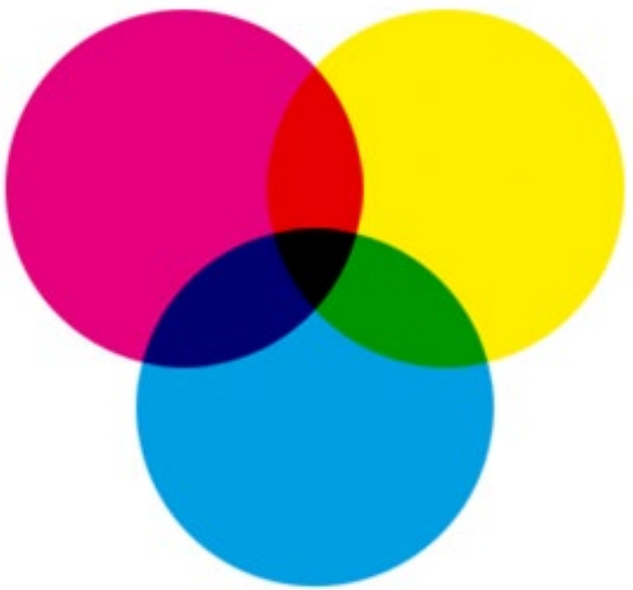
Subtractive color mixing

- The subtractive color mixing comes by mixing different materials that absorb and reflect light rays of different wavelengths.
- The subtractive colors are cyan, yellow, magenta and black, also known as CMYK. Subtractive color mixing means that light will be reduced when more color is added, creating darker colors. The more color added or mixed the less light can be reflected, the darker the color gets, and the less luminosity it possesses.
- The color of the material is determined by the reflected light rays, e.g. mixing dye powders, digital printing.



CMYK

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Pantone matching color system (PMS)

- The name PANTONE has been synonymous with precise color management since 1962.
- PMS is a color system where each color is represented by a unique name and/ or number. Pantone colors are direct, not four-color printed colors.
- The Pantone color scale is used to accurately determine the Pantone colors, which provides the opportunity for the color selected by the customer to be printed (almost in any printing house in the world).
- The PMS system, using the process colors CMYK in printing, is unit dependent (i.e. the resulting color may vary depending on circumstances such as the type of paper and color film thickness used).
- The system is also available in advanced graphics programs such as Adobe Illustrator and Corel Draw.

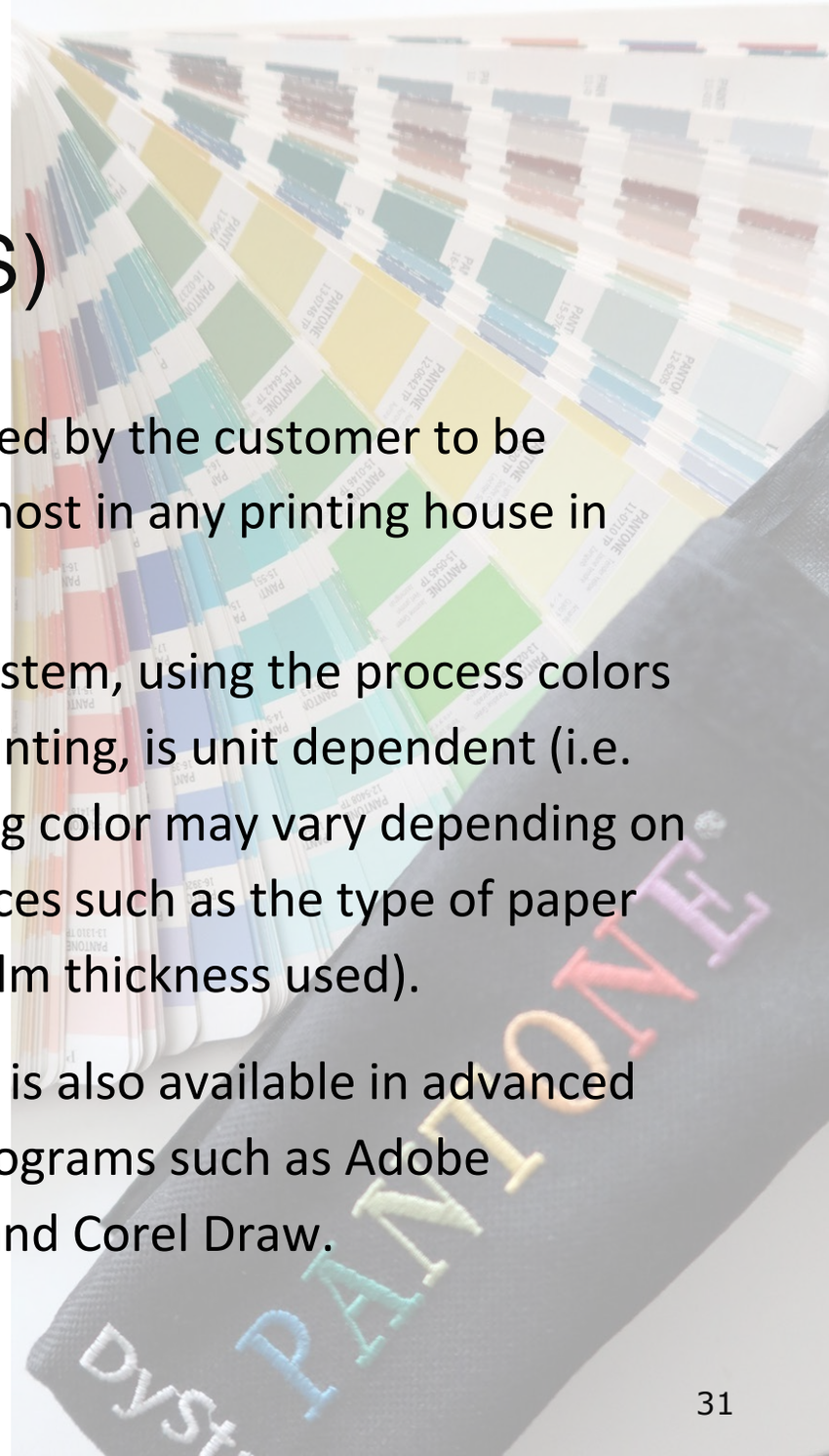

Photo by SusTexEdu

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Coloring (dyeing) **of textiles**

Naturally dyed skeins
on Wikipedia
by Madison60. CC BY-SA 3.0

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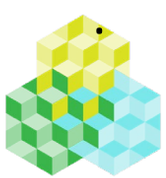
Organic dyes

Organic colors are derived from plants and animals and form soluble dyes which can bond with a substrate such as fabric, paper or leather. In order to be used as a pigment, dyes must be precipitated onto an inert substrate such as alum to form what is called a lake.

- **Vegetable dyes** can come from all parts of the plant: bark (oak), berries (buckthorn), hulls (walnut), leaves (indigo), roots (madder), seeds (annatto), stems (weld), or wood (logwood)
- **Animal dyes** come from ground insects such as the reds of cochineal or kermes which are harvested off of cacti or oak respectively; from insect secretions such as those that produce red lac; or from the glands of sea creatures such as the sepia ink sacs of cuttlefish or the most famously rare Tyrian purple which requires 12 000 mollusk to produce 1 gram of dye.



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UChicago Library: Origin of colors

Crimson, scarlet, carmine

- Crimson is the most expensive textile dye in history and was a symbol of power in Europe and the Middle East in ancient times. It was first used by the Phoenicians (Tyrosian crimson): from the secretion of the gill cavity of the crimson snail they won the dye.
- In ancient Rome, the emperor wore purple clothes, the senators only wore purple ribbons, later the German emperors followed the ancient example.

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… crimson, scarlet, carmine

- The crimson (and scarlet) dress has been preserved in the tradition of the Roman Catholic Church to this day and preserves the ancient color hierarchy.
- The color of scarlet cloth, popular in antiquity and the Middle Ages, was produced from cochineal insects.
- The name and the coloring technology came from Persia. The Persian word "saqirlat" did not originally mean a color, but expensive clothing, and only later became associated with bright red.

In the photo: Cardinal Theodore Innitzer 1933. Wikipedia, source: Wien, Selbstverlag Willy Jakoby.

Public Domain

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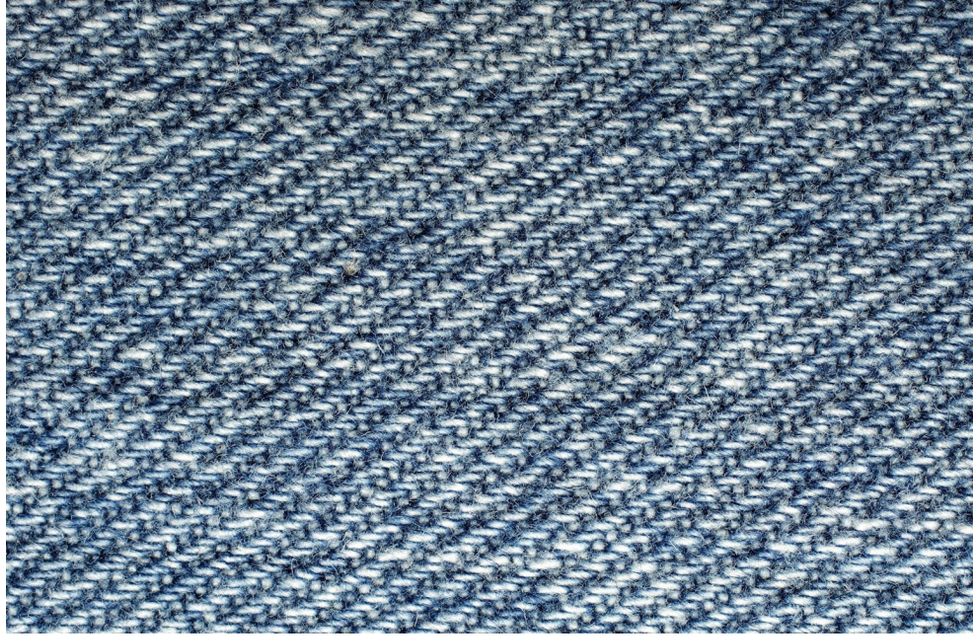
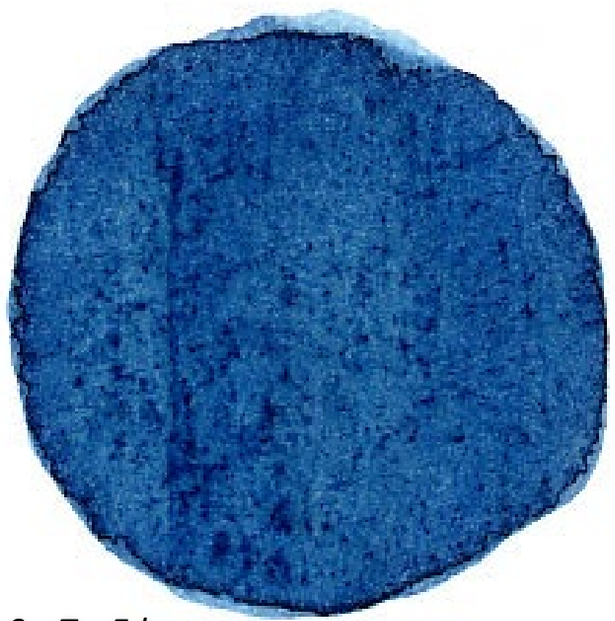
Indigo

- As the name suggests, indigo is a plant shrub from India, from which blue dye was already produced in ancient times. Painter's quince is also an indigo-containing plant, but gives a much weaker blue color.
- More than two hundred years ago, indigo was cultivated in the Caribbean region, hence the origin the caribbean blue. Today, indigo is a textile dye that can also be produced synthetically and it is widespread throughout the world.





Photos:
Denim by SusTexEdu
Extract of Indigo plant applied to paper on Wikipedia by Palladian. Public domain.

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Synthetic organic dye

- William H. Perkin (1838-1907) discovered by accident at the age of 18, during his laboratory work, that it was possible to obtain brightly colored paint from coal tar.
- It revolutionized pigment production, banished old, often toxic or very expensive raw materials and created a huge range of colors.
- Perkin founded a paint factory. The first color that made his name famous was "mauve". In the middle of 19th century it was very fashionable throughout England.

Photo: A plaque commemorating William Henry Perkin in Cable Street, London. Wikipedia / Richard Allen. GNU

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About coloring in general

Coloring and washing of textiles also developed early on.

- The ancient Egyptians already dyed fabrics, and washing and finishing was a separate profession here.
- The Chinese and Indians were also familiar with paints and stains and knew the conditions under which they could be fixed evenly and permanently on materials.

Collections of ancient recipes have survived, from which we know - and from the analysis of the textile remains - that a variety of dyeing plants and animals were used to extract dyes.

Fixation of the paint material was carried out with alum or iron and tin salts.

The painting consisted of wooden or stone tubs and cooking cauldrons, in which the material was moved with wooden sticks, and drying took place on frames. There had to be running water nearby, because it was essential for rinsing.

… about coloring in general

Technical grouping of textile dyeing

- Fabric and yarn are colored uniformly in one color, that is dyeing. Coloring only certain demarcated parts of the fabric, thus creating a colorful fabric, is printing.
- Between these two processes is batik, which is of Chinese origin, but spread in Java and Sumatra and further developed to today's technological level.

Brush painting batik in Sri Lanka.
On Wikipedia by Peter van der Sluijs. GNU.

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Coloring concepts

Dye

From the point of view of textile chemistry, we call dyes those compounds that are colored by themselves and can be fixed on the textile material by a first- or second-order chemical reaction.

Paint

The colored material that is mechanically, e.g. it can be fixed by gluing, it is called paint.

Affinity

Dyes can be attached to the fibre by covalent bonding (reactive dyes), ionic bonding (anionic) and basic (cationic)) and secondary chemical bonding forces.

Affinity is the power of a chemical reaction, which depends on the chemical composition of the substances involved in the reaction and the temperature of the reaction.

Substantiveness

A term generally used only when dyeing cellulose-based fibres.

The adhesion energy of the dye to the fibrous material, i.e. its surface fixation. How quickly the dye is drawn onto the fibre under the conditions of the dyeing.

…coloring concepts

State of equilibrium

The state when the fibrous material is no longer able to absorb more dyes. In this case, even if there is unnecessary dye in the bath, the fibre material will not become darker, because just as much dye accumulates on the fibre as it is removed.

Diffusion

The migration of dye particles in the solution and inside the fibre.

The diffusion capacity of the dye is determined by the molecular size (smaller ones move faster) and affinity (strongly bound ones move slower) or is influenced by the "location" of diffusion (faster in the bath, slower inside the fibre).
The inner surface of the fibre significantly exceeds the size of the external boundary surface of the fibre (e.g. 1 g of cotton fiber per 100 m2, 1 g wool 200 m2 / tennis court area / has an internal surface).

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The properties of colors in general

- Solubility: relative to a given temperature, expressed in "grams/liter"; how much water is needed for the solution, what bath ratio can be used.
- Balancing and migrating ability: important for achieving uniformity of coloring; the initial inequalities (impurities left in the textile material, yarn-strand alternation.
- Temperature differences, poor dye bath current flow, etc., favorable migration; depends on the molecular size, diffusivity, affinity of the dye, electrolyte and heat sensitivity: some people draw up quickly and unevenly even with a small amount of salt added (they are salt-sensitive, so the electrolyte must be dosed in portions); Some for boiling they decompose, their color permanently dulls, their shade changes (temporary heat sensitivity does not cause permanent changes).
- Combinability: in order to achieve a given color, only dyes that have almost the same draw-up curve should be mixed (the tendency of the dye draw-up is the same as a function of time and temperature)
- Color fastness:
  - production: the resistance of the dye to production effects
  - usage: adequate tolerance of the colored textile material in everyday use (color depth and hue; hold-up)

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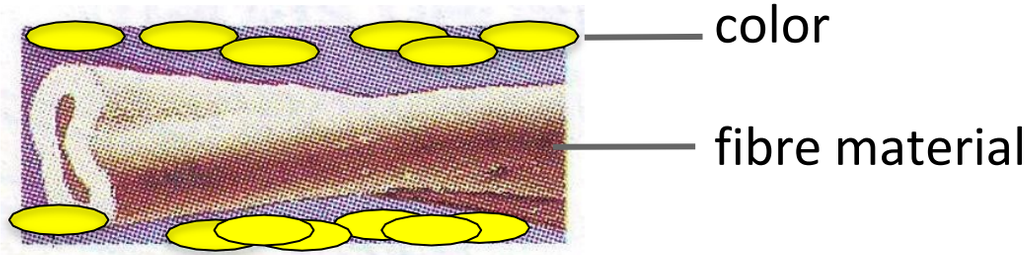
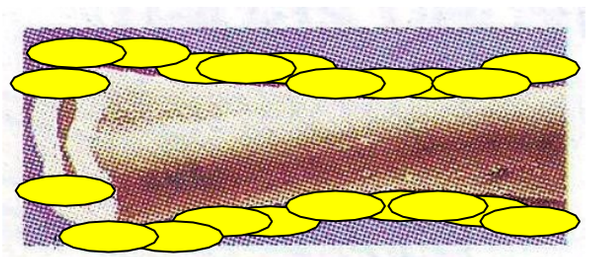
Principle of dyeing process

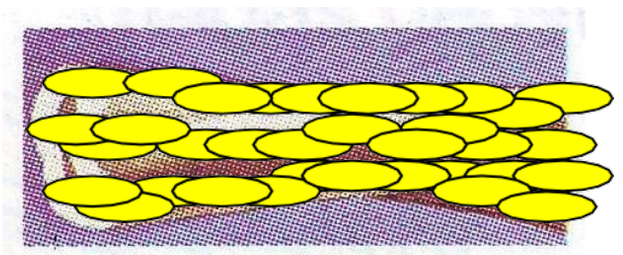
Migration of the dye in the dyeing bath near the fibre.



Temporary binding of the dye at the interface of the fibre.



The migration of the dye into the interior of the fibre and the permanent bonding in suitable parts.



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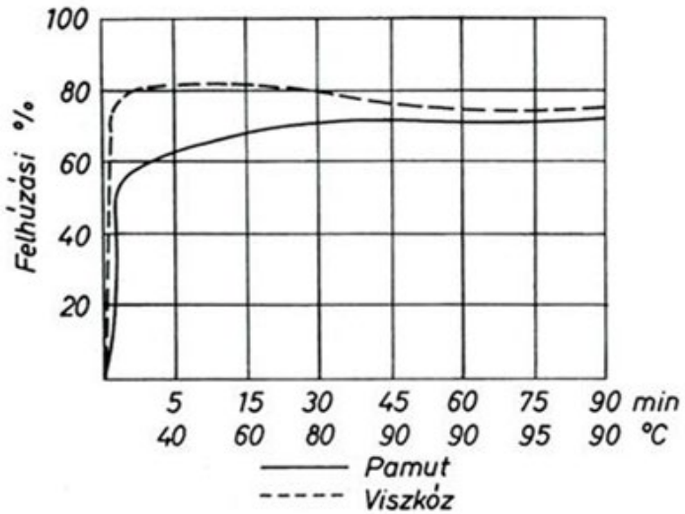
… principle of dyeing process

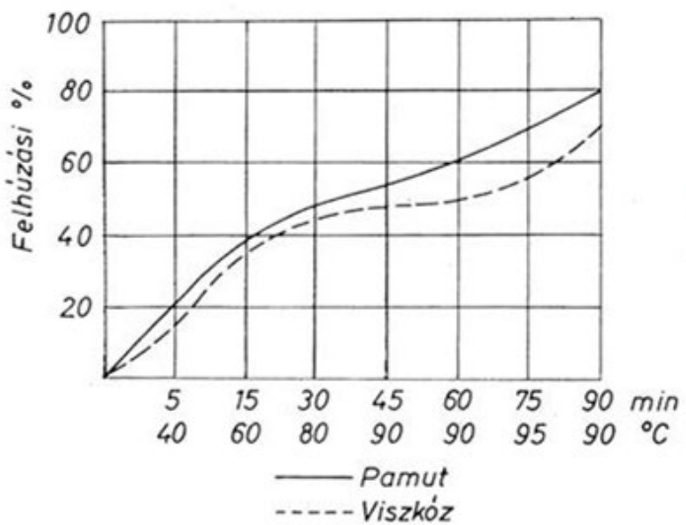
- A certain shade can often be achieved by mixing several dyes.
- Different dyes behave differently under different dyeing conditions. In the case of dye mixtures, it is therefore very important to know how the individual dyes behave in the given case.
- Dyes with a similar draw-up curve should be chosen.

Dye draw-up curves

Fast drying direct dye



Slow drying direct dye



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... principle of dyeing process

According to working principle:

- Dyeing device: the dyeing bath is flowed through the stationary textile material, included equipment in which both the textile material and the dyeing bath are in motion. The textile material is moved in the dyeing machine resting dyeing bath.
- Textile material according to degree of processing: yarn, fabric (woven, knitted, etc.), products (e.g. tights, socks, etc.)

Photo by SusTexEdu

According to operation conditions:

- Atmospheric: open or covered equipment used at atmospheric pressure
- Overpressure: used to raise the boiling point of the dye bath, hermetically sealed equipment: (HT= High-Temperature), in which a with excess pressure, a bath temperature of over 100 °C can be created (e.g. when dyeing polyester, even a 130 °C bath does not turn into steam).

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… principle of dyeing process

- Prewetting the textile material to be colored (surfactant, etc.).
- Applying the dye to the surface of the fibre material, then ensuring migration into the fibre.
- Fixation of the dye inside the fibre depending on the chemical structure and type of the dye, connection with second order binding forces or chemical reaction with its design.

- Complete removal of unbound dye remaining on the surface of the fibre with methods depending on the nature of the dye, optimal wet color fastness properties to reach.

Finishing operations:

- Saponification (dye "recrystallization")
- Post-treatment (when needed) to increase wet color fastness and to improve color fastness against light.

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Dyeing methods

1. **Exhaust method**
2. **Continuous method**

Photo by SusTexEdu

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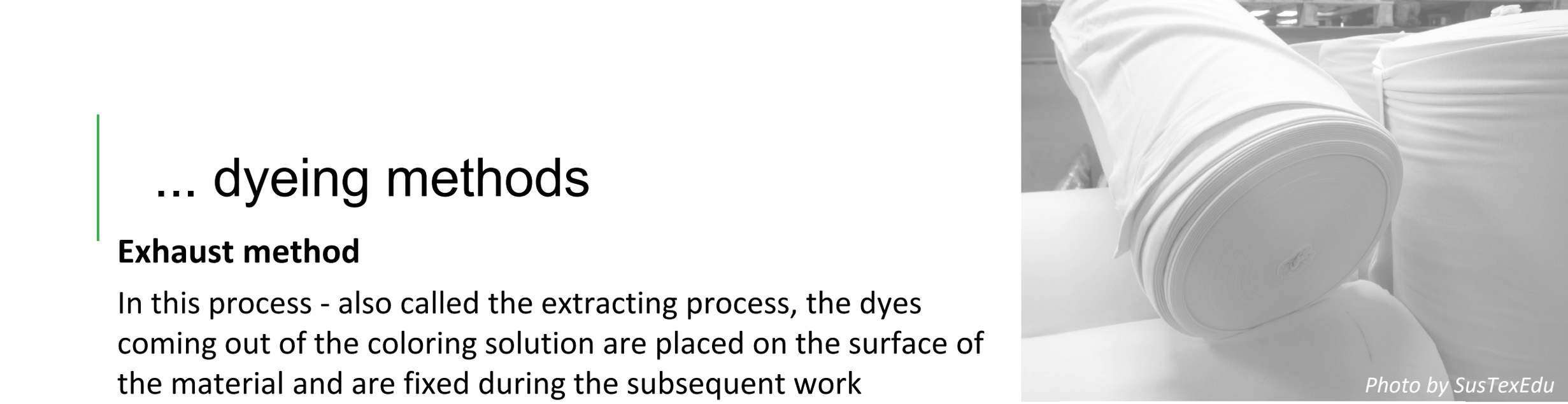
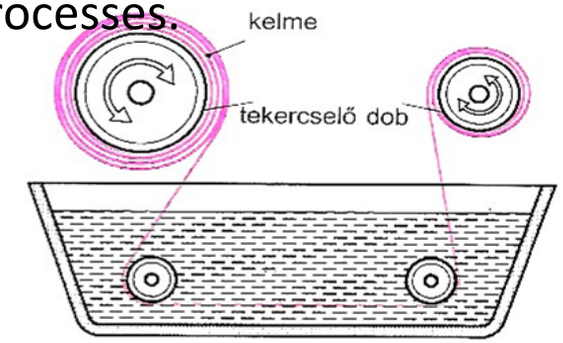
... dyeing methods

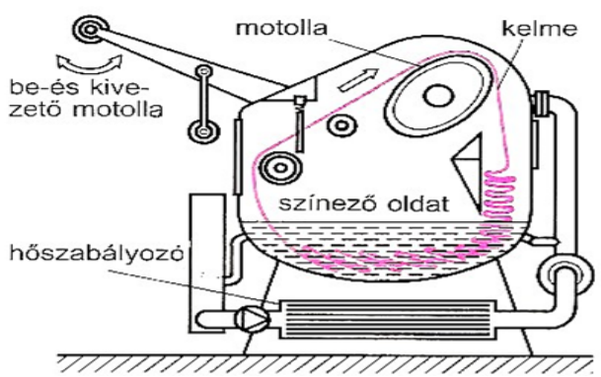
Exhaust method

In this process - also called the extracting process, the dyes coming out of the coloring solution are placed on the surface of the material and are fixed during the subsequent work processes.

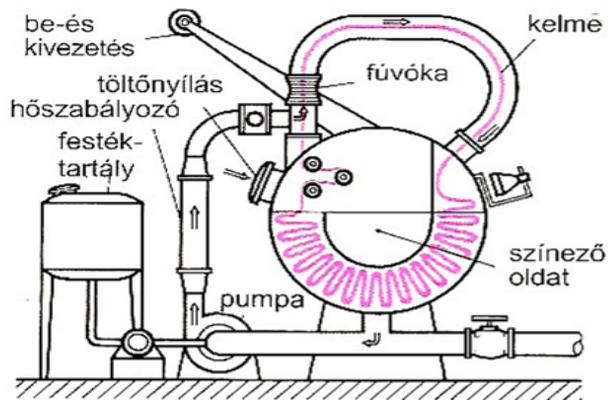




1. Width coloring equipment (jigger)
The product to be dyed is passed through the dyeing bath in a stretched, wrinkle-free state.
Advantage: A uniform color distribution is created over the entire width of the product.
Application: from medium to heavy fabrics.



2. Mottled coloring equipment
The product to be dyed is pulled across the dyeing bath without tension, in a wide or ribbon-like manner.
The advantage: there is no tension, so there is no stretching either.
Application: For knitted and crocheted fabrics, light cotton fabrics.



3. Nozzle coloring equipment
The fabric to be dyed and the dyeing solution pass through a tube with a constriction. The pressure of the coloring solution carries the material to be colored with it.

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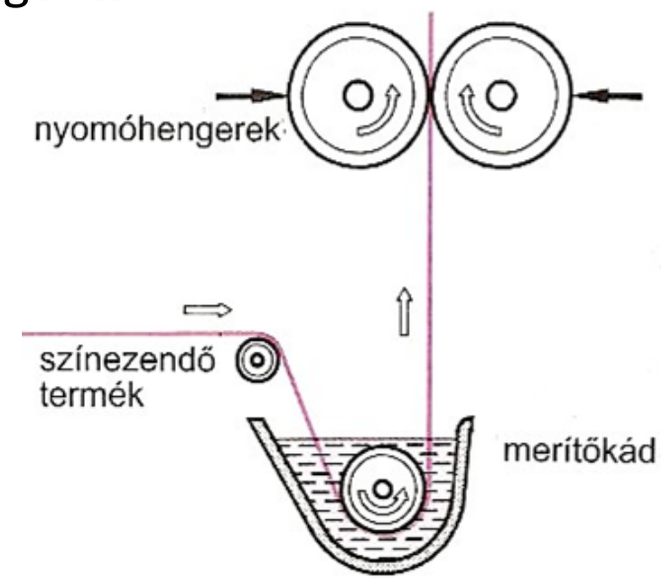
… dyeing methods

Continuous method

With this process, which is also known as the saturation or impregnation process, the coloring solution or dye dispersion is applied to the fabric in the dipping tub and is pressed into the material with the help of rubber pressure rollers.

Thanks to the pressure rollers, the excess treatment solution can be squeezed out evenly across the entire width of the fabric.

After saturation, the dye can be fixed continuously. The saturation machine is a part of every continuous finishing process. The machine, which handles the full width of the piece goods, mainly uses concentrated treatment solutions, e.g. is used for the uniform application of coloring baths and impregnating agents.



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Coloring of yarns

1. **Hank yarn dyeing process**
2. **Package yarn dyeing process**
3. **Warp beam yarn dyeing process**
4. **Space yarn dyeing process**

Photo by SusTexEdu

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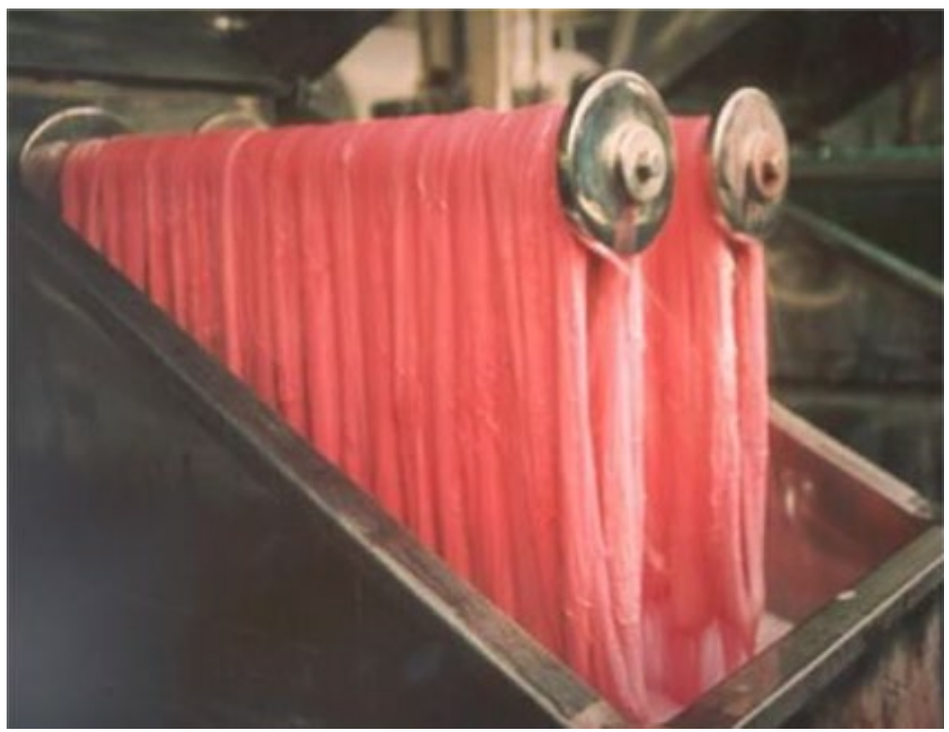
… coloring of yarns

- For mechanical patterning (e.g. tarcan weaving, colored knitting, etc.) yarns of specific colors need to be colored beforehand.
- The yarns can be colored in the shape of hank, cross coil and chain cylinder.

1) Yarn hanks were previously dyed by hanging them on sticks, in open tubs, with strong manual movement (danger of tangling of fine yarns and felting of wool yarns); with the hank dyer, the hanks to be dyed take place on the rotating, perforated arms (the dye bath flows onto the fibre material); in devices with a suspension system, the yarn hanks are on a support bar that can be moved up and down, with sufficient slack (the dyeing bath is moved alternately "up and down" during the dyeing process).

… coloring of yarns

1) Hank yarn dyeing process. Material holder insert for cross tube coloring and sewing system device.



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… coloring of yarns

2) Before dyeing in the cross bobbin, the yarn content is wound onto a perforated package with optimal tension; in the closed device with the pin-on system, the dyeing bath from the inside to the outside, or flows from the outside to the inside through the yarn package (with the help of a flow pump with variable valve position),

3) In the case of yarn-shaped dyeing (colored warp yarn if required), the yarn content wound on a perforated metal cylinder, also in a pin-on dyeing device.

4) Space dyeing is a technique of localized color application that produces a unique multicolored effect.

After coloring, dehydration (centrifugation, air pressure, etc.) and drying follow (e.g. with hot air); it may also be possible to color directly.

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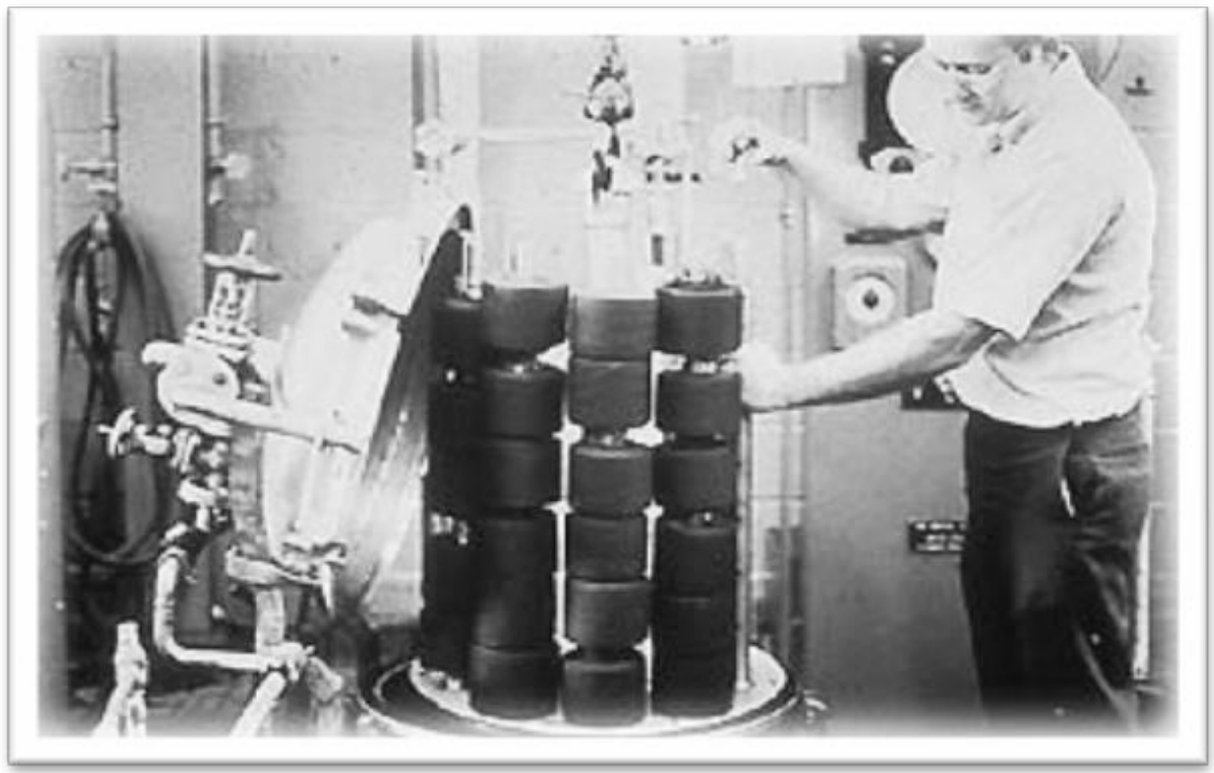
… coloring of yarns

2) Package yarn dyeing process. Yarn cones after coloring.



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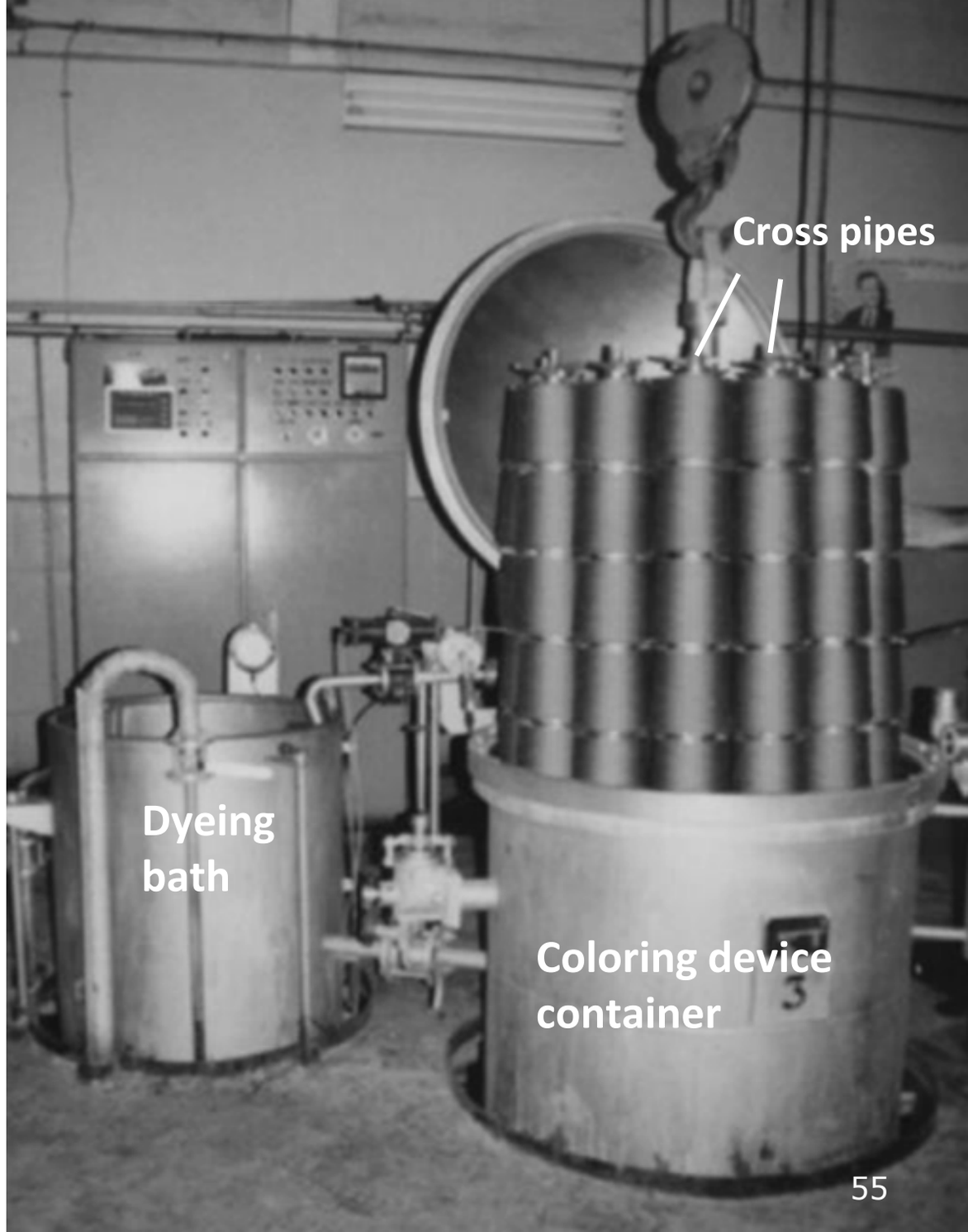
… coloring of yarns

… package dyeing device



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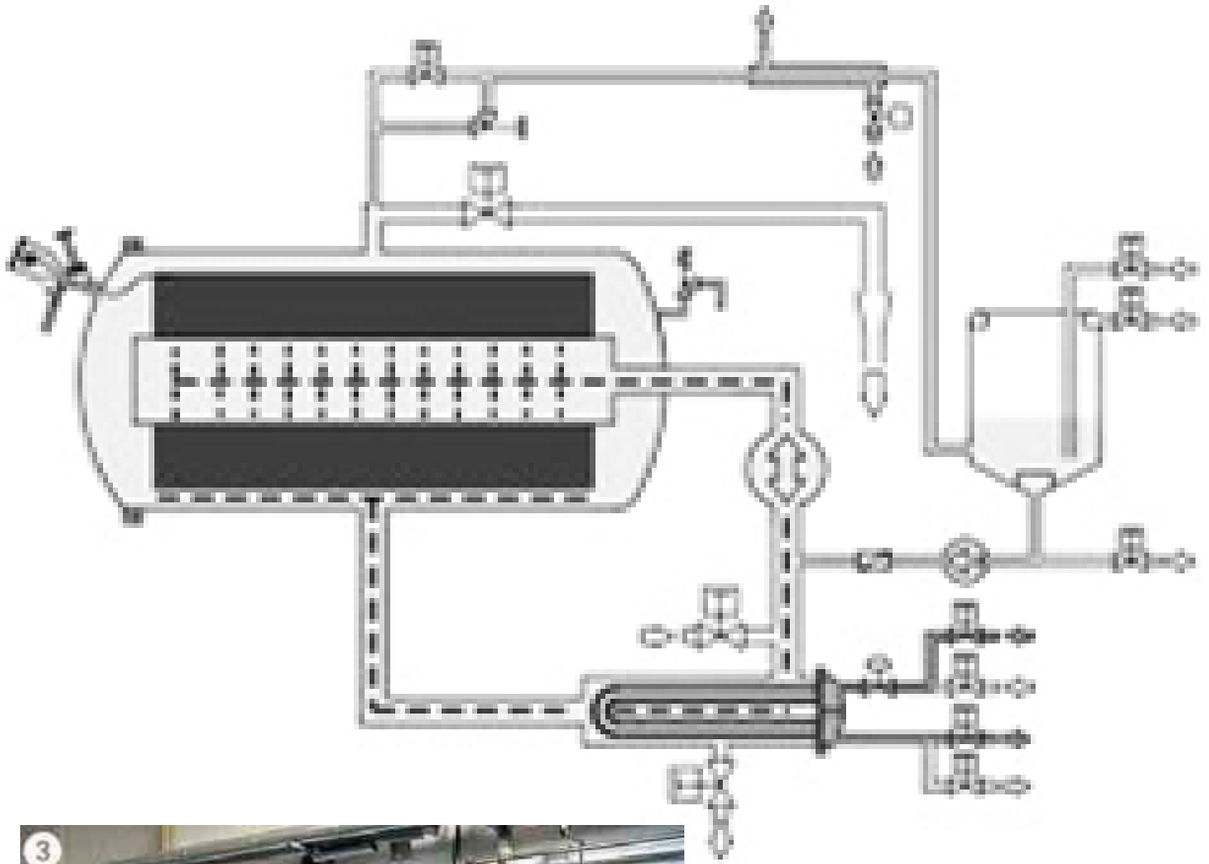
… coloring of yarns

3) Warp beam yarn dyeing process

- The warp yarns are wound on a perforated metal cylinder as a material holder.
- It is important to ensure the correct thread tension during winding (the "formation of channels" leads to uneven coloring and tangling).
- Dyeing is carried out in a special device with a pin-on system (dye bath flow from the inside to the outside and vice versa through the threads).



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Fabric printing

The main printing methods

- relief printing
- rotary printing
- screen printing
- transfer printing
- digital printing

Photo by SusTexEdu

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Fabric printing methods

Relief printing

The places to be printed stand out from the printing form. Book printing, woodcut, linocut.

Seal printing, block printing:

Sample application with a seal (stamp) or block. Pattern printing with a pattern made of wood or metal.

Flexo printing or pad printing:

Sample application with a rubber roller or sheet, suitable for a structured printing, e.g. on carpet.

Gravure printing

The places to be printed are located recessed in the printing mold

Copper engraving, zinc etching, engraving, steel engraving cylinder, or rouleau pressure. The printing paste is applied to the textile from a pressure roller.

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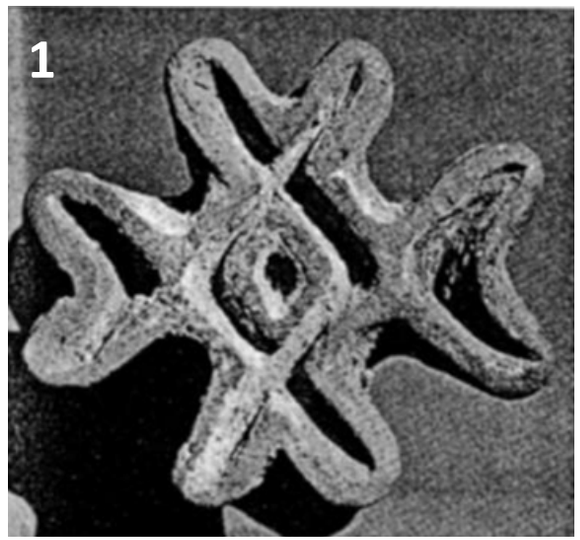
Relief printing

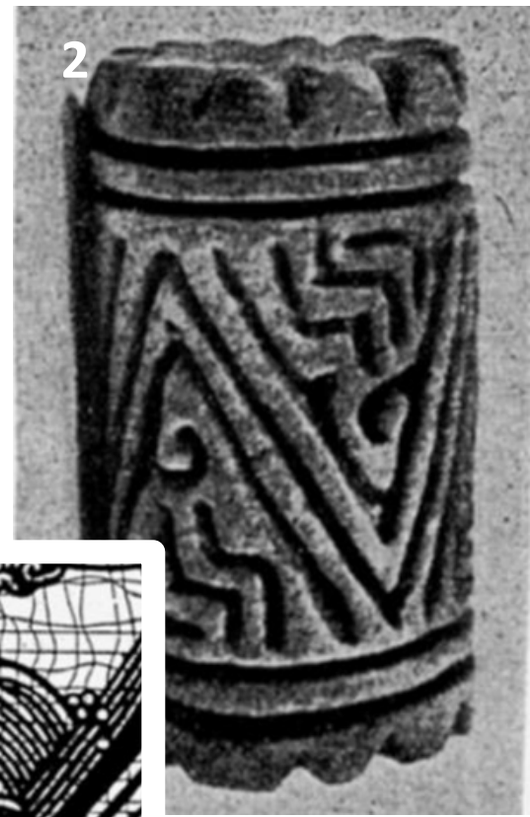
Pattern tools

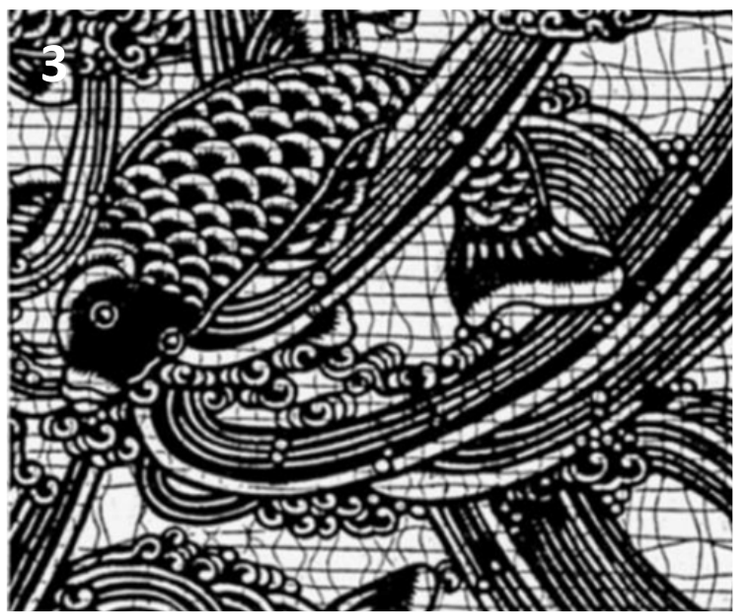
Primarily made of wood or ceramic. (1)

Ancestor of continuous patterning tools (high pressure). (2)

Cut out of paper, thick as silk pattern tool; stenciling (ski pressing). (3)







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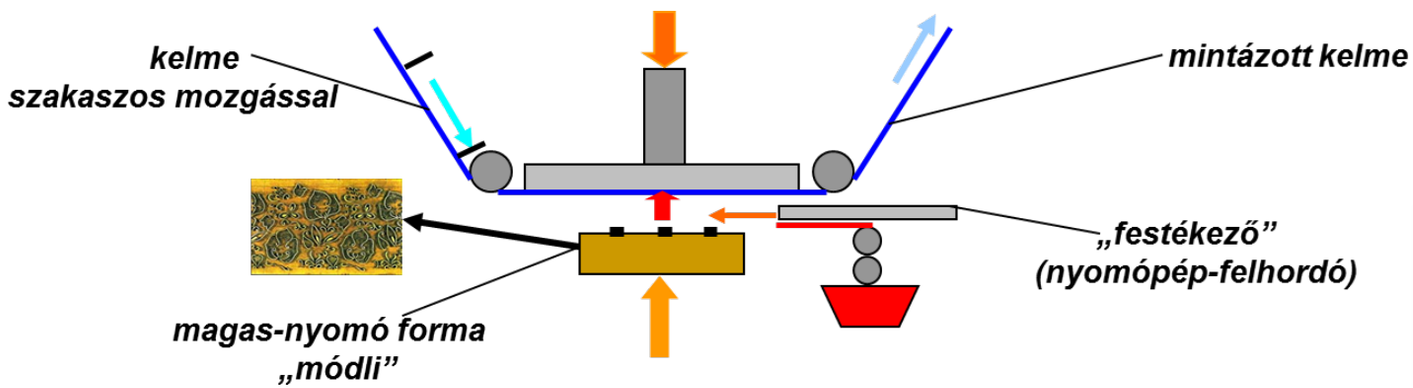
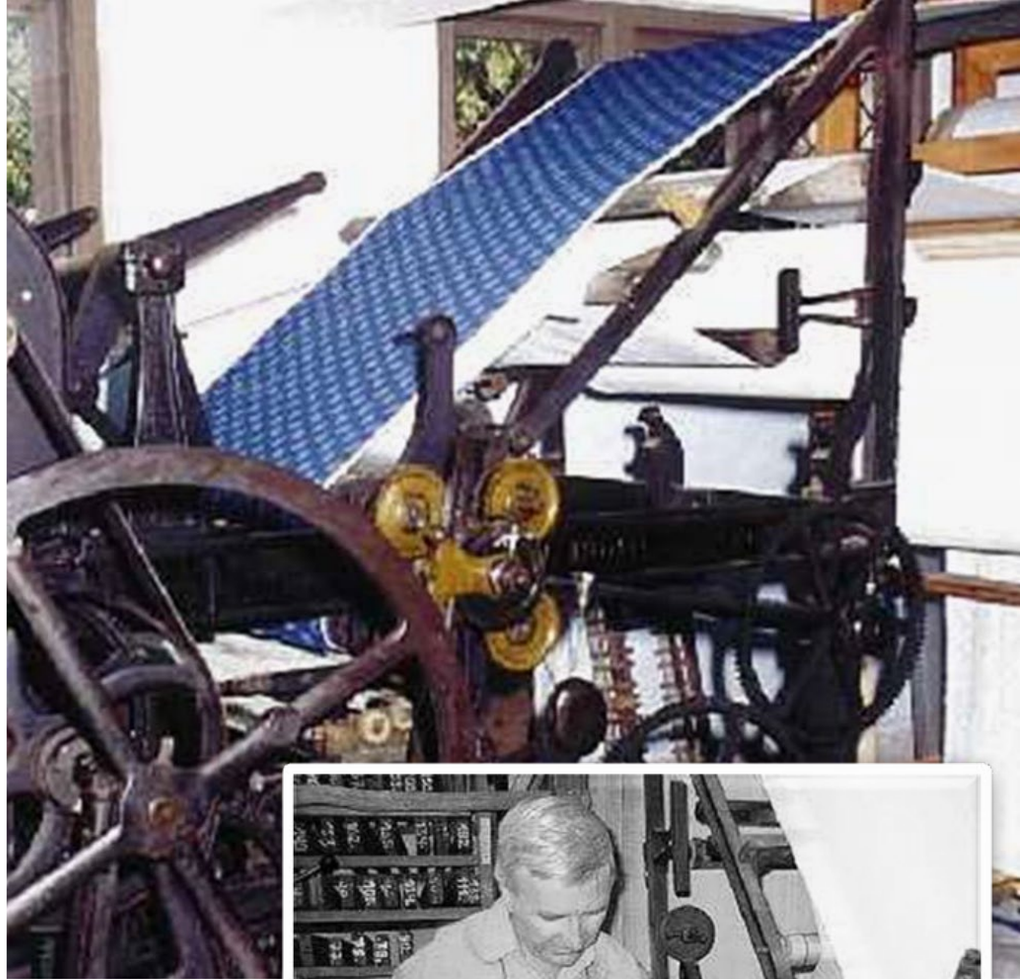
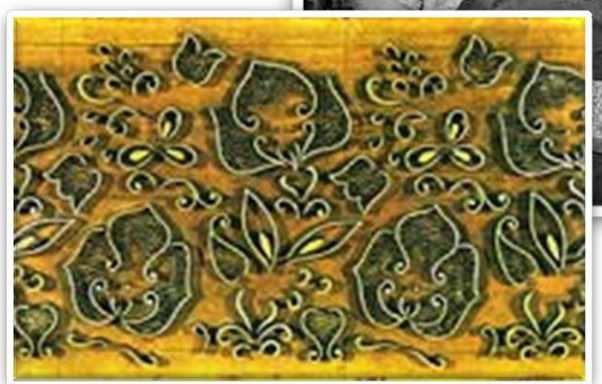
… relief printing

A perrotin machine in operation and the pressing tool (photos on right).

Below the working principle of the Perrotin machine: The fabric moves through the machine in stages so that the pattern can be pressed onto the material with the flat form.







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… fabric printing methods

The parts to be printed and not to be printed are at almost the same height in the printing mold on the same plane.

Screen printing

Screen printing is a process where ink is forced through a mesh screen onto a surface. Making certain areas of the screen impervious to printing ink creates a stencil, which blocks the printing ink from passing through the screen.

Digital printing

Ink-Jet. Four dye-spraying nozzles (pink, yellow, blue, black) spray the desired color on the textile material or non-textile substrate.

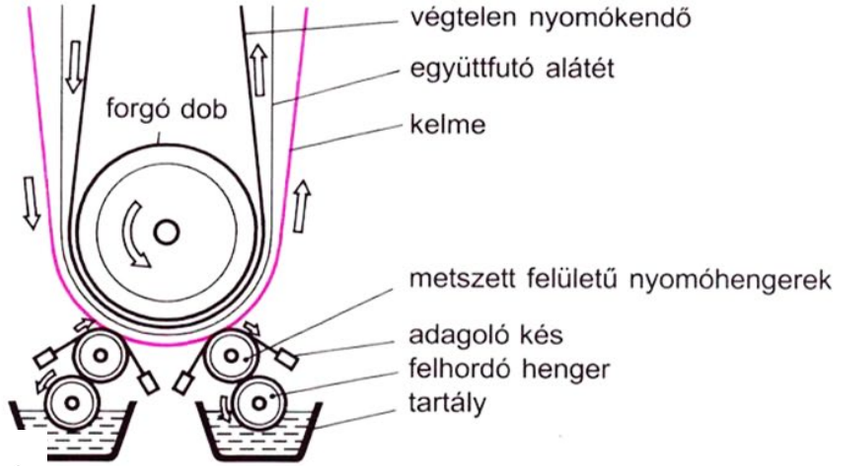
Transfer printing

Laser copier. Thermal transfer pressure. The pattern to be printed is digitally printed onto a carrier material, e.g. on paper are pressed. The pattern to be printed is transferred to the textile material to be printed with a heatable press or roller.

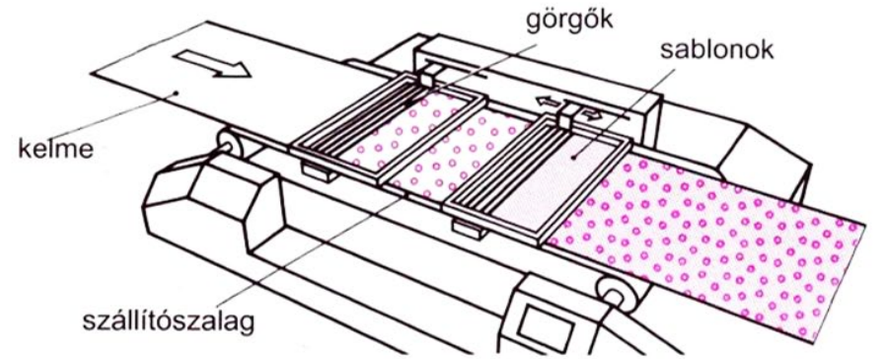
Printing technologies

The drawing beside shows the principle of operation of the various printing technologies.

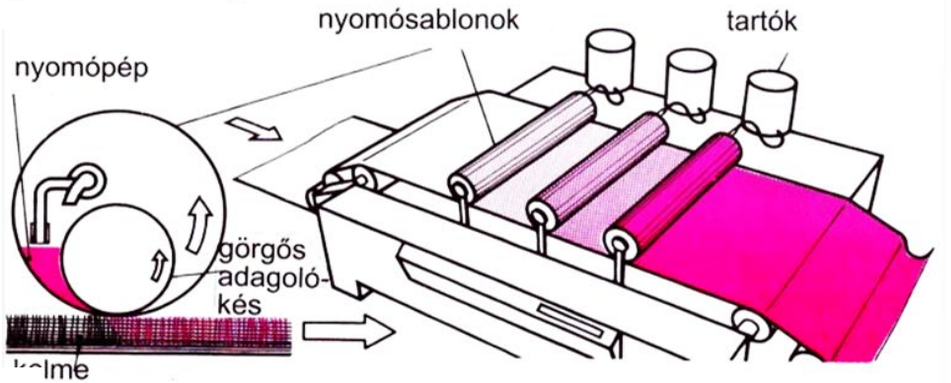
1. cylinder pressure
2. flat film printing
3. rotary film printing



1 **A hengernyomás alapelve**



2 **A sík filmnyomás alapelve**



3 **A rotációs filmnyomás alapelve**

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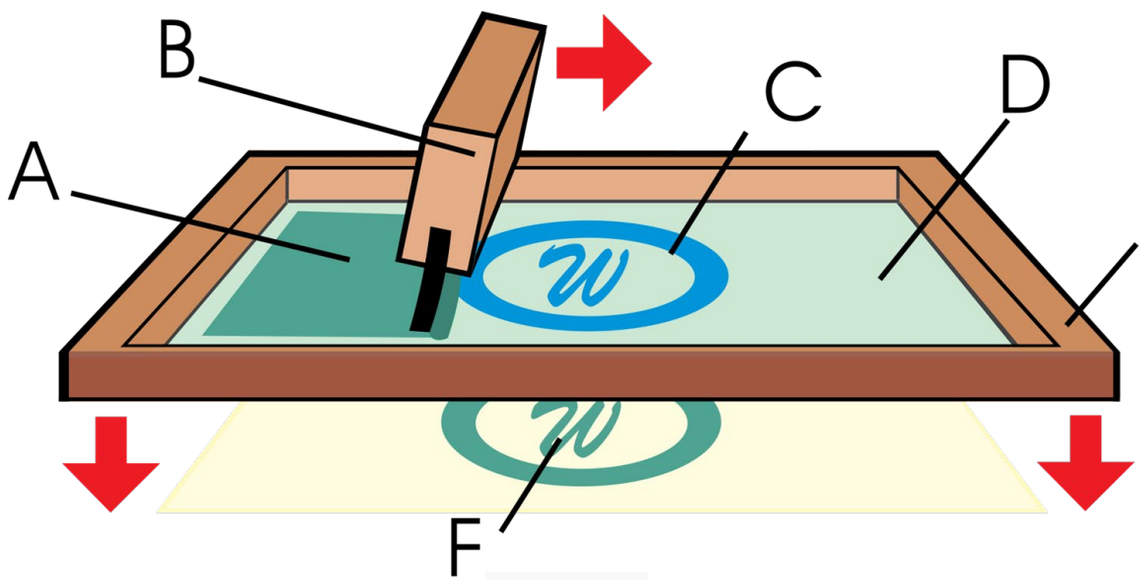
Screen printing

Intermittent printing per color, the pattern created by the photo process is transferred to the material to be printed with a hand press.

Image beside: A. Ink. B. Squeegee. C. Pattern. D. Photo-emulsion. E. Screen. F. Printed pattern



Screen printing, image by Harry Wad on Wikipedia. CC BY 2.5

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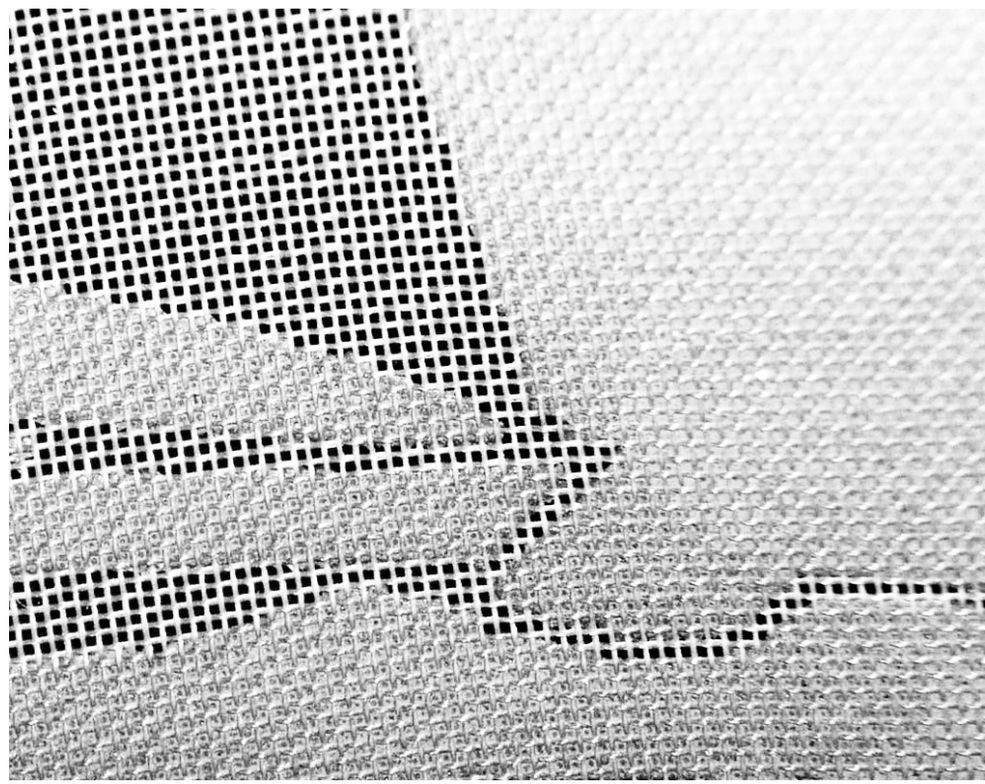
… screen printing

For manual print, a pressing mold covered with polyester mesh fabric is used. The density of the fabric varies depending on the use. After the light-sensitive emulsion has been applied and dried, the sample is exposed to the screen. The pattern is pressed onto the fabric by using a press knife or squeegee on the finished template.



Silk screen mesh. Photo 2005 by J-E Nyström on Wikipedia. CC BY-SA 3.0

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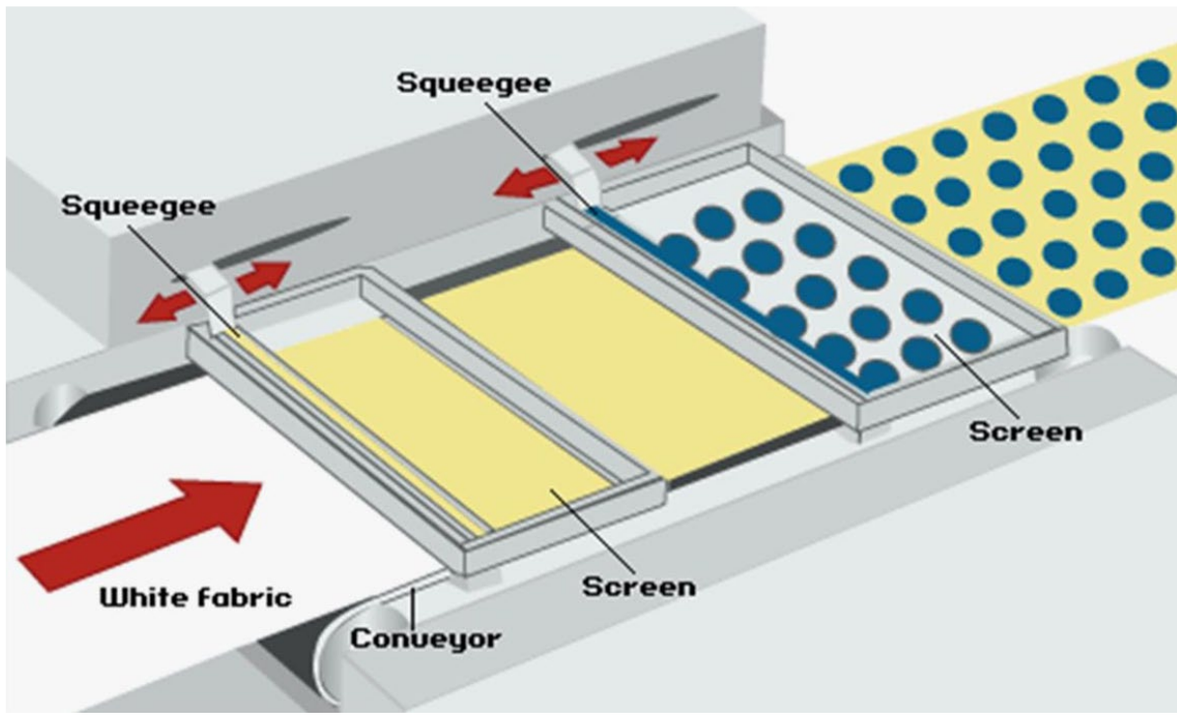
… screen printing

Flat film printing

On the flat film printing machine, the printing pulp is contained in the screen fabric template stretched over the rectangular frame. The number of templates varies per machine, usually 6-12 colors are printed.

According to the appropriate pattern, the screen fabric allows or blocks the passage of the printing pulp onto the fabric.

The uniform press pulp transfer is facilitated by the press knife running along the entire width (or length) of the template, the "edge" of which is made of a rubber sheet.



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… flat film printing

The fabric or knitted fabric to be patterned is attached to a conveyor belt with a rubber belt so that it cannot be deformed during pressure.

The conveyor conveys the fabric with a 1-1 rapport size when the templates (sieves) are in the upper position, i.e. removed from the fabric.

After the transfer, the templates can be placed on the fabric, then the pressing knife moves along the screen and pushes the printing pulp through the screen fabric.

The templates are then automatically raised and the fabric moves forward.

At the end of the conveyor belt, the fabric can be separated from the pressure cloth with sufficient pulling force.

… screen printing

… flat film printing

The pressure cloth is washed, dried and provided with fresh adhesive dots to meet the fabric prepared for pressure.

In the development of flat film printing pulps, different machine manufacturers develop different fabric transfer and template movement using different techniques.

The performance of the machines can also vary greatly from 8 to 25 m/min.

Compared to manual film printing, the productivity of flat film printing machines is approx. It is 10 times larger, but still relatively slow due to its intermittent operation, which is why rotary film printing machines were developed in order to increase production.

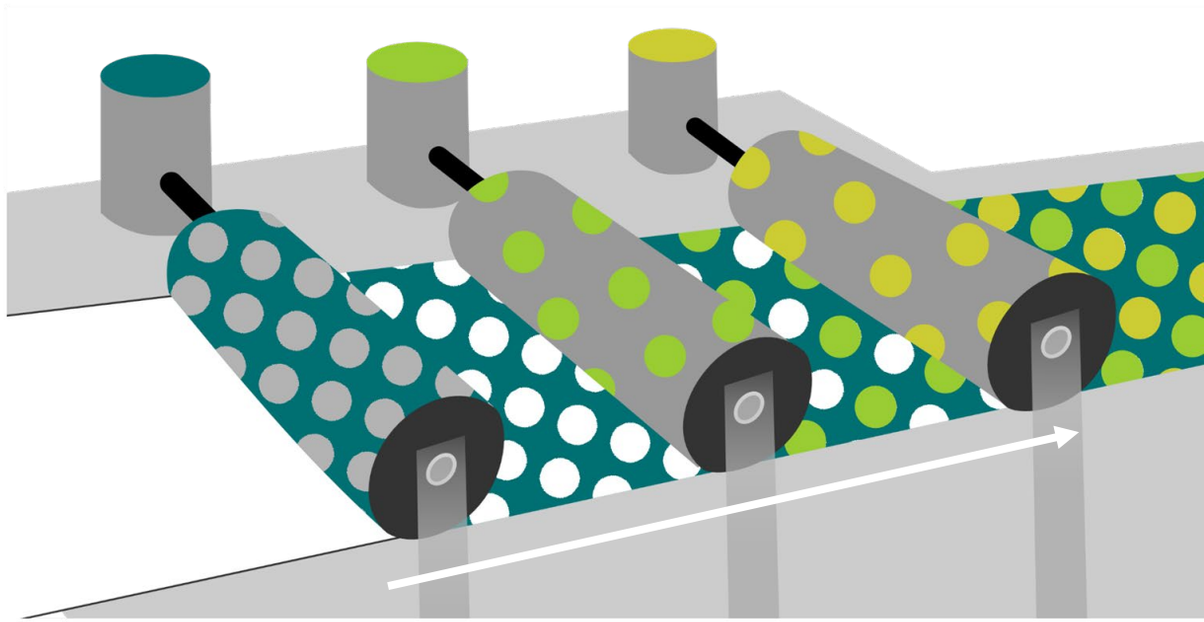
… screen printing

Rotary printing

The cylindrical templates used in rotary film printing machines made the printing process continuous. At the same time, the length of the printing machine is also smaller than that of the flat film printing machine, because the cylinders require less space (40-50 cm / color).

The fabric is positioned and guided with a conveyor belt, similar to the flat film printing machine. The fabric moves at a speed of 80-100 m/min.

A very delicate part of the printing operation is the solution of the movement of the printing cylinders in synchronization with each other and with the printing cloth. It is also important to set the cylinders strictly parallel.



Rotary screen printing, image by SusTexEdu

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Rotary printing

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Fabric printing styles

Fabric can be printed in three different styles: direct, discharge, & resist styles.

- **Direct printing**

The most common style of printing textile fabric is direct printing. The dye is directly applied onto white fabric or colored fabric. The printed portion is significantly darker than the dyed background. The direct style of printing is used in block printing, screen printing, or roller printing methods.

- **Discharge printing**

Discharge printing in textile is also known as extract printing. It is based on the chemical destruction of the original dye in the printed area. The discharging agents used can be oxidizing or reducing agents, acids, alkalis and various salts.

For discharge printing, the ground of the substrate should be dischargeable. It is recommended that dyed discharge fabric should be pre-padded with 2-3 GPL Resist salt.

… fabric printing styles

The actual amount of discharging agent requirement for optimum discharge will depend upon:

- the dyes to be discharged
- the depth of the ground
- the fabric being printed.

If no colour is added to the discharge print paste, the result is a white discharge. Discharge is only carried out by reduction.

- **Resist printing**

In the resist style of printing style, RFD fabric is first printed with resist paste which prohibits the penetration of the dye into the fabric.

The fabric is then dyed and subsequently, the resist paste is removed & leaving the desired pattern.

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Learning materials

- Different Pretreatment Process of Textile Materials by Textile Tutorials
- Explanation of Pretreatment Process in Textile (blog)
- Types of Yarn Dyeing Process In Textile Industry
- A Study on the Effects of Pre-treatment in Dyeing Properties of Cotton Fabric and Impact on the Environment on the Journal of Textile Science and Engineering (pdf)
- **Several videos** are to be found by Textile Education

Tips for learning more about colors

How do we see color: *https://www.pantone.com/eu/en/articles/color-fundamentals/how-do-we-see-color*

Properties of colors
https://www.pantone.com/eu/en/articles/color-fundamentals/what-are-the-properties-of-color

Different color spaces
https://www.pantone.com/eu/en/articles/color-fundamentals/understanding-different-color-spaces

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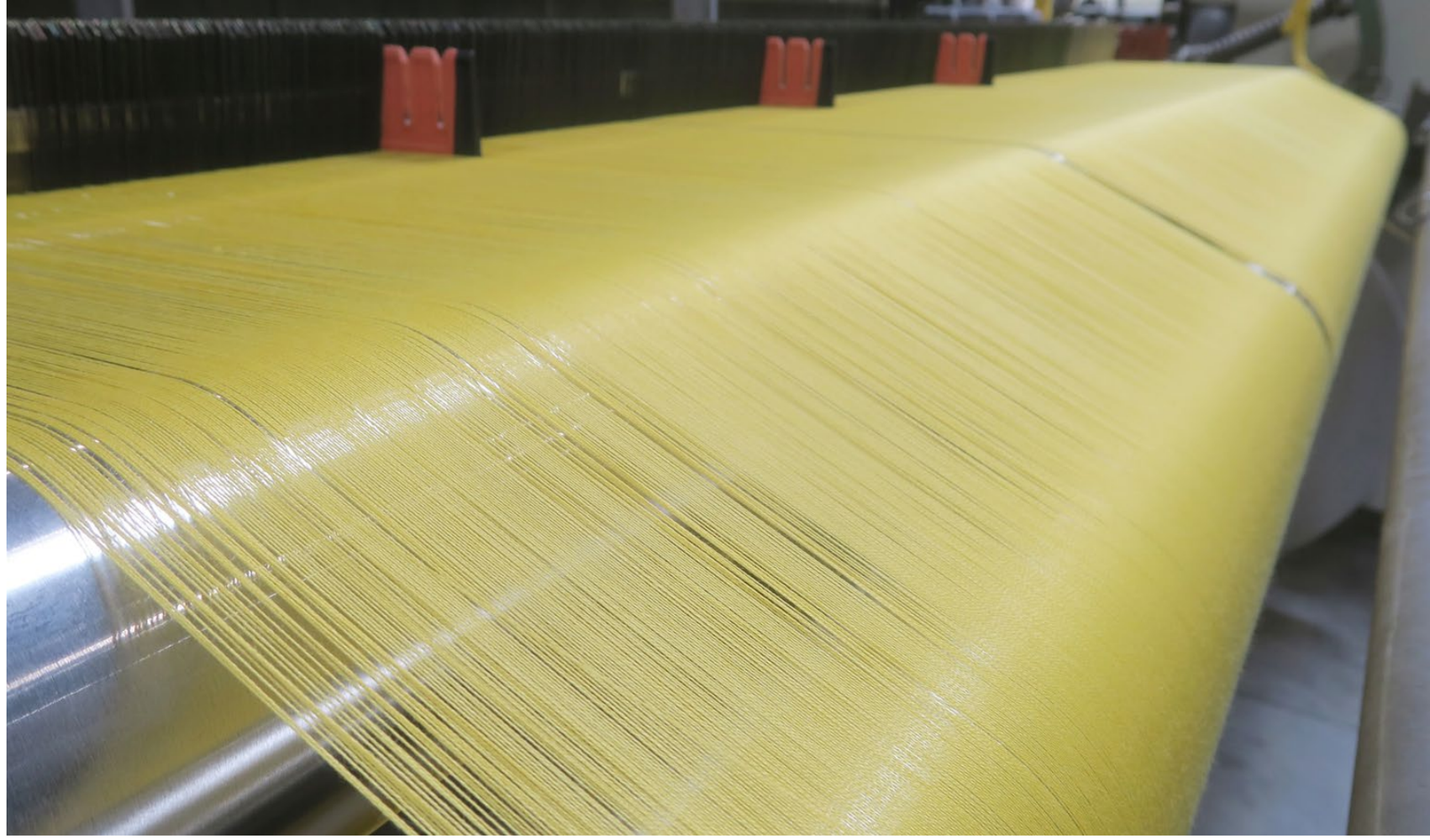
Visit the project website to see all the intellectual outputs of the project.



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