Industrial Biomass Processes Chem 2340

Thad Maloney

Aalto University
School of Chemical
Engineering

100124

Why this course?

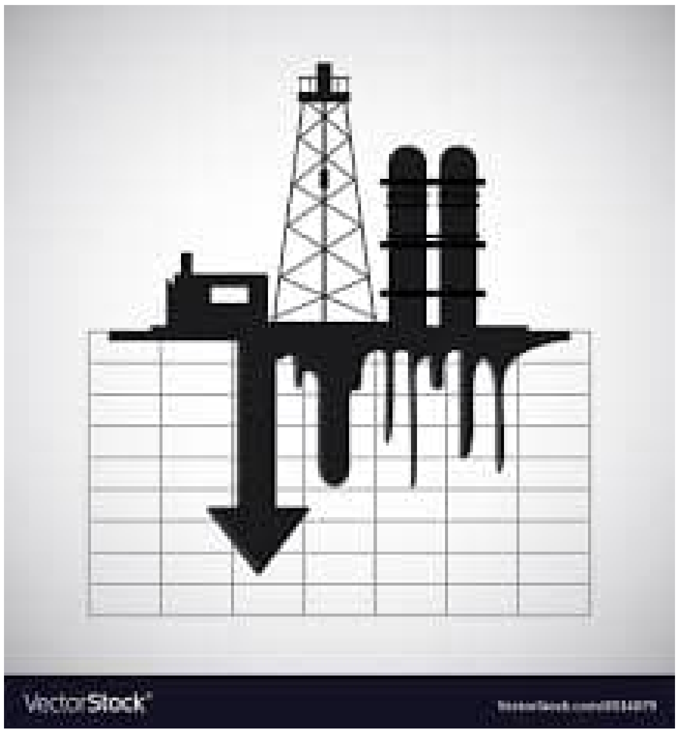
Introduction into several of the important concepts, processes, unit operations, products and technical issues in the *bioeconomy.*

Course content

- 8 lectures on selected topics, lecture slides and assigned reading
- Selected reading assigments

Lectures

Date	Lecture	Lecturer	Time,
10.1.24	Introduction	Maloney	10:15-12:00
17.1.24	Paper industry unit ops	Maloney	10:15-12:00
24.1.24	Board structure and raw materials	Hiltunen	10:15-12:00
(31.1.24)	no lecture!	--------------	-----------------
7.2.24	Wood products and composites	Rautkari	10:15-12:00
(14.2.24)	no lecture! (Reading material on Sustainability in bioindustry)	------------	--------------
21.2.24	(evaluation week)	------------------	---------------
28.2.24	Industrial Drying	Paltakari	8:15-10:00
6.3.24	Paper and board - Finishing and printing	Hiltunen	8:15-10:00
13.3.24	Paper and board converting	Hiltunen	8:15-10:00
20.3.24	Pulping and biorefinery	Quang	8:15-10:00
27.3.24	Sustainable construction	Hughes	8:15-10:00
(3.4.24)	no lecture	----	------------
(10.4.24)	no lecture	-------	--------------
17.4.23	EXAM (remote at MyCourses)		13:00-14:30



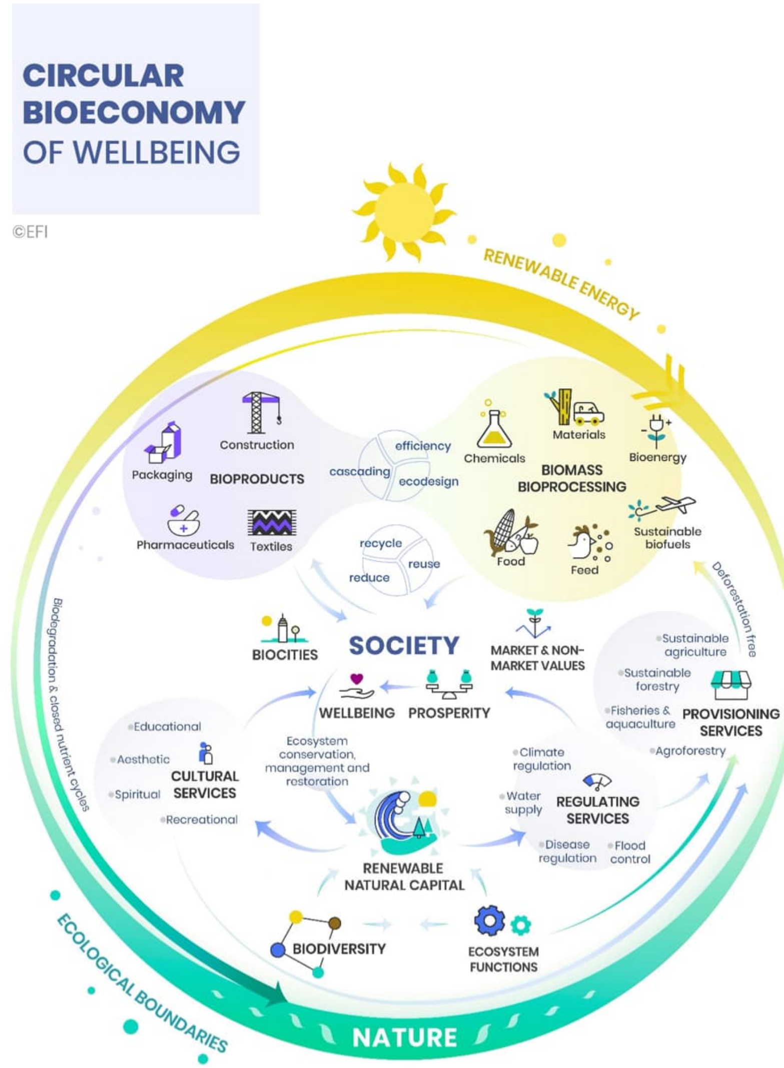


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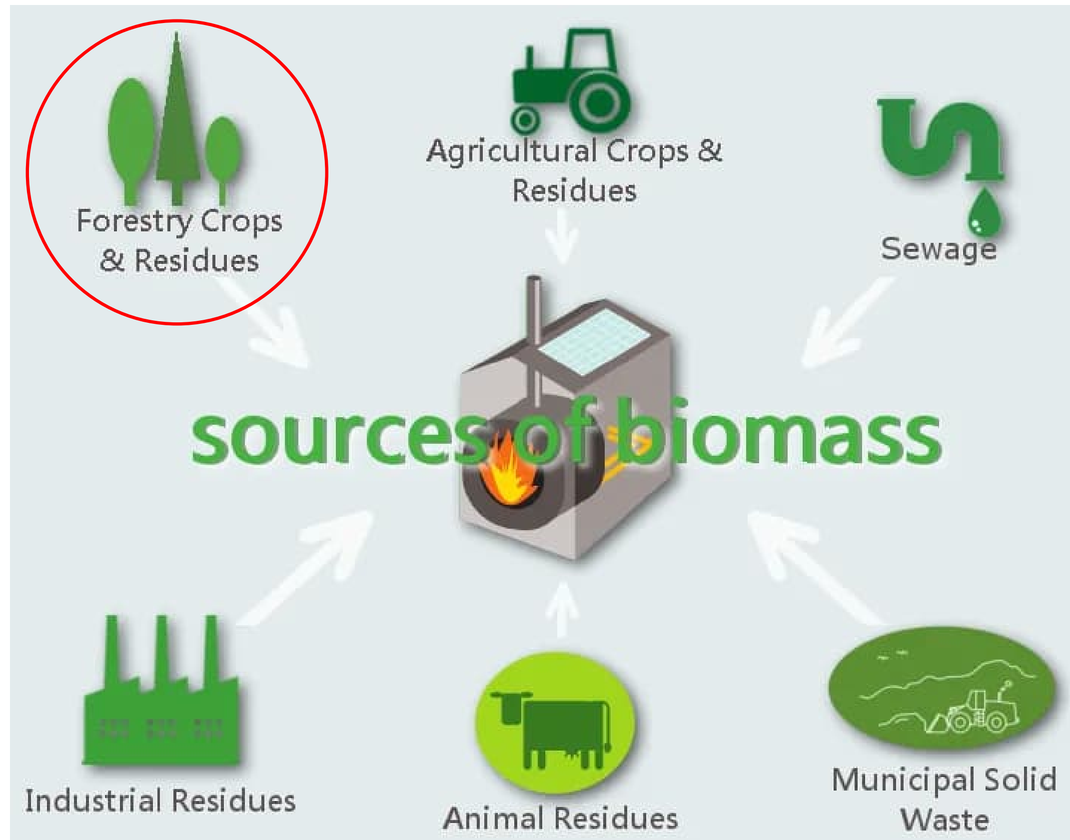
Photo: Pixabay


CO_2
WOOD PRODUCTS
RECYCLING


Forestry Crops & Residues
Agricultural Crops & Residues
Sewage
sources of biomass
Industrial Residues
Animal Residues
Municipal Solid Waste

Wood value chain

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Paper Industry – backbone of the bioeconomy

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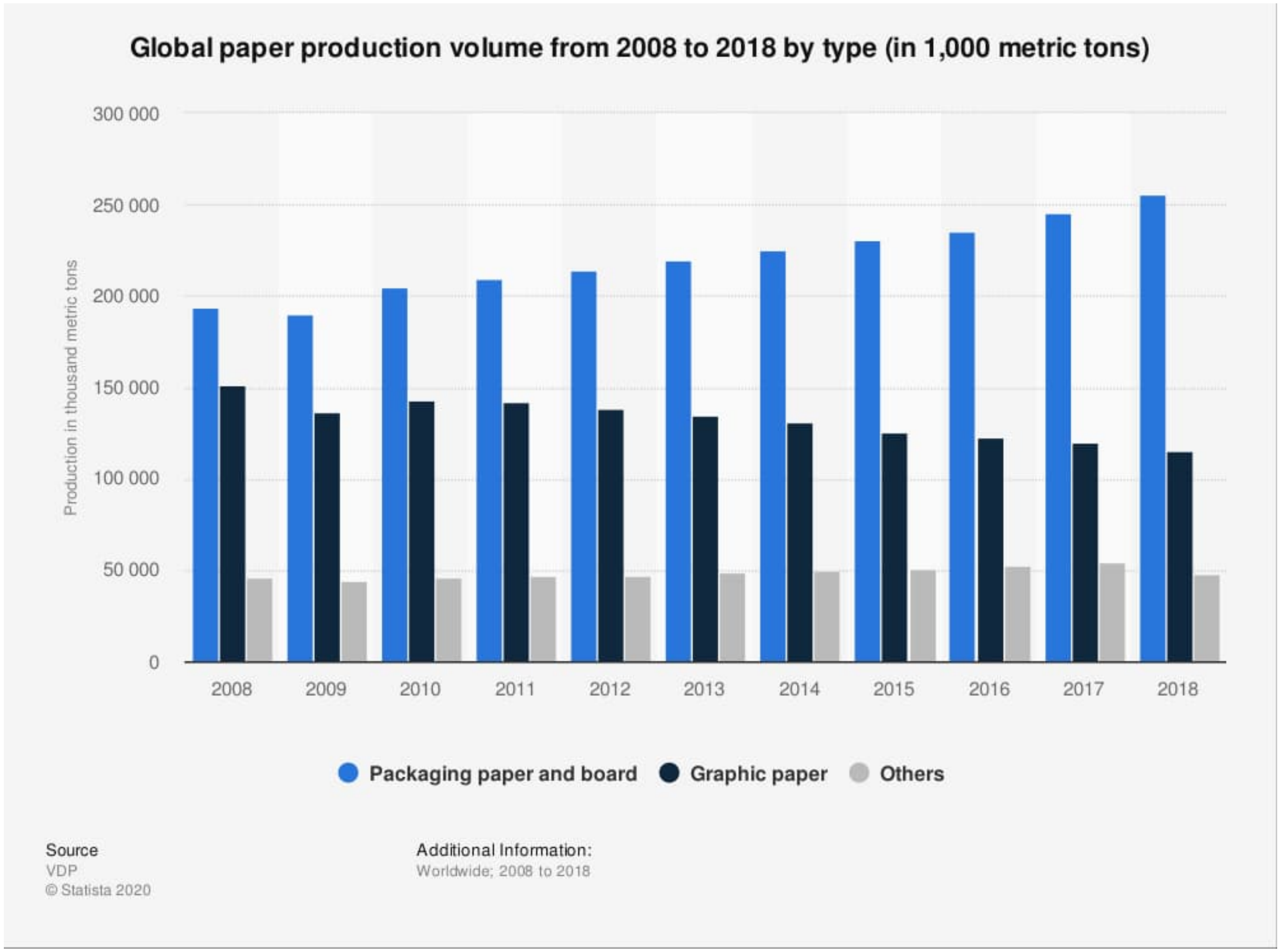

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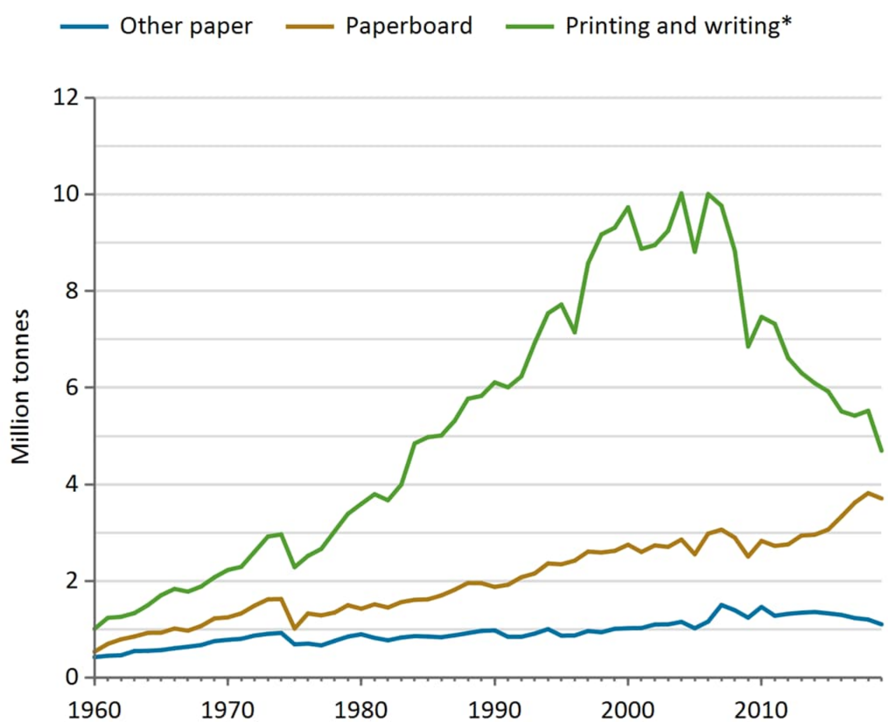
PAPER AND PAPERBOARD PRODUCTION IN FINLAND



Production, million tonnes	2019	Change from previous year
Printing and writing*	4,7	-15,0 %
Other paper	1,1	-8,2 %
Paperboard	3,7	-2,9 %
Total	9,5	-9,8 %

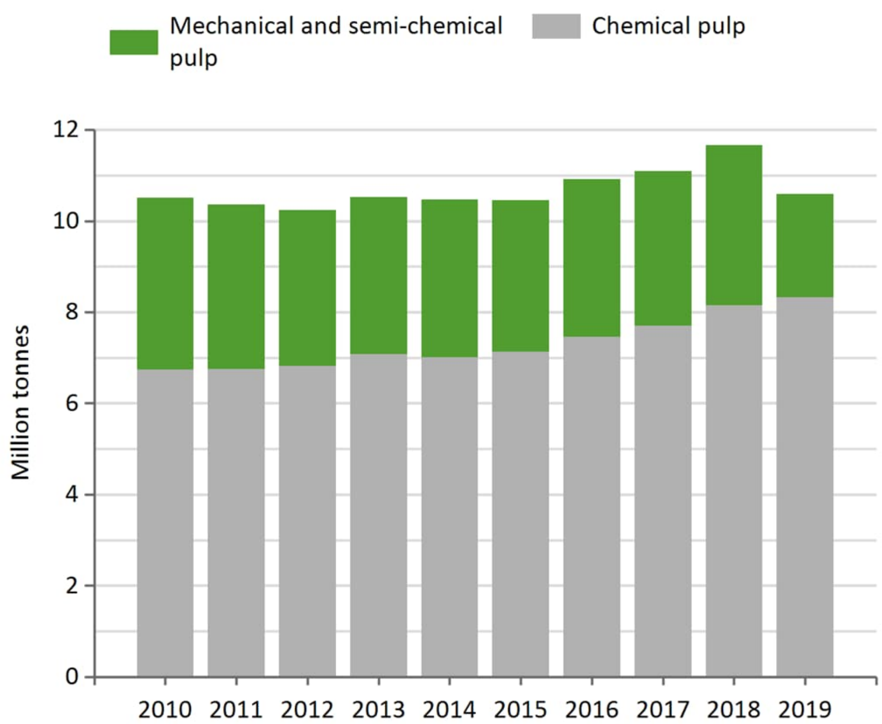
* incl. newsprint

SOURCE: Finnish Forest Industries Federation

6.2.2020

Finnish Forest Industries

PULP PRODUCTION IN FINLAND



Production, 1000 tonnes	2019
Chemical pulp	8 300
Mechanical and semi-chemical pulp	2 250
Total pulp	10 600

* change from previous year

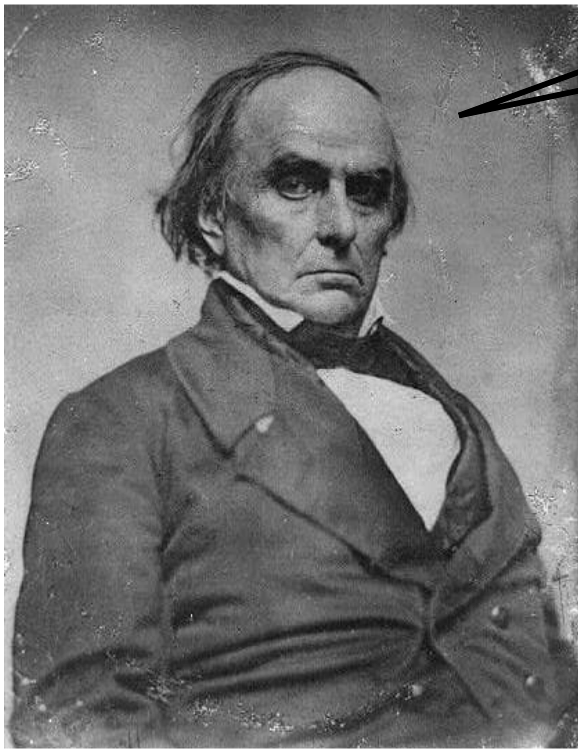
SOURCE: Finnish Forest Industries Federation

6.2.2020

Finnish Forest Industries

Paper – what is It?

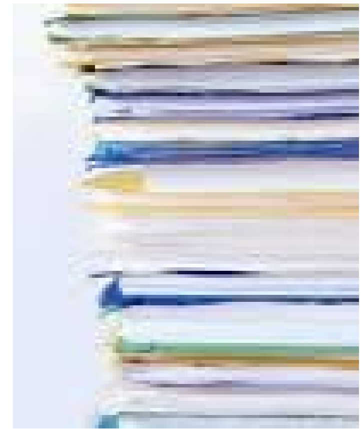
1 a (1) : a felted sheet of usually vegetable fibers laid down on a fine screen from a water suspension.

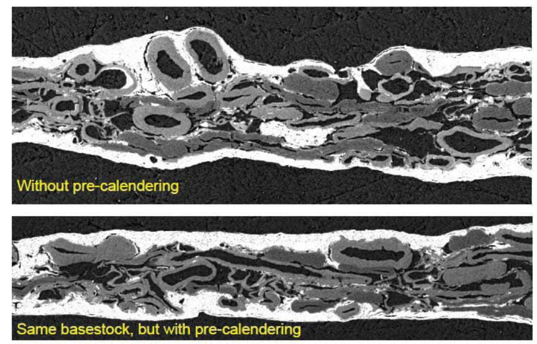


Daniel Webster

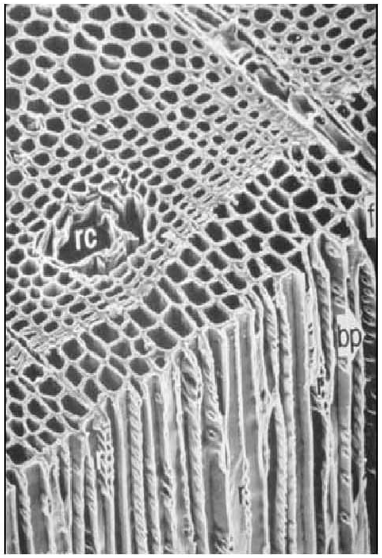
Paper characteristics

- Macroscopic structure: A 2 dimensional material e.g. dx =1000, dy=1000, dz=1.
- Microscopic structure: A 3- dimensional material composed of nearly random (stochastic) structural elements.
- Raw materials: A material made largely from natural fibers and pigments, with nanomaterials growing in importance.
- Mechanical architecture: A material composed of random fibers with hydrogen bonded joints. A hydrogen bonded continuum
- A visco-elastic material
- Manufacturing method: a material produced in a roll-to-roll operation from a fiber suspension





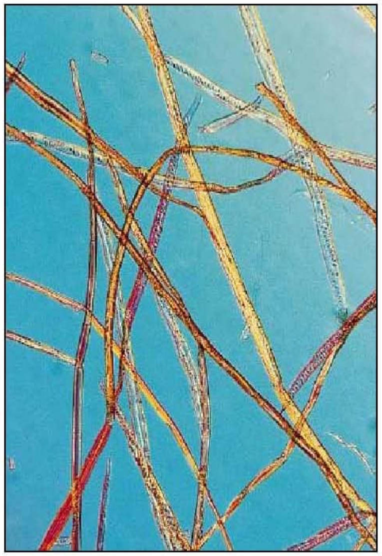
The papermaking process



Wood

Separation of fibres

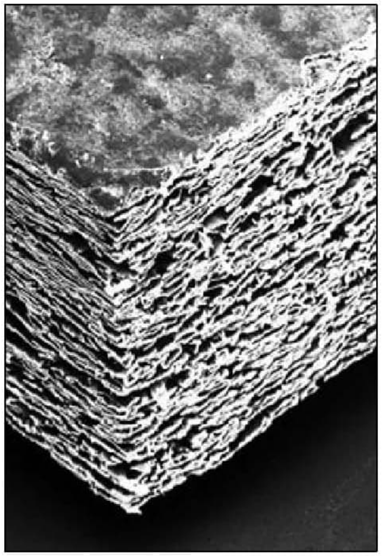
Dilution In water



Fibres

Forming of web

Removal of water



Paper

Why was paper invented?

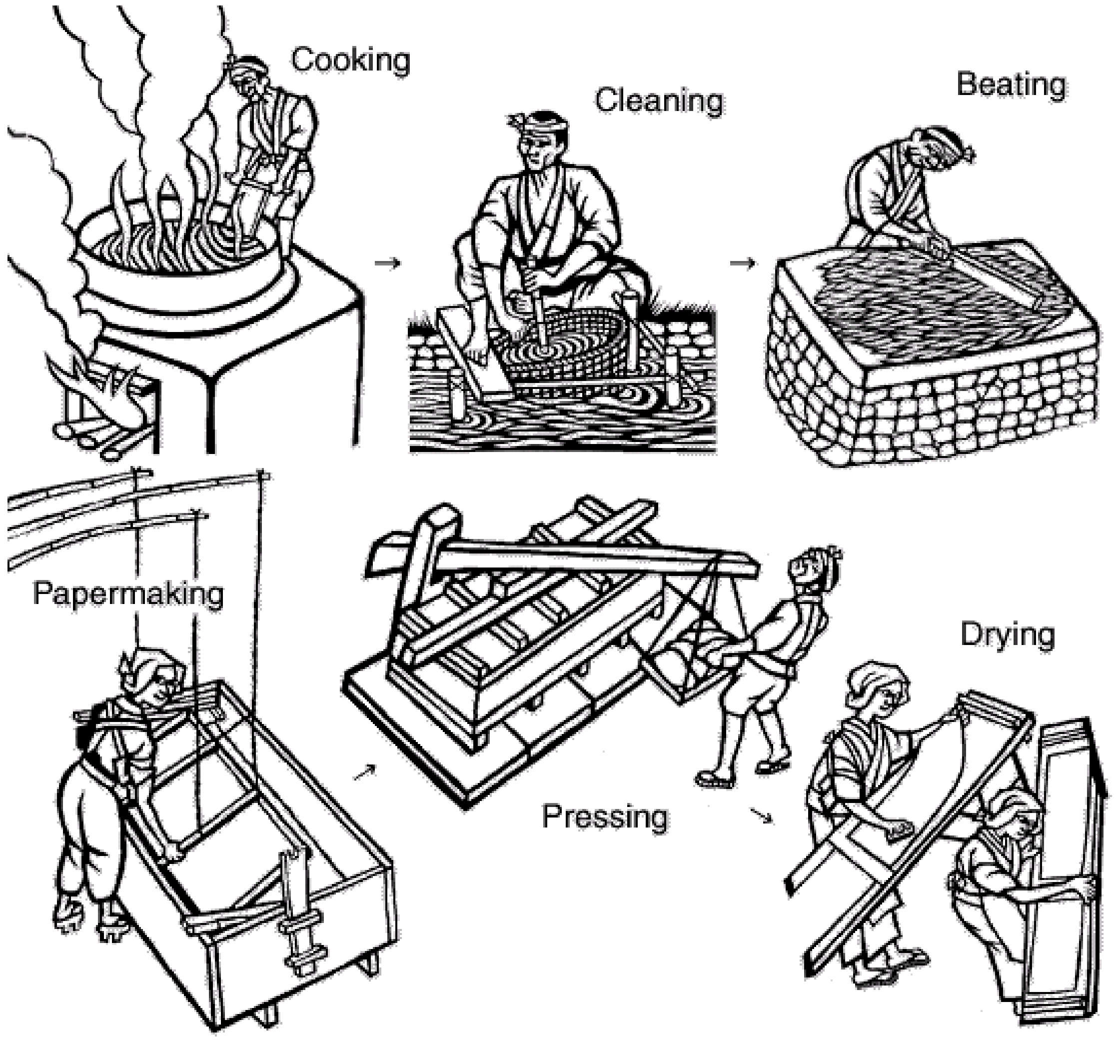
Man has a deep and basis need to communicate!

Tsai Lun solved his problem

In circa 104 ad the Chinese eunich Ts'ai Lun discovered that mashed up mulberry bark could be filter from a water suspension on a silk cloth and would form a web that, when dried, was strong and suitable for writing. Later on, other fiber sources were explored.

The secret stayed in China for centuries, but was smuggled to Europe by Arab traders sometimes after the 10th century.

Papermaking by hand - Asia



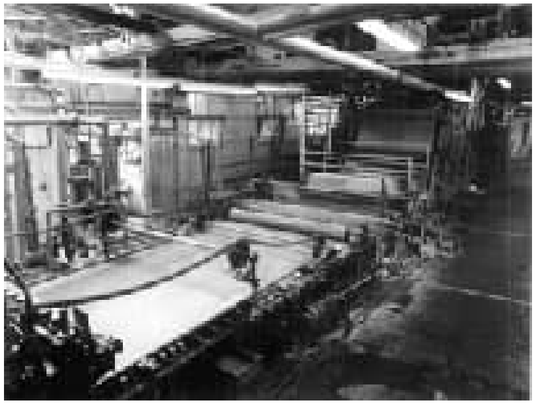
Invention of movable type printing press

In 1440 Johannes Gutenberg completed the first changable type printing press in Mainz, Germany. The invention reduced the costs of books dramatically, spreading literacy and culture rapidly throughout Europe.

Paper has always been closely associated with culture, education and the development of man-kind

- After the discoveries of Gutenberg the *need of paper* began to grow quickly
- In the 1500’s and 1600’s France produced most of the paper needed in Europe.
- The demand for paper greatly exceeded supply.
- In 1803 the Fourdrinier brothers’ paper machine produced continuous web.
- Paper machines replaced hand-manufacture during the first half of 19th-century- the supply of paper expanded greatly and the price of paper fell dramatically. The era of mass media was born!

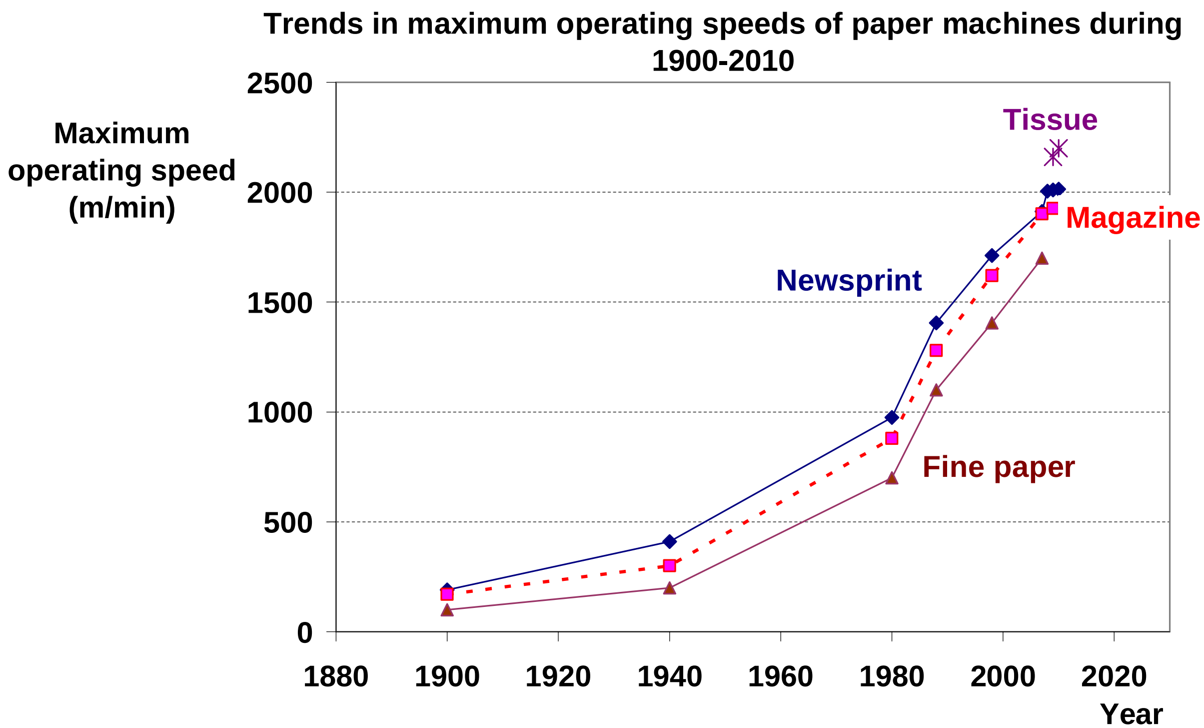
The early papermaking machines were of two main types: the Fourdrinier and the cylinder. The former, invented in 1799 by Louis Robert, but called after the Fourdrinier brothers, who greatly improved the basic model, consists essentially of an endless wire cloth stretched between rolls. The wire forms a flat horizontal or slightly inclined surface onto which the pulps is poured.



Early paper machine

The development costs for the first paper machines were extremely high, and eventually drove The Fourdrinier brothers bankrupt

History paper machine speed



Characteristics of the manufacturing process

1. Paper manufacturing is a mature manufacturing technology, characterized by cost sensitivity
    - Massive scale at the expense of process flexibility
    - High degree of integration
2. The process must achieve high degree of functional quality and low quality variation
3. The overall manufacturing process consists of many interlinked continuous and semi-continuous processes. Each sub process must be optimized and the overall process must be optimized.
4. Process automation is a key part of the manufacturing platform.
5. The paper machine has traditionally been the center of the manufacturing process, but recently focus has shifted upstream to pulp, chemical and energy related process.
6. An essential aspect of paper manufacture is that it is an aqueous process

Key targets and demand on raw material

1. Paper mills may exists as stand alone operations or *integrated* together with pulp manufacturing.
2. The central target for pulp mills has historically been to produce even, high quality fiber for the paper mill, though other targets are gaining importance.
3. Other raw materials, pigments and chemicals can be produced on site or delivered to the mill.
4. Raw materials are one of the most important product development tools, as the manufacturing equipment tens to be large and inflexible.
5. The various raw material streams interact in complex ways, placing challenges on mill operations and introduction of new raw materials.

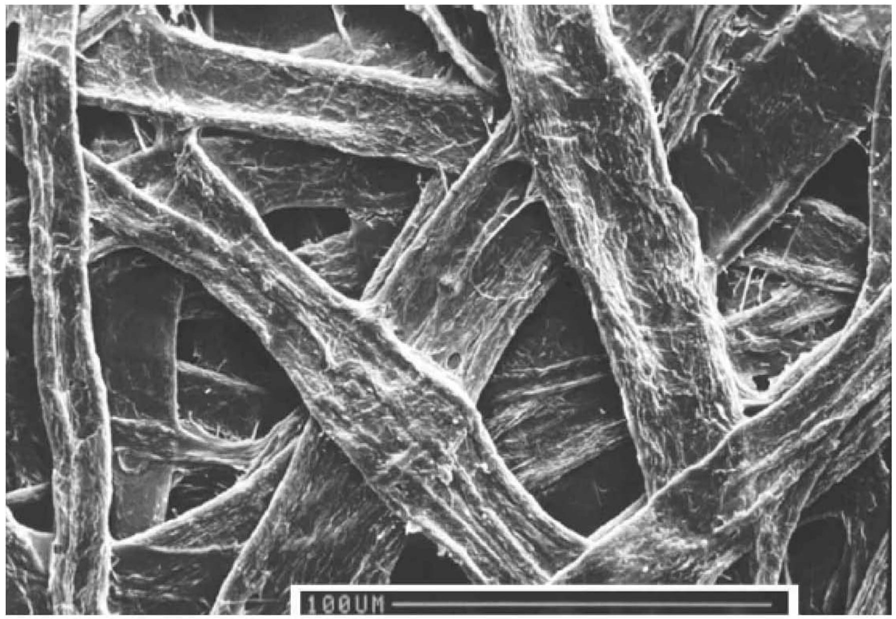


Figure 1.16 **Linerboard,** the surface-layer in corrugated cardboard, is manufactured mainly from bleached pine Kraft pulp in a yield interval of 47–52%. The pulp is only slightly beaten. The pulp and structure is chosen mainly to give high compression strength, creep resistance, toughness in converting and delamination resistance.

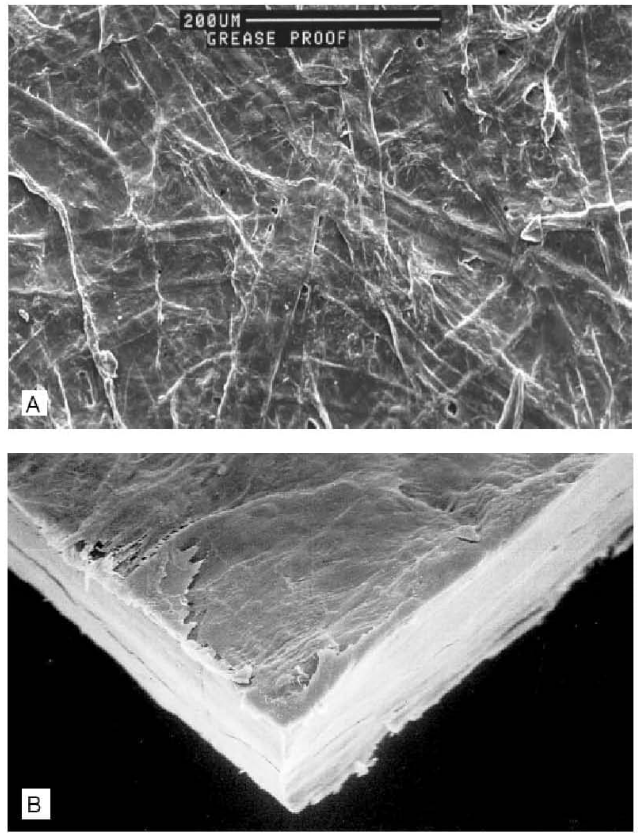


Figure 1.20 **Greaseproof paper.** The fibres in the greaseproof paper are so well beaten that the fibre structure in the paper has been "erased". The paper becomes transparent, has a low opacity. Greaseproof paper is used e.g. for drawing, baking and sandwich paper.

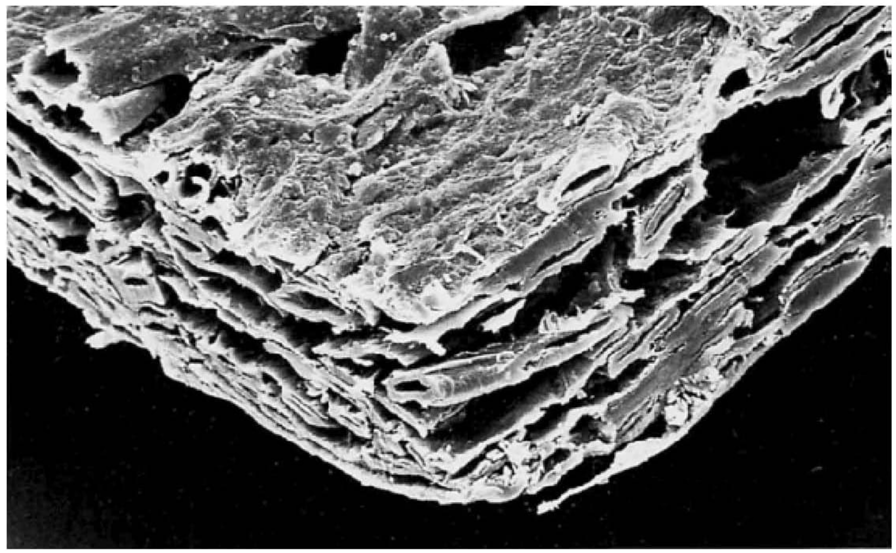


Figure 1.21 **Copy paper,** often consists of chemical, undamaged fibres, often a mixture of softwood and hardwood. Note the open paper structure. The fibres and structure is chosen mainly to give flatness and, good surface properties.

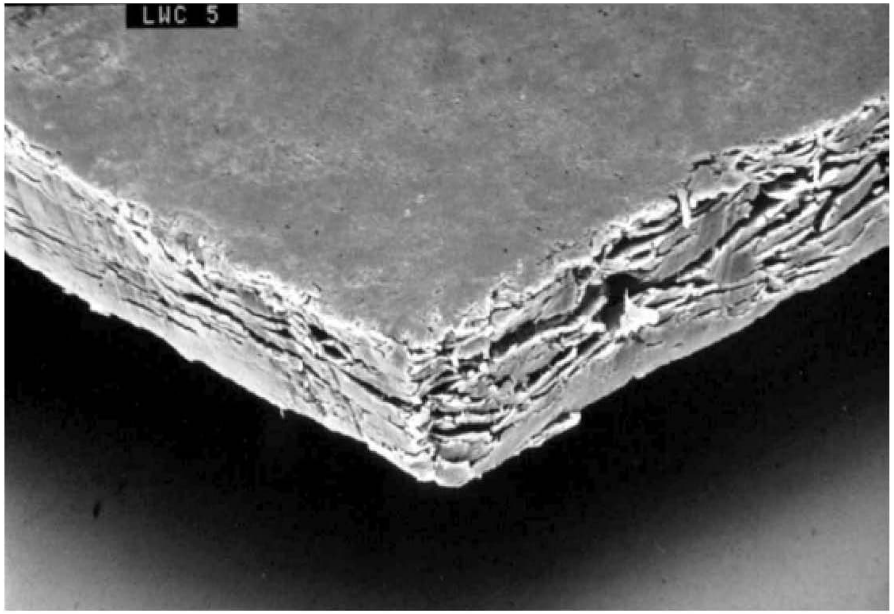


Figure 1.22 **LWC, Light Weight Coated paper,** consists of mechanical, fibres, reinforced with chemical fibres and with a coating layer. The fibres and structure is chosen mainly to give good runnability in printing presses and to provide a good base paper for the coating.

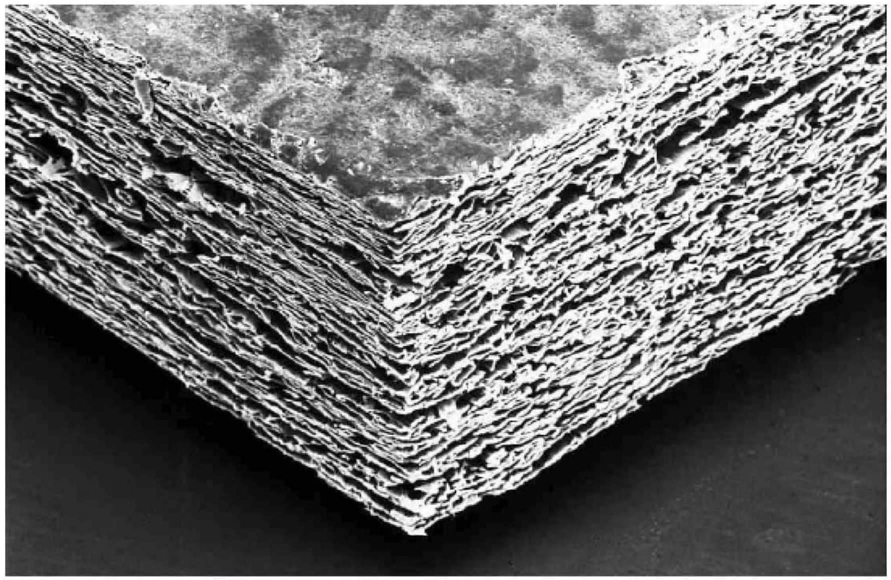


Figure 1.23 **Coated carton board.** Carton board is manufactured by a multi-layer technology, e.g. with a surface layer of bleached kraft pulp and mechanical pulp in the middle, or with several layers of the same type, e.g. bleached Kraft pulp. The coating layer makes the carton board surface more even and more suitable for high-class print. The fibres and structure is chosen mainly to give bending stiffness, good converting properties and surface properties.

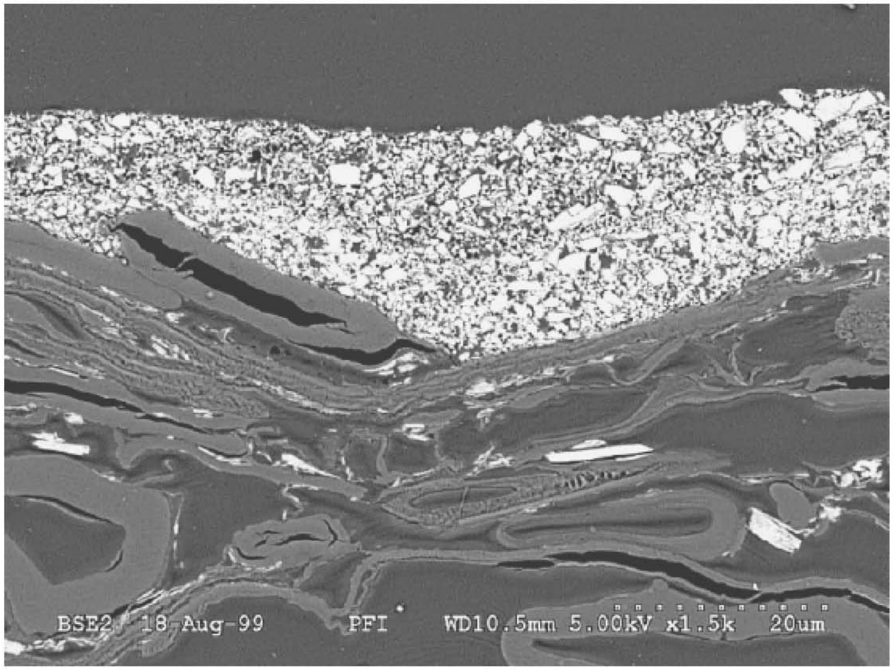


Figure 1.24 The coating layer of a coated carton board seen in the thickness direction. Note the cross-sections of the fibres.

Properties of different Materials compared to Paper

Table 1.2 Material properties

Material	Elastic modulus	Density	Tensile stiffness index	Bending stiffness-index
	E	ρ	$E^w = \frac{E}{\rho}$	$S^w = \frac{S^b}{w^3} = \frac{E^w}{12 \cdot \rho^2}$
	MN/m^2	kg/m^3	MNm/kg	$Nm^7/kg3$
Steel	210 000	7 800	25	0,03
Titanium	120 000	4 500	25	0,10
Aluminium	73 000	2 800	25	0,30
Magnesium	42 000	1 700	25	0,70
Glass	73 000	2 400	25	0,40
Concrete	15 000	2 500	6	0,08
Carbon fibre composites	200 000	2 000	100	2,00
Wood in grain direction	14 000	500	25	8,30
Paper, linerboard in MD	15 600	700	22	3,70

Paper & Board Grades

- Paper Grades
  - Printing and Writing Papers
  - Wrapping and Packaging Papers
  - Tissue
  - Specialty Papers

- Board Grades:
  - Carton Board
  - Container Board
  - Special Board

Paper Grades – Wrapping & Packaging Papers

- Sack Paper:
  - Toughness and high porosity crucial parameters
  - High consistency refining
  - Micro creping
  - Mainly SW chemical pulp

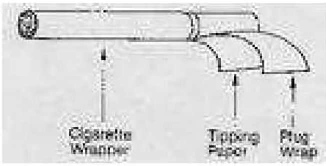
- Kraft Paper:
  - Carrier bags
  - Wrapping papers
  - Greaseproof for cooking and baking => low porosity

Corrugated Board
Liner + Corrugating Medium

Tissue Products

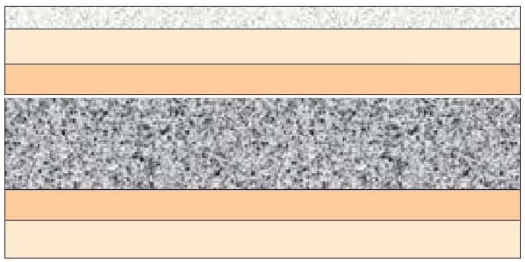
Paper Grades – Specialty Papers

- Electrical papers
- Absorbent papers
- Filter papers
- Cigarette paper
- Building papers
- Functional papers



Cartonboard – White Lined Chipboard

5 PLY WLC



DOUBLE OR TRIPLE COATED

TOP PLY	BLEACHED HW & SW
UNDERTOP PLY	DIP, BCTMP, GW
FILLER PLY	OCC, OMP, ONP, GW
UNDERBACK PLY	OCC, DIP, OMP, ONP
BACK PLY	BLEACHED HW & SW, OCC

- Basis Weight 200 – 450 g/m^2
- Typically 3 – 5 plies with Fourdrinier forming technology
- High content of recycled fibers, primarily in Filler ply
- End use: Dry food, tools, electronics

Paper functional properties and structure

Functional Paper Properties

During manufacturing, converting and end-use of paper there are many demands for functional mechanical properties. A few illustrative examples of this are given below.

- *Example 1)* Bending stiffness paper is probably the most important mechanical proper of paper and carton board. *Figure 1.1* illustrates the obvious importance of bending stiffne for a milk carton.

Figure 1.1 **The bending stiffness is important for milk cartons as well as most paper grades.**

It was shown already half a century ago that the lifetime decreases linearly in a semi-logarithmic plot as shown in *Figure 1.3*.

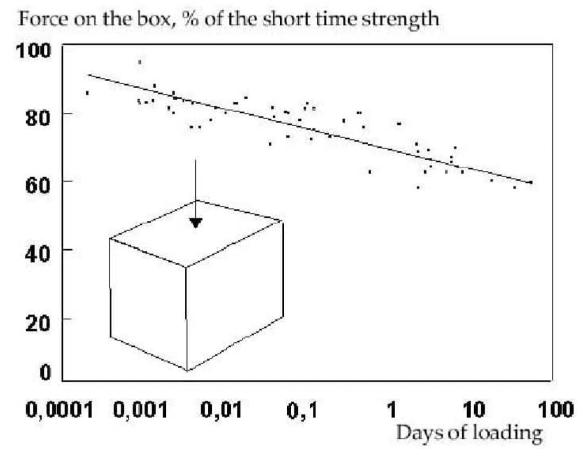


Figure 1.3 **The lifetime, the time to failure of corrugated boxes as a function of the time of loading.**

❑ *Example 2)* During storage of corrugated boxes and cartons, the structure may collapse due to creep in compression forces after a certain time of loading, *Figure 1.2*. The term lifetime is sometimes used to describe the time to break.

❑ *Example 3)* During manufacturing, rewinding and printing, thin paper grades may experience web breaks. The breaks may be caused by high loads, defects or inferior fracture properties. *Fig. 44.4* shows a web break in a paper machine.

Figure 1.4 **A web break in a paper machine.** (Nordiskafilt)