Lecture in line with the course

„Biotechnology of trees and fungi“

Cellulose - Hemicellulose

Dr. Christian Schöpper
Phone: 0551 - 39 9745
mailto: cschoep@gwdg.de

Major cell wall polysaccharides

⇒ Celluloses

⇒ Hemicelluloses

⇒ Pectic polysaccharides

Cell wall components

⇒ Microfibrillar structure

- ⇒ Celluloses (β-1,4 glucan)

⇒ Matrix structure

- ⇒ Pectins (galactan, arabinan, etc.)
- ⇒ Hemicelluloses (xylan, mannan, etc.)
- ⇒ Proteins (arabinogalactan, enzymes, etc.)
- ⇒ Phenolics (lignin, ferulic acid, etc.)

Polysaccharide composition (%) in different cell wall layers

	Middle lamella, primary wall	Secondary wall S_1	Secondary wall S_2 outer part	Secondary wall S_2 inner part
Birch				
Galactan	16,9	1,2	0,7	0,0
Cellulose	**41,8**	**48,8**	**49,4**	**60,0**
Glucomannan	3,1	2,8	2,1	5,1
Arabinan	13,4	1,9	1,5	0,0
Spruce				
Galactose	16,3	8,0	0,0	0,0
Cellulose	**33,4**	**55,2**	**63,6**	**64,3**
Glucomannan	7,9	18,1	24,4	23,7
Arabinan	29,3	1,1	0,8	0,0

Chemical composition of Japanese soft- and hardwoods

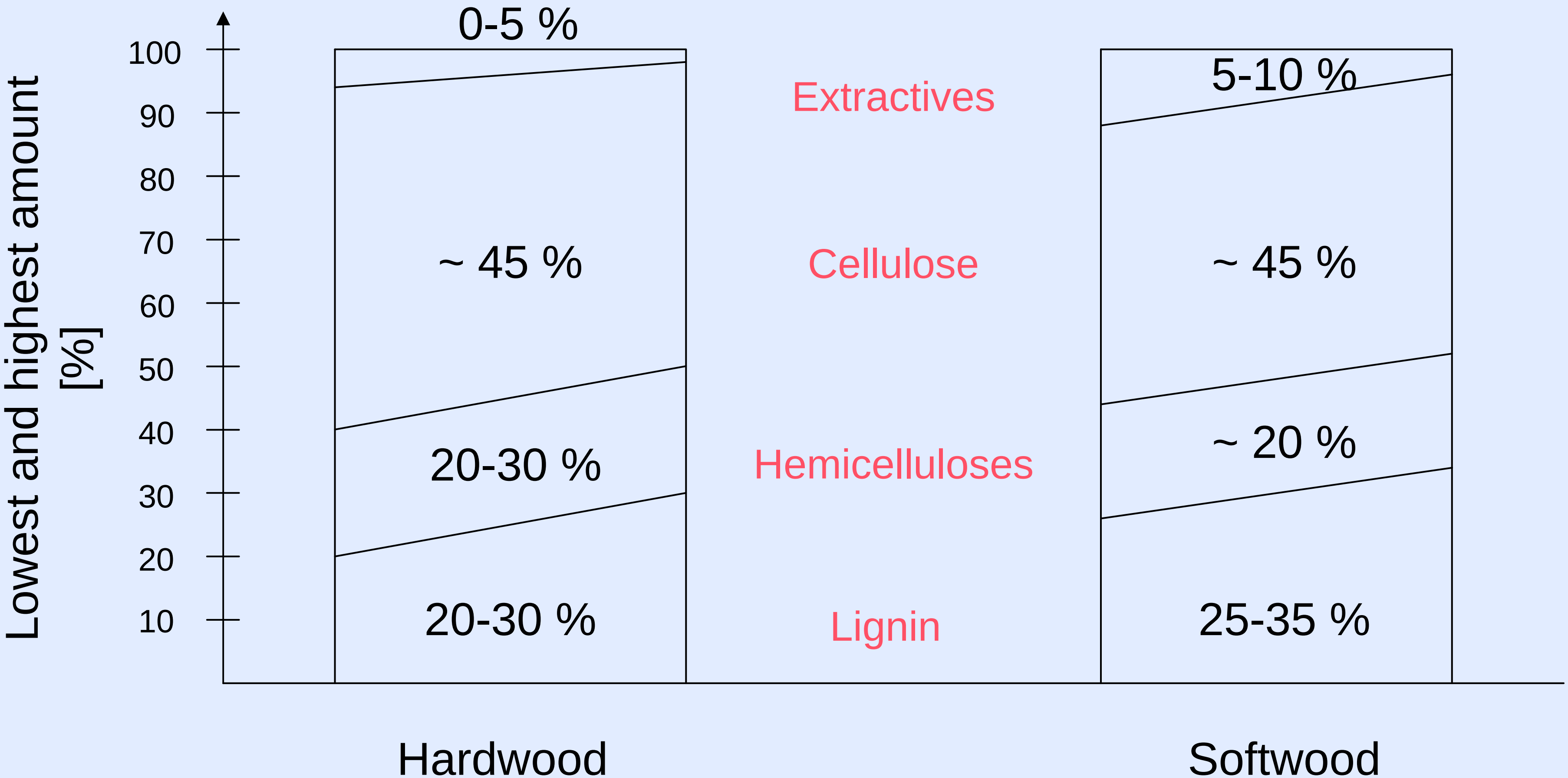
	α- cellulose (%)	**Pentosan (%)**	**Mannan (%)**	**Galactan (%)**	**Proteins (%)**
Pinus densiflora	**31.0 - 41.3**	9.9 - 12.9	3.5 - 10.1	0.3 - 0.8	0.8
Abies firma	**38.2**	8.5 - 10.9	7.9	1.3	0.9
Larix kaempferi	**30.6 - 38.9**	4.8 - 11.8	4.1 - 7.8	0.6 - 9.0	0.3 - 0.5
Fagus crenata	**40.7 - 45.9**	21.3 - 26.9	0.0	0.1 - 1.6	0.4 - 1.2
Quercus serrata	**37.1 - 43.5**	18.3 - 24.0	0.0	0.4 - 1.8	0.7 - 1.0
Acer mono	**37.1 - 48.9**	18.7 - 25.7	0.0	0.3 - 1.5	0.6 - 0.7

Amount of different sugars in wood

	1 Galactose (%)	2 Glucose (%)	3 Mannose (%)	4 Arabinose (%)	5 Xylose (%)
Average amount in **softwood**	9.3	64.5	12.0	3.3	10.3
Average amount in **hardwood**	2.3	65.2	2.6	1.5	28.3

1 - 3 = hexoses, 4 and 5 = pentoses

Cellulose and hemicellulose amount in softwood and hardwood



Characteristics of hemicellulose

- ⇒ The term hemicellulose unites all carbohydrates of wood that can be easily hydrolysed
- ⇒ Built up by different glycosidic complex chain molecules that are linked to pentose and hexose
- ⇒ Hemicelluloses feature an average degree of polymerisation of 120 - 200
- ⇒ Next to hexose and pentose further units like uronic acids are contained in hemicelluloses

Assembling units of hemicelluloses - softwood

"Softwood-xylan"

```
- X - X - X - X - X - X - X - X - X - X - X - X -
      |           |               |
      Gs          Ar              Gs
```

X = Xylose, Gs = Glucoronic acid, Ar = Arabinose

Assembling units of hemicelluloses - softwood II

“Softwood glucomannan“

- M - G - M - M - M - M - G - M - M - M - G - M -

Ac (attached to the 2nd M) Ac (attached to the 5th M)

G= Glucose, M = Mannose, Ac = Acetyl

Assembling units of hemicelluloses - hardwood

“Hardwood-xylan”

```
- X - X - X - X - X - X - X - X - X - X - X - X -
      |   |         |                 |
     Ac  Gs        Ac                Ac
```

X = Xylose, Gs = Glucoronic acid, Ac = Acetyl

Characteristics of cellulose

⇒ Built up exclusive by ß-D-glucose units

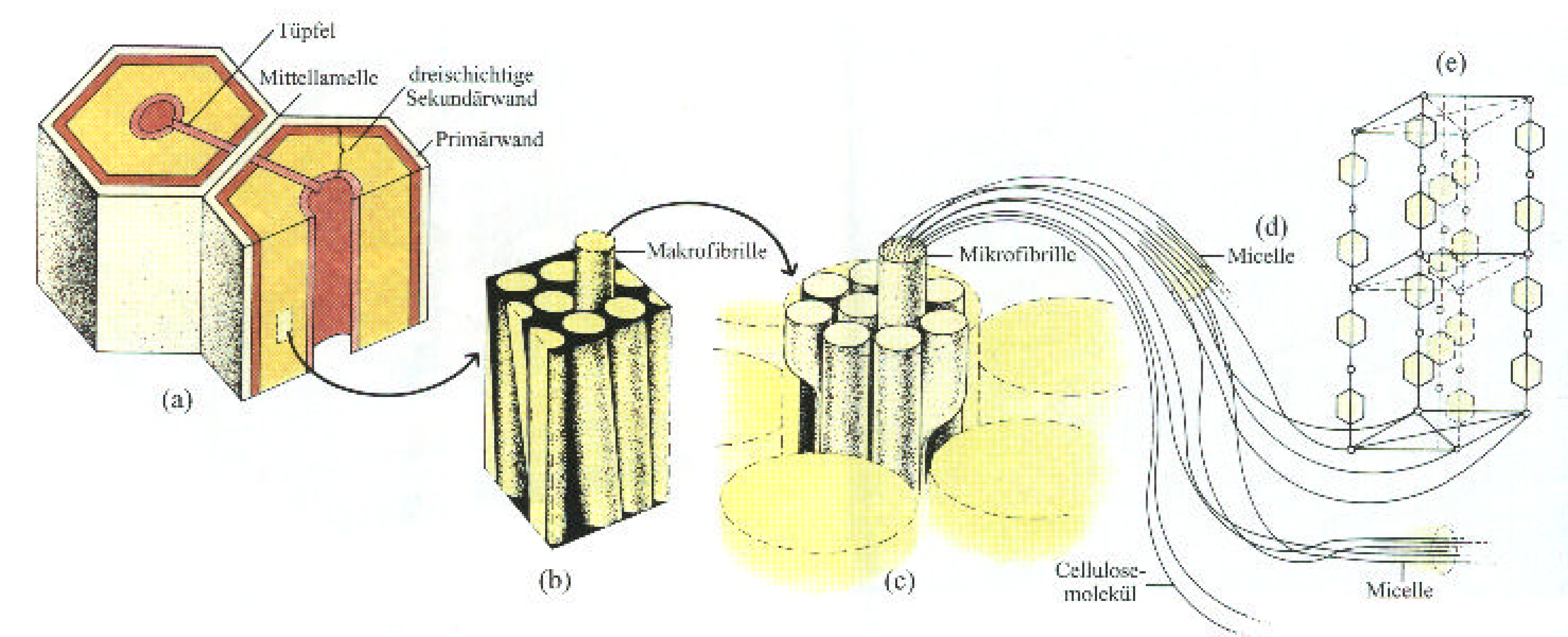
⇒ ß-D-glucose units are linked to high molecular chain molecules

⇒ The average degree of polymerisation of cellulose in a native state is 10.000 to 15.000

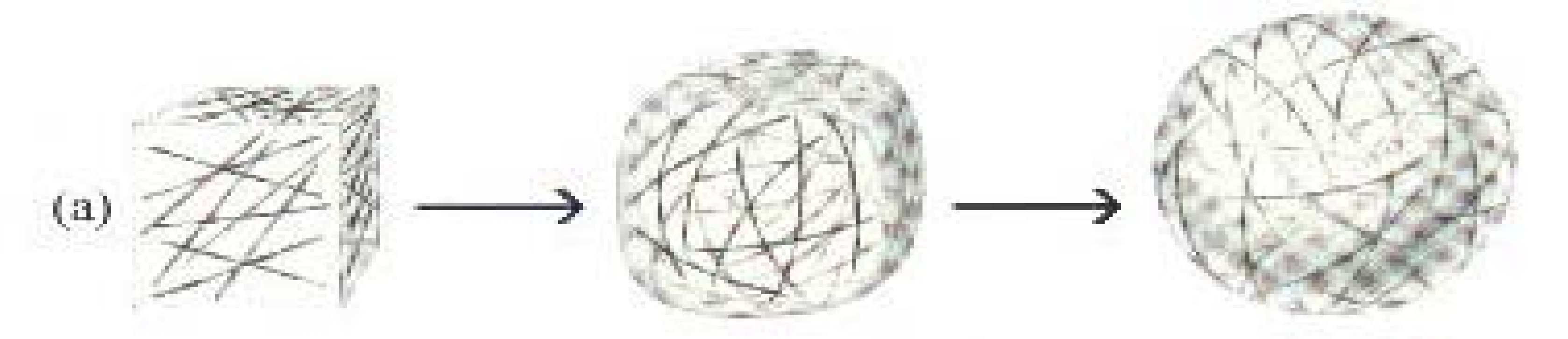
⇒ A fast growing tree produces approximately 14 g of cellulose per day

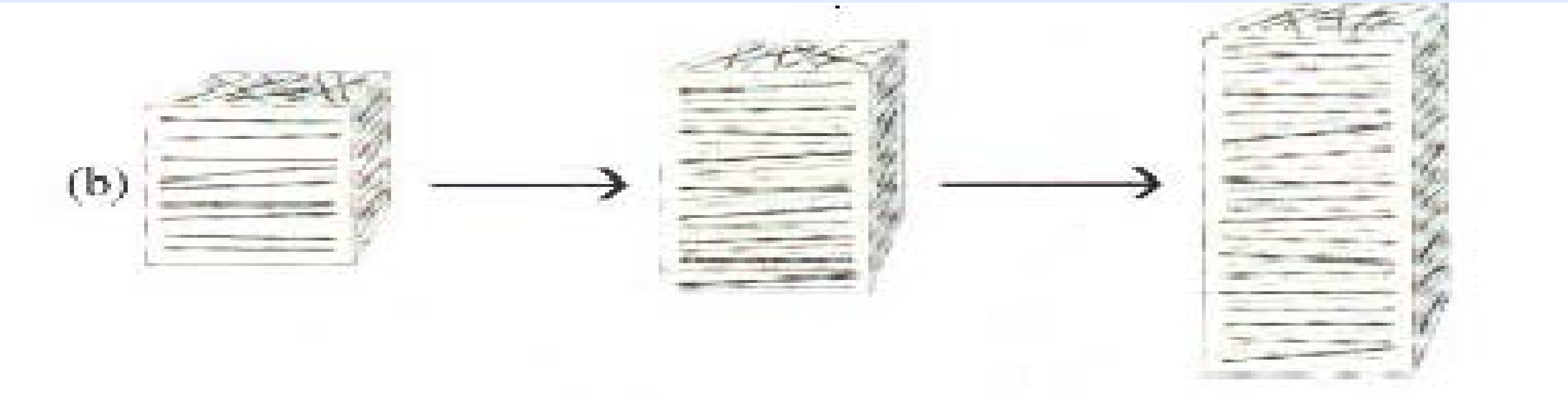
⇒ Cellulose is the most important produced biomass worldwide!

Appearance of cellulose

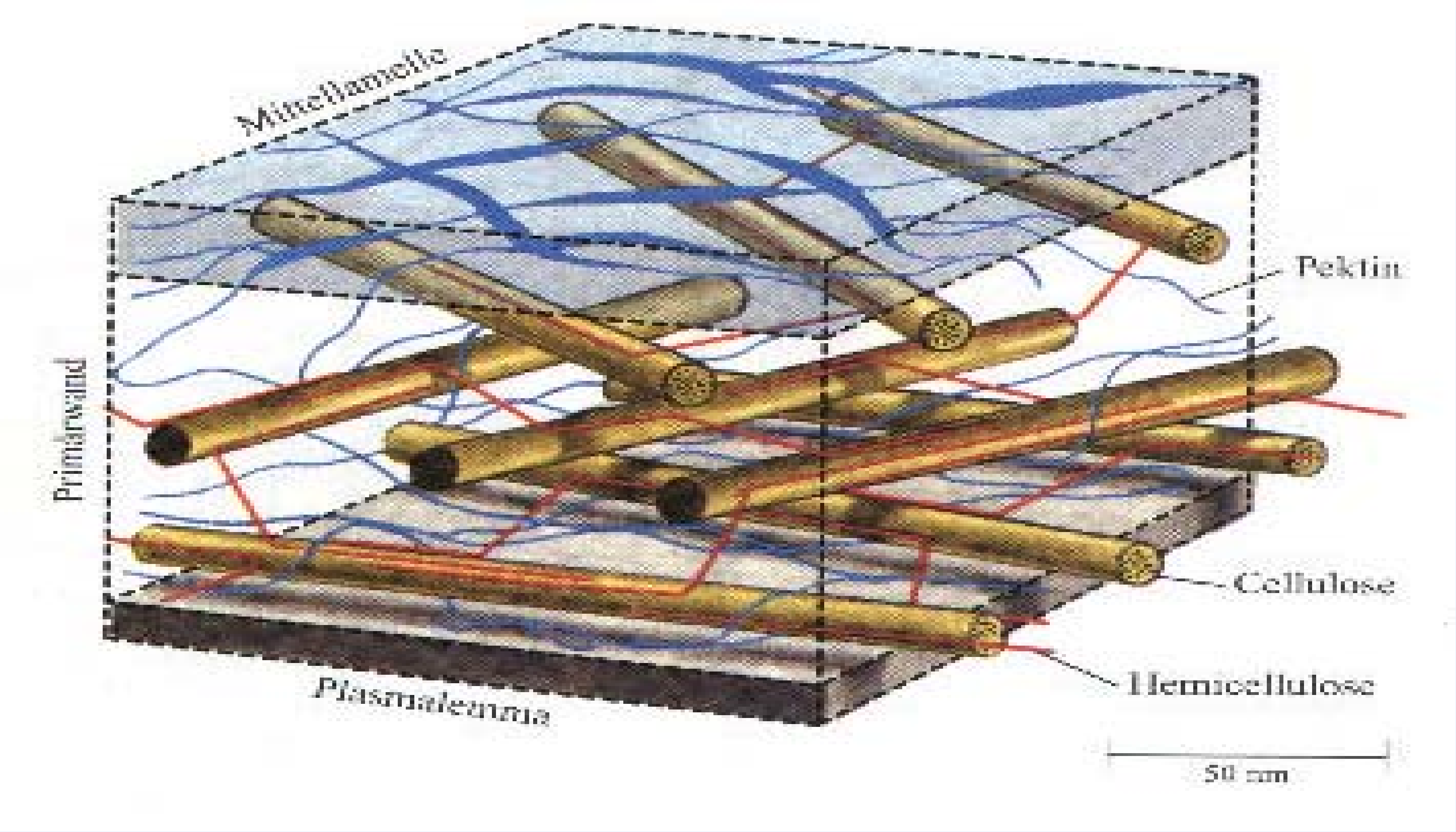


Orientation of cellulose

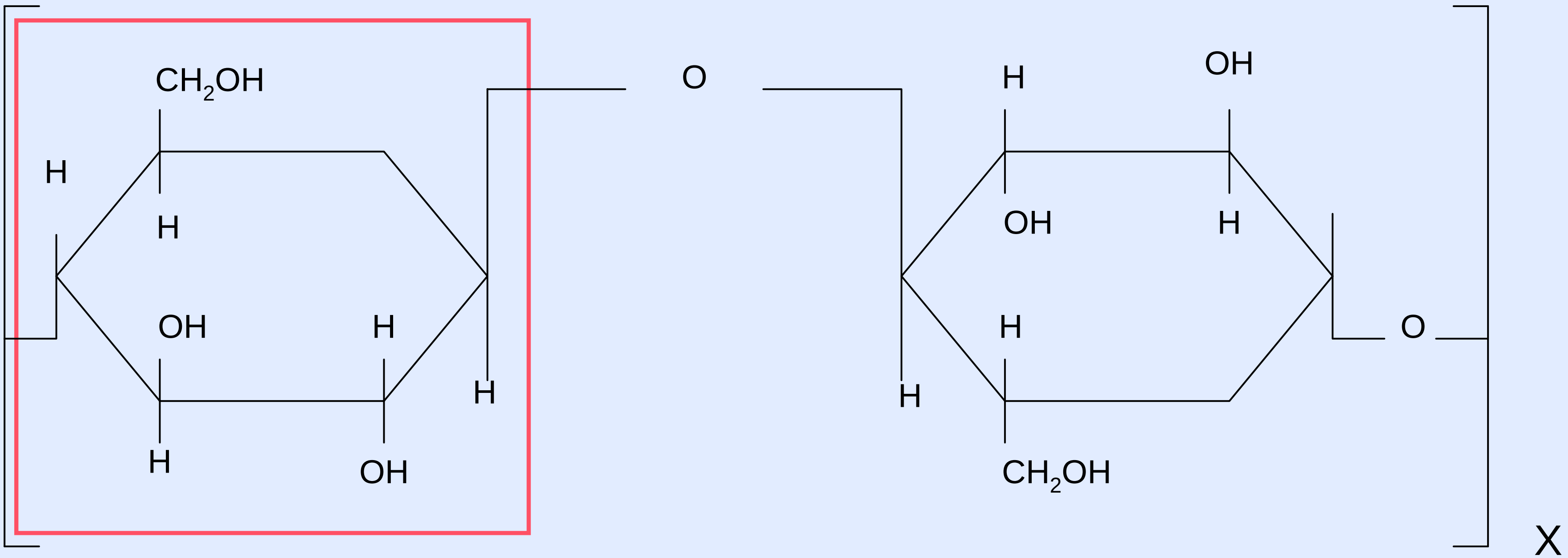




Cellulose formation



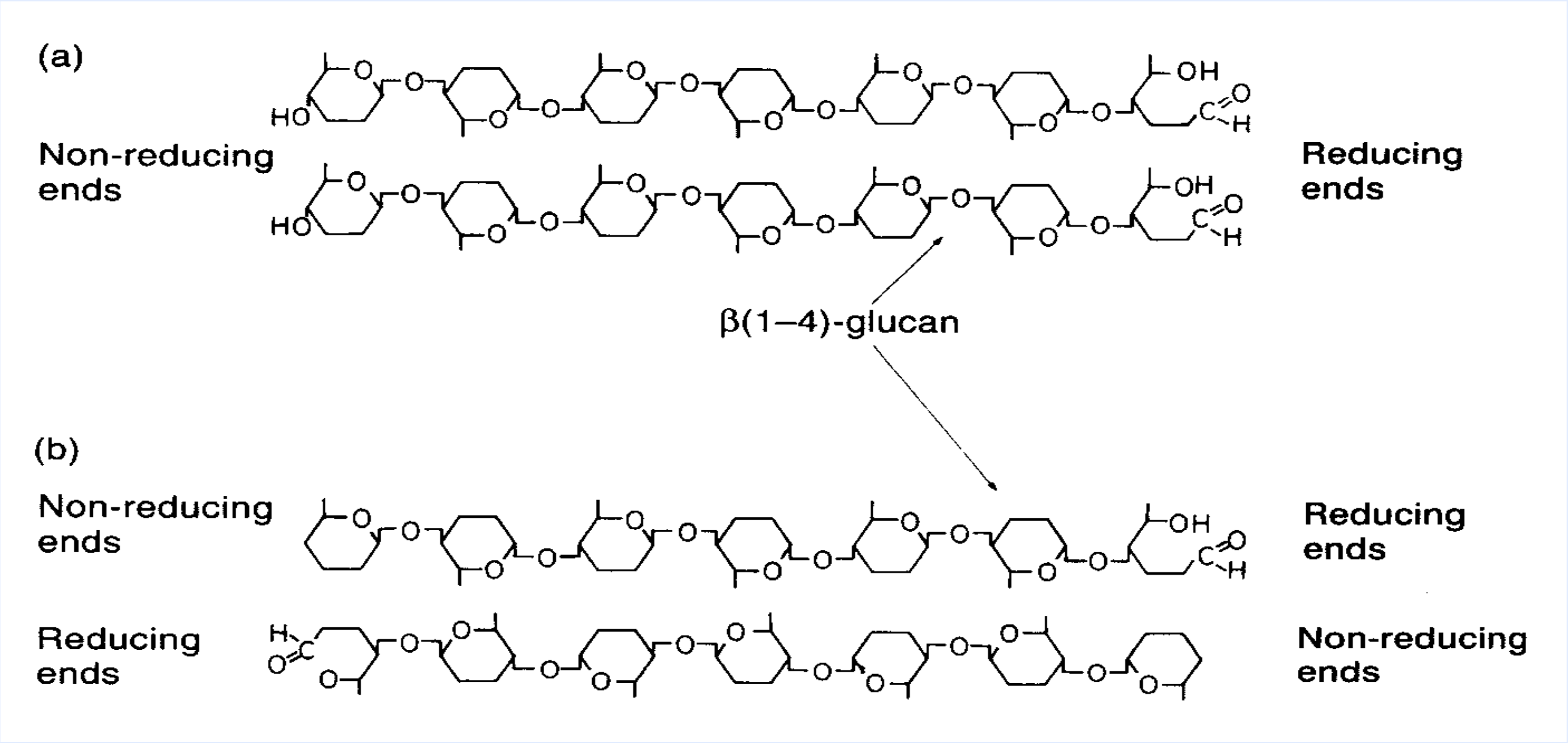
Chemical structure of cellulose



ß-D-glucose unit

X = degree of polymerisation

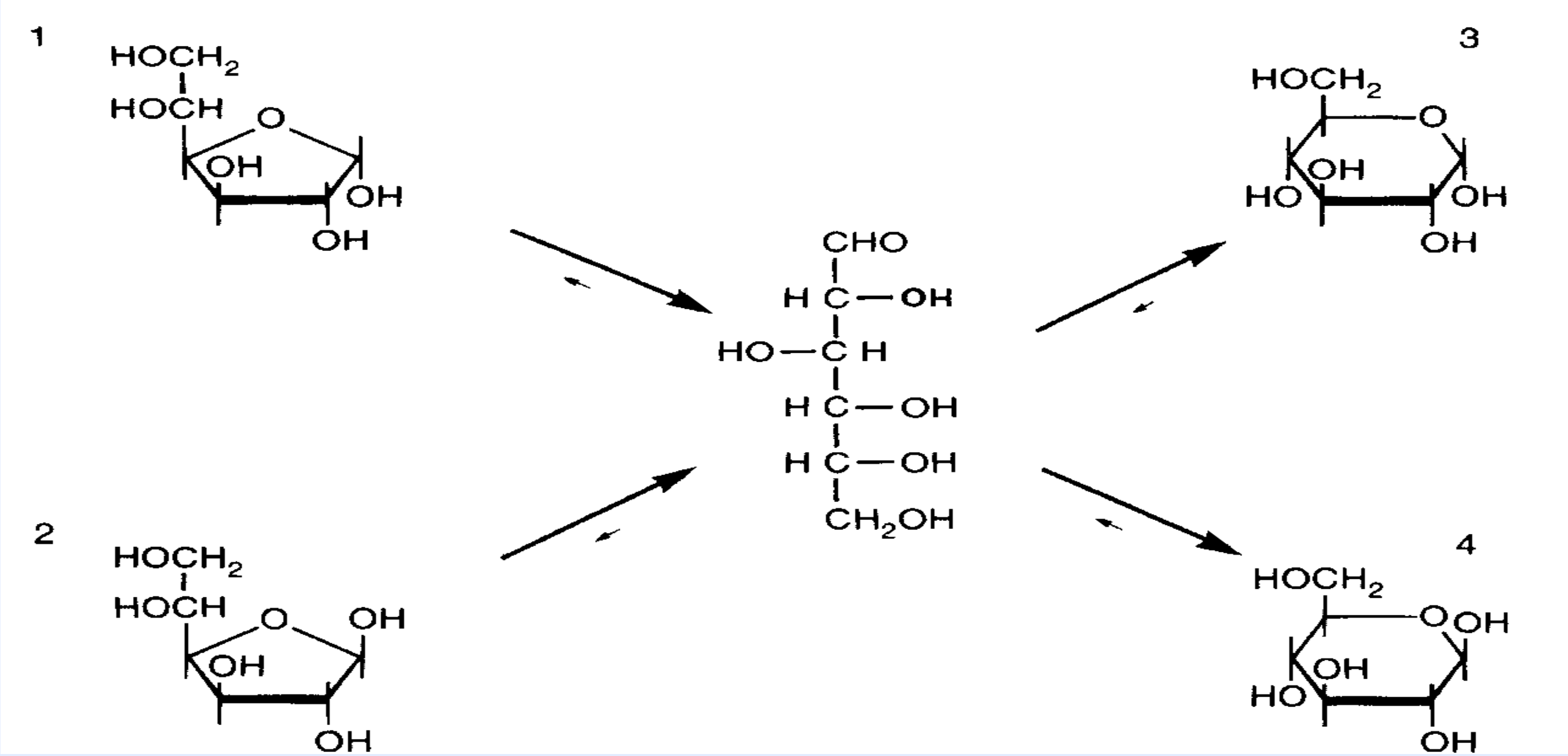
Cellulose in crystalline structure



(a): parallel configuration

(b): antiparallel configuration

Furanose - pyranose



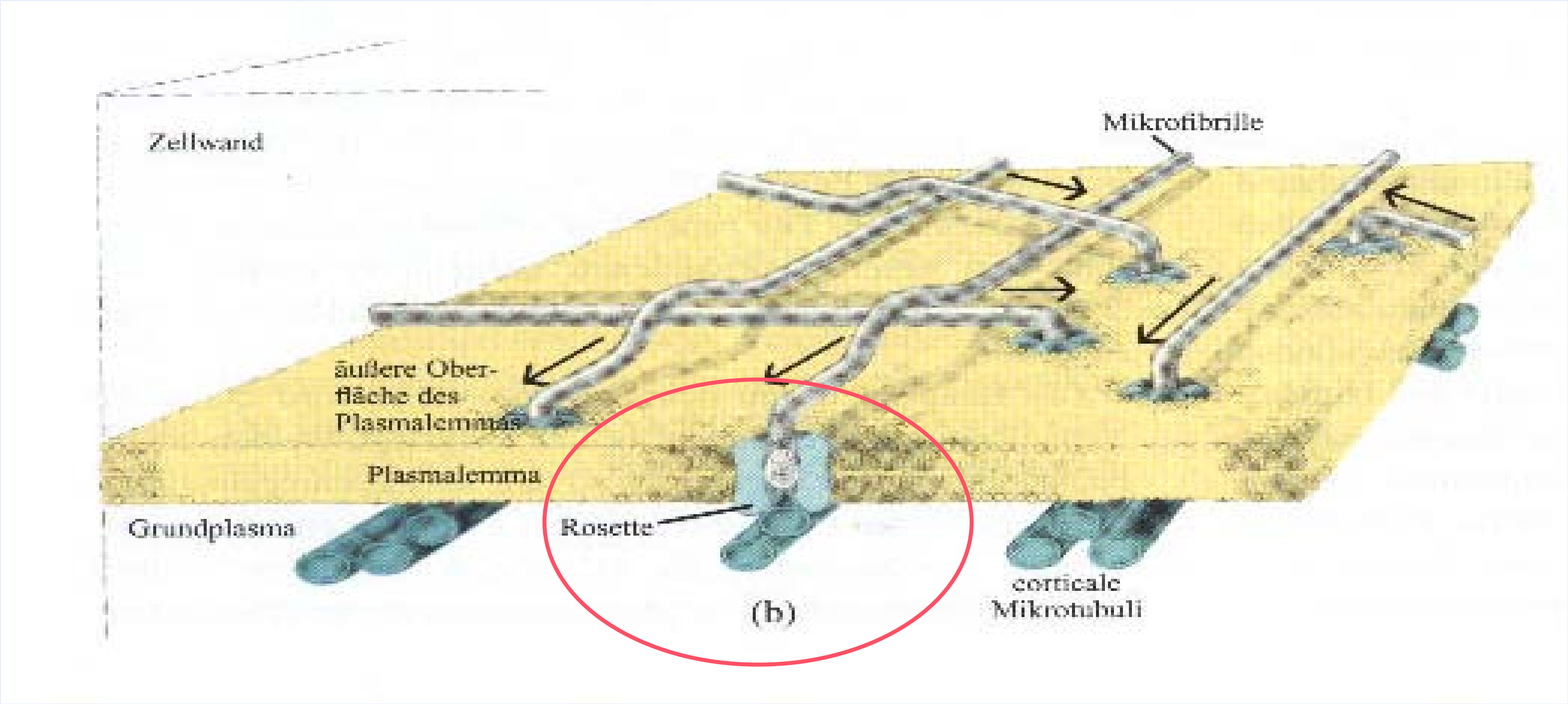
(1): α-D-glucofuranose (< 1%)

(2): β-D-glucofuranose (< 1%)

(3): α-D-glucopyranose (36 %)

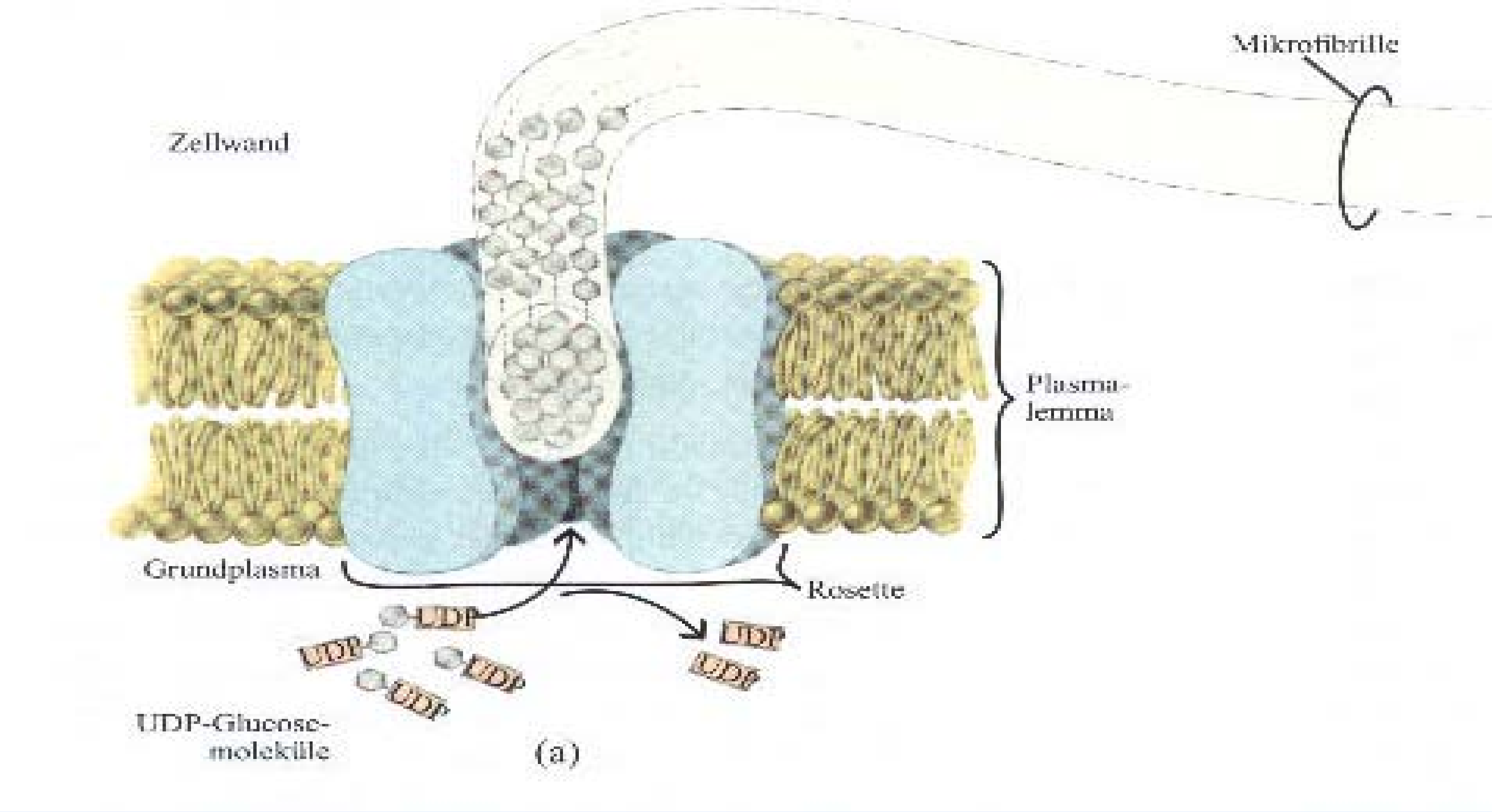
(4): β-D-glucopyranose (64 %)

Cellulose synthesis I



Cellulose synthetase is located in rosettes in the plasma membrane using UDP glucose as substrate for polymerisation

Cellulose synthesis II



Determination of holocellulose

1. Weigh in 2 g of extractive free wood and put in 100 ml Erlenmeyer and add 80 ml water
2. Add 0.25 ml acetic acid (100 %), 0.75 g $NaClO_2$ and close Erlenmeyer with a bubble or a cover
3. Put in hot water bath at 80°C for 1 h
4. Repeat steps from 2 and 3 three times for hardwoods and four times for softwoods
5. Cool the samples in ice water bath and filter the samples on a glass filter in a vacuum suction
6. Wash the samples with 100 ml ice water and than with 25 ml acetone
7. Put the samples on oven dried aluminium cups and dry at 105 +/- 3° C and than weigh the samples

Wise, L. E.; Murphy, M., D'Addieco, A. A. 1946: Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. Paper Trade J. 122:11-19

Literature

⇒ Higushi, T.: Biochemistry and Molecular Biology of Wood. Springer Series in Wood Science 1997

⇒ Nultsch, W.: Allgemeine Botanik, Thieme Verlag, 1991

⇒ Brett, C., Waldron, K.: Physiology and biochemistry of plant cell walls. Chapman and Hall, 1996

⇒ Heldt, H.: Pflanzenbiochemie, Spektrum Verlag, Heidelberg, 1999

⇒ Croteau, R., Kutchan, T., Lewis, N.: Natural Products (Secondary metabolites) in Biochemistry and Molecular Biology of Plants, eds. Buchanan, B., Gruissem, W., Jones, R. American Society of Plant Physiologists, 2000

⇒ Dixon and Palva: Stress-induced phenylpropanoid metabolism, Plant Cell 7, pp. 1085-1097

⇒ Lohmann, U.: Holzhandbuch, DRW Verlag, 1998

⇒ Taiz, L., Zeiger, E.: Physiologie der Pflanzen, Spektrum Akademischer Verlag Heidelberg Berlin, 2000

⇒ Boudet, A., M., Kajita, S., Grima-Pettenati, J., Goffner, D.: Lignin and lignocellulosics a better control of synthesis for new and improved uses, TRENDS in Plant Sciences, Vol. 8 No. 12, December 2003

⇒ Campbell, M., M., Sederoff, R.: Variation in Lignin Content and Composition, Mechnisms of Control and Implications for the Genetic Improvement of Plants, plant Physiology 110, pp. 3-13, 1996