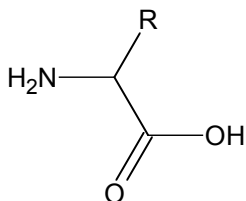


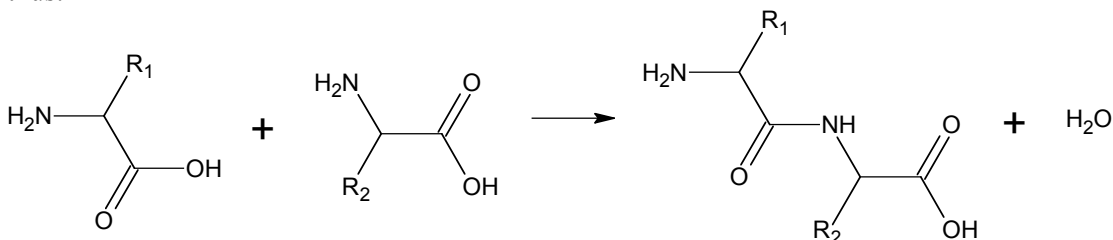
APPENDIX 2: TEXTILE FIBRE POLYMERS - NOTES.

WOOL

- Polypeptide, made up of amino acids, which have the general form:



- Formed by the peptide linkage union of α -amino acids (with the elimination of water), thus:



- The nature of the side group R creates the more-than 20 different amino acids, and thus the wide variation of proteins occurring naturally.
- In wool, R is distributed among the following functional groups (only those with >2% w/w are specified):

Structure	Name	Percentage (w/w) ¹
Inert:		
-H	Glycine	6.5%
-CH ₃	Alanine	4.1%
-CH(CH ₃) ₂	Valine	5.5%
-CH ₂ CH(CH ₃) ₂	Leucine	9.7%
Acidic:		
-CH ₂ CHOOH	Aspartic acid	7.3%
-CH ₂ CH ₂ COOH	Glutamic acid	16.0%
Basic:		
-(CH ₂) ₄ NH ₂	Lysine	2.5%
-(CH ₂) ₃ NHC(=NH)NH ₂	Arginine	8.6%
Hydroxyl:		
-CH ₂ OH	Serine	9.5%
-CH(OH)CH ₃	Threonine	6.6%
-CH ₂ C ₆ H ₄ OH	Tyrosine ²	6.1%
Ring:		
-CH ₂ -CH ₂ -CH ₂ -	Proline ³	7.2%

¹ Rounding errors result in total >100%.

² Structure involves a benzene ring with -OH group attached.

Double:



Cystine⁴

11.8%

Others:

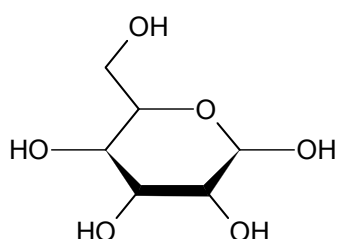
Phenylalanine, Histidine, Methionine, Tryptophan:

3.4%

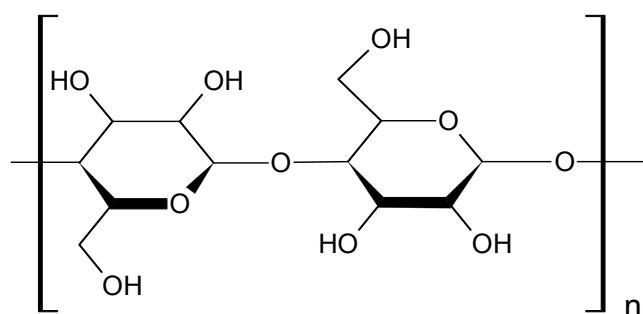
- The chemical properties of wool fibres are influenced by the properties of these functional groups – clearly there is a huge range of reactivity possible.
- Interaction of other molecules through covalent bonding, hydrogen bonding or van der Waals forces is possible.
- Dissolution of the fibre can be achieved by strong alkali, which disrupts the disulphide bond, then breaks down the polypeptide chain.
- Not easily wet with water (surface is hydrophobic), but the interior is very hydrophilic.

COTTON

- Cellulose is poly(1,4β-anhydroglucose), with glucose as the monomer unit:



- β-glucoside linkages form between carbon atoms 1 and 4, with the loss of water (hence the name anhydroglucose), to form the polymer, thus:



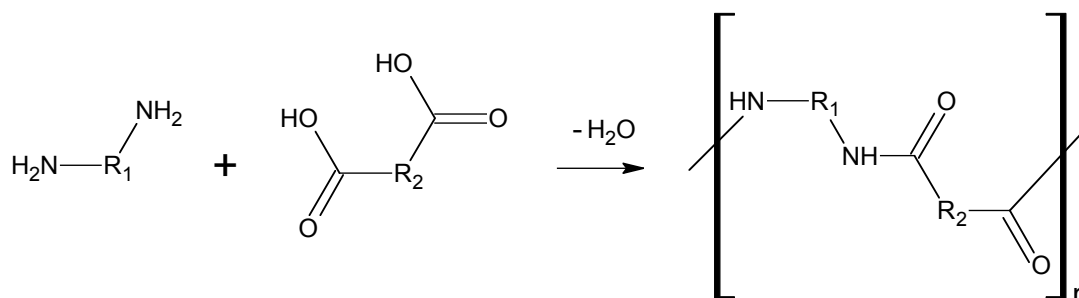
- In cotton the degree of polymerisation is ~10,000 (c.f. linen ~36,000 and viscose ~400), with a high level of orientation of the chains (linen is even more highly oriented).
- Chemical reactivity of cellulose related to:
 - i. β-glucoside linkages, which can be hydrolysed under strongly acidic conditions.
 - ii. -OH groups, in small molecules they confer water solubility, but the high degree of polymerisation and order prevent this. They provide the only site for reactivity and hydrogen bonding. Van der Waals interactions are also possible.
- Wettable and highly absorbent (-OH groups).

³ Attaches to the central C and also to the adjacent N of the amino acid (displacing one of the Hs from the latter).

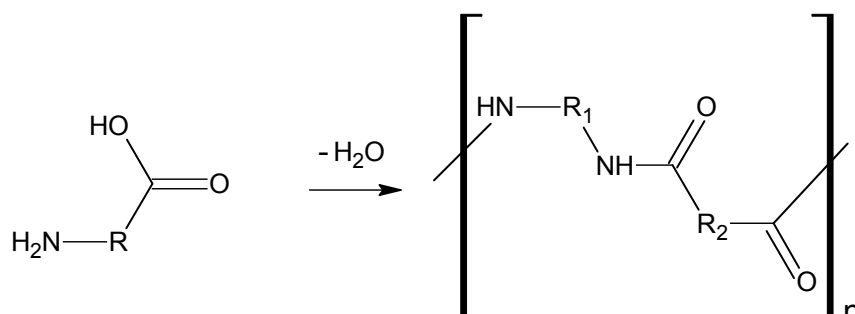
⁴ Attaches between adjacent protein chain molecules or between two positions in the chain; and therefore a function of polypeptide systems only. The reduced form, cysteine (-CH₂SH), is the precursor amino acid (also formed by disruption of the disulphide bond).

NYLON

- Polyamide, formed by condensing di-amines with di-acids. For example, nylon 6.6⁵, where $R_1=6$ and $R_2=6$:



- Alternatively, formed by polymerising amino acids. For example, nylon 6, where $R=6$:



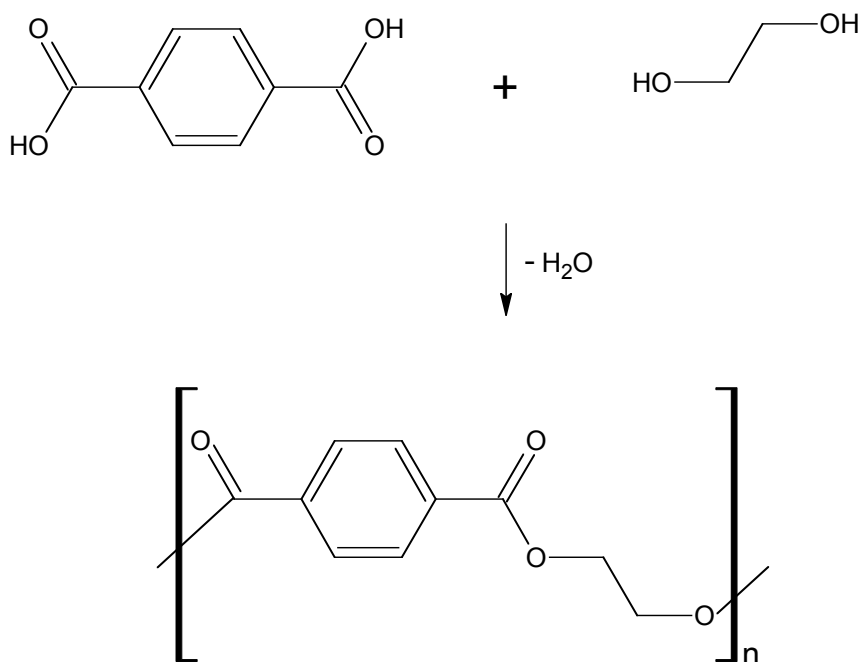
- The R groups can be aliphatic (straight carbon chains) as in the examples above, or alicyclic (saturated ring), or aromatic (benzene ring) such as Kevlar or Nomex.
- Nylon 6.6 has a degree of polymerisation of about 50-100 and is highly crystalline. There is also a substantial degree of hydrogen bonding between polymer chains.
- Low absorbency (in spite of hydrogen bonding sites), due to high crystallinity, low chemical reactivity, but easy to dye because polar amines attract polar dyes, and disperse⁶ dyes are attracted to hydrocarbons.

POLYESTER

- Polyester is prepared by the condensation of terephthalic acid with ethylene glycol (diagram on next page).
- Very high crystallinity – aromatic groups reduce flexibility of the chain, and there is high inter-chain attraction between aromatic nuclei.
- Low absorbance due to crystallinity and no polar groups (i.e. no $-\text{OH}$ or $-\text{NH}_2$).
- Low reactivity, only vulnerable to surface ester hydrolysis in hot alkali. Dyed with disperse dyes under high temperature and pressure.

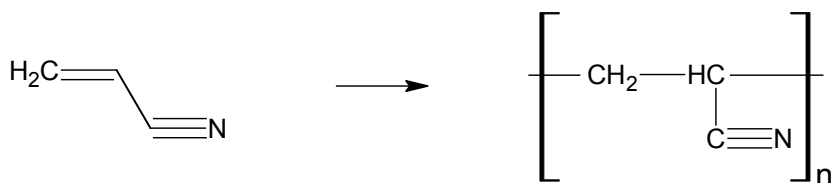
⁵ Aliphatic polyamides are named by quoting the number of C atoms in the repeating unit, (or units for poly(amides) made from two reactants – nylon 6.6 has 6 carbon atoms in the di-amine and 6 carbon atoms in the di-acid).

⁶ Disperse dyes are insoluble in water (they form a dispersion in the dyebath) and are ‘forced’ into the fibre using additives and high temperature and pressure. They are soluble in organic solvents.



ACRYLIC

- Polyacrylonitrile is an addition polymer formed from the monomer acrylonitrile via free radical initiation:



- The polymer is actually atactic⁷ with low crystallinity, but there are strong attractions between CN groups and H atoms on adjacent chains (hydrogen bonding) to provide an excessively compact structure (difficult to dye).
- Copolymerised with up to 15% of another monomer, sometimes incorporating aromatic rings, which open up the structure, allowing penetration of dyestuffs.
- Low absorbency (due to tight structure), in spite of hydrogen bonding, low reactivity (including resistance to oxidising agents), although hot alkali can degrade.

POLYPROPYLENE

- Polypropylene is an addition polymer formed from the monomer propene (a.k.a. propylene) via stereo-selective polymerisation using Ziegler/Natta catalysts (diagram on next page)
- No hydrogen bonding, but highly ordered nature means very chains are in close proximity and van der Waals interactions are therefore strong.
- No absorbency (no polar groups), and chemically inert (only strong oxidiser or boiling organic solvent will degrade). Cannot dye by normal means (have to dope dye).

⁷ Uncontrolled addition polymerisation produces atactic polymers that have irregular stereochemistry and tend to be grease-like. Generally the isotactic or syndiotactic (with uniform or alternating bond positions respectively) forms are required. These structures can approach very closely to each other, which enhances the hydrogen or Van der Waals bonding. Catalysts are used to preferentially form these types.

