From cell to higher structures II (animal and plant tissues)

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Content

1. Plant tissues

A) Covering tissues
B) Basic tissues
C) Conducting tissues

2. Animal tissues

A) Connective tissue
B) Epithelial tissue

3. Tissue maintenance and renewal

Plant tissues

Do plant cells need a wall?

1) A plant cell stripped of its cell wall is very **fragile**

2) Even a small change in osmotic pressure can cause it to swell and rupture because the **plant cell lacks intermediate filaments**

3) **The cell wall is** therefore **essential** for the cell

Primary and secondary cell wall

The newly emerging plant cell first forms **a primary cell wall** - it is able to expand as the cell grows

Based on the osmotic imbalance between the inside of the cell and its surroundings, **a botnavial pressure = turgor**

Turgor controls the growth of the cell

After the cell growth stops, **a stronger secondary cell wall** is formed. Depending on the specialization of the cell, it can be waxy, woody, etc...

The cell wall is resistant but not rigid

Osmotic swelling

Fresh salad

Withering salad

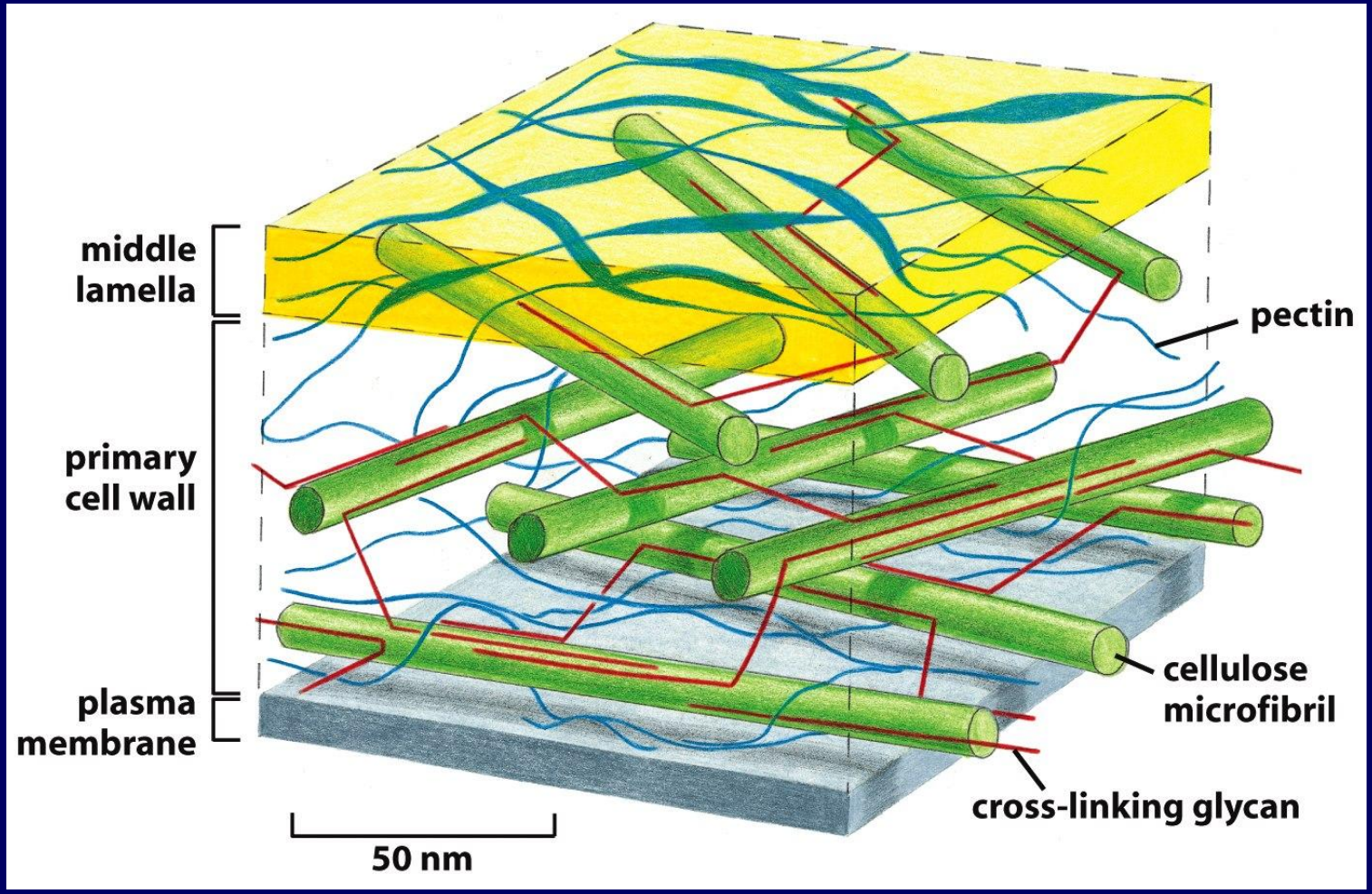
Cell wall as extracellular matrix

It is composed of long fibres oriented in the direction of pressure. These fibres are usually composed of the polysaccharide **CELLULOSE**, which gives the cell wall its tensile strength

The cellulose fibres are interwoven with other polysaccharides (**pectin, glycan, hemicellulose**) and some structural proteins to form a very strong complex structure

The **lignin network** also contributes to the strength and impermeability to water of the woody mesh

Primary plant cell wall model



The middle lamella connects two adjacent cell walls

Plant cell wall formation

Cellulose is synthesized outside the cell by enzyme complexes that are embedded in the plasma membrane

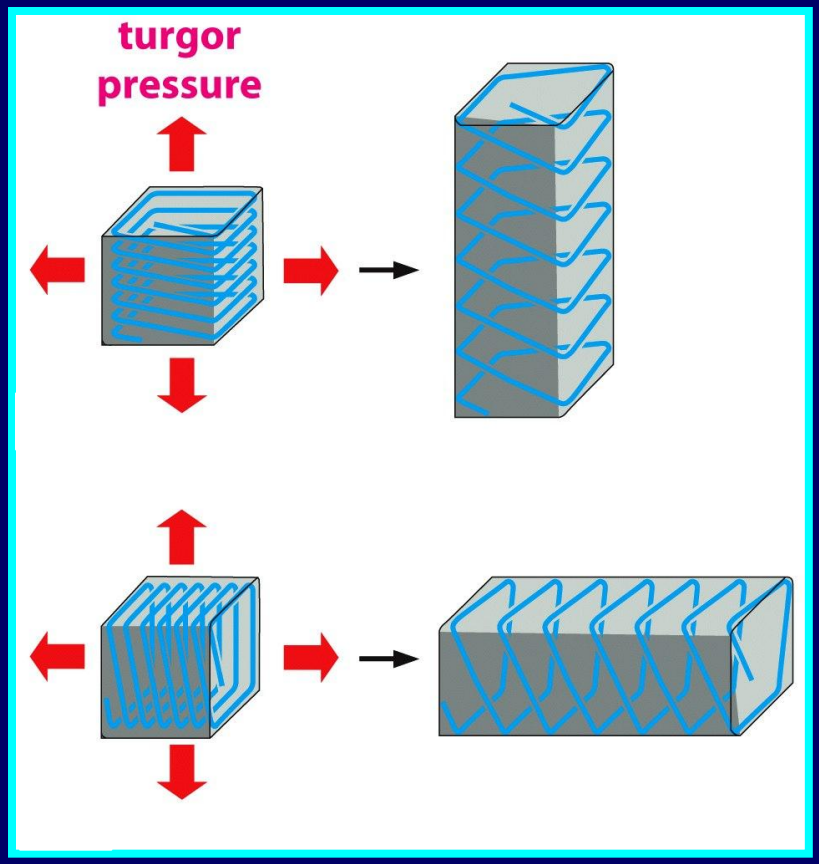
The process of cell wall formation

- transport of carbohydrate monomers across the membrane
- incorporation of the monomer into the growing polymer chain at the point where the chain is attached to the membrane
- the individual cellulose chains join together to form microfibrils
- Similarly oriented microfibrils form fibrils

Direction of plant cell wall growth

Enzyme complexes move in the membrane while synthesizing cellulose. The pathways in which the enzyme complexes move determine the direction in which cellulose is deposited = **ORIENTED DEPOSITION OF CELLULOSE INTO THE CELL WALL**

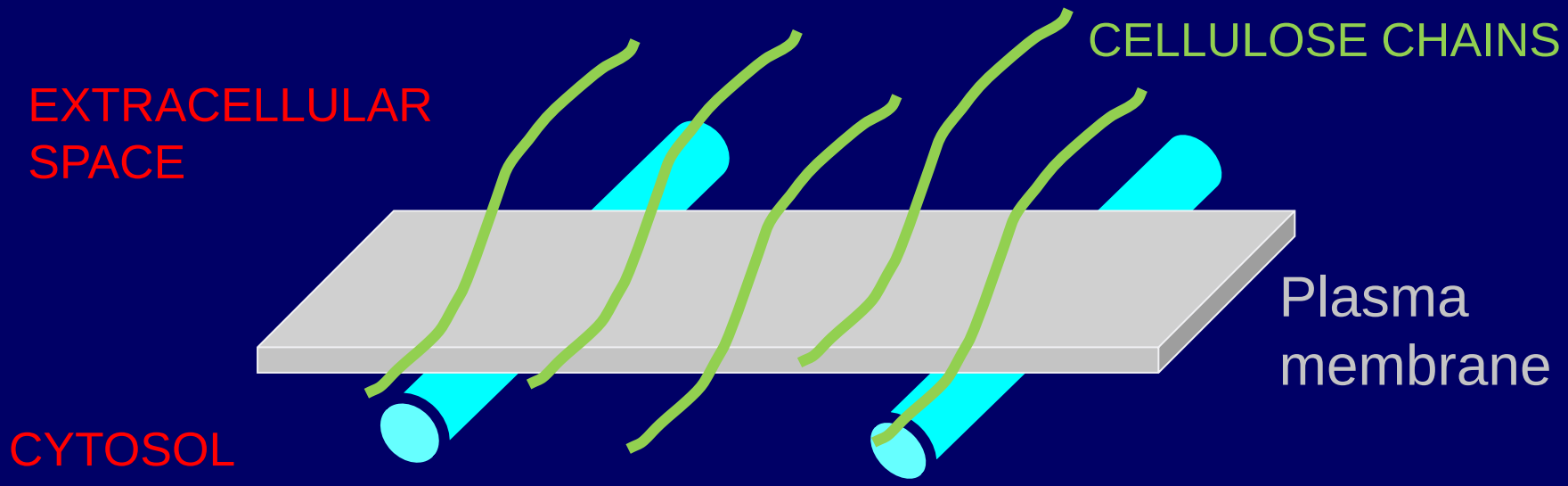
This allows the cell wall to better resist the tartar pressure - turgor



The cell elongates in a direction perpendicular to the orientation of the microfibrils

What controls enzyme complexes?

- Beneath the plasma membrane are microtubules arranged according to cellulose fibres outside the cell
- Microtubules direct the movement of enzyme complexes
- In this way, microtubules regulate the shaping of the plant cell and the patterning of the tissue



Microtubules attached to the plasma membrane

The stem cells of a plant growing in the dark orient their microtubules horizontally. How does this affect the growth of the plant?

Microtubules horizontally = cellulose fibres horizontally
→ cell will grow vertically
→ stem elongates vertically = escape from darkness

Plant tissue - one more definition

A collection of cells of common origin, structure and function

Tissues exist only in vascular plants

Clasification of tissues

According to the ability to divide

- Meristematic (dividing) tissues
- Permanent tissues (formed by the action of dividing tissues and fulfilling a specific function)

According to the function

COVERING TISSUES – cover the surface of the plant

CONDUCTING TISSUES – conduction of solutions in the plant body

BASIC TISSUES – all other cells in the plant located in the space between the covering and conducting tissues

Covering tissues 1/3

- These are the primary outer tissues
- They form a protective outer layer that is in contact with the external environment
- Facilitates the entry of water and ions into the roots, regulates gas exchange in the stems and leaves

The cell types

- **Epidermal cells (form the epidermis)**
- **Modifications of epidermal cells - ducts, trichomes...**

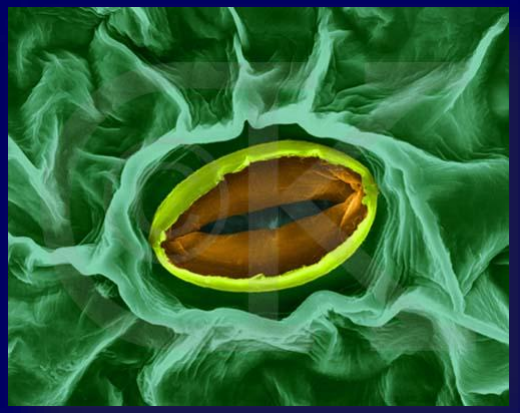
Covering tissues 2/3

1. Epidermal cells (epidermis)

It forms a single cell layer covering the stem, leaves, roots,... The cell walls may be covered with a waxy layer. Protects against desiccation and regulates gas exchange through vents.

2. Ducts (100 per 1mm^2 of leaves epidermis)

They are holes in the epidermis. Brightness of the pore is regulated by two specialized epidermal cells
= clamp cells around the pore (ventral cleft). The clamp cells react to changes in turgor -
- they hatch and the fissure enlarges.



Covering tissues 3/3

3. Trichomes

They are superficial outgrowths of epidermal cells
They have different shapes and different functions

- unicellular (root hair)
- multicellular (secretory-glandular trichome)

- covering (protects against excessive water evaporation, sun, herbivores)
- grandular (produce essential oils, ethers...used for protection, trapping insects)
- absorption (water and mineral absorption in epiphytic plants)

Basic tissues 1/5

They account for most of the plant's weight

Functions as assimilation, storage, excretion

Types of cells in basic tissues

1. Parenchyma (the most common)
2. Sclerenchyma
3. Collenchyma

Basic tissues 2/5

Parenchyma - Parenchyma cells are found in all types of plant tissues. They are living cells with a thin cell wall. They have many functions and are capable of further division.

- **Meristem cells**
  - in the apical and lateral growth apices
  - in root tips

  They are the most proliferatively active and produce new cells for plant growth

- **Mesophyll cells**

  They're cells in the leaves and stems. Photosynthesis takes place in them.

Basic tissues 3/5

Parenchyma - Parenchyma cells are found in all types of plant tissues. They are living cells with a thin cell wall. They have many functions and are capable of further division.

- **Storage cells**
  they store the sugars and other organic substances formed in them They make up most of the weight of fruit and vegetables.
- **Transfer cells**
  are characterized by complex layers of cell wall and plasma membrane. The increased surface area facilitates rapid transport of nutrient solution from cell to cell = **xylem parenchyma**

Basic tissues 4/5

Sclerenchyma - cells with strongly and **uniformly thickened secondary walls**

- The lumen of the cell is often compressed and occupies a tiny volume
- Protoplast sometimes dies, wall lignifies
- Occurrence often in the woody or bast part of conductive meshes

Performs a mechanical function

It occurs as single cells (sclereids,...) or as a continuous tissue (flax fibres)

Basic tissues 5/5

Collenchyma

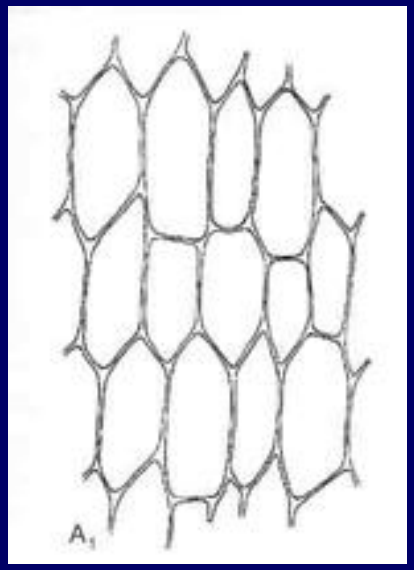
- Cells with an **unevenly thickened cell wall** that is thicker than that of parenchymatous cells
- In contrast to sclerenchymatous cells, the secondary wall is absent
- Therefore, they can grow with the growth of the whole plant

Even in adulthood, these cells are alive and form a strong and flexible support for the leaves or stem

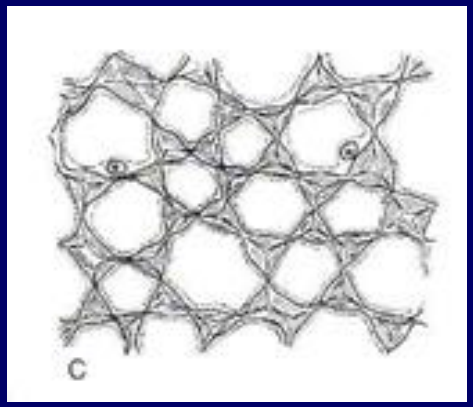
Occur in stems, petioles, may contain chloroplasts

Simple comparison

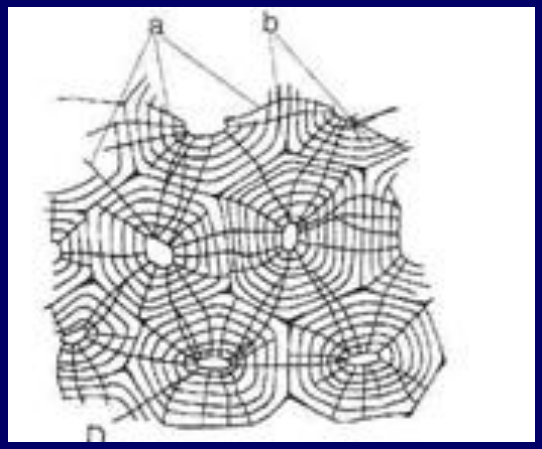
Parenchyma



Collenchyma



Sclerenchyma



Conducting tissues 1/4

- These tissues transfer water, ions and solutes between organs and provide mechanical support for the plant
- Forms vascular bundles running through the entire plant composed of **XYLEM** and **PHLOEM**
- Conducting cells are in contact with parenchymal cells (active transport of some ions takes place there)
- **Mechanical support is provided to the vascular bundles by groups of collenchyma and sclerenchyma cells**

Conducting tissues 2/4

XYLEM - transfers water and dissolved ions from the soil to the whole plant, i.e. from the root to the leaves. This is the so-called **upward - transpiration current**

Consists of

- **tracheids and tracheae**. These conducting cells are dead cells in adulthood (apoptosis) without a plasma membrane with a thickened and friable secondary wall. The end wall is lost and so long tubes are formed.
- **xylem fibers**
- **xylem parenchyma**
- **xylem schlerenchyma**

Conducting tissues 3/4

PHLOEM – serves to distribute assimilates from the leaves to the roots, but also to other non-green parts of the plant such as flowers, fruits and seeds. Most often it is the distribution of sucrose, water and other organic substances. This is the so-called **assimilation stream**.

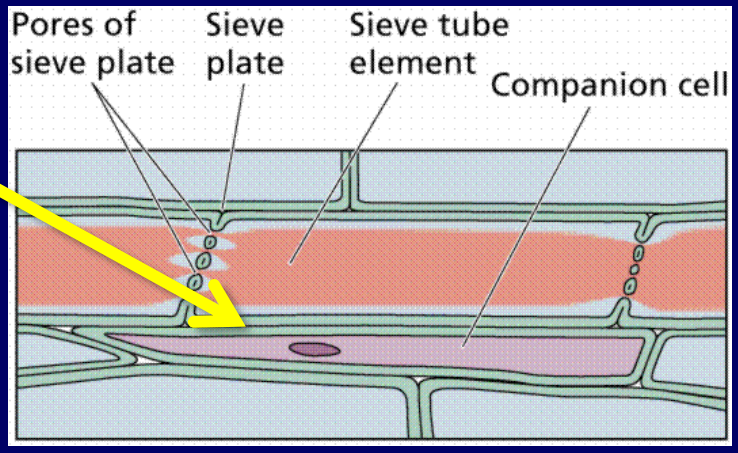
Consists of sieve tubes, companion cells, bast fibers, phloen fibers, intermediary cells, and phloem parenchyma. Sieve tubes are arranged into long tubes. Even in adulthood, they are living cells with a plasma membrane, but without nucleus, ribosomes, vacuoles.

These conductive cells are connected to each other by perforations = enlarged and modified **plasmodesmata**

Conducting tissues 4/4

Metabolic and other functions are handled by **companion cells**

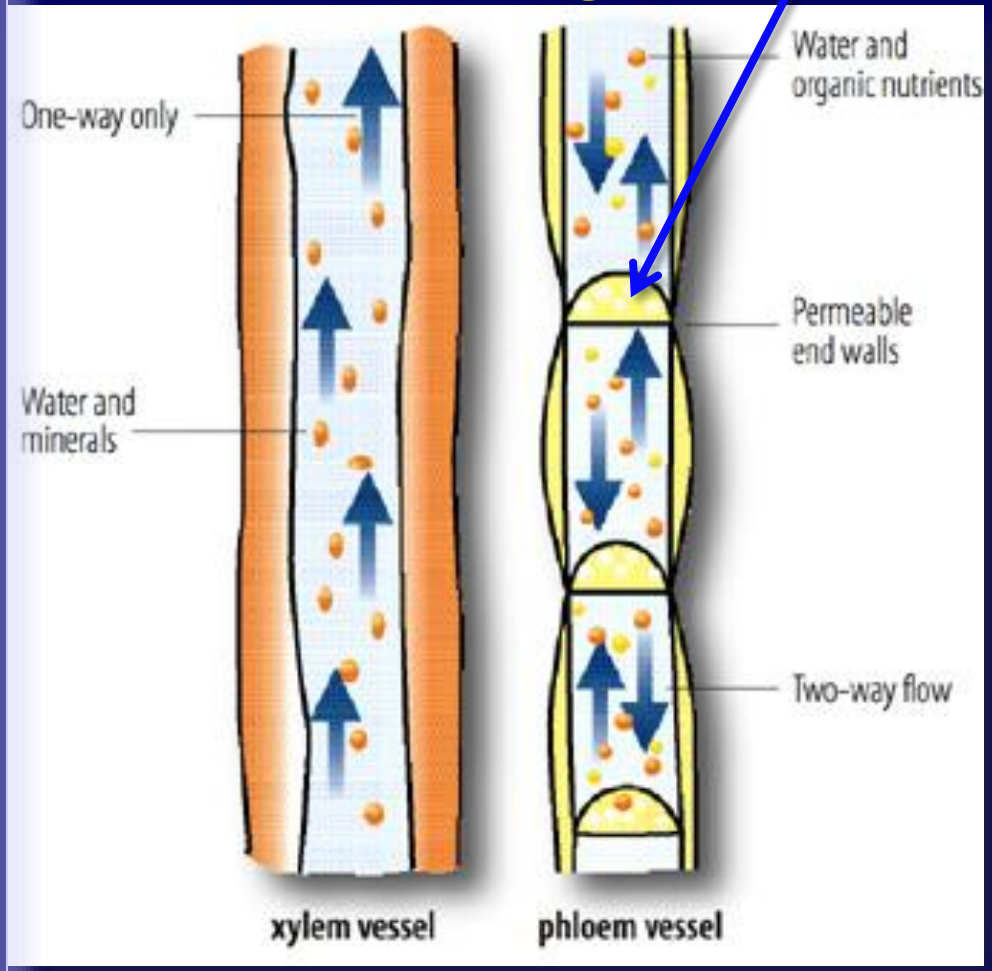
They are formed together with sieve nets uneven distribution of a single mother cell.
From the larger cell becomes a sieve cell, the smaller one becomes the parent cell.



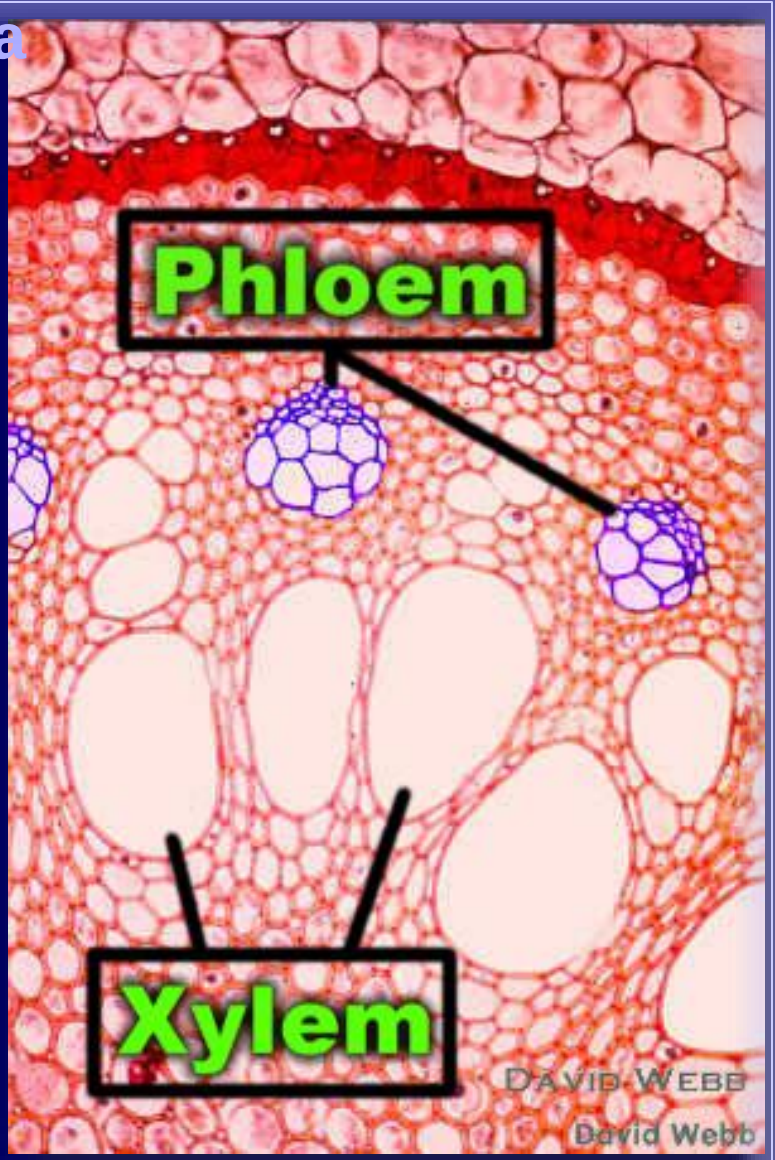
Companion cells also help to actively transport soluble nutrient molecules out of the sieve cells through porous lateral plates in the sieve cell wall.

plasmodesmata

FLOEM



XYLEM



Cross-cut by root

Animal tissues

Diversity of animal tissues

Traditionally, there are four main types of animal tissues

- **connective tissues**
- **epithelia (epithelial tissues)**
- **nervous tissues**
- **muscle tissues**

The difference between connective tissue and the rest

It is the main one in terms of structure and structure of tissues

Connective tissues

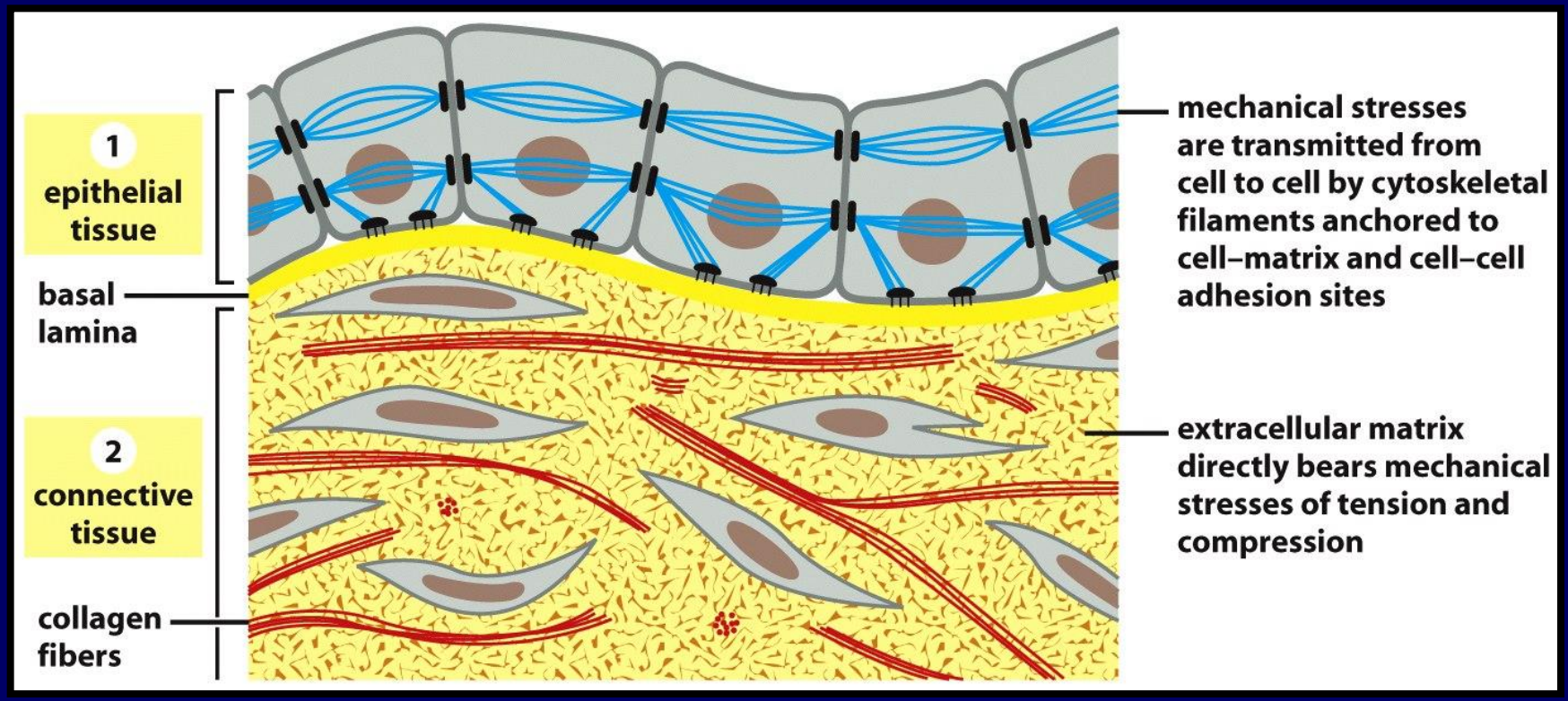
Bones, tendons, cartilage, vitreous

Much of the tissue is made up of extracellular matrix. Cells producing this matrix are scattered in it independently. The basis of the extracellular matrix is COLLAGEN.

Epitheail tissues

The extracellular matrix is in the minority - it forms a thin layer - the basal lamina. Cells are connected to each other and to the basal lamina. The mechanical load is carried by their cytoskeleton.

The difference between connective tissue and the rest



CONNECTIVE TISSUE

The tensile strength of tissues is determined by

In plants by the presence of CELULOSIS

In connective tissues, fibrillar protein is the basis of COLLAGEN

- occurs in all multicellular animals - in mammals it represents 25% of the total amount of all proteins
- there are many variants of collagen - mammals have about 20 genes for collagen

Other important components are

PROTEOGLYCANS

Cells in connective tissue

- Fibroblasts, fibrocytes in skin, tendons
- Chondroblasts, chondrocytes in cartilage
- Osteoblasts, osteocytes, osteoclasts in bone

Cells produce collagen and other matrix components. Collagen molecules are synthesized intracellularly, released by exocytosis, and arranged into polymeric units outside the cell, and these up to large aggregates.

Collagen molecules are secreted in the form of the precursor PROCOLAGEN (to avoid overwhelming the cell with formed aggregates). The enzyme COLAGENASE cleaves the terminal peptides from procollagen to the outside of the cell, which then allows the subsequent formation of collagen structures.

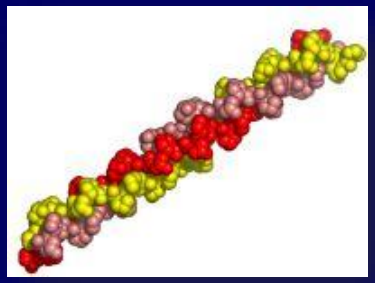
Extracellular matrix in connective tissue

COLLAGEN

PROTEOGLYCANS

Collagen

Provides tensile strength



Collagen structure

- The collagen molecule has a triple helical structure (three polypeptide chains wrapped around each other)
- The collagen molecules then form fibrils (polymer)
- Collagen fibrils form thicker collagen fibres

Arrangement of collagen fibrils

Fibroblasts not only secrete collagen, but also control its deposition and the orientation of collagen fibrils - they move over it, stretch it and help to strengthen it.

Tanned skin is macerated collagen

Disorders in the assembly or cross-linking of collagen

Hyperelastic skin, e.g. glycine replacement
(each third aminoacid is GLYCINE)

Some types of collagen, tissue distribution 1/2

Fibril-forming collagens

Collagen I. + V.	Bones, skin, tendons, internal organs
Collagen II. + XI.	Cartilage, intervertebral discs
Collagen III.	Skin, blood vessels, internal organs

Collagen polymerising into a flat sheet

Collagen IV.	Basal lamina

Collagen forming adhesion fibrils

Collagen VII.	Layered lining under tile epithelium

Some types of collagen, tissue distribution 2/2

Collagens associating with other fibrils

Collagen IX.	Cartilage, intervertebral discs
Collagen IV.	Cartilage, intervertebral discs

Non-fibril-forming collagens

Transmembrane collagen XVII	hemidesmosomes
Proteoglycan core - collagen XVIII	basal lamina

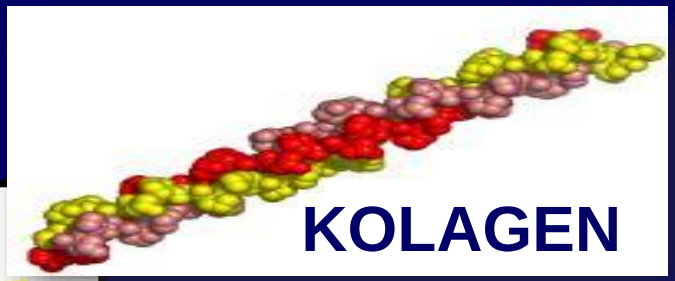
The cause of the pathology may be a mutation in the gene for collagen, but also for collagenase → in a poorly functioning collagenase

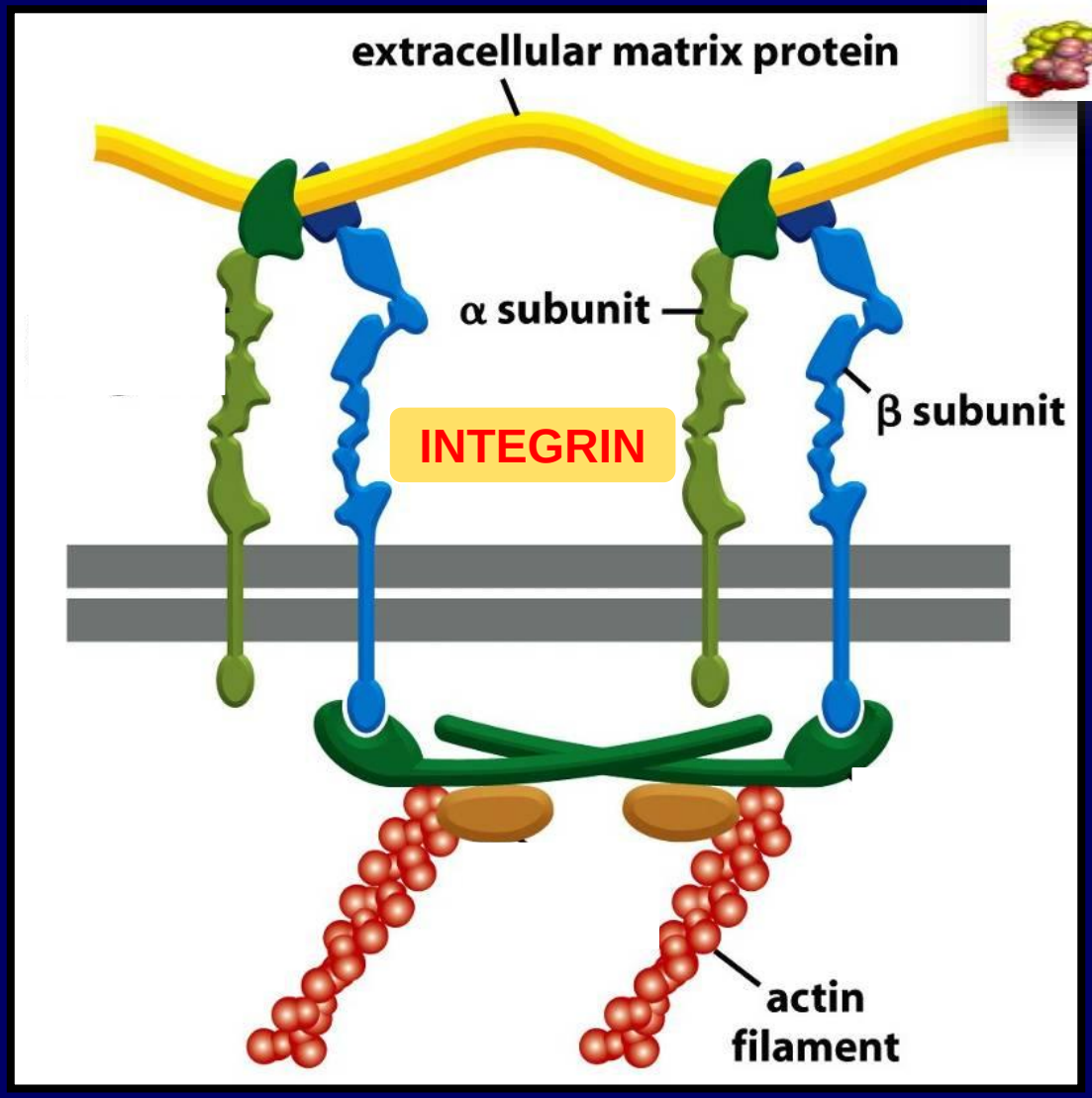
How do they hold the cells in the matrix?

Cells (fibroblasts, osteoblasts) attach to the extracellular matrix (collagen) via the fibronectin molecule

- One end of **fibronectin** binds to **collagen**
- The other end binds to the extracellular portion of the transmembrane receptor protein **INTEGRIN**
- The intracellular part of the integrin molecule attaches to actin filaments - part of the cytoskeleton

In this way, the tension between the cell and the matrix is transferred via integrin molecules to the cell cytoskeleton. This allows tissues to withstand great force.





Plasmatic membrane

Proteoclycans

Aggrecan, Perlecan, Decorin, Betaglykan, …

The structure

They are diverse extracellular molecules. The core of the molecule is made up of proteins to which are attached negatively charged molecules - **glucosaminoglycans** (**GAGs**), which are 95% composed of a carbohydrate component (polysaccharides).

Examples of GAG molecules

- ☺ chondroitin sulphate
- ☺ keratan sulphate
- ☺ hyaluronic acid and its derivatives

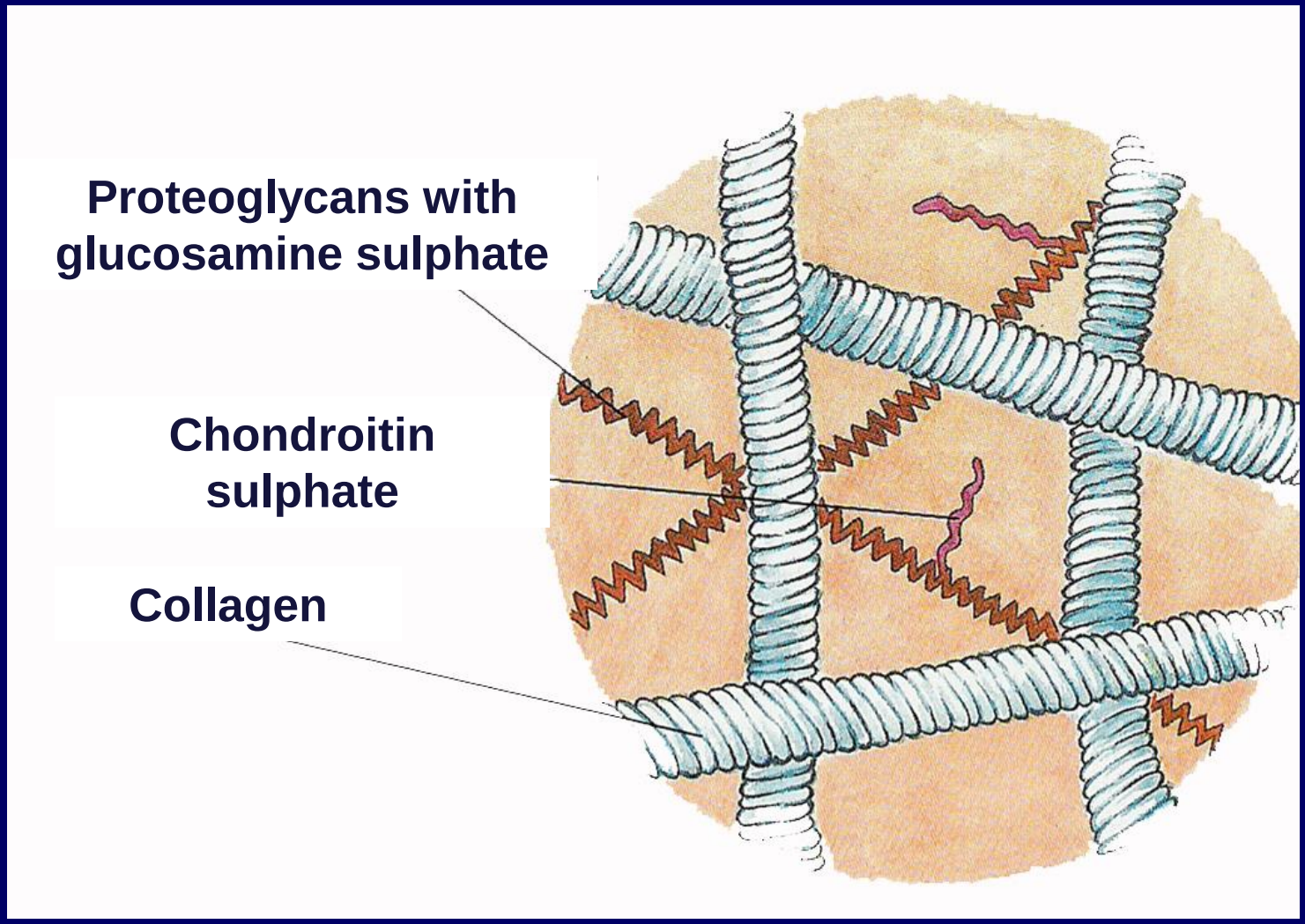
Proteoglycans and the collagen network

Proteoglycan molecules are retained in the collagen network → the matrix is strong, flexible and resistant to pressure

Function

- filling material preventing compression of the extracellular matrix
- formation of gels with different pore sizes and charge densities serving as filters
  - ☺ regulate the passage of molecules through the matrix
  - ☺ control the migration of cells in the matrix (blockage, stimulation)
  - ☺ binding of growth factors and other signalling proteins

Cartilage


Proteoglycans with glucosamine sulphate
Chondroitin sulphate
Collagen

Amount of proteoglycans

The amount of proteoglycans in the extracellular matrix (EM) varies by tissue type

Compact connective tissue (tendon, bone)

- EM composed mainly of collagen
- little glucosaminoglycans (GAGs)

+ calcium phosphate crystals

Rosolic connective tissue (vitreous humor of the eye)

EM composed of a very small amount of collagen, only one type of glucosaminoglycan molecules and water

EPITHELIA (EPITHELIAL TISSUES)

Where are the epithelia located?

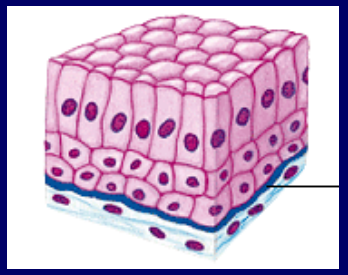
Epithelia cover the outer surface of the body and line all the internal cavities. They can be made up of one or more cell types and can fill

A WIDE VARIETY OF FUNCTIONS

- **protective barrier** ...covering epithelium
- **secretion of hormones, enzymes, tears, milk**, ... glandular epithelium
- **absorption of nutrients** (intestinal epithelium) ...resorptive epithelium
- **elimination of substances** (tubular epithelium)
- **formation of sex cells** (germinal epithelium)
- **detection of signals** (photoreceptors, hair cells in the inner ear)

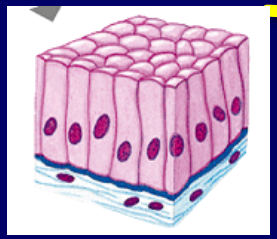
Epithelia predominate

There are about **230 distinguishable cell types** in the vertebrate body, up to **60% of which are organized into epithelia** (cells are joined together to form a continuous layer)



Layered
(multilayered)

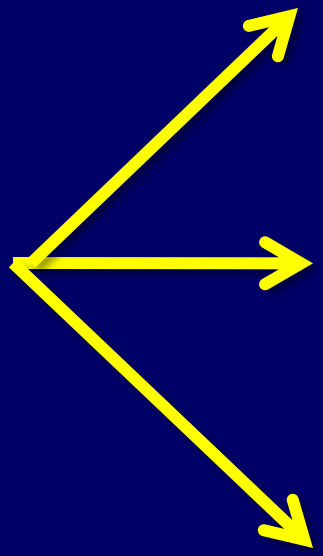
Multiple layers of cells *e.g. skin*



Simple
(single layer)

A single layer of cells
e.g. intestinal lining, tubular cells in the kidneys

Epithelial cell shape



Columnar (cylindrical) epithelium

High cells

Cube epithelium

Multiple layers of cells

e.g. skin

Squamous epithelium

Flat cells

Polarization of epithelia 1/2

Apical surface of the epithelium
is free, exposed to air or aqueous solution

Basal surface of the epithelium
It is connected via the BASAL MEMBRANE (basal lamina) to other types of tissues lying beneath it = usually **connective tissue**

Polarization of epithelia 2/2

Apical and basal sides of epithelia are different, which is due to different internal organization of individual epithelial cells (different sets of membrane transporter proteins, asymmetric organization of organelles - GA, secretory vesicles, cytoskeleton, receptors...)

Polarization is essential for the function of the epithelials!!

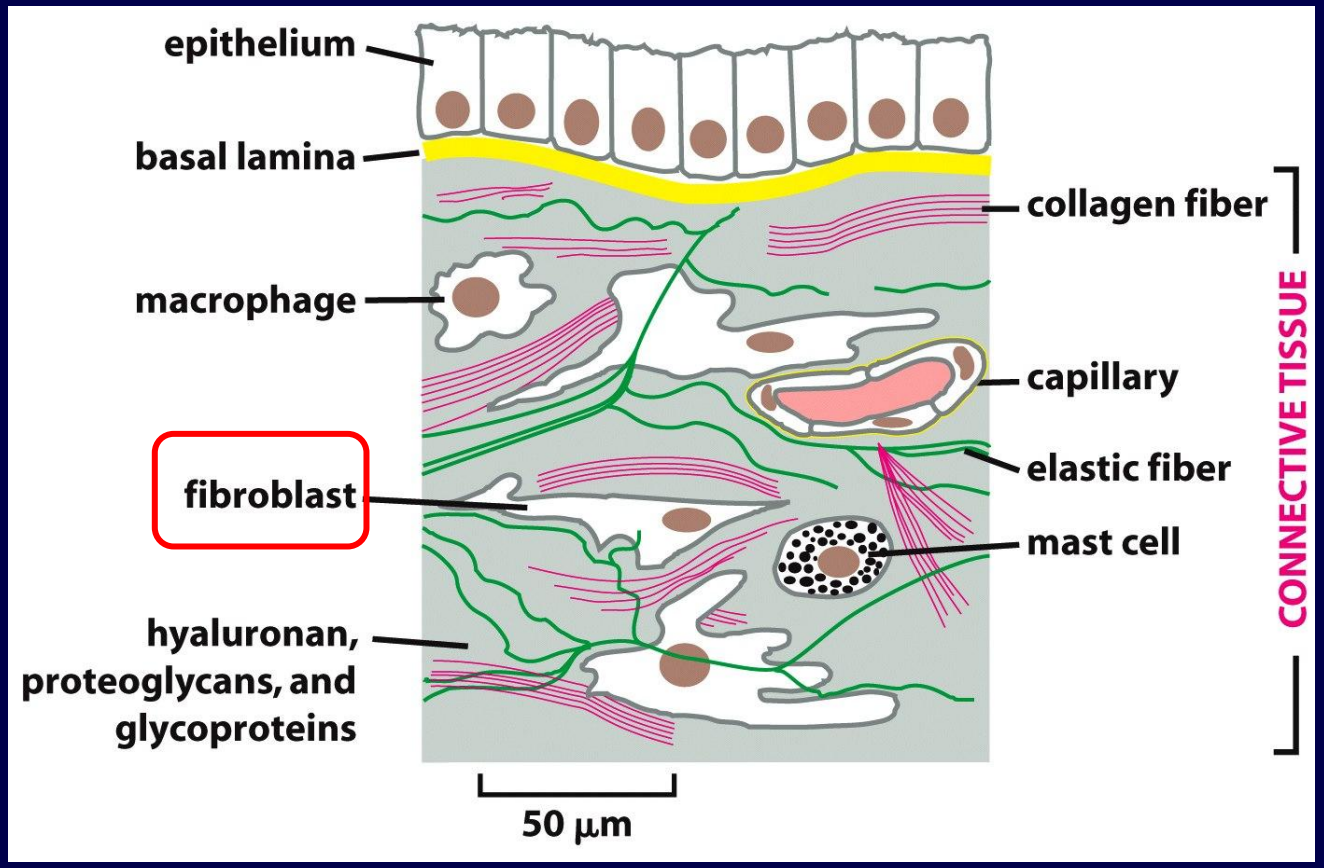
Intestinal epithelium

(mixture of resorptive and cup cells)

Resorptive cells absorb nutrients through their apical membrane, export them to the underlying tissues via the basal surface

Cup cells secrete mucus, but only through their apical part (into the lumen of the intestine!!)

Connective tissue under the epithelium



The tissue contains a number of different cells and extracellular matrix components. The predominant cell type is the fibroblast, which secretes extracellular matrix.

Basal lamina - basement membrane

It is a thin rigid flexible layer of extracellular matrix under the basal surface of the epithelium. It connects the epithelium to other types of underlying tissue = **connective tissue**

The basal lamina is small in volume but plays an important function in body structure

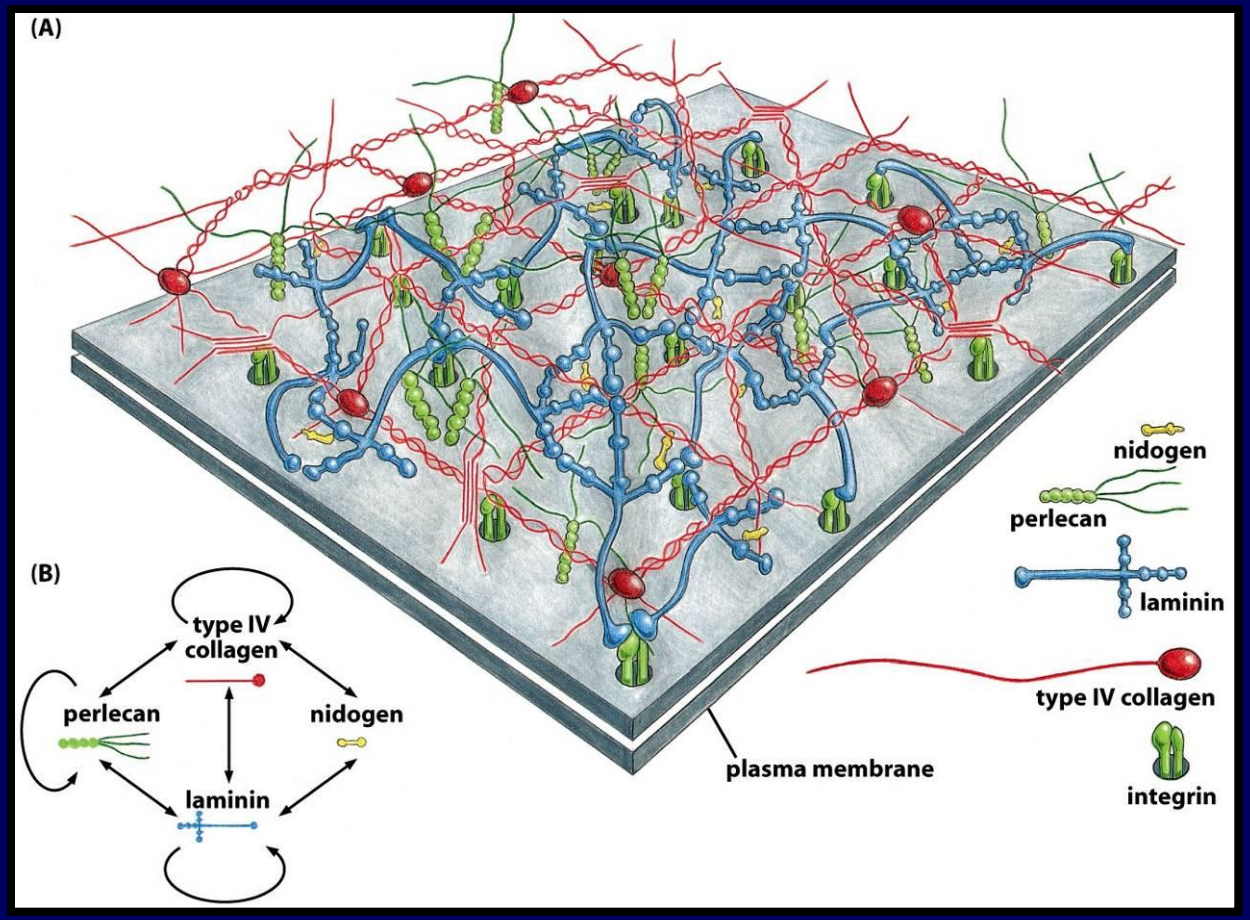
Basal lamina is typical for all animal epithelia

Basic components of basal lamina

Collagen type IV	Polymer units moulded into the shape of a flat sheet
laminin	It is a glycoprotein with a binding site for integrin - the link between the extracellular matrix and cells
nidogen	Glycoprotein
perlecan	Proteoglycan (MW 600 000)

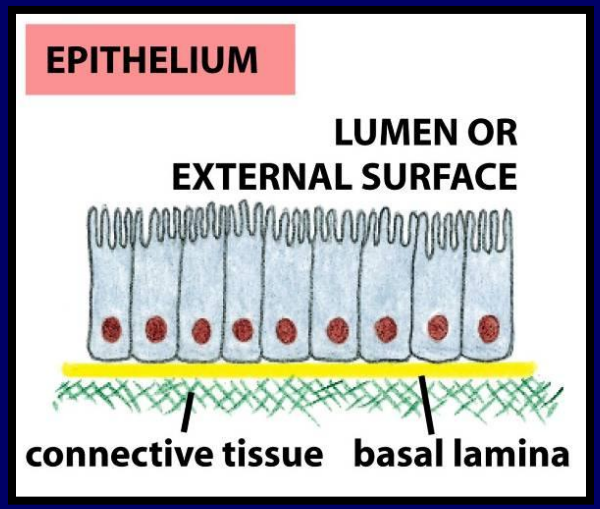
Model of basal lamina structure

The basal lamina is formed by a network determined by specific interactions of proteins: laminin, collagen-type IV and nidogen with the proteoglycan perlecan.

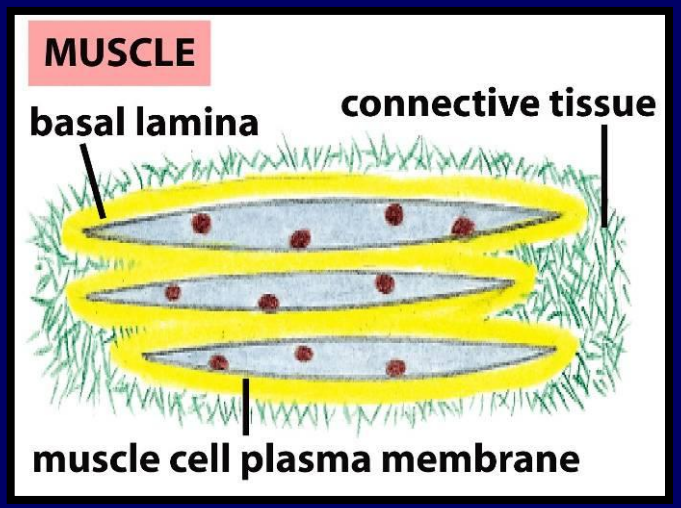


Types of basal lamina arrangement

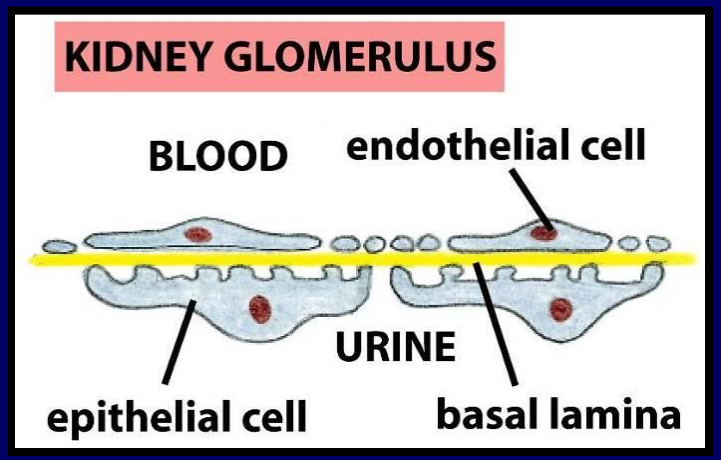
It lies under the epithelium



It surrounds certain cells



It's between two layers of cells



Functions of the basal lamina

- **Acts as a molecular filter** (unusually strong basal lamina is present in the renal glomerular epithelium)
- **Selective barrier to cell movement**
- **Prevents direct contact of epithelial cells with fibroblasts in the underlying connective tissue**
- **Allows tissue regeneration in case of damage** (muscles, nerves, epithelia)

Tissue maintenance and renewal

Basic concept

Animal tissues are very different

Each tissue is a sophisticated interconnection of many cell types

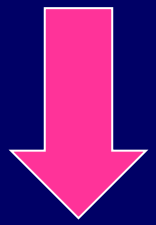
(epithelial cells, connective tissues...)

- all cell types must remain in the tissues
- cells must be renewed so that tissue organisation is maintained

This is possible due to the following factors

- **Cell communication**

  There is constant communication between cells, cells also receive signals from the external environment (growth factors,...)



NEW CELLS ARE ONLY CREATED THERE, WHERE THEY ARE NEEDED

To This is possible due to the following factors

Selective intercellular adhesion

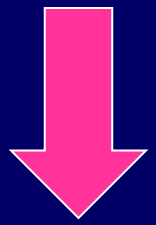
Different cell types have different types of adhesion molecules (cadherins, etc...). They tend to bind selectively only with the same cell type

SELECTIVE ADHESION PREVENTS CHAOTIC MIXING OF DIFFERENT CELLULAR TYPES IN TISSUE

This is possible due to the following factors

- **Cell memory**

  The cell "remembers" from embryonic development , autonomously stores and passes on to offspring the information about which genes in the genome must be expressed to produce a given cell type



THIS PRESERVES AND MAINTAINS THE DIVERSITY OF CELL TYPES IN THE TISSUE

Cell renewal in tissues occurs at different rates

Many differentiated cells are no longer able to divide themselves = **terminally differentiated cells (erythrocytes)**

Their restoration is only possible by dividing

stem (precursor) cells (hematopoietic stem cells)

Tissue renewal requires complex control, only the cell types the body needs are divided,....

(see cell cycle control)

Unsupervised

Tumour = cancer