Animal Tissues I: Epithelia and Blood

This Factsheet will explain what is meant by the term ‘tissue’ and describe the structure of epithelial tissues and blood. These are the animal tissues that have most frequently been tested in examinations.

Muscular tissues and nervous tissues will be covered in a later Factsheet, but have been described in Factsheet 46, Muscles, April 1999 and in Factsheet 20, Nerves and Synapses, April 1998.

What is a tissue?
The study of tissues is called **Histology**, from the Greek words ‘histos’ meaning ‘tissue’ and ‘logos’ meaning ‘a study of’. The usual definition of a tissue is that it is ‘a collection of cells of similar type and function’. This definition is too simplistic, in the following respects:

- All tissues contain **three** types of components, these are: cells, **ground substance** (intercellular material) and **formed elements** (made by the cells).
- A tissue may have several types of cells, each with different functions, which are ‘integrated’ to perform the functions of the tissue as a whole. A classic example is blood.
- The ground substance, which is basically a polymer of hyaluronic acid, binds the cells together. It is found in the basement membranes of epithelia, and in modified form as blood plasma, cartilage matrix and bone matrix.
- Formed elements are produced by cells and are usually fibres, such as collagen or elastic fibres. The basement membrane of epithelia contain a network of fine fibres, called reticular fibres.

Epithelial tissues
Epithelial tissues are divided into two groups, these are, covering epithelia and glandular epithelia. This factsheet will only describe the covering type since the histology of glands derived from epithelia is not in A-Level syllabuses. Covering epithelia, as their name suggests, cover biological surfaces in animals, so that their basic function is one of protection. In **simple epithelia** all the cells touch the basement membrane and so they consist of only one cell layer. In **compound epithelia** only the lower layer of cells touch the basement membrane and they contain several cell layers. The types of simple epithelia on syllabuses are: **simple squamous** (pavement), **cuboidal**, **columnar** and **pseudostratified columnar**. The types of compound epithelia on syllabuses are: **transitional** and **compound (stratified) squamous**. Fig. 1 and 2 show the structure of these types of epithelia.

Fig 1. Structure of compound epithelia as seen in vertical section (light microscope)

**Transitional epithelium** (eg. bladder and ureter)
- Surface cells are resistant to acids and bases in urine
- Cells can slide over each other to enable sideways stretching
- Elastic fibers in basement membrane allow stretching

**Compound (stratified) squamous epithelium** (eg. skin)
- Exfoliating (shedding) skin flakes and cells
- Cornified layer of dead keratinised cells
- Granular layer of living cells developing keratin
- Germinative layer of cells which can undergo mitosis

Fig 2. Structure of simple epithelia as seen in vertical section (light microscope)

**Simple squamous epithelium** (eg. covering mesenteries)
- Flattened squame cells
- Disc-shaped nucleus
- Basement membrane

**Simple cuboidal epithelium** (eg. kidney tubule)
- Cuboidal cells
- Globe-shaped nucleus
- Basement membrane

**Simple columnar epithelium** (bronchioles)
- Mucous goblet cell
- Oval nucleus
- Cilia
- Basement membrane

**Pseudo-stratified columnar epithelium** (eg. trachea)
- Columnar cells
- Interstitial cells
- Basement membrane
Table 1 summarises the distribution and functions of epithelia.

<table>
<thead>
<tr>
<th>Type of epithelium</th>
<th>Where found</th>
<th>Comments/functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple squamous</td>
<td>lining mesenteries, lining capillaries (endothelium), renal capsule, alveoli of lung</td>
<td>Damp with tissue fluid so allows friction free movements of organs. Thin to allow efficient exchange through capillary walls, renal capsule and glomeruli and to allow efficient gas exchange in alveoli.</td>
</tr>
<tr>
<td>cuboidal</td>
<td>kidney tubules, lining thyroid follicles, lining smallest bronchioles</td>
<td>In kidneys and thyroid the cells have striate borders (microvilli) to increase the exchange surface area.</td>
</tr>
<tr>
<td>columnar</td>
<td>lining stomach, lining small intestine and large intestine, lining smaller bronchi and bronchioles</td>
<td>In the digestive tract it secretes a mucus lining to protect against self digestion. In the ileum it has a striate border (microvilli) to increase absorptive area. In the bronchi it has mucus and cilia to trap and remove dust and bacteria.</td>
</tr>
<tr>
<td>pseudostratified columnar</td>
<td>lining trachea and main bronchi, lining nasal mucosa, lining oviducts and vas deferens</td>
<td>This always secretes a layer of mucus and possesses cilia. In the respiratory system this is to trap and remove dirt and bacteria in the air. In the oviduct it is to move the oocytes or sperm along. In the vas deferens it is to move sperm along.</td>
</tr>
<tr>
<td>transitional</td>
<td>lining bladder and ureters</td>
<td>This can be between 2 and 7 cells thick due to its ability to stretch laterally in order to accommodate urine in the bladder. The surface cells can also resist erosion due to the acids and bases in urine.</td>
</tr>
<tr>
<td>compound squamous</td>
<td>epidermis of skin, lining buccal cavity and pharynx, lining urethra and vagina, lining the last third of the rectum</td>
<td>In the skin the keratin protects against frictional wear and water loss. The epithelium prevents the entry of pathogens and is continually replaced by mitosis from the lower layer.</td>
</tr>
</tbody>
</table>

**Exam hint - questions often ask about adaptations of specific epithelia to fit their functions in particular locations.**

**The histology of blood**

The components of blood are shown in the diagram below:

![Blood components diagram](image)

**Plasma** is a straw coloured watery fluid which makes up about 55% of the blood volume. As part of its composition it contains plasma proteins, such as albumins (responsible for much of the osmotic pressure of blood), globulins (including antibodies) and clotting factors (such as fibrinogen and prothrombin). Many substances, such as sugars, waste products, carbon dioxide and hormones are transported dissolved in the plasma.

**Erythrocytes** (Fig 3) are packets of the red coloured, oxygen carrying protein, haemoglobin, surrounded by a cell membrane. The nucleus is lost during differentiation in the red bone marrow so that a mature red cell is shaped like a biconcave disc. This disc shape gives it a large surface area in relation to volume, as required for efficient gas exchange. The shape can also be distorted to enable cells to squeeze through capillaries and sinusoids as narrow as 6 micrometres in diameter. Thus the passage of red cells is slowed up allowing more efficient gas exchange in the capillaries. The ratio of red cells to white cells in blood is around 1000:1.

![Erythrocyte diagram](image)
The structure of the five types of leucocyte is shown in Fig 4. The granulocytes have granules in their cytoplasm and multilobed nuclei (i.e. they are polymorphonuclear), whereas the agranulocytes have no granules and have an oval or horseshoe shaped nucleus.

The granulocytes and monocytes can all move through the tissues by amoeboid action. Lymphocytes cannot, since they do not have enough cytoplasm to form pseudopodia. They move passively with blood and tissue fluid flow.

Fig 4. The structure of leucocytes (light microscope)

<table>
<thead>
<tr>
<th>Neutrophil</th>
<th>Eosinophil</th>
<th>Basophil</th>
</tr>
</thead>
<tbody>
<tr>
<td>phagocytosed bacteria</td>
<td>red staining granules</td>
<td>blue staining granules</td>
</tr>
<tr>
<td>faint granules</td>
<td>lobed nucleus</td>
<td>lobed nucleus</td>
</tr>
</tbody>
</table>

Lymphocyte

<table>
<thead>
<tr>
<th>Monocyte</th>
</tr>
</thead>
<tbody>
<tr>
<td>spherical nucleus</td>
</tr>
<tr>
<td>cytoplasm</td>
</tr>
<tr>
<td>phagocytosed bacteria</td>
</tr>
<tr>
<td>horse-shoe shaped nucleus</td>
</tr>
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</table>

It is important to know the specific functions of the different white cells:

**Neutrophils** are active phagocytes against antibody coated bacteria and virus particles. They have pseudopodia for locomotion and for engulfing. Their cytoplasmic granules are packets of lysozyme used for digesting the protein components of bacteria and viruses.

**Eosinophils** phagocytose the debris of antigen-antibody reactions and secrete anti-histamines to counteract the histamine released in allergies. They also secrete antibodies against parasitic worms and flukes.

**Basophils** secrete histamine and serotonin both of which stimulate the inflammatory response, and heparin, which suppresses unnecessary blood clotting.

**Monocytes** are very powerful phagocytes against antibody coated bacteria and viruses.

**Lymphocytes** secrete antibodies and are concerned with the immune response.

**Practice questions**

1. Read through the following passage and then fill in the spaces with the most appropriate word or words.

Blood consists of a straw coloured fluid called ____________ in which are suspended several types of cells. The plasma contains various proteins, such as albumins, concerned with maintaining the ____________ of blood, ____________ which include antibodies and ____________ which is involved in clotting. The red cells are concerned with the transport of ____________ and ____________, and contain ____________ to enable this. Neutrophils and ____________ are involved with phagocytosis, ____________ produce heparin which acts as an ____________, and ____________ are concerned with producing antibodies.

2. Epithelial tissues in the mammalian body may have several structural modifications. Explain the importance of the following modifications:
   (a) mucous goblet cells in the epithelium lining the inside of the stomach. 2
   (b) microvilli bearing cells lining the duodenum and ileum. 2
   (c) mucous goblet cells and cilia in the epithelium lining the trachea. 2
   (d) keratin in the epidermis of the skin. 2

3. The table below shows certain features of columnar epithelial cells, lymphocytes and neutrophils. If a feature is correct place a tick in the box, but if it is incorrect place a cross in the box.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Columnar cell</th>
<th>Lymphocyte</th>
<th>Neutrophil</th>
</tr>
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<tbody>
<tr>
<td>Contains lysosomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May possess microvilli</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present in the wall of the small intestine</td>
<td></td>
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<tr>
<td>Secretes antigens</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Has a nucleus with several lobes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can move by amoeboid action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produces globulins</td>
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<td></td>
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**Total 9**
Answers
Semicolons indicate marking points

1. plasma;
   osmotic pressure/potential;
   globulins;
   fibrinogen/prothrombin;
   oxygen;
   carbon dioxide;
   haemoglobin;
   monocytes;
   basophils;
   anticoagulant;
   lymphocytes;

2. (a) secrete mucus which forms a lining over the surface;
   which protects the epithelium against attack by acid and enzymes
   in the stomach;
   [note spellings: ‘mucus’ is the substance (noun) but ‘mucous’
   describes the substance or cell (adjective)].

   (b) microvilli increase the surface area;
   enabling better absorption of the products of digestion;

   (c) secreted mucus traps dust/bacteria/spores/equivalent in air flow;
   cilia beat the trapped material up to the glottis/throat for swallowing;

   (d) keratin helps to waterproof the skin/reduce water loss;
   is also friction resistant/helps to reduce wear due to friction;

3. | Feature                          | Columnar cell | Lymphocyte | Neutrophil |
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