Hair

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Toptoto

There are between 120 000 and 150 000 hairs on a human head.

GCSE key words
Specialised cells
Protein
Oxidation
Reduction
Mitosis

Hair can be cut and sculpted into the latest fashionable shapes and can hold fast to all the colours of the rainbow. This article describes how hair grows and how its physical structure and chemical make-up are affected by hair products.

Hair is an outgrowth from the skin of mammals. Some mammals are covered completely and some are more or less bare, although even the barest will have a few hairs lurking in odd corners.

How does hair grow?

Hair grows as a result of cell division within **hair follicles**. These are downgrowths of the outer layer of the skin, the **epidermis**, 4 mm or so into the underlying layer, the **dermis** (Figure 1). At the base of each hair follicle there are special cells that divide by **mitosis** to make new cells — some form layers around the root of the hair, others form the hair shaft.

When new cells are added to the base of the hair shaft, the older cells are pushed upwards. The hair also grows because these cells become longer. As this happens they make the protein **keratin**; as soon as they are full of keratin, they die. At this point they have been pushed up by no more than 0.5 mm — so all this happens within the hair root. From thereon upwards the hair is made up of the remnants of these dead cells.

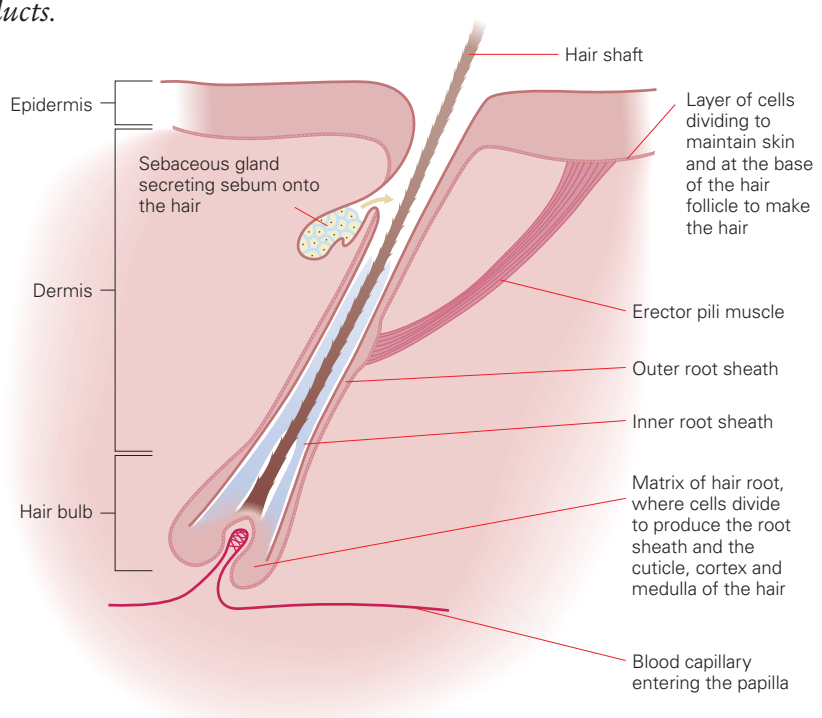


Figure 1 *Structure of a hair follicle*

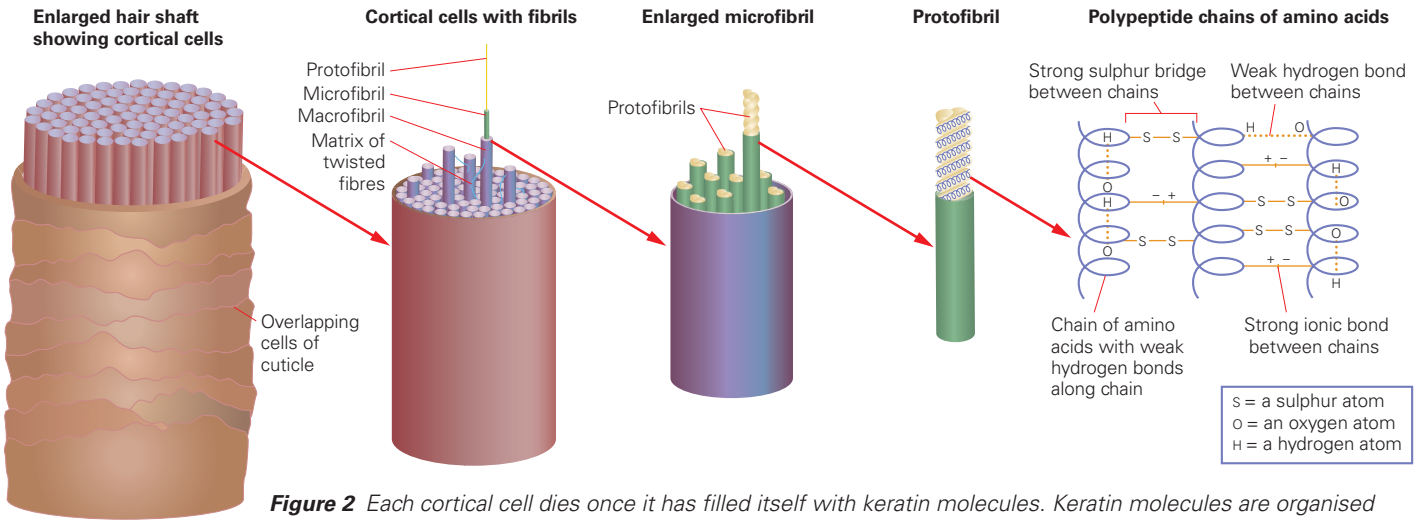


Figure 2 *Each cortical cell dies once it has filled itself with keratin molecules. Keratin molecules are organised into protofibrils,microfibrils and macrofibrils. Each protofibril contains three coiled helices of keratin*

The hair shaft

There are 250 hairs per cm^2. The average scalp is about 600 cm^2.

Each hair shaft is made of two or three layers: the cuticle, the cortex and sometimes the medulla.

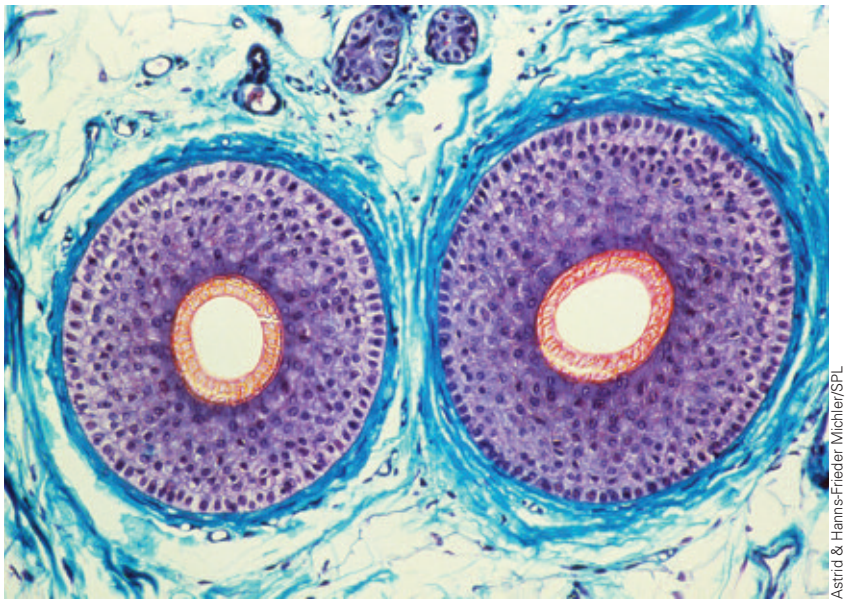
Cuticle

The **cuticle** is the outermost layer. It is made of flattened cells that overlap like the tiles on a roof or scales on a fish. The cuticle protects the inside of the hair shaft from damage and stops water from penetrating it. The cells can slide over each other, still protecting the cortex even if the hair is curled artificially. The edges of these cells face towards the tip, so a hair feels rough to your fingers if you run them towards its root.

Hair grows between 12 cm and 16 cm a year. This means that the tip of a hair of that length is 1 year old.

Close to the root, the newly-formed scales are perfectly smooth and regular. Further along the hair, they appear less regular and more eroded. First they become scratched and their edges start to splinter; then they become loose and move apart. Towards the tip of longer hairs the scales may be patchy or lost altogether.

Below: *Cross-section of two human hairs. Magnification x150*



Astrid & Hanns-Frieder Michler/SPL

Cortex

Underneath the cuticle is the **cortex**, which makes up the bulk of the hair. It is made of the protein keratin. Keratin molecules are coiled (Figure 2). The turns of the coil are held together by a weak type of chemical bond called a hydrogen bond. The keratin molecules are grouped into protofibrils, composed of three chains of keratin. Protofibrils are also held together by bonds or bridges between the atoms of the different chains. There are more weak hydrogen bonds, but there are also some stronger ionic bonds and covalent sulphur bridges.

When you stretch a hair, you are straightening the coiled proteins in the cortex. When you release the hair, the proteins coil up again if the hair was only stretched a little – hair is elastic at up to a 5% stretch. In fact, you can stretch hair by up to 50% of its starting length before it breaks. The cortex contains the pigments that give your hair its natural colour, tucked in among the keratin and protected by the transparent layer of cuticle cells.

Medulla

In the middle of some hairs is the **medulla**, a soft, spongy mass of tissue. Coarse hair generally has this layer, while fine hair usually doesn't.

Sebum

To fill the gaps between the protective cuticle cells and to keep your hair shiny and flexible, sebaceous glands in the skin opening near the top of the hair follicle produce **sebum**, an oily substance. This also makes dirt stick to your hair. When you shampoo your hair, you wash away this protective oil and the dirt that clings to it. Conditioner chemicals can replace sebum if hair gets too dry.

Reshaping hair

The structure of hair means that it can be styled and reshaped in a variety of ways. Some styles are only temporary, but others are more long lasting.

Tangles and backcombing

Does your hair get in a tangle? When hair gets older and longer, the damaged, rough scales of the cuticle become caught up with the scales on neighbouring hairs. Hair then tends to tangle and may produce knots — this is often made worse when you comb it. But if you comb your hair deliberately from its tips towards the roots (backcombing), more scales are prised loose. The roughened hairs then tangle together, so that the backcombed styling keeps its form.

Temporary styling

When hair gets wet, hydrogen bonds are weakened and may break. When wet hair is moved into unusual shapes, the arrangement of the chains of keratin is also slightly altered. When the hair dries, hydrogen bonds reform in new positions. Because the bonds are now in different places, the hair will stay in its new shape. This explains why if you go to sleep with wet hair, you wake up with it set in a mess. It's down to reformed hydrogen bonds. Of course, you can do the same thing in a controlled way with blow-drying, tongs and straighteners and achieve an effect you want.

Once the hair gets wet again the new bonds break and, if left undisturbed, the original arrangement of bonds is re-established and the hair returns to normal. Some of the stronger bonds holding keratin together are not broken by water and this can help to pull the keratin (and the hair) back to its original shape. Box 1 describes how stronger bonds can be broken and reformed to create a more long-lasting hairstyle.

Hair colour

The natural pigment in hair is called **melanin**. There are two types:

- Eumelanin occurs in the form of small granules in the cortex, which have a colour varying between brown-red and black.
- Phaeomelanin occurs as diffuse spots, with colour varying from yellow to red.

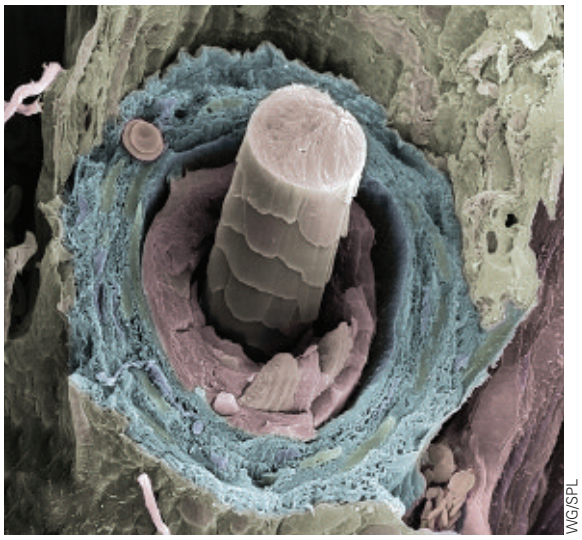
The proportions of these two melanins determine your exact hair colour.

Hair colour can be altered artificially. **Semi-permanent colourings** settle on the scales of the cuticle and become established outside the cortex — the hair's natural melanin in the cortex is unaffected.

Permanent colouring is achieved by getting the pigments across the cuticle and into the cortex, where chemical reactions occur to generate the colour. However, the precursor molecules are very large and so cannot penetrate the cuticle in its normal state. The cuticle becomes more permeable under alkaline conditions; as the hair swells, the scales separate and precursors can enter the cortex through the gaps.

One way to activate the various precursor chemicals to develop a colour is using atmospheric oxygen. Oxygen from the air also lightens melanin in the hair naturally, in particular when associated with water and sunlight. Oxygen can be generated artificially by reacting an alkaline agent such as ammonia and an oxidising product based on hydrogen peroxide.

When the desired colour has been developed, the use of an appropriate mildly acidic shampoo closes up the cuticle's scales. The pigment is now protected by the cuticle, just like the natural melanin pigments, so that the coloration lasts a long time — until all those undyed hair shafts start to emerge from their follicles.



WG/SPL

Left: *Single hair follicle*

Box 1 Long-lasting styling

Hydrogen bonds are easily broken and reformed. Other bonds between parts of keratin molecules are much tougher. In particular there are so-called **disulphide bridges** which are formed by sulphur-containing amino acids — one of the 16 types of amino acid found in keratin. These bonds are very resistant to water and can only be broken by a reaction involving a chemical applied to hair.

When hair is 'permed' disulphide bridges are broken down by **reduction**, using a slightly **alkaline** liquid known as curling liquid. Once this has been done, the keratin chains become more flexible. Hair may then be curled or straightened. The result is made long lasting by using another chemical to build new bridges according to the new position of the keratin chains. This involves the process of **oxidation** and is achieved using an acidic solution of hydrogen peroxide, the fixing liquid. The form is created by rollers and the degree of curl is determined by the diameter of the rollers.

Box 2 Useful website

The following website has many more fascinating facts about hair:
http://www.hair-science.com

If you have a head of hair 20 cm long, the total surface area of your hair is 6 m^2.

We lose between 50 and 100 hairs a day.

If all the hairs grown on your head in a year were put end to end they would measure about 18 km.

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