Hair

Introduction
Teachers who have not used the problems before should read the section Using the problems before starting.

Prior knowledge
Concept of bond length and knowledge of amino acids. A detailed knowledge is unnecessary as students are encouraged to consult textbooks and data books during the exercise.

Resources
Scientific calculators, tables of bond lengths and access to suitable textbooks in which to find the structures of amino acids should be made available for reference.

Group size
3–4.

Possible methods
Question (i)
One method is:

'I go to the barber every six weeks and he cuts off about 3 cm of hair. I get my hair dyed; after about 2 weeks there is about 1 cm undyed.'

Therefore:

1 cm (0.01 m) of hair grows in 2 x 7 x 24 x 60 x 60 seconds
or
1 m of hair grows in 2 x 7 x 24 x 60 x 60 x 100 seconds.

This equals a growth rate of 8.3×10^{-9} ms^{-1}. Given the accuracy of the data, the growth rate of hair can be assumed to be about 10^{-8} ms^{-1}. A number of approximations have to be made. The answer should, therefore, be taken as no more than a general indication of the value.

Question (ii)
The size of an amino acid molecule has to be estimated in order to calculate the approximate number of amino acids joining a hair per second. Most amino acid molecules have similar structures ie $H_2N{-}CHXCO_2H$ where X is different for each amino acid.

To get an idea of the length of a molecule, the bond lengths in the chain can be added together and this approximates to 0.5×10^{-9} m (0.5 nm). The number of molecules joining each chain per second, is calculated by dividing this figure into the growth rate figure calculated in question **(i)** (10^{-8} ms^{-1}):

$$\frac{10^{-8}}{0.5 \times 10^{-9}} = 20 \text{ molecules joining each chain per second.}$$

This is a simple answer but for a fuller answer the number of chains growing along each hair would have to be taken into account.

A reasonable guess for the cross-section of a hair is 10^{-5} m (0.01 mm). This equates to an area of about 10^{-11} m^2.

A reasonable guess for the cross-section of a typical amino acid molecule is that it is about the same as the length calculated above of 0.5 x 10^{-9} m. This equates to an area of about 10^{-19} m^2.

Therefore, there are about 10^8 amino acid chains per hair. If this figure is used, along with that from above of 20 molecules joining each chain per second, the revised estimate is 2 x 10^9 molecules joining each hair per second.

Suggested approach

During trialling the following instructions were given to students and proved to be extremely effective:

1. Working as a group, discuss the first question and try the calculation. Such discussion can play a vital role in working out possible solutions to such problems. Several minds working on a problem together can stimulate the production of ideas that one on its own could not manage. About 10 minutes should be spent on this initially, with further discussion as required.
Because exact answers are not possible, you will have to use your judgement to make sensible estimates.

2. Write up what you did in note form. You should explain how you decided upon the estimates you had to make.

3. Repeat steps 1 and 2 for the second question.

4. Working as a group, prepare a short (ca 5-minute maximum) presentation to give to the rest of the class. If possible all group members should take part: any method of presentation (such as a blackboard, overhead projector, etc) can be used.

Outline the problem, describe what you did and explain your solution and the approximations you had to make. After the presentation, be prepared to accept and answer questions and to discuss what you did with the rest of the class.

Possible extensions

1. Estimate the number of hairs on the human body and calculate the total number of amino acids used each day to keep human hair growing.

2. Estimate the total food intake for an adult and the proportion of protein in this, and hence calculate the approximate protein intake per day. Consider what happens to all of this. The possibilities include: hair salon floors; shaving in the morning if you are male; hair and skin debris down the bath plug; old skin left on the bed sheets (the main constituent of house dust); and excretion as urea.

Notes

1. Students can be reminded that making hair is only one of many uses of amino acids in our bodies – all the fleshy parts of our bodies are replaced at the molecular level every four years or so. Thus we are literally new people every four years or so because every soft part is demolished and rebuilt at the molecular level, usually with no change of shape.

Hair

(i) Estimate the approximate rate of growth of human hair in ms^{-1}.
(ii) Use this figure to estimate the number of amino acid molecules which are incorporated in a growing hair every second.

Many real-life problems do not need an exact answers. Often an exact numerical answer would be misleading.

In science, it is useful to be able to make estimates. This can be important when checking whether an answer makes sense, for example in deciding whether an injection of 10 cm^3 of a drug solution is a reasonable dose. In this pencil and paper exercise, you will need to make approximations to estimate the answers.

You should refer to any sources of information that you think might help such as your notebooks, textbooks and data books. Ask for assistance if you get stuck.