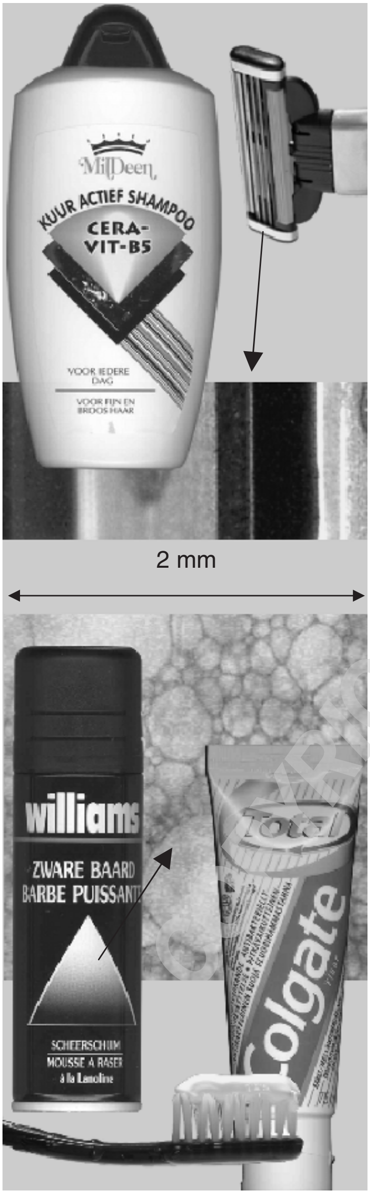
Lesson 1: Look Around



To become a product developer, you must develop an interest in products. You must learn to look around, to find out how things work, and to find ways of improving them. We begin by walking around the house of one of the authors (JAW), which is nothing special. Here is what you see.

Products At Home

In the bathroom you find shampoo, a shaving razor with cream, toothbrushes with toothpaste, and a lot of cleaning agents. The shampoo is a translucent, viscous liquid: a concentrated solution of surfactants in water with thickeners, a pH-regulator and perfume. The razor, with three blades, is sharp. It is made such that the user cannot cut himself deeply. The new metal blades are straight and gleaming under the microscope. The edge is not visible; its radius is no more than a few micrometres. The blade is used with shaving cream: a stiff foam with bubbles of around a tenth of a millimetre. No way of improving these you might think. However, you would be surprised how much they have improved in the past 20 years.

The toothpaste is like a solid, but liquid when sheared. It stays on a toothbrush as a little white sausage. It contains a large fraction of fine solid particles, as you find out by diluting with water and vinegar, and letting the mixture settle. The particles (which are mildly abrasive) are smaller than 30 μm. How could you get toothpaste to be effective in the crevices between the teeth where it really is necessary?

The first thing you see in the kitchen is the coffee machine. The coffee is in the cupboard above it, in a vacuum pack of metal foil. It consists of ground

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particles of about a millimetre of roasted beans. Why not smaller, why not larger? The coffee machine is an intriguing apparatus with a vaporiser that pumps boiling water into a filter where the coffee is extracted. As an engineer you might like to get an understanding of it using two-phase flow theory. Coffee has been around for centuries. Even so, it is still being developed. The companies Philips and Douwe Egberts made the mistake of underestimating the market for their Senseo Crema system which makes coffee using capsules. Good coffee made more quickly than with this machine. The companies have had to refuse customers because of insufficient capacity. There are more ingredients for drinks in this cupboard, but you move on to the next one.

Here you find the pastes. Hazelnut paste is a dispersion of particles in a thick emulsion of two liquids, as is peanut butter. Jam is thickened by natural polymers. Soft cheese, butter and margarine are in the refrigerator; these are complicated structures of fat crystals, oil, water and many other components. All these pastes have a yield stress that is low enough to let them be spread by a knife, but not so low that they run off bread. Users do find the cold butter a bit stiff and the jam a bit thin. As a developer you might want to improve these things. Bread – a solid foam – is a surprising structure when looked at it closely. Fresh bread is often too soft to cut easily.

In the same cupboard you find powders: sugar, salt and powdered sugar. Here you can see a lot under the microscope: the one-millimetre crystals of sugar, the smaller salt crystals (surprisingly battered and not the nice cubes that textbooks would tell you) and the fine, ground particles of powdered sugar. The two coarse powders flow freely, but the powdered one is partly caked and agglomerated. It is also dusty; could that be improved? The package tells that it contains an anti-caking agent E554; you wonder what that is and whether you could not find something with a friendlier name.

The snacks in the next cupboard are bad for consumers: you get hungry when you see and smell them. The manufacturers may be getting into some trouble because they tempt people to eat too much of these. What could you do about that? The 'Wokkels' have an interesting foamed structure; this lets you wonder how they have been made. Coating nuts with chocolate would not seem that easy either. And how do you bake cookies with bits of chocolate in them? If you were to try the chocolate would melt. There is a lot of packaging and marketing to these products. They seem to be changing all the time. Why would that be?

There is a linen cloth decorated with silk flowers on the kitchen table. It is old, and was embroidered by J's mother, 60 years ago. That was on the island of Tasmania, where the family had got marooned at the beginning of the second world-war. The mother got the silk by telling the shopkeeper that she was alone with two young children, and that her husband had disappeared in the fighting on Java. There was not much silk in Tasmania during the war. Under the microscope you see the double structure of the textile: the yarns with a diameter of about 200 μm, which are twined from fibres of about 10 μm. It is this double structure that provides small pores that allow textile to adsorb moisture and other things.

Textile can take up a lot of moisture, but the paper tissue on the window sill can take up even more: it still feels dry with four times its own weight of water. An estimate of the density of the roll tells you that over 90% of the volume consists of air. It is not easy to make a structure like that. The tissue takes up water rapidly, but the capillary rise is limited to about twelve centimetres as a simple experiment shows. You need to understand capillary flow if you want to improve such products. You do not see much under the microscope, but where two sheets have been torn apart you can see the separate cellulose fibres. They are about 10 μm thick.

When textile gets soiled you have to wash it, in a machine in the scullery. The detergent powder is a clever structure of builder (calcium-removing zeolite particles), anionic and non-ionic surfactants, a chemical bleach and biochemical enzymes. The dosing and temperature-history appear to be quite important, and need good programming of the machine. You might wonder how such a system of textile – detergent – washing machine has evolved. The three parts are made by totally different companies!

Out of the kitchen into the living room, where JAW has his desk. Pens are no longer as important as when he was young, but he still has markers in his drawer. They make a nice picture on a piece of paper. The marks are translucent, and you can see that they have about the same thickness everywhere. It is surprising that you can get that with such a simple technique. You might start looking at the cartridges and ink in the printer, but there is no time for that today.

In one of the drawers JAW has a collection of adhesives. This is a diverse lot. The first is rubber in a solvent. The second is a tri-functional monomer and cross-linker that are stored in separate cylinders, but give a strong, stiff polymer after mixing and setting. The third is a little bottle of stuff that hardens almost immediately with any water: you have to be careful not to glue your fingers together. Then a water-based gel to glue paper, and the tacky polymer-on-tape that gives a connection that you can break and re-form many times. This is a nice picture of the development of polymer technology.

In the next drawer there are batteries for a mouse and battery lamp, and behind the laptop is a lithium-ion battery with its dire warnings that it should never be taken apart. Ah, electrochemistry! There are also candles and matches, just in case .... Candles are now a niche product, but once they were the only reliable source of lighting during the night, and bearers of a great industry.

Back to the bathroom where this began; you had skipped the medicine cupboard. As the owners

are getting older, this is gradually filling up with remnants of medicine from times when they were ill. (They know they should tidy them up.) There are also pills that are really being used, and pretty complicated ones too as one can read from the slips of paper that accompany them.

You can easily extend this set of examples. Just go to a supermarket, a pharmacy or a do-it-yourself shop. However, we have finished the tour around the house of Johannes and hope to have awakened your interest in the many aspects of product development that normally do not meet the eye.

Common Factors of Products

This was a diverse set of products, coming from a number of industries and using many different technologies. You might wonder whether they have anything in common: they do. They even have a common name: all are *formulated* products. They are not simple chemicals: they have many components, and each has a purpose. Nearly all consist of several phases which are arranged in a *structure.*[1] This micro- and nano-structure is essential for the application. Making a good structure is often the difficult job. The products often *change* during application: controlling this change can be important. Finally they are judged on their performance, not on their composition.

As an engineer you might encounter any of these products in your professional life. You might become involved in development, application, making or selling of new, better products like these. You will see that their methods of development show many similarities and you will explore these during the course.

Product Development

We end with a few remarks on product development. The time between a first idea and the launching of a new product varies, but is often a few years. This is short compared to the time needed

[1] We will talk more about product structure in the 'Colloids' section at the end of the book.

Figure 1-1 Characteristics of product development

for good research. The amount of work to be done is much larger than most beginners realize; this book will show why. It may require tens or hundreds of person-years, so many people have to work in parallel on product development. All these people have to be paid, and that makes product development expensive: a cost of ten million euros is nothing exceptional.

One not only needs engineers in product development, but all kinds of people. These people will be in different departments or even in different companies; they are often located in several countries. This leads to many communication problems. You will have realized that product development is never done by a single person: one needs more people, often large numbers. These characteristics are summarized in Figure 1-1. In the next lesson we consider how people work together on development.

Summary

We will end every lesson with a summary – although this one hardly needs that.

1. You have seen how many formulated products there are around you, and realized how important they are to you as customers and consumers.
2. Formulated products make use of just about every part of chemistry, but they are not simple chemicals. They always consist of several, and often many, components. Each of these has a purpose.
3. Most formulated products have a micro- or nano-structure that is important for their function; obtaining this structure is often the big challenge.
4. You may expect to encounter such products in your career.
5. Developing a new product is quite an undertaking. It usually requires years of work (and large amounts of money to pay for these). You cannot do it alone.

Further Reading

For everything on everyday products: Ben Selinger *Chemistry in the Marketplace*, 5th edition, Harcourt Brace 1998.