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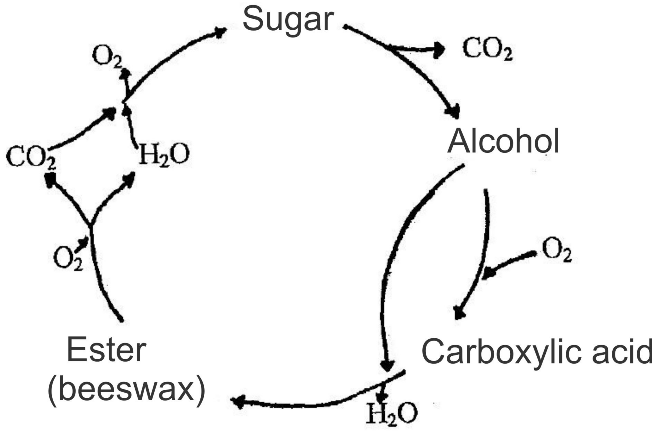
Excerpt from
“Was heiβt ‘lebendiger’ Unterricht?” [What Is ‘Living’ Instruction?], 2003

The Carbon Cycle

The hard work of attempting to explain the *carbon cycle* has occupied many people for a long time – perhaps even since antiquity, depending on one’s point of view – and by now we have been able to glean an abundance of insights. Carbon is a very special chemical element. Together with water, it is the key to all life processes, and as such it is responsible for many of the defining characteristics of the Earth as a whole. Consequently, knowing about its material cycle also strikes me as extremely important. Substances cycle through the world and all things are interconnected – not only reciprocally and in networks but also in cycles of metamorphosing configurations. In my view, this is an insight that the natural sciences have truly achieved only in the last hundred years and that is now gradually beginning to leave an ever stronger imprint on our view of the world. For this reason, all elementary and secondary students should become familiar with at least one such cycle – whether of water, carbon, a commodity, or some other good example – in the course of their school years, and as a rule we should expect them to be familiar with multiple cycles of this sort by the time they graduate from high school.

The Waldorf School chemistry curriculum for grade nine can be interpreted to include an introduction to some of the main features of the carbon cycle. In terms of substances, it leads from sugar through alcohols and carboxylic acids to esters (and secondarily to ethers). In terms of processes, it leads from photosynthesis through alcoholic and acetic acid fermentation to esterification (and dehydration). In all these processes, carbon dioxide, water, and oxygen are the constant companions of carbon. All this can be summarized in a cycle that looks like this when combustion is included:



In fact, beeswax is not a typical ester, neither in comparison to esters that are easily produced in the classroom (such as acetic acid ethyl ester) nor in principle: In chemical terms, beeswax is a mixture that consists largely of esters but also contains other families of chemical substances.[1] The great advantage of beeswax, however, is that it offers a natural transition to combustion. Both experimentally and phenomenologically, combustion is a good conclusion to the carbon cycle, and it is also easier to understand than if we take the much more difficult route via human and animal metabolism, which also leads to the release of CO_2 and H_2O.

The cycle presented above provides a first impression of the carbon cycle and forms the basis of my grade nine chemistry block. It provides opportunities to revisit what was covered in chemistry in grades seven and eight, expanding upon it and raising it to more comprehensive level – ideally, a process that continues all the way to grade thirteen (when it will provide a good foundation for studying the Krebs cycle, for example).

In principle, the cycle can be approached through any one of its five transitional processes. For example, we might choose to begin either with the fermentation of fruit to produce alcohol (a good starting point in autumn), with acetic acid fermentation, by producing (or extracting) esters, by investigating the combustion of a carbon-hydrogen compound, or by conducting experiments in photosynthesis. I have tried a number of different variations, but in my experience, beginning with investigating an example of combustion works best in terms of getting the class involved in independent activity and in learning about experimental techniques and the development and investigation of scientific problems. These are the objectives I attempt to achieve in grade nine in order to begin the transition from the heavily teacher-oriented educational approach of grades seven and eight to ever more independent ways of learning that will ultimately culminate in college readiness. With this in mind, I wondered whether a lesson on the candle[2] would help optimize the first part of the grade nine chemistry block and make these objectives easier to achieve.

If we want time to do many experiments in class, to go into individual aspects in greater depth, and to include several subsidiary topics (in particular, how animals and humans relate to this cycle), covering this block will take three weeks – that is, 15 to 18 two-hour sessions. I allow plenty of time – approximately the first week, or 6 or 7 two-hour sessions – for the discussion of the candle, since I use this time to cover not only the topic itself in the narrower sense but also a certain amount of basic material that will reappear repeatedly in the next two weeks and will then only need to be revisited briefly. As a result, the other four chemical processes (see illustration above) can be quite adequately covered in the number of double sessions remaining. Whenever four weeks are available for the block, I also link to practical applications that are directly related, such as wine and beer production, cosmetics, aromatics in foods, and saponification.

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[1] Meroth in “Natur” no. 12/1987, p. 80

[2] Michael Faraday, The Chemical History of a Candle. Full text available online at www.gutenberg.org/ebooks/14474