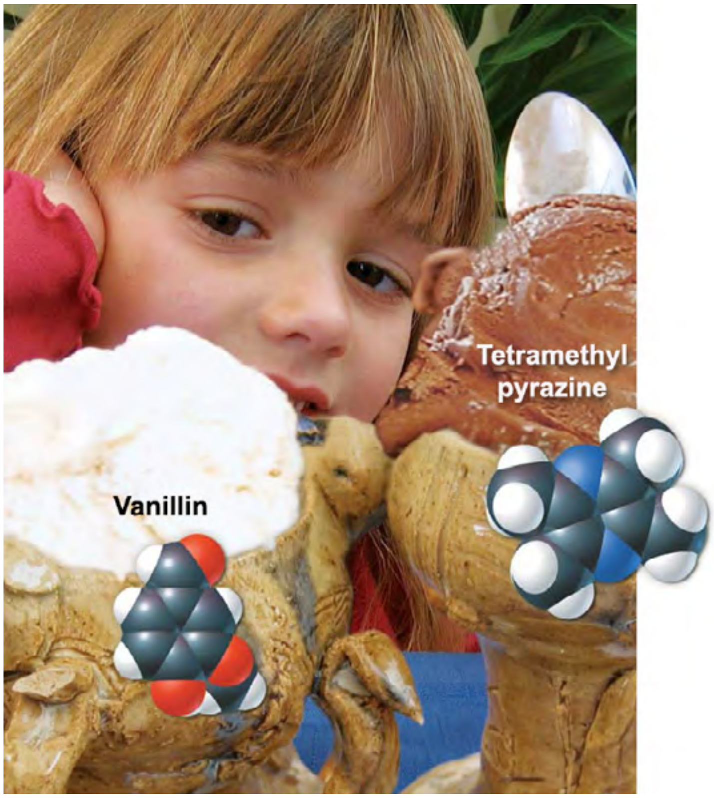


Chapter 12

Organic Compounds

THE MAIN IDEA

Carbon can form a limitless number of chemical structures.

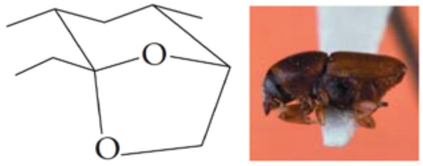
12.7 Organic Synthesis

There is much more to organic chemistry than just learning functional groups and their general properties. Many, if not most, practicing organic chemists dedicate much of their time to the synthesis of organic molecules that have practical applications, such as for agriculture or pharmaceuticals. Often these target molecules are organic compounds that have been isolated from nature, where they can be found only in small quantities. To create large amounts of these chemicals, the organic chemist devises a pathway through which the compound can be synthesized in the laboratory from readily available smaller compounds. Once synthesized, the compound produced in the laboratory is chemically identical to that found in nature. In other words, it will have the same physical and chemical properties and will have the same biological effects, if any.

How is it that an organic chemist synthesizes a complex organic molecule? One common approach is to look at the structure of the desired compound and to imagine cutting certain bonds that the chemist knows would be easy to re-form. The chemist, for example, might imagine cutting the structure into two halves. Each half is then divided into even simpler portions. In essence, the chemist is working backward, starting with the desired chemical product and arriving at a list of smaller reactant molecules that would be needed to build this product. This is called a *retrosynthesis* analysis. The chemist then goes to the laboratory to attempt the actual synthesis. Things rarely go exactly as planned, so the synthetic scheme is modified as necessary. Overall, the process requires a strong working knowledge of how to build various chemical bonds, along with a healthy dose of creativity, luck, and perseverance.

READING CHECK

How might an organic chemist plan for the synthesis of a complex organic molecule?



Multistriatin
(Elm bark beetle pheromone)

∧ **Figure 12.27**

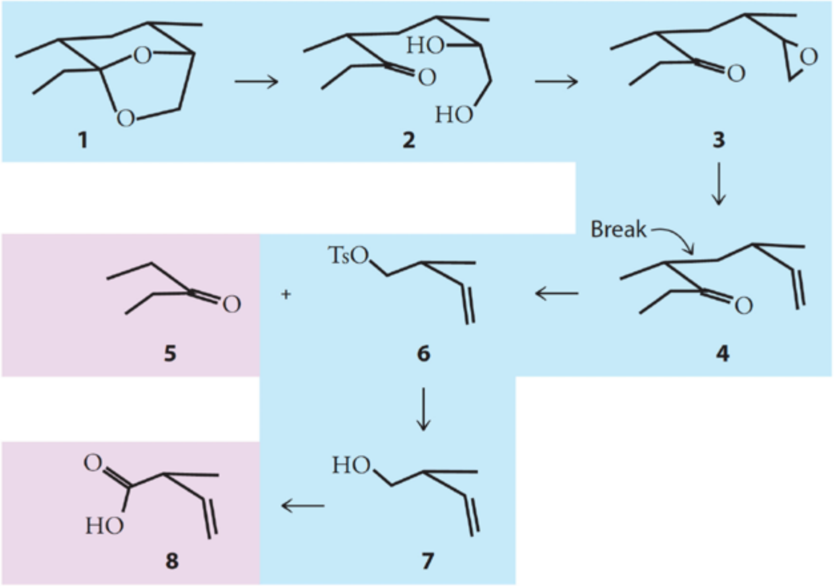
Multistriatin is a pheromone produced only in small quantities by the female elm bark beetle

To illustrate how this is done, we present a retrosynthesis analysis of the compound multistriatin, shown in **Figure 12.27**. This compound is one of the pheromones of the elm bark beetle. It is a fragrant compound released by a virgin female beetle when she has found a good source of food, such as an elm tree. Male beetles follow this scent to the female beetle at the elm tree. The male beetle carries the fungus for Dutch elm disease, so the tree upon which it lands gets infected. Larger quantities of this pheromone, which is produced only in small quantities by the beetle, are useful for traps that capture the male beetles, thereby preventing the spread of the disease. This approach of targeting a specific pest with traps is more desirable than the application of a pesticide, many of which kill beneficial insects and have the potential to contaminate foodstuffs.

The chemical structure for mulitstriatin, **1**, as shown in **Figure 12.28**, may look complicated. The knowledgeable organic chemist, however, recognizes that two oxygen atoms bonded to a single carbon atom can be easily made by reacting a carbonyl group with two adjacent hydroxyl groups, as shown in the first retrosynthetic step. So, if the chemist could create compound **2**, as shown in Figure 12.28, she would be one step away from creating the desired product. The chemist then recognizes that compound **2** could be made from compound **3**, which, in turn, could be made from compound **4**. Studying compound **4** carefully, the experienced chemist recognizes that a bond two atoms away from a carbonyl group is easy to form. This leads her to break compound **4** evenly into compounds **5** and **6**. Compound **5** can be bought from a chemical supply company, while compound **6** requires only a few more steps to come to compound **8**, which is also commercially available.

After developing this retrosynthetic plan and seeking helpful input from her colleagues, the chemist heads to the laboratory to try to make some variation of the forward synthesis work.

Naturally, some organic molecules are more difficult to synthesize than others. Look ahead to Chapter 14 for the structure of the anticancer agent Taxol®, shown in Figure 14.4. This compound is very useful for the treatment of breast cancer, but unfortunately, it is produced in nature by the yew tree in only very small quantities. This prompted teams of organic chemists to synthesize this molecule from easily obtained starting materials. The first total synthesis of Taxol® by K. C. Nicolaou of the Scripps Research Institute in 1994 was a major accomplishment. Other researchers have since refined the synthesis of Taxol®, which has been of great benefit in the fight against cancer. Online, use the keywords *taxol total synthesis* to find the stunning synthetic pathways used by these practicing world-class chemists.



< **Figure 12.28**

A retrosynthetic analysis of the elm bark beetle pheromone multistriatin. The commercially available starting materials for the forward synthesis are in the purple shading.