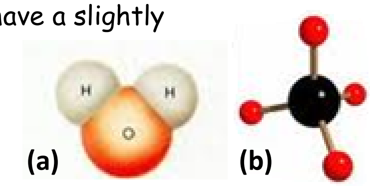
Reading: Why a Molecule's Shape Matters

Each molecule has a characteristic size and shape (see fig. 1). A water molecule, for example, is shaped rougly like a right angle, it's two covalent bonds spread apart by 104.5°. Larger molecules, including many of the molecules that make up living organisms (proteins, carbohydrates, lipids, and nucleic acids), seem more complex, yet are made up of a variety of the smaller VSEPR shapes we have studied.

The shapes of some molecules cause them to have an unequal distribution of electrons. This is called polarity. Polar molecules have more electrons around certain atoms, causing the molecule to have a slightly negative charge on one side and slightly positive charge on the other. For example, in water molecules, the oxygen atom is more electronegative than the hydrogen atoms. This difference in electronegativity results in polar covalent bonds between the oxygen and each hydrogen. If the molecule was symmetrical, these polar bonds would cancel each other out and the molecule would be neutral. But, water molecules are asymmetrical (bent). This causes the region of the atom containing oxygen to be slightly negative and the hydrogens to be slightly positive. Polar molecules are attracted to each other due to these opposing partial charges. This attraction is similar to what we observe in ionic compounds, but not nearly as strong.



(a) (b)

Fig. 1 (a) Bent water molecule
(b) Tetrahedral methane molecule

If you've ever fumbled with a ring of nearly identical keys, you understand that a subtle difference in an object's shape can make a large difference in the way it functions. Living things recognize molecules in much the same way that locks "recognize" keys- by shape. Molecular shape is important to scientists because it is believed to be the basis for how most molecules of life recognize and respond to one another. Examples of this include how we smell, taste, and how nerve cells in the brain communicate with each other (these can even affect our emotions).

Smell

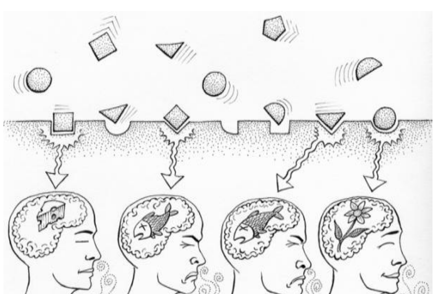
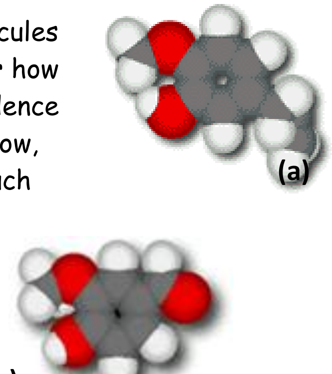


Fig. 2 Receptor site model for smell

Of all our senses, smell is the most primal. Animals need the sense of smell to survive. Although a blind rat might survive, a rat without its sense of smell can't mate or find food. While there have been many ideas about how smell and taste work over the years, the **receptor site model** is currently the most widely accepted theory based on all the evidence collected. Although our sense of smell is our most primal sense, the way that it works is very complex. The average person can discriminate between 4,000 to 10,000 different odor molecules.

<u>How the receptor site model of smell works</u>: When you inhale, molecules in the air are carried past receptor sites (tiny indentations) in your nose. These receptor sites are made up of polar protein molecules. Only molecules that are also polar are attracted to these polar receptor sites. If the molecules also have the right shape and size, they can fit properly into these receptor sites, which transmit impulses to the brain. The brain then identifies these impulses as a particular aroma, such as the aroma of freshly baked bread. The nose is so good at molecular recognition that two substances may produce different sensations of odor even when their molecules seem to differ only slightly. Scientists are unsure of how many receptor sites are in the nose or how many different shapes they represent. They are also unsure if there is a one-to-one correspondence between shape and smell or if some molecules could fit into more than one site. Scientists do know, however, that receptor sites are composed of very large, intricate protein molecules, and are much more elaborate and complex than the simplistic drawings shown in figure 2 above.

Fig. 3 (a) Vanillin molecule
(b) Eugenol molecule


(a) (b)

Let's look at some specific examples: vanillin & eugenol are molecules with distinctive flavors but obviously similar molecular structures. Vanillin ("vanilla") has a soothing, pleasant aroma that can fill a room when cooking with it. Eugenol is found in bay leaves, allspice, and oil of cloves. Eugenol has a short hydro-carbon tail that gives it a stronger odor than vanillin has. One bay leaf is enough to season a pot of soup; more than one or two ground cloves overpower a pumpkin pie. Eugenol has a numbing, analgesic effect. It is used as a dental antiseptic (it is one component of that strange smell some dentist's offices have).

Taste

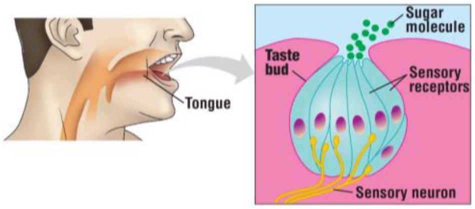


Fig. 4 Receptor site model for taste

Have you ever wondered why food loses its flavor when you have a cold? It's not your taste buds' fault. Blame your stuffed-up nose. Seventy to seventy-five percent of what we perceive as taste actually comes from our sense of smell. Taste buds allow us to perceive only bitter, salty, sweet, and sour flavors. It's the *odor molecules* from food that give us most of our taste sensation.

When you put food in your mouth, odor molecules from that food travel through the passage between your nose and mouth to *smell* receptors cells at the top of your nasal cavity, just beneath the brain and behind the bridge of the nose. If mucus in your nasal passages becomes too thick, air and odor molecules can't reach your olfactory receptor cells. Thus, your brain receives no signal identifying the odor, and everything you eat tastes much the same.

The ability to taste is believed to work in the same way that smell does, through receptor sites. Taste, however, is limited to sweet, sour, bitter, salty and umami (the taste of monosodium glutamate (MSG)). It is interesting to note that around 400 BC the Greek philosopher, Democritus, speculated that the taste of substances was due to the shape of their component particles. Democritus' model was crude, he reasoned that acidic particles would be sharp, as they attacked, and sweet substances would be soft, but his model turned out to be surprisingly accurate. Taste receptors, whose actual structure is presently unknown; have been observed to be very successful in discriminating between different molecules that are interpreted as "sweet." When we taste sweet food, then, these appropriately shaped molecules trigger receptors in taste buds which are very discriminating.

Fortunately for those who are concerned about their weight chemists have been able to synthesize a variety of sweet shaped molecules which trigger the appropriate taste receptor, but contain far fewer calories than the molecules of sucrose which they mimic. With fewer calories, these molecules are less likely to be converted to unfashionable energy reserves (fat cells) by the resource conscious human metabolism.