Biochemistry

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Stimulating chemical communication

Nerve cells communicate with their neighbors at specialized sites called synapses. At a synapse, changes in electrical potential trigger the release of chemicals (known as neurotransmitters) that diffuse across the gap between cells and provoke electrical changes in the receiving cell. Now, chemists at the University of Minnesota have developed a primitive analog of a synapse. They have demonstrated for the first time that chemicals can be released from an electrode surface in response to an electrical signal.

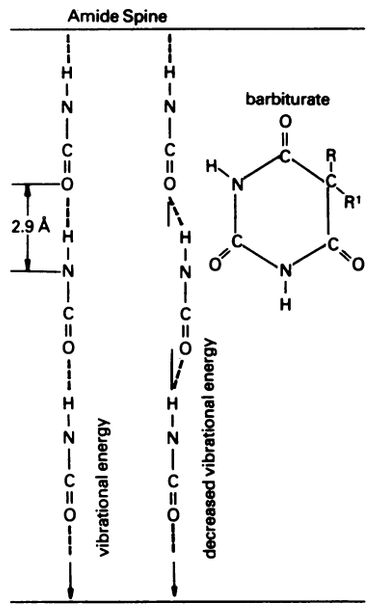
Initially, Larry L. Miller and Aldrich N.K. Lau concentrated on stimulating the release of the neurotransmitter dopamine. They constructed an electrode from a carbon disk with a firmly attached polymer coating, which in turn was covalently bonded to dopamine molecules. Dopamine release occurred only when a sufficiently negative electrode potential caused the covalent bond to cleave. The synapse analog consisted of the polymer-coated electrode, a "receiving" electrode and a droplet of an aqueous solution that filled the gap between the electrodes.

Experiments with the synapse analog showed that, indeed, dopamine was released on command. The delivery of dopamine could be turned on and off several times during the course of an experiment. However, only very small dopamine concentrations appeared in the droplet. Present studies are aimed at developing electrodes that promptly release larger amounts of dopamine or other chemicals.

Miller speculates that electrical devices based on this concept could be used for delivering small amounts of a substance to specific locations at specific times. One potential application would be for carefully controlled drug delivery.

A solitary cause for anesthesia

In the past, no proposed biochemical mechanism has satisfactorily accounted for how anesthetics like barbiturates act on the brain to induce drowsiness or unconsciousness. Now, researchers at the Los Alamos National Laboratory in New Mexico suggest that barbiturates disrupt the flow of energy along protein molecules. They hypothesize that weak hydrogen bonds formed between a barbiturate molecule and an adjacent protein strand disturb the propagation of single, isolated waves, called solitons, along the protein's backbone.



Scott P. Layne and Alwyn E. Scott postulate that solitons travel as concentrated vibrational energy pulses along the hydrogen-bonded spines of alpha-helical proteins. When an anesthetic molecule that contains H−N−C=O groups approaches the protein, new hydrogen bonds form that locally shift a section of the spine and impede the ability of the protein to conduct solitons (see diagram). This barbiturate interaction reduces energy transfer along the protein molecule in the same way that a leak reduces flow in a plumbing system.

Alpha-helical proteins appear to play an important role in communication between a nerve cell's interior and its external environment. They form parts of complex bundles of filamentlike proteins that span the membranes enclosing cells. These membrane-embedded structures protrude from cell walls and can be influenced by chemicals outside the cell. Substances such as hormones "tweak" these proteins and signal their presence to the cell's interior, by way of solitons that carry energy into or out of cells. Anesthetics, then, may alter this signaling process by interfering with soliton propagation.

Layne and Scott also suggest that solitons can be a means for transferring electrons from an electron donor to an electron acceptor over long distances. These electron-carrying solitons may influence the way membranes pump charge to maintain an electrical gradient across a membrane. They note, "With this view, anesthesia can be understood in terms of a loss of both vibrational and gradient energies."

Although the soliton hypothesis seems to account for many of the effects of barbiturates, the principal difficulty is that no one has actually observed solitons in chemical systems. Earlier theoretical calculations at Los Alamos and elsewhere have shown that given enough energy, alpha-helical proteins can maintain a soliton.

"The principal question is whether a normal amount of biological energy is sufficient to form a soliton," says Layne. The distance that a soliton may propagate down a real alpha helix is also open to question. Work is now under way to detect the presence of solitons in biological and synthetic materials.

Polymer crystals for electronic devices

The polymer polyacetylene has attracted considerable attention because it behaves like a semiconductor. With its backbone chain of carbon atoms joined by alternating single and double bonds, polyacetylene is an electrically conducting plastic. Doping polyacetylene with small amounts of other substances can increase its conductivity to that of a metal (SN: 2/6/82, p. 90). Now the polymerization of more complicated starting materials, diacetylenes, is attracting a great deal of research interest. These reactions are unique because they result in large polymeric single crystals (which also conduct electricity) of high crystalline perfection. This contrasts with the spaghetti-like mass of tiny fibrils that results from simple polyacetylene formation.

Jerome B. Lando and M. Thakur of Case Western Reserve University in Cleveland started with the diacetylene monomer: $HC{\equiv}C(CH_2)_8C{\equiv}C{-}C{\equiv}C(CH_2)_8C{\equiv}CH$. When gamma rays irradiated single crystals of this starting material, the diacetylene molecules polymerized. The crystal shape and other characteristics also changed during polymerization.

The resulting blue, needlelike crystals were ideal for X-ray diffraction studies and other analytical techniques. The analysis showed that the polymer crystals were composed of parallel sheets containing polyacetylene and polydiacetylene chains, interconnected by units consisting of eight methylene (CH_2) groups. The distance between parallel sheets was 4 angstroms. Conductivity measurements showed the material was a semiconductor.

Lando says the well-ordered polymeric crystals obtained in his experiments represent an important class of compounds. The regular, rigid structure makes it easier to deduce the effects of doping and other alterations on the crystal lattice. Lando and his group have been able to determine, for example, where iodine fits into the lattice when iodine is added to change the polymer's conductivity. Lando predicts that thin crystalline polymeric films, about 100 Å thick, may be useful in the future for building semiconductor electronic devices.