Research in Progress

Animal Magnetism

Joseph Kirschvink is interested in the birds and the bees and does research on animal magnetism — but in its most literal sense. An assistant professor of geobiology, Kirschvink has discovered tiny amounts of magnetite (Fe_3O_4), also known as lodestone, in the tissues of honeybees, pigeons, tuna, and sea turtles, among others, adding to a growing list of animals that apparently manufacture the mineral biochemically. The discoveries have lent weight to the hypothesis that the orientation behavior of many of these animals, which is known to be geomagnetically influenced, is due to the presence of an internal compass. (Human beings are another story — see Random Walk in this issue.)

Recently magnetic material has shown up in another surprising context. Kirschvink, working with Frank L. Tabrah and Stanley Batkin from the Cancer Center of the University of Hawaii School of Medicine, found anomalously high concentrations of what they think is magnetite in mouse tumors. They worked with two types of tumors — YC-8 lymphoma and Lewis lung tumor, freezing sample tissues to immobilize the magnetite and inducing magnetism in them by briefly exposing them to a strong magnetic field. They then measured the magnetism in the samples with a highly sensitive superconducting magnetometer. Kirschvink, Tabrah, and Batkin found the equivalent of one to five crystals (about one-tenth of a micron in size) per cancer cell in the mouse tumors. Normal distribution of magnetite crystals, which have been detected in the tissues of monkey brains and human adrenal glands, is one per 100 to 1000 cells.

The scientists also exposed the cultured mouse tumor cells to varying magnetic fields to determine whether their growth rates would be affected. While the Lewis lung tumor cells showed no growth response to the fields, the YC-8 cells did. Exposing these cells to a 2000 Hertz oscillating magnetic field accelerated the cell growth, while exposure to a 60 Hertz rotating field produced by a spinning permanent magnet retarded growth significantly. Further research is needed to understand this phenomenon, but Kirschvink theorizes that the rotating magnetic field produces damage to the cells either by mechanically torquing the magnetite or by inducing damaging currents.

Whether this might have any bearing on cancer treatment is still unclear. The scientists also studied three types of human carcinomas and did not find unusually high concentrations of magnetite. These tumors do not grow as quickly, however, and since there are also more than 100 different kinds of human tumors, much research remains to be done to determine the possible significance of magnetite in cancer.

Also still unknown is the precise location in the cells and the biological function, if any, of the magnetic crystals. They might simply represent some form of iron storage, but many tumors have high concentrations of the iron storage protein ferritin and would not need magnetite for that purpose.

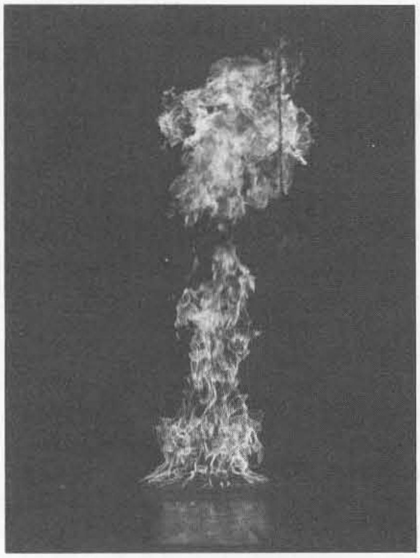
Caltech will soon have its own clean laboratory for research on ferromagnetic material in animal tissues. Since Kirschvink is dealing with nanogram (one-billionth of a gram) quantities of material, background contamination is a big concern; even a few specks of dust could be more magnetic than some tissues. Located in the subbasement of Arms Laboratory of the Geological Sciences, it will be sheathed with 4000 pounds of soft transformer steel, magnetized to cancel the earth's magnetic field. □ — JD

Where There's Smoke

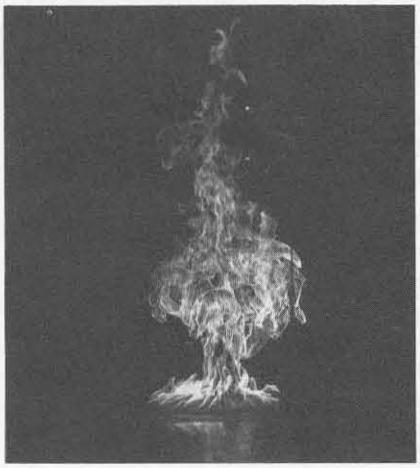
A fire starts in one room of a house. Hot gas produced by the flame mixes with fresh air as it rises and forms a distinct layer under the ceiling. As the layer becomes deeper, the hot gas also starts to flow out under the door lintel into the next room. The combustible materials in the first room, meanwhile, are heated by radiation from the flame, and they begin to decompose into gaseous fuel. Sometimes this fuel is ignited almost simultaneously in all parts of the room and causes the entire room to burst into flame — flashover.

For several years Edward Zukoski, professor of jet propulsion and mechanical engineering, and Toshi Kubota, professor of aeronautics, have been studying the fluid dynamics of the early stages of the fire-spread process in order to be able to predict the motion of combustion products before the flashover point. An understanding of the many interacting physical processes occurring in the fire has become particularly urgent because the increasing use of plastics as building and furnishing materials has introduced a host of fire safety problems, which present building codes and safety regulations don't handle very well. These problems arise in part because of differences between the combustion of natural materials, such as wood, and the new plastics. While burning wood forms a char layer that retards decomposition, heat causes plastics to disintegrate (or pyrolize) at low temperatures. Thus large masses of gaseous fuel can be added to a fire in a relatively short period of time. Since almost all of the combustion actually takes place in the gas phase, this rapid pyrolysis can cause a fast buildup of a fire.

In the early stages of a room fire, when the hot gases are gathering under the ceiling, the properties of this well-stirred smoke layer can be considered roughly homogeneous. This fact has formed the basis of a two-layer model for the description of fire spread. For example, Zukoski's group, which includes graduate students Baki Cetegen and William Sargent, has divided a room into two zones or homogeneous blocks of space — a hot layer near the ceiling and a cooler zone



When a vortex-like puff that has risen to the top of the flame burns off (left), the top of the flame drops to the next puff.



near the floor. Equations for the conservation of energy and mass can then be used to follow the temperature and vertical extent of both zones as a function of time.

Their computer model of the behavior of these two zones is based on observations and measurements of room fires in the laboratory. They are not, of course, tracking billowing smoke through the halls of Karman Laboratory but use an experimental "room," 4′ x 4′ x 8′, with fireproof walls and a large 8′ x 8′ hood to remove products of combustion from the laboratory. They set their fires with natural gas — a mixture of hydrocarbons that is predominantly methane.

In their experimental setup for studying the fire plume, the researchers control the level of the interface of the two zones with the large hood placed above the fire. The hood fills with hot gas from the plume to form the upper layer, and hot gas is drawn out from the upper zone through the side of the hood. When these flows are in balance, a stabilized interface height is maintained, and measurement of the flow rates between zones is possible. The rate at which the products of combustion diluted with air enter the hot zone is critical to the growth and spread of fire.

Mass transfer between the layers takes place at three points: at the interface of the layers, where the fire plume plunges into the upper layer, and at the fire plume itself. The latter is the most significant of these processes, say Zukoski and his colleagues; the fire acts as a pump, pulling in the cooler air, mixing and heating it, and carrying it to the upper zone. The rate of production of hot gas and the temperature of the gas depend heavily on the rate at which this entrainment happens.

Besides measuring this entrainment rate, the investigators have studied the flame itself and the heat transfer processes produced by the plume. The flame geometry has been recorded on videotape (30 frames-per-second), in still photographs, and with a shadowgraph system. A clear pattern of three different zones within the fire plume emerged from the pictures. At the base, a column of flame the size of the perimeter of the burner could be seen, and above the top of the flame, a typical bouyant plume of hot gas. In between, the pictures showed the presence of periodic pulsations, or puffs, in the flame — vortex-like structures that rose to the top of the flame and disappeared, presumably because combustion was complete. Then the next lowest puff became the top of the flame. Zukoski and Kubota believe that these complicated turbulent puffs play an important role in the entrainment of cool air from the room into the fire.

The computer model of the entrainment process — a simple numerical program that can be applied when the heat release rate is known — is virtually completed. The model is being modified to include a calculation of the rate of convective heat transfer produced by the plume. Zukoski and Kubota view their model as one element in a more ambitious calculation that will lead to the prediction of the spread of fire and combustion products through a complex building. They believe it will be useful in assessing accurately the safety of architectural design and new materials, and in the future the model may be used as part of a fire code. The research is funded by the Center for Fire Research of the National Bureau of Standards. ☐ – *JD*