Physical Sciences

To branch or not to branch

The feathery forms glistening on a frosted windowpane and the branched structures sometimes evident on the polished surface of a chunk of metal are both examples of the kind of intricate patterns that can form when a pure substance or an alloy freezes. Guided by a number of novel theoretical models and the results of several ingenious experiments, researchers have made considerable progress in the last few years toward understanding the factors that determine the type of branched, or dendritic, patterns into which a material can crystallize. Two sets of experiments now shed light on the origin of sidebranches – offshoots from the main branches that form and grow as a substance freezes into a tree-like shape.

X.W. (Chester) Qian and Herman Z. Cummins of City College of the City University of New York studied the effect of applying a brief, tiny heat pulse near the tip of a growing dendrite. They discovered that although the initial, heat-induced deformation at the solid-liquid boundary was too small to observe directly, it initiated the formation of a new branch growing out from the dendrite's side. This observation, reported in the June 18 PHYSICAL REVIEW LETTERS, supports the notion that an amplification of minute, random temperature fluctuations leads to sidebranching during dendritic crystal growth.

"Until our work, nobody had actually seen the evolution of an individual sidebranch," Cummins says. "There's a very small amount of spontaneous temperature fluctuation that's there all the time and gets amplified to make the ordinary sidebranches. But if we put on a slightly bigger [heat] pulse right at the tip, then that will get amplified faster. So you should see a sidebranch grow out quite close to the tip where the ordinary noise is still too small to see."

In another recent set of experiments, he says, researchers in Paris, France, have shown that by periodically changing the overall temperature pattern surrounding a dendrite, they can produce sequences of sidebranches in a way that matches the pattern of temperature perturbations. "That's also an important piece of the story," Cummins says.

Cummins and his colleagues are now studying the effects of applying periodic heat pulses to a dendrite tip in order to determine how the pulse rate affects the formation of sidebranches. Theory predicts that the efficiency of producing a train of sidebranches synchronized with the pulse rate should be highest at some frequency characteristic of the system.

These experiments and related theoretical work should provide insights into the way metals and other substances solidify. "It's not inherently different whether you do the growth in a carefully thermostatted microscope or whether it happens in the atmosphere or in the foundry," Cummins says. "The physical processes are still the same."

Out of the shadows

A team of researchers has developed a powerful new mathematical procedure that allows them to reconstruct the internal structure of objects that diffuse, or scatter, incoming radiation, whether in the form of light, sound waves or particles such as neutrons. To produce an image of what lies within a solid target, the new technique relies on complicated, computer-intensive manipulations of data in the form of fuzzy "shadowgraphs" produced by an array of detectors that record the scattered radiation emerging from the target.

This imaging procedure has potential applications in medicine, industry and geophysics. For example, the analysis of shadowgraphs produced by infrared lasers probing animal tissue could produce images of the tissue's internal structure. J.R. Singer and his co-workers at the University of California, Berkeley, describe their image-reconstruction technique in the May 25 SCIENCE.

Science & Society

Energetic appetites take ecologic toll

An extraterrestrial observing Earth "might conclude that cattle is the dominant animal species in our biosphere," muses David H. Wright, an ecologist at the University of Georgia in Athens. In a new analysis of "species energy curves," he notes that bovines consume more than 2 percent of all the photosynthetically derived energy in Earth's land-based environment and some 3.3 times more calories than the planet's roughly 5.32 billion humans consume. And yet, Wright asserts, cows appropriate far less photosynthetically derived energy than humans do.

The fallacy inherent in comparing bovine and human calorie consumption, he argues in the July AMBIO, is that it ignores the human tendency to "waste" valuable calories. For example, Wright notes that people don't eat whole cereal grasses or whole animals. Moreover, he says, what the human species discards is as likely to be landfilled as returned to the food web and shared with other species. The human/bovine comparison also ignores humanity's tremendous appetite for land and biological materials – from real estate for paddocks and paved roads to flax and trees for paper and lumber. In siphoning off these resources – especially the land, which collects solar energy – humans severely limit the energy available to meet the most basic needs of other species, Wright observes.

Wright estimates that human activities tie up between 20 and 30 percent of the potentially available photosynthetically fixed energy in terrestrial ecosystems – some 650 to 800 exajoules (1 exajoule = 10^{18} joules) annually. And as the global human population increases to an expected 6.1 billion by the year 2000, its share of photosynthetically derived energy will likely reach 24 to 37 percent, he says. Through a complex series of calculations, Wright shows how this increased use threatens to extinguish 3 to 9 percent of the planet's land species. And pollution and sport hunting "will only make it more difficult for the average species to survive in the face of human restrictions on natural energy flow," he says.

Wright acknowledges that energy-use estimates provide at best a "coarse" statistical prediction of species risks, but says they do offer ecologists a needed gauge of the magnitude of effort required to protect species diversity.

Offshore leases: Most on hold for '90s

President Bush upset a number of large U.S. oil and gas developers late last month when he canceled five scheduled sales of leases to drill for energy resources in environmentally sensitive tracts off the coasts of California, Florida and New England. The leasing sales cannot be rescheduled until after the year 2000, Bush said – and only then pending the results of further environmental studies.

Bush said the move reflects his acceptance of recommendations by a federal interagency task force established last year to study potential ecologic impacts of offshore drilling (SN: 2/18/89, p.103). The task force, which focused on the California and Florida sites, concluded that further steps are needed to protect the environment before the Interior Department, which conducts the sales, can ensure safe development of these tracts. Interior officials say the tracts hold 2.6 billion barrels of proven oil reserves and potential reserves of 8.2 billion barrels.

At the same time, Bush announced he had agreed to establish a National Marine Sanctuary in California's Monterey Bay, permanently banning oil and gas drilling there. He also directed the Interior Department to delay leasing and energy development for at least a decade on several other outer-continental-shelf tracts off the coasts of Washington and Oregon. Finally, the President initiated procedures that he said "may lead" to a federal buyback or cancellation of existing leases for tracts off southwest Florida.