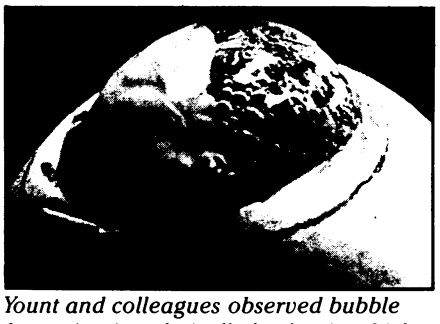
water surrounding rapidly turning boat propellers. Because it cannot "keep up" with the turning blades, the water "pulls away," Vann explains. The resulting cavity is corrosive and causes pitting and failure of the propeller. One obvious application of mechanical nucleation theory, therefore, is in the design of ship propellers.

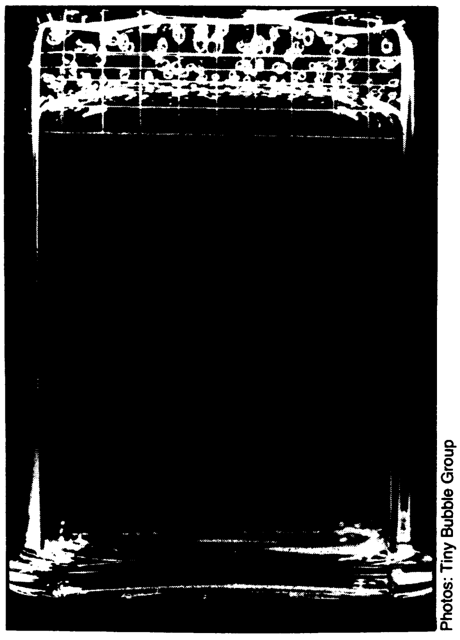
The Tiny Bubble Group's skin-stabilized nuclei model shares the other half of the nucleation field — dissolved gas nucleation — with several additional theories. One of those theories states that de novo formation of bubble nuclei is possible because of the natural motion of fluid molecules. One type of de novo bubble formation is easily illustrated by using a box filled with marbles to represent fluid molecules. Shaking the box — to simulate natural molecular fluctuations — causes de novo gaps between the "molecules." Under certain pressure conditions, according to the de novo theory, bubbles form from those gaps.

Yount says that the de novo theory could explain the gaseous nucleation that occurs in divers only if those divers were under 1,000 atmospheres of pressure, or about 10,000 meters of sea water: Fluids have to be supersaturated with gas under those high pressures before bubbles form from the small, de novo gaps. Since the gas bubble formation in divers involves pressures much lower than that, another mechanism of bubble formation must be involved, Yount says.

Experiments with transparent shrimp provided some of the earliest and most dramatic evidence that the bubble mechanism in divers involves those precursor micronuclei so vital to the Tiny Bubble Group's nucleation model. A. Evans and colleagues of the University of Newcastle upon Tyne theorized that if gas micronuclei do indeed exist and can expand to form visible bubbles, destruction of those micronuclei should decrease bubble formation. The British researchers, in studies reported in the April 19, 1969, NATURE, first observed bubble formation through the translucent carapace of shrimp when they decompressed the sea creatures to altitude pressures, or less-than-atmosphere pressure. Evans and co-workers then subjected another group of shrimp to a



Yount and colleagues observed bubble formation in gelatin (below) — in which bubbles can easily be counted — and in a hen's egg (above) — an example of an intact biological system.



Photos: Tiny Bubble Group

New ingredients for diver's dozen

Decompression tables are like opinions, says Richard D. Vann: "Everyone has one, and there is something wrong with every one of them." And, continues the researcher from Duke University Medical Center in Durham, N.C., the set of U.S. Navy Air Decompression Tables — a schedule of underwater ascents widely used by military and civilian scuba divers to prevent cases of the bends — is no exception.

In fact, a study released early this year reports a 1.25 percent incident rate of decompression sickness among Navy divers. "This means that the U.S. Navy can on an average expect about one case of decompression sickness every 8 or 9 working days," says report author Thomas E. Berghage of the Naval Health Research Center in San Diego, Calif. While this rate is acceptable for Navy divers who have decompression chambers and medical personnel close at hand to treat the bends, "The tables probably should be revised for civilians," Berghage says. For that reason, Vann, Berghage and 21 other researchers recently met for an Undersea Medical Society workshop in Bethesda, Md., to review and update 12 assumptions incorporated in the Navy's decompression model.

The objective of all decompression tables, whether formulated by the Navy or by companies engaged in underwater salvage work, is to prescribe safe rates of gas-eliminating ascent for scuba divers. A quantity of gas is absorbed by the blood and tissues during every dive and released when the pressure decreases — when the scuba diver begins to surface. To ensure that most of the gas will diffuse safely out of solution without forming the bubbles associated with the bends, different schedules of ascent are specified for different depths and exposure (bottom) times of dives. According to the Navy tables, for example, a 210-minute dive in 40 feet of sea water (fsw) requires a 2-minute decompression stop at 10 fsw.

The 12 assumptions underlying the Navy's schedule of such decompression stops consist of five ideas on gas uptake in the diver, three concepts of gas elimination and four assumptions governing phenomena associated with pressure reduction, or a diver's ascent. One of the gas-uptake assumptions is that only the partial pressure of inert gas need be considered in the decompression problem. In other words, theorists have based their decompression schedule calculations solely on the amount of nitrogen gas absorbed by the body during the dive, disregarding the possible effects of the other gas constituent in the scuba diver's air supply—oxygen. While this is a logical assumption — unlike the inert gas nitrogen, oxygen seldom attains very high pressure in the tissues because it is constantly being consumed — workshop participants agreed that it is an oversimplification of the decompression problem. That the partial pressure of oxygen is an important factor in constriction of blood vessels, for example, should somehow be incorporated into future decompression models, Berghage explains.

Another gas-uptake assumption discussed at the workshop is that compression procedures have no effect on decompression. This means that decompression theorists assume that certain types of decompression procedures — defined by the rate, number and depth of descents — *cannot* play a role in lessening the risk of decompression sickness. The decompression schedules, therefore, ignore the possibility that "spikes" of compression — such as quick, deep dives — crush gas nuclei, the theoretical precursors to bubbles, thereby eliminating some of the potential for bubble formation upon decompression.

But results of studies presented at the workshop by David Yount, formerly of the University of Hawaii and now of Stanford University in Palo Alto, Calif., seem to confirm the existence of crushable precursors to bends-causing bubbles. Although the implications of his studies are still a matter a debate, the research of this bailiwick of bubbles is a much needed novel approach to the problems of decompression, Berghage says. Prior to physicist Yount's entrance, the field of decompression theory was limited to the specialties of physicians and physiologists, Berghage explains. "It took someone totally divorced from the area to shed some new light on the problem; it took a fresh view like Yount's to really change our thinking."