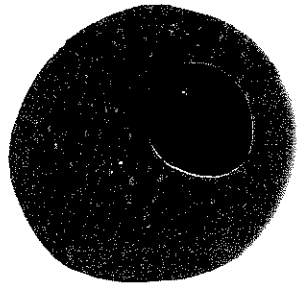
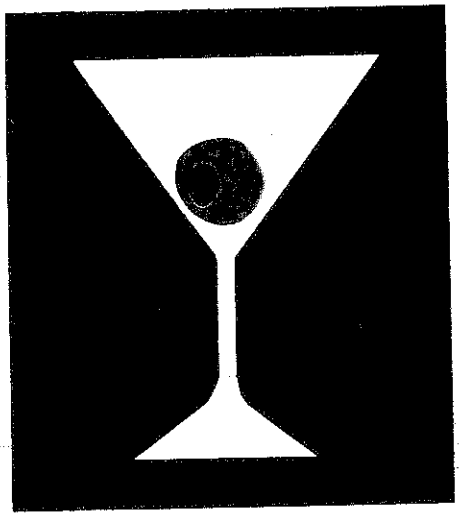
NITROGEN NARCOSIS. Nitrogen narcosis, "Rapture of the Deep," or depth drunkeness, as it is sometimes called, is a condition which begins to affect most divers at a depth of around one hundred feet. However, some individuals are susceptible in shallower depths. As has been pointed out previously, the greater the depth, the greater the partial pressure of nitrogen, and the larger the amount of this gas dissolved in the blood and tissue fluids. This excessive amount of dissolved nitrogen in the system causes a sense of "well being" or euphoria sometimes accompanied by dizziness similar to that which follows the consumption of alcohol. This similarity has produced a rule of thumb known as "Martini's Law." At 50 feet, the effect of nitrogen is the same as that produced by one martini on an empty stomach. At 100 feet, the effect is that of two martinis and so on.

The exact cause of nitrogen narcosis is unknown; however it disappears when a shallower depth is attained. There are no after effects.

Diving to the depths that produce marked symptoms of nitrogen narcosis is in the realm of the Senior Diver and should not be attempted by the novice.

MARTINI'S LAW





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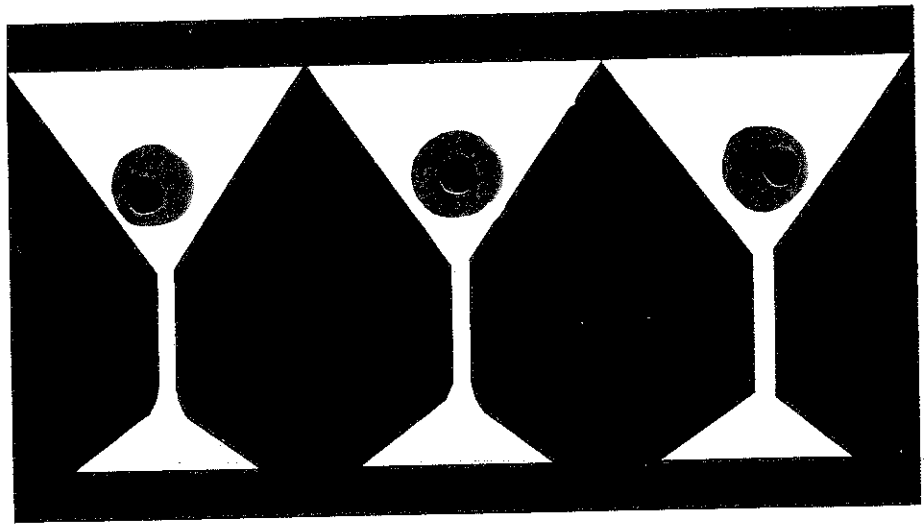

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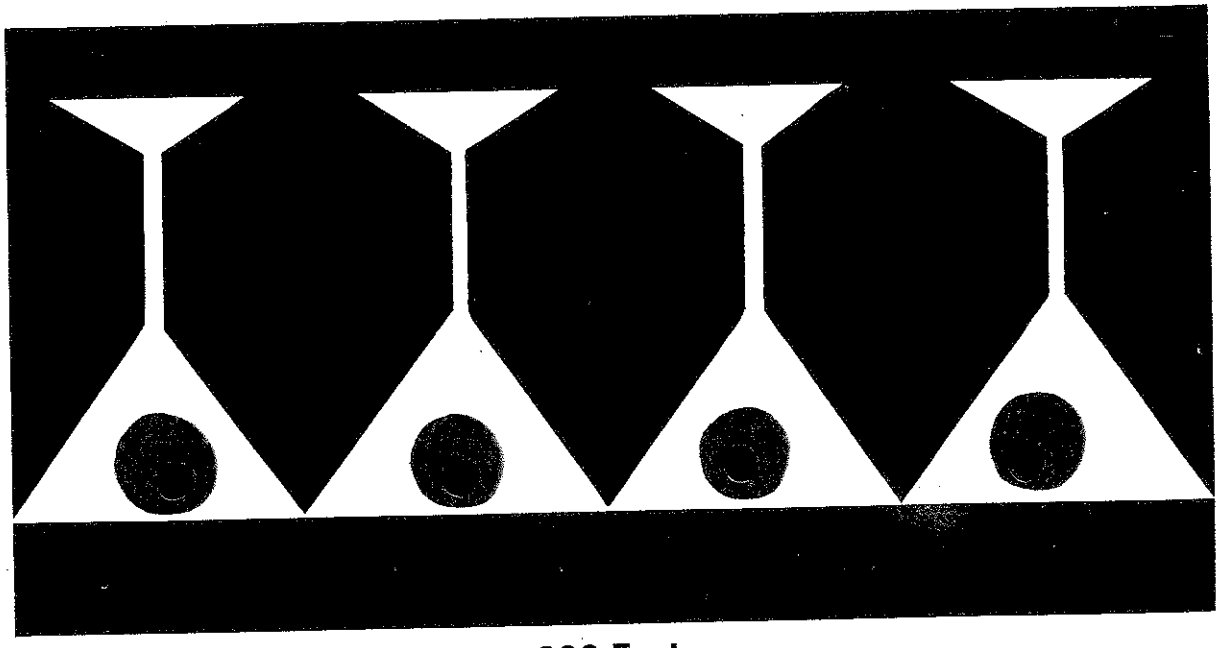

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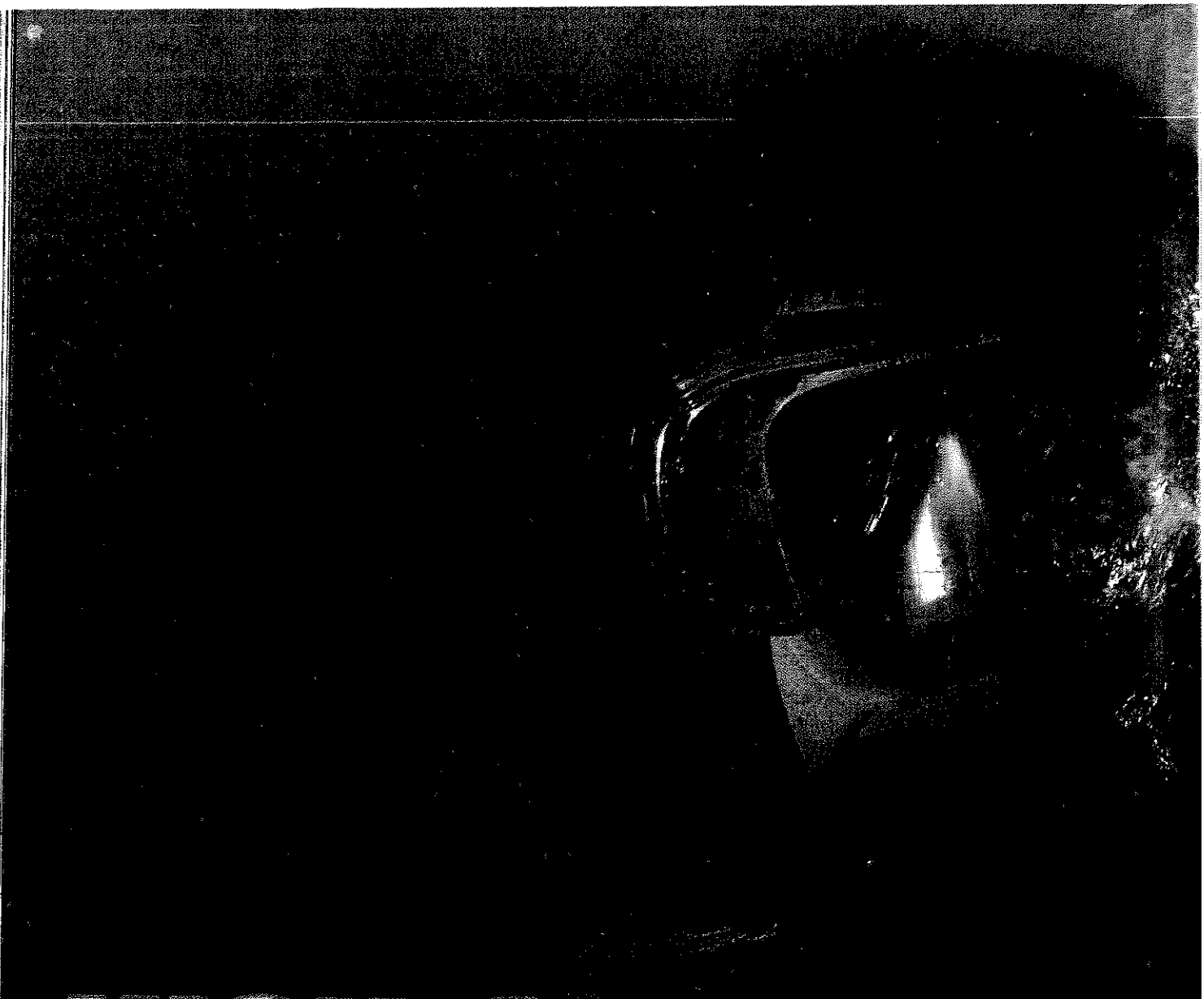


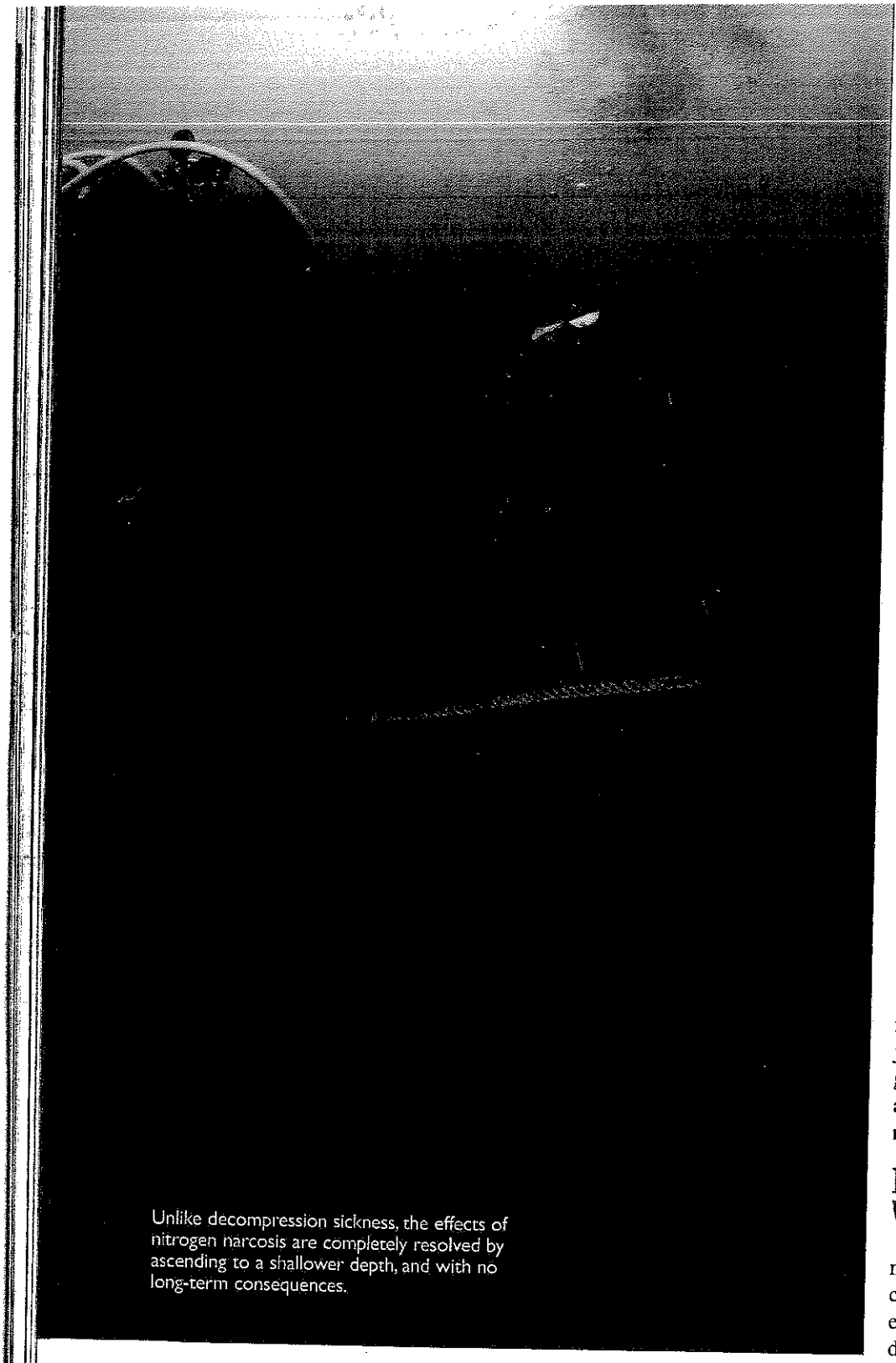
HIGH ON DEPTH

Scuba diving is pretty unique as far as a leisure activity goes, and for lots of reasons. Not the least of which is that it takes place in an environment completely foreign, and hostile, to human existence. It's also the only sport that I know of in which you literally have to pay for the air you breathe. But perhaps the most unique aspect of diving is that even if we do everything right we can still fall victim to life-threatening disorders. Furthermore, the deeper we go, the greater the risk we incur. This is in stark contrast to almost every other sport or recreational endeavor in which you'll normally have to do something wrong before you get into any kind of trouble. Not so for divers, though. We're exposed to hazards merely by being underwater.

A Closer Look at Nitrogen Narcosis

By Alex Brylske, photos by Joseph C. Bovala

At the root of almost every problem a diver faces is the fact that the air he or she breathes is under continually varying pressure. On ascent, when the pressure decreases, problems can arise when the air-filled spaces of our body, most notably our lungs, aren't vented and expand to a point beyond their maximum capacity. The result is a lung expansion injury such as an air embolism. In parlance of scuba instructors, we sometimes refer to this as the "direct" effects of pressure. Yet, other problems can result from the simple absorption of the inert component of our breathing gas mixture.



Unlike decompression sickness, the effects of nitrogen narcosis are completely resolved by ascending to a shallower depth, and with no long-term consequences.

Unlike the mechanical nature of injuries caused directly by changes in the volume of bodily air spaces, like the lungs, ears and sinuses, these more subtle consequences are what we term the "indirect" effects of pressure.

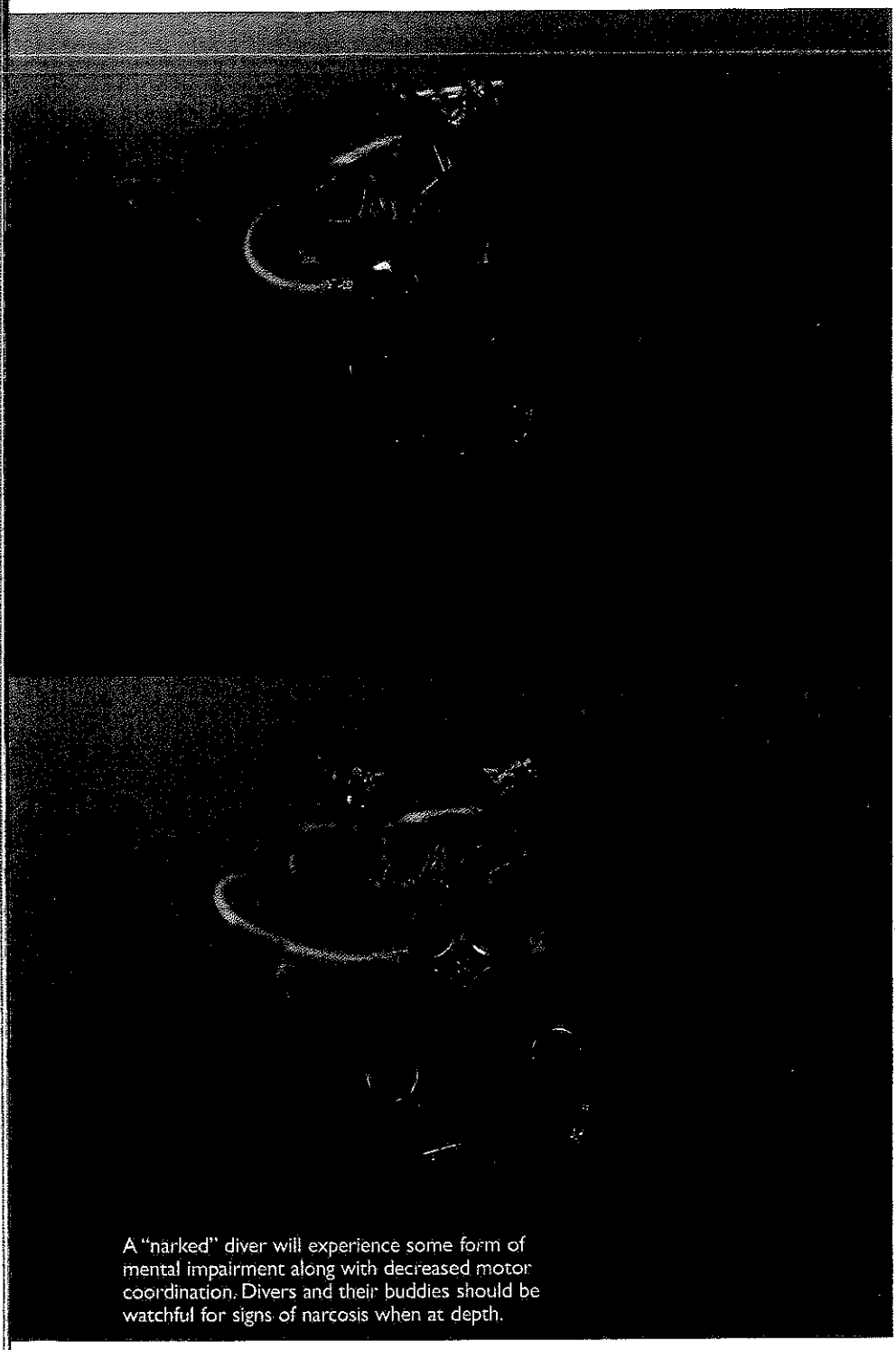
In recreational diving, the inert component of our breathing gas is nitrogen, although for technical divers it can also be helium. On ascent, the disorder of concern is decompression sickness, which is caused by dissolved inert gas (nitrogen or helium) escaping our tissues too quickly to remain in solution, and thus forming bubbles. However, there is also another indirect effect of pressure that's associated only with descent and it's almost as familiar to non-divers as is the "bends." It's formally called nitrogen narcosis, but scuba's own inventor, Jacques Cousteau, gave it the much more lyrical name, l'ivresse des grandes profondeurs ("rapture of the deep"). As Cousteau once wrote, "The chief symptom of this phenomenon, to put it bluntly, is the sensation of becoming as drunk as a hoot owl."

Without exception, every scuba training course covers nitrogen narcosis, but usually teaches only that it's caused by breathing nitrogen at high pressure; its effects increase with depth, normally becoming quite noticeable around 100 feet (30 m); and ascending to a shallower depth will relieve the symptoms. Case closed.

While these are certainly the highlights, this is anything but an in-depth explanation of this important condition. Additionally, the growing popularity of technical diving has made recreational divers more aware and curious about diving to much greater depths than our own limit of 130 feet (39 m). But whether you're interested in learning more about the challenges of deep diving as a bridge to technical diving, or just want a better understanding of what goes on inside your body at any depth, a more thorough insight into narcosis isn't a bad idea.

How Long Have We Known?

While we call the condition nitrogen narcosis, almost any gas can have a narcotic effect when breathed under enough pressure. The condition produces a state like alcohol intoxication or breathing nitrous oxide ("laughing gas") at surface pressure. The good news is that, unlike decompression sickness, the effects of narcosis are completely resolved by ascending to a shallower depth, and with no long-term consequences. Therefore, provided a diver is



A "narked" diver will experience some form of mental impairment along with decreased motor coordination. Divers and their buddies should be watchful for signs of narcosis when at depth.

aware of its symptoms and ascends to manage it, narcosis rarely develops into a serious problem.

Another interesting fact is that, aside from inert gases, it appears that we can also succumb to narcosis from high enough levels of that vital gas, oxygen. The reason is that too high a level of oxygen within the tissues can leave some of it unmetabolized, thus enabling oxygen to behave like an inert gas.

We've known about nitrogen narcosis for about as long as technology has enabled people to breathe air under pressure. In 1834 a French researcher, Victor Junod, was the first to describe it, noting "the functions of the brain are activated, imagination is lively, thoughts have a peculiar charm and, in some persons, symptoms of intoxication are present." As a cause, he proposed that narcosis resulted from high-pressure gas causing increased blood flow, therefore stimulating nerve centers.

A bit later, in 1881, a physician named Walter Moxon proposed that pressure forced blood to inaccessible parts of the body and the stagnant blood somehow caused emotional changes. Others believed it was a result of psychological factors, such as latent claustrophobia.

It wasn't until 1935 that a diving physiologist named Albert Behnke — the father figure of the U.S. Navy's diving program — suggested that it was the nitrogen component of air responsible for the narcotic symptoms. In 1939, Behnke and his colleagues were also the first to demonstrate that gases other than nitrogen, such as helium, could cause narcosis.

That year was also auspicious for yet another reason. On May 23, 1939, the U.S. Navy submarine, *Squalus*, suffered a catastrophic valve failure during a test dive off New Hampshire's Isle of Shoals. Fortunately it came to rest in just 240 feet (73 m) of water, rather than the crushing depths just offshore. Only a quick salvage-and-rescue operation would save the lives aboard, but the depth made air diving operations less than ideal due to the effects of nitrogen narcosis. The situation provided the Navy with its first opportunity to try the then-experimental gas mixture heliox (helium-oxygen) to complete the rescue; and the *Squalus* salvage operation went down as one of the most famous and successful in U.S. Naval history.

What's Up With That?

To understand the current theory for what causes nitrogen narcosis, you must first know a bit about how the nervous system works. Electrical nerve impulses are transmitted throughout the body via nerve cells called neu-

The Finger Test

Several years ago a technical diving guru came up with a simple but effective way for dive buddies to check each other for signs of narcosis. One diver displays a number of fingers, and the buddy must respond with one more or less (depending on prior agreement). As this requires a bit of thought, an improper response could be an indication that the diver is impaired. Of course, the technique doesn't work if both buddies are impaired, so it isn't foolproof.

rons. These neurons, which are made partially of lipid (fat) tissue, transmit electrical signals to other neurons at junctions called synapses. The narcotic potency of an inert gas is a function of its solubility in fat tissue — those that dissolve more easily into fat are more narcotic. The greater the solubility, the less partial pressure is needed to induce narcosis. Sedation occurs, it's thought, because the inert gas causes the synaptic membrane to expand, which slows or stops transmission of electrical impulses.

By the 1960s an alternative to the nitrogen theory was proposed, suggesting that narcosis was caused by high levels of carbon dioxide resulting from reduced respiratory efficiency. Although researchers have refuted the carbon dioxide theory, it has been shown that high levels of carbon dioxide will enhance the onset and severity of nitrogen narcosis. More recently, scientists have been looking at neurotransmitter receptor protein mechanisms as a possible cause of narcosis.

Regardless of the mechanism involved, the result is a slowing of our mental processes and reaction time. Essentially, information cannot be processed as fast as the input is received, and our performance of tasks ranging from reasoning to manual dexterity suffers.

A portion of the brain called the reticular center, which is responsible for receiving and distributing nerve impulses throughout the body, is particularly susceptible to this anesthetic effect. It's interesting to note, however, that although this theory is based on solid evidence, to this day no one is absolutely certain about what causes nitrogen narcosis.

What Are the Effects?

Most divers are taught that the symptoms of narcosis usually don't occur until a depth of around 100 feet (30 m). But that's really the depth at which symptoms become noticeable; subtle impairment starts in as little as half that depth. In fact, studies done by the U.S. Navy have documented that some highly susceptible individuals are affected by nitrogen narcosis at pressures as low as 2 atmospheres (33 feet [10 m]). Studies also show that, in virtually every diver, by the time they reach 3 atmospheres (66 feet [20 m]) there's a measurable slowing of mental processing, although at this depth you're usually unaware of any change. By 4 atmospheres (99 feet [30 m]) most are aware of some impairment. In the depth range of 4-5 atmospheres (99-165 feet [30-50 m]), divers can experience a variety of debilitating symptoms. (For more details on depth-related symptoms, see the chart in the sidebar, "Signs and Symptoms of Narcosis.")

The effects of narcosis are also highly variable among individuals, and even with the same individual on different days. Some divers even believe they're virtually immune to the disorder, citing their ability to function well below 100 feet (30 m) without any apparent effect. But the truth is, no one is immune. Everyone is affected; the only questions are when, how and to what degree.

How Do Divers React?

In divers, the effects of narcosis generally start with some form of impairment of mental function. This may include loss of memory, reasoning ability or a reduced ability to concentrate or to make sound judgments. These symptoms are especially dangerous because they often occur at times when divers need their wits about them the most; yet the individual may not even be aware that anything is wrong. As these symptoms can cause lapses in judgment, a "narked" diver can easily run out of air or overstay his allowable bottom time. It also makes a breakdown of the buddy system much more likely.

As depth increases, the symptoms can progress to impaired motor coordination, and in some divers a reduced or delayed response to sound and visual stimuli. This, combined with decreased mental capability, puts the diver at great risk. In extreme depths — beyond 165 feet (50 m) — symptoms can become quite severe, and include extreme confusion, sleepiness and even hallucinations.

Most textbooks caution divers about the sudden and abrupt onset of symptoms, but many experienced technical divers disagree. They contend that the onset of narcosis, while subtle, can be detected in its very early stages. Symptoms they often point to include a reduced ability to read one's gauges, and an increased awareness and sensitivity to sound. "Perceptual narrowing," a condition akin to tunnel vision, is also a very common early symptom. It's important to note, however, that only those who are highly experienced at deep diving are likely to recognize such subtle symptoms. It's also not uncommon for victims of narcosis to have amnesia, reporting no recollection of events that took place at depth.

Both research and practical experience indicate that the effects of narcosis can be enhanced by several factors. Two such factors are the environment you dive in and your mental state. For example, some studies have shown that divers

Signs and Symptoms of
Narcosis

Depth
33-100 feet (10-30 m)
Signs and Symptoms
- Mild impairment of performance of unpracticed tasks.
- Mildly impaired reasoning.
- Mild euphoria possible.

Depth
100-165 feet (30-50 m)
Signs and Symptoms
- Delayed response to visual and auditory stimuli.
- Reasoning and immediate memory affected more than motor coordination.
- Calculation errors and wrong choices.
- Idea fixation.
- Overconfidence and sense of well-being.
- Laughter and loquacity (in chambers), which may be overcome by self-control.
- Anxiety (common in cold murky water).

Depth
165-230 feet (50-70 m)
Signs and Symptoms
- Sleepiness, impaired judgment, confusion.
- Hallucinations.
- Severe delay in response to signals, instructions and other stimuli.
- Occasional dizziness.
- Uncontrolled laughter, hysteria (in chamber).
- Terror in some.

Depth
230-300 feet (70-90 m)
Signs and Symptoms
- Poor concentration and mental confusion.
- Stupefaction with some decrease in dexterity and judgment.
- Loss of memory, increased excitability.

Depth
300-plus feet (90-plus m)
Signs and Symptoms
- Hallucinations.
- Increased intensity of vision and hearing.
- Sense of impending blackout, euphoria, dizziness, manic or depressive states, a sense of levitation, disorganization of the sense of time, changes in facial appearance.
- Unconsciousness.
- Death.

in warm, clear-water environments — conditions likely to evoke a sense of comfort and control — are more likely to experience a sense of overconfidence, well-being and euphoria. But, in a less secure environment, such as cold, dark water, or in a less secure state of mind, symptoms of anxiety are more likely. In some cases, even terror and panic have been noted. This is a very important consideration because, as your diving environment and your mental state change, you can never assume that your susceptibility and response to nitrogen narcosis will always be the same.

There's also evidence of the importance of psychological factors, and how the onset of nitrogen narcosis could be influenced by what's termed "negative modeling," a form of self-fulfilling prophecy. One such study of anticipatory behavior modeling conducted back in 1965 resulted in some very interesting findings. The study involved three groups. The first group was taught that virtually all divers succumb to narcosis at 130 feet (39 m), and that symptoms would be severe. The second group was taught about narcosis, but was told that it was far from certain to occur and its severity was downplayed. The final group was given a three-hour lecture on narcosis, including a review of all known research, and told that strong willpower could greatly reduce its effect. Each group was then given a series of cognitive exercises in a recompression chamber at depths ranging from 100 feet (30 m) to 240 feet (73 m).

The results showed an apparent correlation between how the divers were trained and their ability to deal with narcosis. For example, no members of the first group could perform past the 200-foot (61-m) level, and two subjects from the second group were also unable to perform. Amazingly, however, members from the third group actually showed better performance at 200 feet than at their surface test, and all but one subject continued to function well to the final depth of 240 feet. While one single study is far too little to form solid conclusions, instructors may do well to keep these results in mind the next time they teach their students about narcosis.

Another contributing factor is alcohol consumption or taking drugs that block nerve transmission. The drugs in question include not only prescription medications, but also over-the-counter remedies for conditions such as seasickness, diarrhea and nasal congestion. Besides drugs, high levels of carbon dioxide, exertion and fatigue can also contribute to the onset and severity of symptoms. There's even some evidence that an increase in oxygen partial pressure might influence the early onset of symptoms.

What Can I Do?

While no one is immune to nitrogen narcosis, there are some things you can do that might reduce its effects. First, be very careful about exceeding depths deeper than you're used to unless you have advanced training or are under supervision of more experienced divers. Even if you're an experienced deep diver but haven't done it in a while, it's a good idea to work up to a deep dive by making a few progressively deeper "rehearsal dives." Be sure to practice the tasks you'll perform on the deep dive, too.

Often, especially when on a holiday, we can't always choose our buddy, and even if we can, we aren't always that discerning. However, when deep diving, it's important that you both know and trust your buddy. Prior experience with an individual gives you a "baseline" for what constitutes normal behavior. This insight will make it easier for you to recognize signs of nitrogen narcosis sooner than you might with a buddy whom you don't know well.

Most divers are taught that the symptoms of narcosis usually don't occur until a depth of around 100 feet (30 m). But that's really the depth at which symptoms become noticeable; subtle impairment starts in as little as half that depth. In fact, studies done by the U.S. Navy document that some highly susceptible individuals are affected by nitrogen narcosis at pressures as low as 2 atmospheres (33 feet [10 m]). Studies also show that, in virtually every diver, by the time they reach 3 atmospheres (66 feet [20 m]) there's a measurable slowing of mental processing, although at this depth you're usually unaware of any change.

It may seem obvious, but deep diving requires use of a high-quality, well-maintained regulator. A poor-performing regulator can cause stress that, in turn, can exacerbate narcosis. So, make sure that your equipment is in top working order, and has been serviced within a reasonable period of time. One way you can get optimal performance is by remaining relaxed and moving in a slow deliberate manner.

Another common-sense guideline is to avoid drinking alcohol or taking any drugs for at least eight hours before diving. If you must take drugs, never take them for the first time before diving. Always know what effect a drug has beforehand. If the drug has a psycho-active effect or gives you a dry mouth, don't take it before making a deep dive. It could greatly increase the likelihood or effects of nitrogen narcosis.

Remember the KISS principle: Keep It Simple, Stupid. A simple dive plan means that you won't overload yourself with too many tasks. When deep diving you can't help but be impaired to some degree. Trying to accomplish too much will only increase the likelihood of poor performance or forgetting something.

Always try to begin a deep dive in a calm, relaxed frame of mind. Consider using the mental rehearsal techniques detailed later, and — most importantly — never hesitate to call off the dive if for any reason it just doesn't "feel right."

Deeper water almost always means colder water, so wear adequate exposure protection. Remember, your wet suit will lose some of its effectiveness on a deep dive because of compression. Studies have documented that nitrogen narcosis can suppress the shivering response. This could lead to a false sense of your true state of thermal stress. In turn, moderate hypothermia can exacerbate the mental impairment caused by nitrogen narcosis.

Heed the advice and insights from more seasoned deep divers. Experienced deep divers often report that narcosis is at its worst when first arriving on the bottom. Therefore, don't be too quick to get on with the dive; take a minute or two to acclimate once you're on the bottom. Stop, relax, check your air supply and equipment and confirm that your buddy is alright before proceeding.

Deep diving is not something you want to learn by trial-and-error. It's strongly advised that you take a formal

deep diving course from an experienced instructor. In addition, most courses will have you perform a timed task, such as solving an arithmetic problem or opening a combination lock, at the surface, and then compare it with the time it takes you to do the same task at a depth of 100 feet (30 m) or more. Interestingly, some divers are able to perform the task better at depth than at the surface, and then mistakenly conclude that they're immune or not very susceptible to narcosis. That's a dangerous and false assumption because, as numerous studies have shown, the reality is that their improved performance is merely the effect of practice, not any indication of reduced sensitivity to nitrogen.

When deep diving, especially, be sure to keep a vigilant eye on your buddy. Ideally, never let more than three or four breaths go by without visually confirming their location, and verifying his or her mental state. (See the sidebar "The Finger Test" on Page 48.)

Finally, there's the issue of descent rate. Researchers have evidence that correlates a rapid descent with an increased likelihood of nitrogen narcosis. Logically, then, to reduce your risk, you should avoid descending too rapidly. But it's not quite that simple. On the other side of the issue, evidence also shows that a rapid descent might help divers avoid decompression sickness by crushing gas micronuclei. As this issue is still under debate, the best advice is probably to descend at a deliberate but comfortable rate. Another way to perhaps prevent or control narcosis is to use a reference line to provide a constant visual orientation during the descent.

What Can We Learn From Technical Divers?

While scientists remain divided on the issue, experienced technical divers are adamant that divers can stave off some of the effects of narcosis by continued and frequent deep diving. This is probably due to both physiological adaptation, and because the seasoned diver develops coping skills, such as concentrating more intently on the task at hand. The adaptation is only temporary, however, and decays over a matter of days or weeks once diving ceases. The coping skills may last longer. A high motivation to complete the task appears to help reduce symptoms, as well.

Applying these ideas, technical divers often use special techniques to prepare for a deep dive. The first is to acclimate to the planned depth through a series of "rehearsal dives." These are dives made over several days, in progressively deeper water, where divers engage in tasks similar to what they'll do on the final dive.

The second preparation technique used by technical divers is mental imagery. Before entering the water, the diver sits quietly with eyes closed and imagines, as vividly as possible, making the dive. This lets the diver anticipate what's likely to happen, and deal with any problems in a calm, considered and deliberate manner. Should any of these problems actually occur during the dive, he'll be better able to handle the situation as he has, in a sense, practiced overcoming the problem before the dive. In addition, the imaging technique may help avoid the common problem of "task fixation," in which concentrating so hard on overcoming one problem, the diver forgets about something else. An example might be fixating on adjusting a buckle, but forgetting to check your air supply. Mental imagery is also an aid to relaxation, and helps prevent starting your dive in an overly anxious mental state.

The effects of nitrogen narcosis are insidious. The early stages are virtually imperceptible; and by the time signs do become obvious to a buddy, the victim can be beyond the point of helping him or herself. Proper planning, preparation and awareness can prepare you to deal with the condition, and may even somewhat help you stave off the effects. But no matter what anyone tells you, everyone is affected. It's just a matter of when and where.