Edited by
Harald Apelt

Do divers really need underwater lamps?

It is a simple question to which there is no simple answer, as it all depends... If you are mostly diving in Southeast Asia or the Caribbean where visibility is fantastic, during days of bright sunshine and in waters of 20m or less, you probably don't need one. But if you plan on diving in lakes, doing night dives, penetrating wrecks or do any sort of technical dive, then a good lamp becomes an essential part of your diving gear.

How to choose Lamps

By Harald Apelt

PETER SYMES

WOLFGANG POLZER

What do you need? Which lamp type is best for you? It all depends, as the article explains...

What makes an underwater lamp a good lamp?

First of all, it needs to be bright and closely reproduce the colour of daylight, so it shows the colours as realistic as possible. For a long burn time, it needs to be equipped with a high capacity accumulator. A short charging time is also essential, especially of you plan on having several dives in a row.

Size and weight is also of importance because of weight limitations and space restrictions when it comes to bringing it on an aircraft. It is not really a question of build quality, but rather of comfort, in how the lamp can be transported in an aircraft. Due to airline regulations the bulb or lamphead has to be transported separately from the accumulator, so divers are normally required to detach the bulb.

There is a wide variety of different lamps and techniques available. First of all, you will have to determine which sort of diver you are. As mentioned before, the requirements for a lamp are different, and that's why you should decide which type of diving you are going to use it for. Do you need a system of extreme durability and power for extended cavern dives, or just a small lamp for your BCD pocket?

Do you require a 10 Watt backup-light or a 100 Watt high performance spot? And which system will meet your requirements best? Is it a halogen-lamp, a Xenon-light, the "power pack" HID (High Intensity Discharge) or the LED-technique (Light Emitting Diodes)?

This tiny HID from Singaporian Aunoc is less than three inches long and will fit into any pocket, yet it boasts an impresssive output

Underwater lamps can be classified into three basic categories:

There are handlamps with batteries, rechargable handlamps with accumulators or *acculamps*, and lamps with external battery packs or *accu-tanklamps*. The operation of these three types are quite different.

Those divers who need a lot of light for a long time, will become fans of an accu-tanklamp. The canister with the accumulator is normally fixed on the side of the tank and is connected with a cable (*umbilical*) to a lamp head which is held in the hand. The lamp head quite often has a special grip—a so-called Goodman-grip— which makes the use of the lamp head very comfortable. For cavern dives, there is also a special version that fixes the lamp heads to the helmet. These accu-tank lamp are often the choice of tech- and wreck divers. Videographers also tend to prefer the tank-system because of its high capacity.

The XHL-4500 rechargable handlamp from Metalsub represents the mid-sized solution

The battery pack can be attached to your tank with a clamp

The lamp head is connected to the battery canister via an "umbilical"

HENRIK ZEBIS

With a "Goodman-grip", you can carry the lamphead on the back of your hand

SCUBALIGHT

The disadvantage of these lamps is their high price and their high weight. These are the main reasons why they are not widely used by classic sport divers.

The powerful and high quality alternatives to these complex systems are the accu-handlamps. They are normally made of aluminium tubes, have an integrated accumulator-pack of different power, and they are available with all kinds of above mentioned bulbs.

The cheaper alternative to this kind of lamps are the battery lamps. They are mostly made of plastic and can be used with rechargeable or normal batteries. These batteries—whatever is used—can be easily removed and makes this type of lamp very comfortable for

The high-end lamp type. HIP Lamps like the H10 from American Diverite with eight hours of burn time are the choice of many technical divers

DIVERITE

flight transportation. The lower price of the battery-lamps seems to be a good argument for scuba divers as well.

The biggest disadvantage of these two more professional types of lamps lies with the accumulator. They have to be handled with care. One highly important aspect is quite often neglected by the owners: Reading the instruction manual. Here you'll find the important answers to which kind of accumulator is used in your lamp, how and in which intervals it must be loaded, and how to prevent the damages of memory effect or wrong long-term storage.

New technology

The newest technological development is a mixture of all three types of lamps. These modular systems are designed by several companies (for example Green Force or TillyTec Lightsystem) with a lot of creativity and imagination.

The lamp is divided in different segments, which is the reason why it is possible to interchange the different lamp heads with different accumulator-packages, too. It is a big advantage because now you can start with a "small" solution and "upgrade" later to a more powerful system.

In the end, you are able to reduce or upgrade the battery-pack of your light-system, use two different lamp heads and set up the exact light-system you need for your next dive.

The limits to what you would like to invest in the best hobby in the world is really only set by the size of your budget.

Durable, cheap and with good perfomance. Lamps like this battery LED lamp (left) and 10 W with rechargable NiCad batteries have become commonplace

The LED lamp has a burn time of more than six hours on just three standard batteries. The lamphead is rated at +50,000 hours lifetime

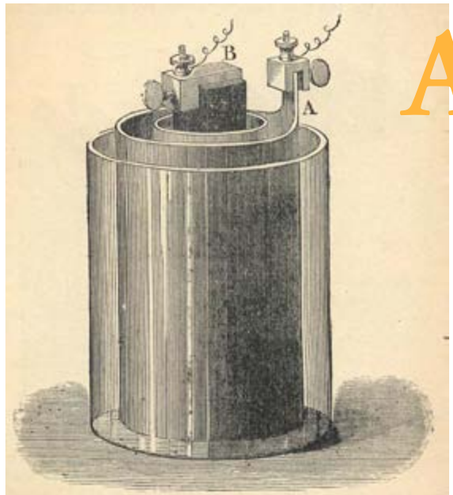
HARALD APELT

SCUBAPRO

Scubapro's bid for a modular lamp system. The lamp heads are available in halogen, HID and LED

Big battery packs can be mounted on the tank or on the harness

URS ANLIKER



Batteries & Accumulators

If the bulb is the heart of an underwater lamp, the accumulator is its soul

Cadmium, which is used in rechargable batteries, is also an environmental hazard

HARALD APELT

Charging your lamp

Do you have to open it to charge it, exposing the delicate innards to the elements? You also have an o-ring to look out for and make sure it is watertight every time you close the lamp after each charging session

If the bulb is the heart of an underwater lamp, the accumulator is its soul. And as with humans, the soul can be difficult to comprehend. There are a lot of different types of accumulators available for underwater lamps, but at present, none of them is absolutely perfect. All of them generate electricity through some chemical process inside, and all of them have certain characteristics that affect them from being a perfect energy storage.

Good price

The most widely used accumulators in diving lamps presently are nickel-cadmium-accumulators (NiCad). They have been used worldwide for many years, and because of mass production, are reasonably priced.

But there are a few disadvantages with this technology. As Cadmium is environmentally problematic the European Parliament has passed a ban using NiCad-accumulators in diving lamps in the European Union—and, as usual, at the same time they granted an exemption for the continued use of NiCad-accumulators in power tools. The ban is going to take effect from October 2008.

Downsides

The technical disadvantages of NiCad-accumulators include the need for new lamps to undergo up to ten cycles of charging and discharging before they reach their full capacity. Another problem is caused by the self-discharge effect, which is responsible for suboptimal shelf life. But the most noted disadvantage of NiCad-accumulators is the memory effect, which is due to mistakes and bad handling by the user when recharging the accumulator. Last but not least, at the end of its usable life, a NiCad-accumulator has to be disposed of as hazardous waste (and so do the other types of batteries).

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Extermal charging is more practical

The next generation of accumulators were the nickel-metal-hydride accumulators (NiMh). They have a good rate of possible recharging cycles: 500 up to 1000 charge cycles can be reached with these accumulators. Unfortunately, these accumulators tend to become weak once they get overcharged. They also tend to discharge during storage and react with a loss of capacity at low temperatures around zero degrees Celsius.

The options

So what is the best solution for our diving lamps? For quite a while, the general consensus seemed to be that the lithium-ion accumulators, which have proven their value in mobile phones and laptop computers, would also be the perfect solution for diving lamps. They are small, light weight and have a short charging time. They can be charged without opening their container, at any time, and in any state of charge. And they also work fairly well in the low temperatures below freezing. In addition, no self-discharge and no memory-effect is known in this technology. So, it seemed like a perfect solution until some cases of notebooks and cell phones caught fire, resulting in the closer scrutiny of this technology. Lithium-ion accumulators are indeed tricky to handle and can become dangerous, as they might react to physical damages with explosions and burnouts. The worst issue is that once they catch fire, they are nearly impossible to extinguish.

The charging technology for these accumulators is a complicated matter, especially when HID bulbs are used. Then, the operation of a lithium-ion accumulator becomes a very complex process. That's why most of the manufacturers of lithium-ion accumulators are not issuing any warrants for the usage of these accumulators in diving lamps. Except Sanyo. This company is delivering their accumulators only to lamp producers, who ran a special test and have integrated a special PCB-electronic device that powers down the accumulator in case of technical problems. Manufacturers like German Kowalski is using the Sanyo accumulators for the lithium-ion HID-lamp "maxum", and they are in good company as some aircraft manufacturers have chosen to use the same cells in their airliners. This and the certification by the Federal Aviation Administration (FAA) ensures that the technology is considered safe and can be used without problems, provided that the safety and processing issues are being handled correctly.

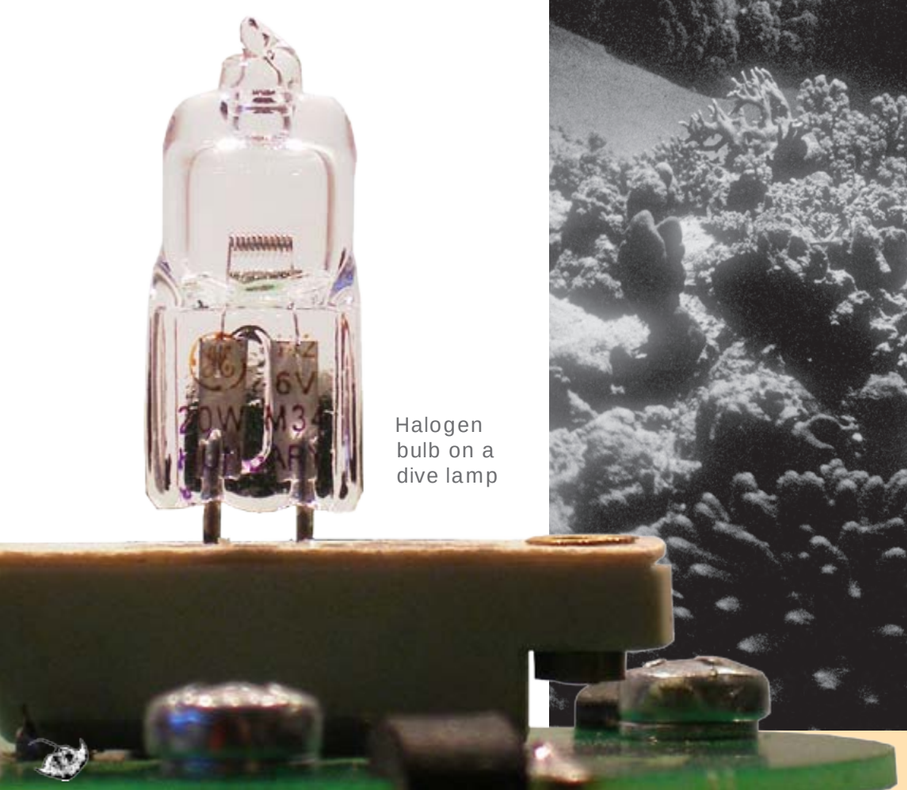
Nearly the same technology is used in the lithium-manganese accumulators. They keep their efficiency in cold water and a good shelf life. Another advantage is that they don't need safety electronics and may be charged in closed containers, too. They are said to be safer, but they are not as powerful as the lithiom-ion versions, and long-time storage without use might reduce lifetime of these accumulators.

Which type of accumulator is best for you depends on your intended usage—as well as the size of your wallet.

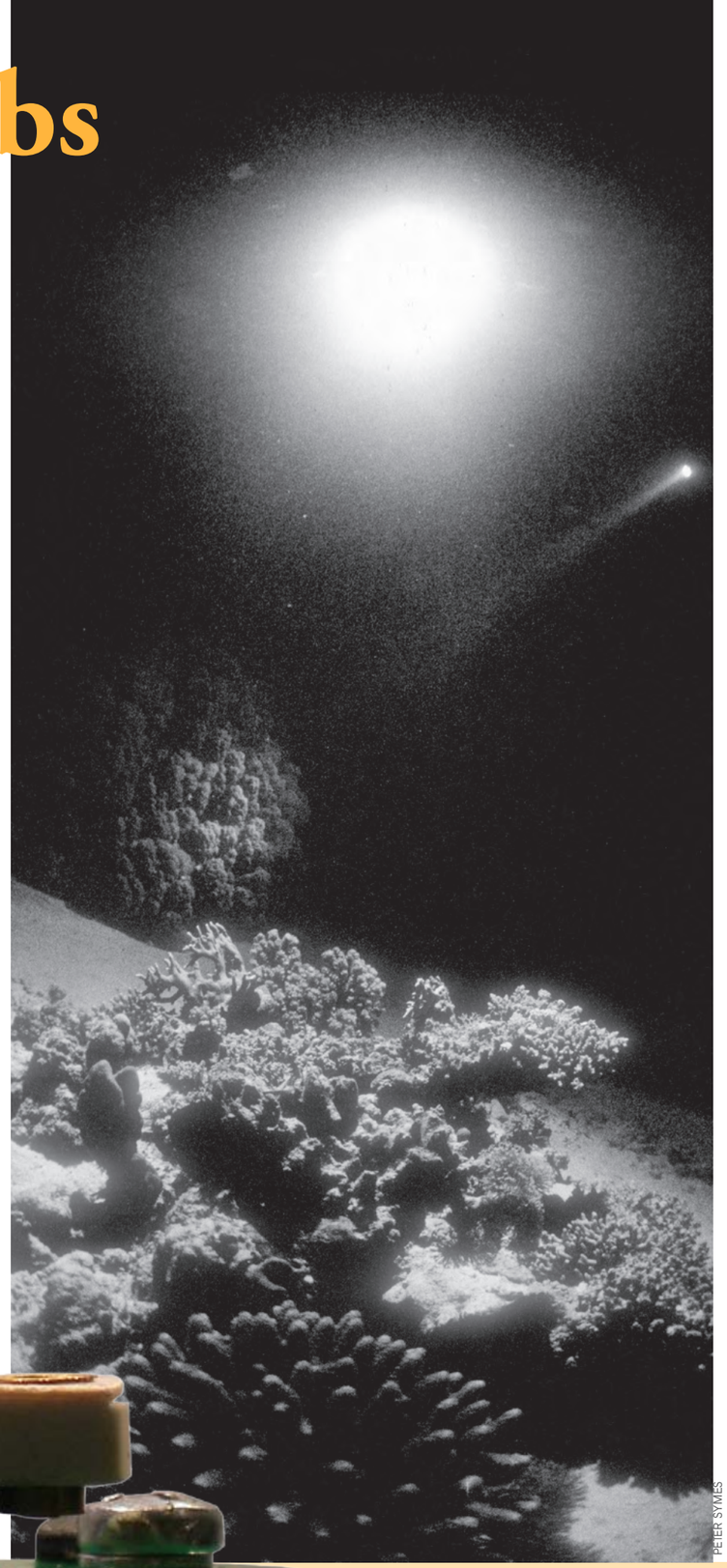
Bulbs

U.S. Patent 0,223,898 by Thomas Edison for an improved electric lamp, January 27, 1880

Just imagine. You are out on a night dive somewhere nice with a group. You switch on your new 50 or 75W dive lamp flood-lighting the whole reef for everyone to see, instantly making you the person of the day.



Halogen bulb on a dive lamp



PETER SYMES

Thanks to a little help from technology and the latest developments in light bulb manufacturing, we now have an impressive output at our fingertips. It has only been a few years since the LED-technology (Light Emitting Diodes) was the laughing stock, but now it's on the cutting edge. State-of-the-art used to mean Halogen bulbs. Later, Xenon bulbs became the buzz word, and then—as seen in cars—HID-bulbs (High-Intensity-Discharge) were all the rage.

Let's take a closer look at the differences.

Halogen

The halogen lamp is similar to the conventional non-halogen incandescent lamp in that it employs a tungsten filament in a gas-filled, light-transmitting glass-shell and produces the same type of light. It has a colour temperature of about 3600 Kelvin, which means it emits a slightly red and "warm" light. (See next page for explanation of "Colour temperature").

The major difference is that a halogen vapour (Iodine or Bromine) is added to the inert gas inside the glass bulb, and the gas pressure and bulb temperature are much higher than in non-halogen lamps. Also, the bulb is made of fused quartz, high-silica glass or aluminosilicate "hard" glass, which is capable of withstanding the high operating pressures and temperatures.

Tungsten

Tungsten-halogen lamps operate in a "halogen regenerative cycle", which maintains constant light output and colour temperature of about 3600 Kelvin throughout the life of the lamp. The halogen cycle permits the use of more compact bulbs than those of conventional tungsten-filament lamps of equal ratings, and also permits either increasing lamp life to approximately twice that of conventional tungsten filament lamps having comparable wattage and colour temperature.

Xenon

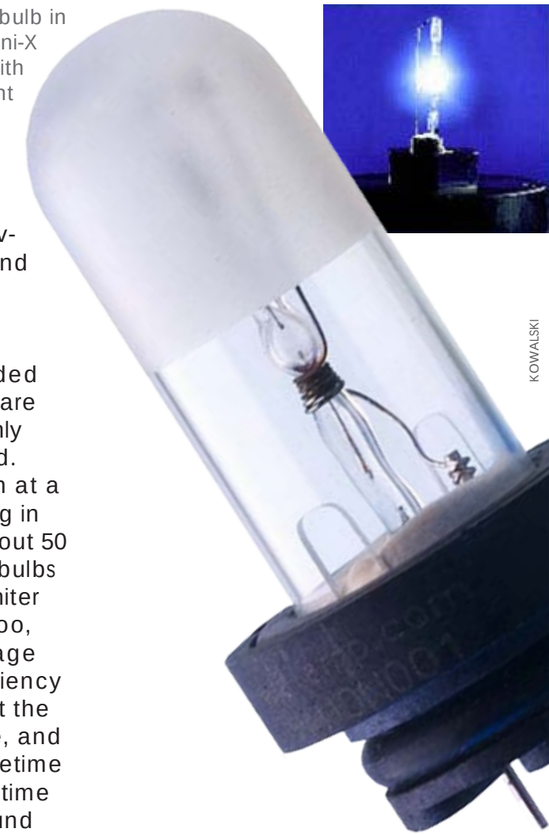
The halogens were succeeded by the Xenon-lamps. These are similar to halogen-lamps, only filled with Xenon gas instead. This makes the filament burn at a higher temperature, resulting in an increase in output of about 50 percent. That's why Xenon bulbs seem to be brighter and whiter than halogen bulbs. They, too, can be used with over voltage that increases the light efficiency as well. The downside is that the higher working temperature, and the over voltage reduces lifetime of the bulb. The nominal lifetime of a Xenon bulb is only around 100 hours. Halogen-bulbs will last up to ten times as long.

HID

HID-technology was first widely used in cars. HID stands for *high-intensity discharge*, which is the technical term for the process which produces the light by striking an electrical arc across tungsten electrodes housed inside a specially designed inner fused quartz tube. This tube is filled with both a gas and metals. The gas aids in starting the lamp. When a HID-lamp is switched on, an ignition spark of about 25,000 Volt ionizes the gas, which is under high pressure. The metals produce the light once they are heated to the point of evaporation, forming plasma.

Note that a HID bulbs are, in fact, also filled with Xenon gas which may lead to some confusion.

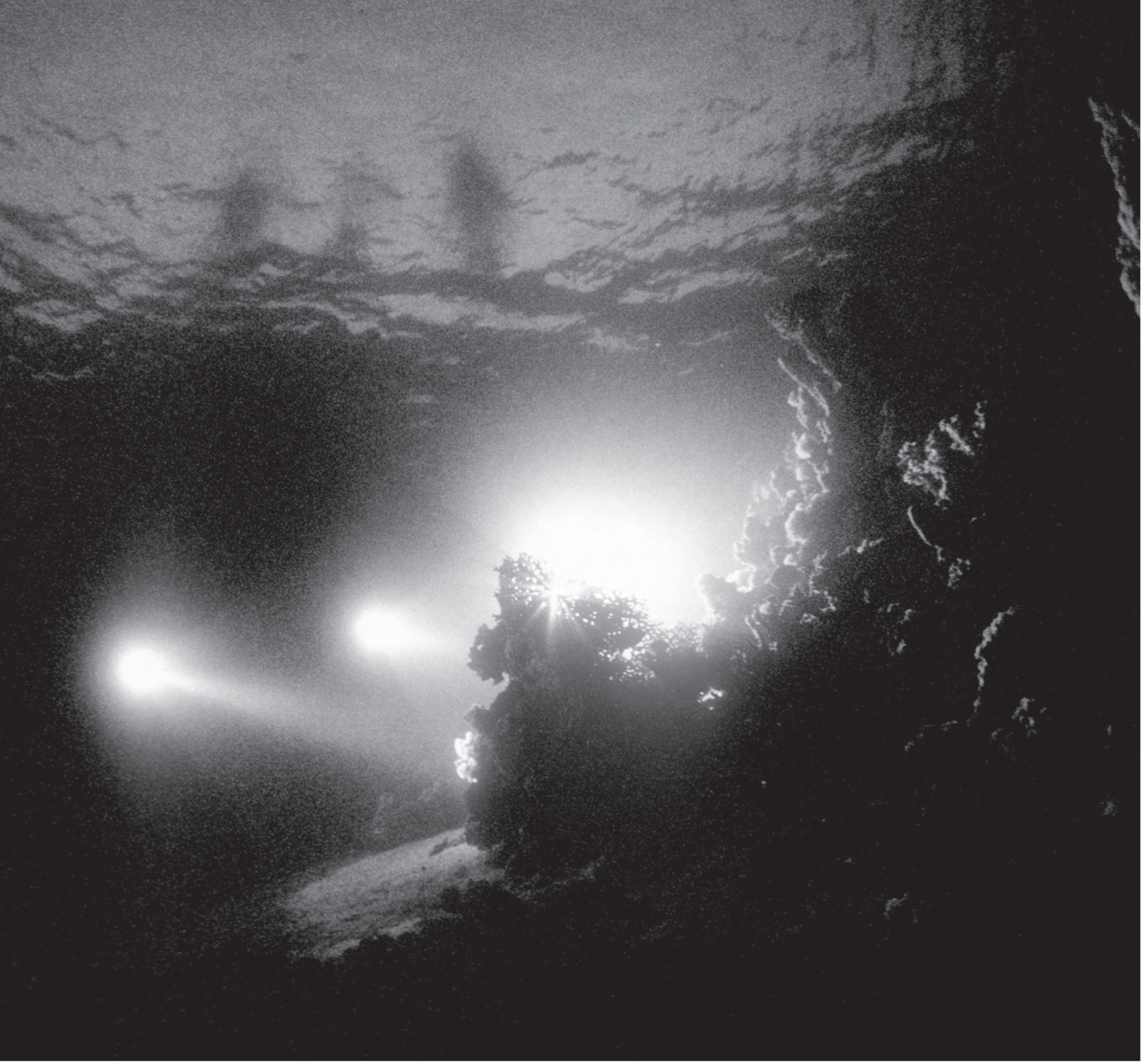
The Xenon bulb in Kowalski's XR mini-X produces a light with a white to bluish tint



KOWALSKI

A HID bulb for a car, clearly showing the glass tube and the electrodes across which an electric arc is struck

PHILIPS



PETER SYMES

Why it is called colour *temperature?*

As we know from the glow of i.e melting iron it changes colour according to how hot it is. This phenomenon is used to link colour with temperature. The colour temperature of the thermal radiation from an ideal black-body radiator (a hypothetical material that reflects or emits no other light) is defined as equal to its surface temperature in Kelvin degrees. 5500 K is widely considered "standard daylight"

After ignition a rather complex piece of electronic circuitry adjusts the voltage from the high ignition levels down to a process-voltage of about 60 to 90 volt. Once running, the arc produces a better and brighter light than the lamps with filaments while using less energy.

By comparison HID bulbs produce between 2,800 and 3,500 lumens using between 35 and 38 watts of electrical power, while the performance of halogen filament bulbs lies between 700 and 2,100 lumens while consuming between 40 and 72 watts at 12.8 Volt.

The light from HID lamps has a distinct bluish tint when compared with tungsten-filament headlamps. The bluish tint is less absorbed by water so the HID-beam has a better penetration than a comparable halogen beam.

HIDs are well suited for cave and wreck diving. But not optimal for the casual diving on reefs in daylight in depths of no more than 10-15m. As the red parts of the light spectrum are being absorbed first by the water with the blue colours being filtered last, what you mostly need at these shallower depths is boosting the red tones.

Xenon HID

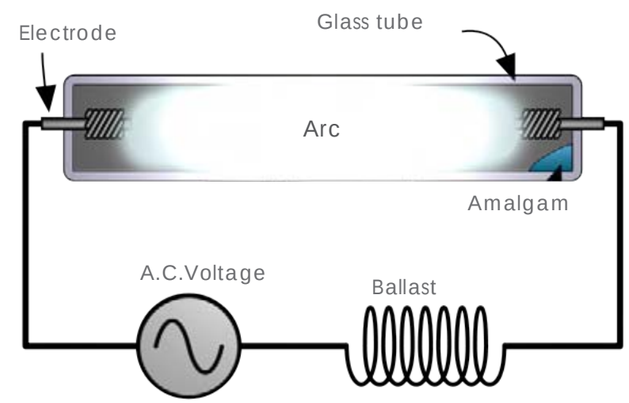


Diagram over a HID bulb

Another advantage of HID-lamps over halogens is their much longer lifetime of about 5000 hours. In addition, the colour temperature of HID lamps of 5500 to 6000 Kelvin closely resembles that of daylight (5700K) making it near ideal for photo- and videography. This is also why these lamps have gained such popularity with indoor gardening and made it practical, especially for plants that require a lot of light, like vegetables and flowers. They are also used to reproduce the intense tropical sunlight for indoor aquariums.

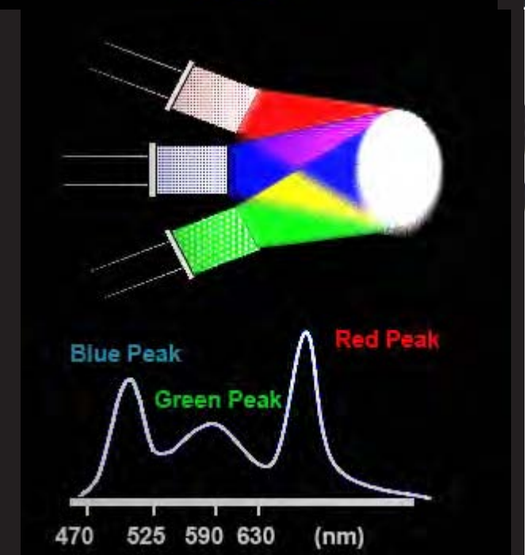
Consequently you are not looking for the neutral or even bluish colours of HID lamps for normal scuba dives at daytime.

By contrast the higher colour temperature of HID-lights photo and video purposes makes them the choice of photo- and videographers. Especially when it comes to illuminating the shady parts of the reef on day dives and to the illumination of wrecks and caverns the advantages of HID-technology really shows.

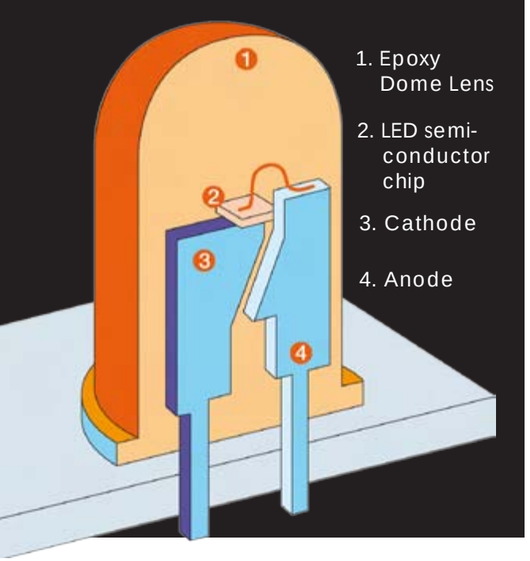
Scanning Electron micrograph of a light bulb filament (75x(

The Halogen bulb emits a reddish light

HARALD APELT



Making white light with the LEDs



LEDs as most of us know them.
Omnipresent, innocous, not sexy at all

mb sub is the first
to introduce a diving lamp
based on the new Osram Ostar LED

What is: Lumen?

The lumen (symbol: lm) is the SI unit of ***luminous flux***, a measure of the perceived power of light. Luminous flux differs from *radiant flux*, the measure of the total power of light emitted, in that luminous flux is adjusted to reflect the varying sensitivity of the human eye to different wavelengths of light.

A standard 100 watt incandescent light bulb emits approximately 1700 lumens in North America and around 1300 lumens in 220 V areas of the world.

Definition
$1\ \text{lm} = 1\ \text{cd}\cdot\text{sr} = 1\ \text{lx}\cdot\text{m}^2$

SOURCE: WIKIPEDIA

'Laughable' LEDs

For many years LED's were simply thought of as small and dim lights in electronic devices and signal lamps. How times have changed. There are quite a lot of technicians and scientists who now believe that the LEDs will be the lights of the future.

LEDs are characterised by a low energy consumption, extremely long life span, compact dimensions, and they are shock and vibration resistant. Another advantage of this innovative illuminant is that it has a very low failure rate and emits no ultra-violet or infrared radiation. In recent years, there have been significant developments with substantial improvements in this technology. Recently, a major breakthrough took place with the development of the Osram *Ostar* light emitting diode.

The technical innovation lies in a perfect interplay between various manufacturing techniques. LEDs consist of semiconductor crystals that grow on a substrate during manufacture. Up to now, the substrate remained in the diode after manufacture, where it absorbed much of the light produced.

Thanks to a new production technology this substrate can be removed and the surface of the light generating layer coated with a thin metal film. This metallised side now serves as a reflector and is placed close to the top of the LED. The result is that the LED can emit almost all of its light at the top, which causes a major increase in brightness.

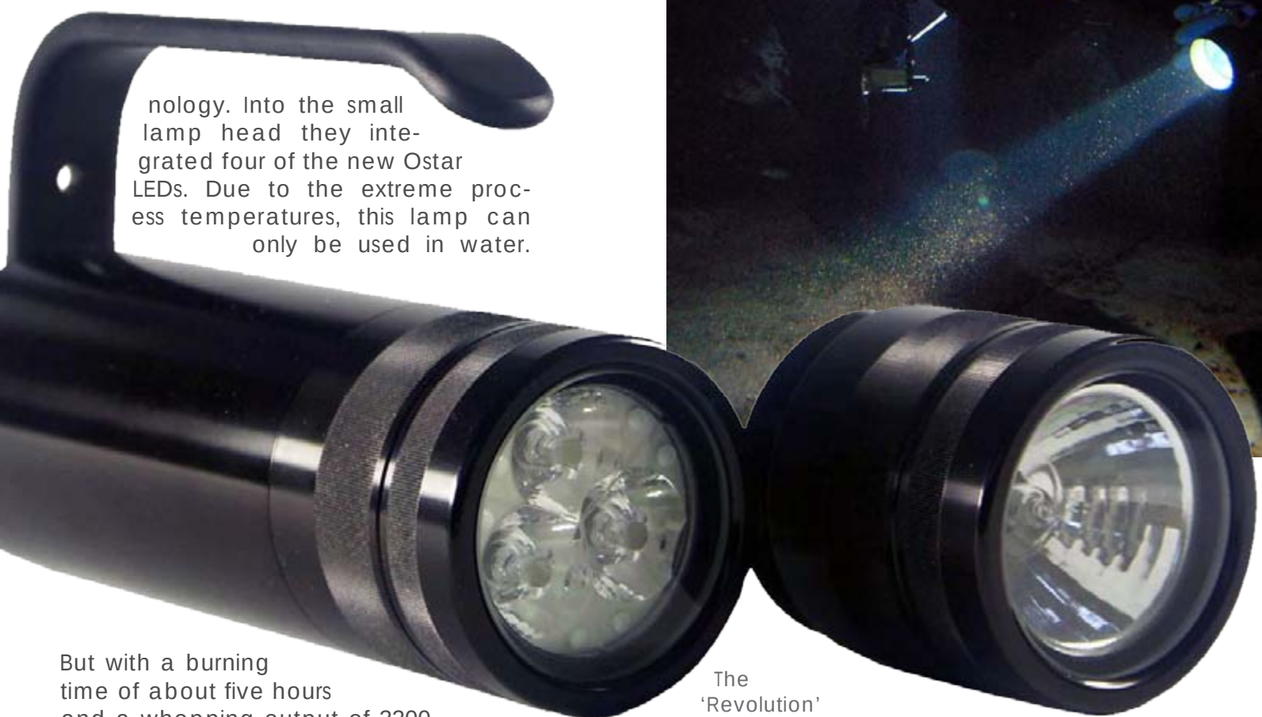
The Ostar high brightness LEDs are built with a multichip-onboard-technology with four- and six-chip-versions. The LED is the first LED to exceed 1000 lumen in output—and that is just with the 15 Watt version. That means that diving lamps equipped with this chip will produce the brightness corresponding to that of a 50 Watt halogen lamp. The first prototype is already built, and the output is perfect. German lamp constructor Michael Bienhaus from mb sub is the first to introduce a diving lamp based on the new Osram Ostar LED. He has already marketed an underwater hand lamp, the "Photon". It comes

The Osram Ostar LED chip packs
six LED in an array

with a two stage dimming and 12.6 Volt 1.6 Ah LiMn (lithium-manganese) accumulator. This power package has a burning time of about 60 minutes followed by an additional 30 minutes of emergency lighting. All this just weighing in at a little more than half a kilogram of weight—a big step towards optimizing dive gear. As the LED module costs about 37 Euro, the complete hand lamp will be sold for 472 Euro.

Pushing the envelope

Sources have also informed us that a group of German lamp nerds have already constructed a 20 Ah tank lamp with this technology. Into the small lamp head they integrated four of the new Ostar LEDs. Due to the extreme process temperatures, this lamp can only be used in water.



The 'Revolution' from mb sub is equipped with three 3 Watt LEDs (left). There are three interchangable heads available in the system. The two others are halogen and HID

But with a burning time of about five hours and a whopping output of 3200 lumen—which is about 200 percent more than a strong HID burner makes—it is now possible to illuminate an entire reef at night and in bright colours. (For more information's about this lamp project see www.tauchfunzel.de—unfortunately, only available in German).

The next revolution of underwater lamp-technology has just begun in earnest. And at least in this regard, the future looks bright indeed. ■

URS ANLIKER

Reliable lamp systems are essential when it comes to the more demanding types of dives. Don't skimp on quality

LEDs are characterised by a low energy consumption, extremely long life span, compact dimensions and they are shock and vibration resistant.

How to shop for an underwater lamp

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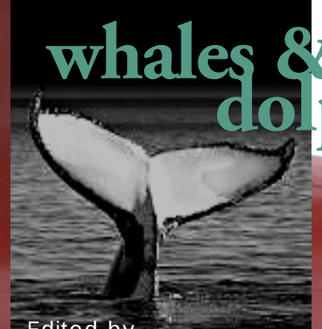
10 tips for beginners

1. First consider which kind of dives you want the lamp for. Then find the type of lamp that will match the requirements.
2. Next, try and get an overview of which lamps are on offer in this segment and select some "candidates" to your liking. Don't put emphasis on look and aesthetic design, but on the technical details.
3. Purchase a lamp with a high quality accumulator from a shop with good reputation. Why? Because accumulators have a limited life span, and you want to make sure that your new lamp hasn't already been spending a good part of it sitting on a shelf in the back of a shop.
4. Your charging device should have an integrated quick charge circuit and a total discharge protection to make sure that use of the lamp and the charging will be done with consideration.
5. Lamps with exterior charging should be preferred. You shouldn't need to open a lamp to charge it with the risk of subsequent leaks or damage to the delicate parts while open.
6. The lamp should be dimmable or have two or rather three different power levels.
7. For the sake of safety reasons, the lamp should have an integrated automatic SOS signal generator
8. Ask your dealer for technical data on the lamp such as burning time, recharging time and light performance presented in a data sheet or a manufacturer brochure.
9. If your budget allows a more convenient solution, you should prefer a modular system where you can upgrade your accumulator or use different lamp heads.
10. Decide upon the weight of your lamp. Each kilogram counts when checking luggage in at airports, and the weight limits will only become more of an issue in the future. Also, as airline regulations already require that accumulator and bulb must be transported separately, it is an advantage having a modular lamp system. ■

URS ANLIKER

"Boys with toys"

Divers with good lamps have more fun



Edited by
Peter & Gunild Symes

Ships Asked to Avoid Whale Route

The endangered right whale is to get extra protection from collision with container ships, which are seen as a key threat to the species.

Despite being protected since 1937, the right whale is close to extinction, with scientists estimating a global population of only 400.

A new1,800-sq-km zone, the Roseway Basin south of Nova Scotia, has been set aside as a safe haven from shipping after the International Maritime Organization (IMO) ratified a Canadian proposal to designate the zone an "Area to Be Avoided". The voluntary restriction asks ship captains to steer around the area.

It is close to a major shipping route between North America and Europe, and scientists say the slow-moving mammals have been killed in collisions with huge cargo vessels.

The restrictions will apply between 1 June and 31 December, when whales are known to congregate in the area.

Though the designation is voluntary, conservation groups say other such protected areas have seen a drop in shipping traffic. ■

Humpback and fin whales spotted north of Alaska

Humpback whales have swum into the Beaufort Sea off Alaska's northern coast, far beyond their usual range. Some of the whales were spotted by observers involved with the oil industry.

US federal officials monitoring the waters say it's too soon to determine whether it's a trend or an anomaly. No one was expecting humpbacks near the activity connected to Outer Continental Shelf lease sales, said Brad Smith, a protective resources biologist for the National Marine Fisheries Service.

Fin whales have also been detected by acoustic monitoring in the Chukchi Sea north of the Bering Strait this summer. The fin whales were recorded as far north as Point Lay, a coastal Inupiat Eskimo village of 235 about 700 miles northwest of Anchorage.

Environmental groups say the presence of humpbacks hundreds of miles north of their usual habitat is likely another sign of the effects of global warming and the shifting Arctic ecosystem. They are calling for more study of the endangered animals' habits before industrial activity is allowed to expand off Alaska's northern shores. ■

Quest tracks nursery of Blue whales

Scientists are on the verge of positively identifying the first known breeding and calving area for the elusive blue whales.

Researchers with Oregon State University's Marine Mammal Institute in Newport hope to confirm that a remote nutrient-rich region in the tropical Pacific Ocean, south of Mexico and about 750 miles west of Costa Rica, is the critical habitat for the endangered whales, which is the largest animal on the planet.

If the researchers finds the site, the team hopes the international community will take steps to ensure the area—far outside any nation's jurisdiction—is protected.

The area of upwelling where some blue whales gather in the winter shifts from year to year may have prevented whalers from pinpointing exactly where the whales were each winter. Bruce Mate, an OSU professor and the institute's director said the blue whales—from the eastern north Pacific stock—are going to be 400 to 1,000 miles west of Costa Rica.

"There's never been a known breeding and calving area for blue whales in the entire world," Mate said. "But because we've tracked animals now for a number of years, this is where we expect them to be."

Once the whales are found, the researchers will study the whales' behaviors, including whether the animals are feeding and the interaction between mothers and calves. They also will do a complete examination of the water, taking salinity and temperature measurements as well as collecting samples of the marine organisms. ■

MARCELO MAMMANA

"I think their communication system is a lot more complicated than we gave them credit for"

Parlez-vous Whelsh?

Whale conversation decoded

It may sound like wops, thwops, grunts, moans and squeaks to the human ear, but it is the complex conversations between remarkable ocean mammals.

Over the past three years, researchers from University of Queensland have recorded and analysed thousands of hours of humpback whale sounds off the coast of Queensland. And what their analysis points to is that a secret and ancient language of the deep sea does indeed seem to exist—a finding that hardly comes as any surprise to the many admirers of the famous humpback whales songs.

From high-pitched squeaks, shrieks and cries to purrs, groans and low yaps, at least 34 recurring sounds, which can be correlated to different specific social setting, have now been identified. Some last less than one second, while others stretch for more than ten. Some noises represent aggression and competition, others affection and concern.

"I think their communication system is a lot more complicated than we gave them credit for," lead researcher Dr Rebecca Dunlop said. "I've found that they have this massive repertoire."

While only humpback males are known to perform the famous whale "song", the social sounds are made by all humpbacks—males, females and calves.

The "wop", for example, is common in mother and calf pods. "It's one of the most common that you'll hear," she said. "It's probably a mum-calf contact call."

Other, higher-frequency signals are used when males are competing for the affections of a female. "These high-frequency cries and screams (are also heard) when they're having a bit of a row," she said.

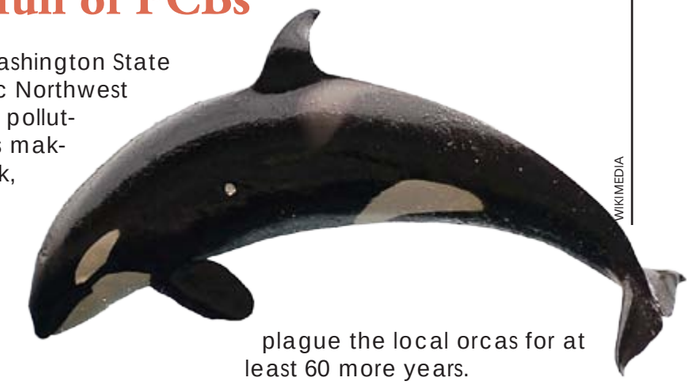
Dr Dunlop describes the male "purring" sound as a "C'mon baby" call to females, used as a mating signal. "The lower the sound, the bigger you are," she said.

The sounds are recorded using an antenna attached to a buoy about one kilometer offshore.

Dr Dunlop's paper, co-authored with the UQ's Michael Noad and published this month in the Journal of the Acoustical Society of America, catalogues the vocalisations of migrating east Australian hump. ■

SOURCES:
THE TELEGRAPH, JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA

Orcas full of PCBs



WIKIMEDIA

Orcas off Washington State in the Pacific Northwest are so full of pollutants that it is making them sick, researchers have found.

Writing in the Marine Pollution Bulletin, U.S. and Canadian scientists have reported that the levels of PCBs, a long-banned industrial chemical in blubber from orcas that frequent Puget Sound, was still high enough to cause health problems.

The chemicals cling to fat and can cause reproductive and immunological problems. While the researchers noted a slight decline in the level of PCBs over time, the chemical lingers on 30 years after it was banned,

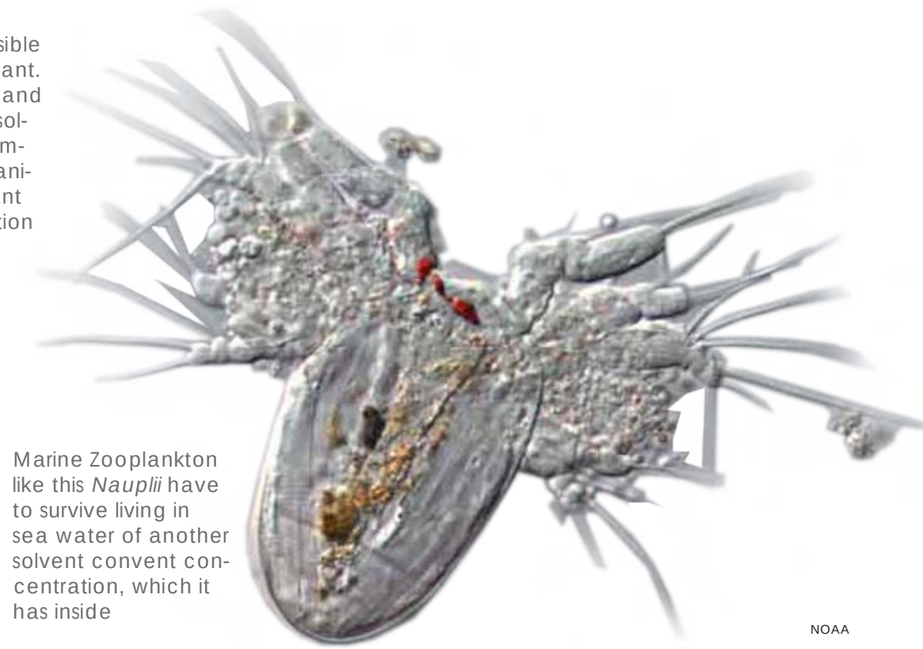
Another recent publication predicted that problems from PCB contamination would plague the local orcas for at least 60 more years.

Also troubling was the increase in the amount of commonly used flame retardants called PBDEs, or polybrominated diphenyl ethers, which are structurally similar to PCBs and can cause similar ailments. Thousands of tons of PBDEs are added to TVs, computers and furniture cushions among other items to make them fire-resistant. They can last for years in the environment.

Washington leaders earlier this year approved a ban on some uses of the chemicals because of health worries. ■

The surface tension of water is a visible physical property of water which permits water skaters to skate on the surface of the water

Osmosis is less visible but more important. Without osmosis and the passage of solvents across membranes, neither animal cells nor plant cells could function



Marine Zooplankton like this *Nauplii* have to survive living in sea water of another solvent convent concentration, which it has inside

NOAA

Text by Michael Symes

Osmosis

A crucial phenomenon for living organisms

We have written much here in this magazine about the different properties of water. Some of them, such as surface tension, are of importance to the ability of aquatic fauna to function in their given environment. For example, surface tension permits water skaters to skate on the surface of the water where its habitat is neither the water below the surface nor the air above.

However, more than a purely physical phenomenon, osmosis is of importance for life itself, for no physical phenomenon has any greater importance in biology than does osmosis. Without osmosis neither animal cells nor plant cells could function. Not only this, osmosis also appears in many different guises in our everyday existence. So, what is this strange phenomenon?

Osmosis

First, a definition: osmosis is the passage of a solvent from a region of high solvent concentration through a semi-permeable membrane to a region of low solvent concentration. In by far the majority of cases, especially biological, the solvent will be water.

Now, although this definition of osmosis is complete in itself, it is rather abstract for the general reader, and therefore, requires some amplification. What it means is this. If there is a concentrated solution of sugar, say, on one side of a suitable membrane (see below) and a less concentrated solution on the other side, then water will pass from the less concentrated side through to the other side where it will attempt to 'thin' the concentrated solution. The flow of water will cease when an equilibrium is established where the pressure on both sides of the membrane is the same.

The osmosis relationship

The basic relation for osmosis for a dilute solution is the *van't Hoff equation*:

$$PV = n_p RT$$

where P is the osmotic pressure and n_p is the amount of solute in moles in a volume V of solvent. R, the gas constant, is 8.314 J $K^{-1}mol^{-1}$ and K is the absolute temperature.

For example, sucrose, $C_{12}H_{22}O_{11}$, has molecular weight of 342.30. A 1% solution is water will therefore contain 1/342.30 0=0.00292 moles of sucrose. This is very small compared with the 1000/18 = 55.5 moles of water in a litre of solution. From the molar point of view, it is a concentration of 1 in 19000 i.e. very dilute.

Assuming ideal conditions, the osmotic pressure produced by a 1% sucrose solution in water at room temperature (23ºC) is thus given by:-

$$P = 0.00292 \times 8.314 \times 296 / 0.001\ Nm^{-2}$$
$$= 7186\ Nm^{-2}$$
$$= \text{ca. } 0.72 \text{ atmospheres pressure}$$

The osmotic pressure produced by a 1% sucrose solution in water at room temperature is ca. 0.72 bar

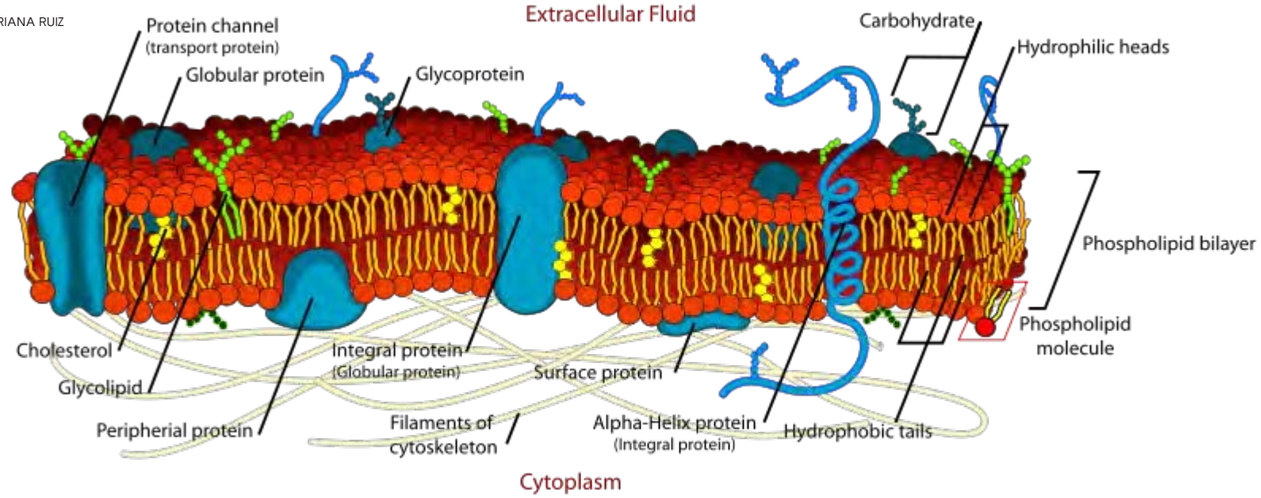
As one atmosphere can support a column of water 10m in height, this means that a 1% solution of sucrose could support a column of water 7.2 m in height. Thus, such a solution of sucrose could pump water to the top of a 7m high tree.

It is evident from the equation that if the osmotic pressure is known for a given concentration of solute, then it is possible to determine its molecular weight. It should be noted that this is not only true for water as the solute but also for other solvents. For example, the molecular weight of polyvinylchloride (PVC) can be determined by osmotic pressure measurements in cyclohexanone solution.

Semi-permeable membranes

Semi-permeable membranes are very thin films of a material, such as cellulose, that permit some molecules to pass through while hindering others. The molecules are separated from each other by their size, so that a small molecule such as water can easily pass through the membrane whilst large molecules such as sugars cannot. Semi-permeable membranes can occur in nature either as a plant cell walls or animal cell walls. From the point of view of osmosis, the main difference between these two is that a plant cell consists of a cell membrane supported by a strong cell wall while an animal cell has no cell wall, only a membrane.

MARIANA RUIZ



The cell membrane is a semi-permeable lipid bilayer common to all living cells. It contains a variety of biological molecules, primarily proteins and lipids, which are involved in a vast array of cellular processes

Different concentrations of salts on either side of the membrane creates an osmotic pressure that tends to drive water through the membrane. Maintaining this difference requires a lot of energy

For many technical purposes semi-permeable membranes can be tailored from synthetic polymers to permit specific molecules to pass through.

Picked vegetables

If you like your pickled gerkins or onions crisp, then use osmosis. When vegetables are put into brine, osmosis will occur through the semi-permeable cucumber or onion skin, so that the water inside the vegetables will pass out into the concentrated brine. This will give the pickles that desired crunchiness.

Preservation of food stuffs

If there are bacteria or yeast cells present in concentrated sugar solutions, then they will dehydrate due to osmosis and either die or become inactive. This is why sugar is used to preserve fruits in jams, etc.

Osmotic balance in animal cells

It is clear that if an organism is to function efficiently, if at all, then an osmotic balance must be maintained between the contents of its cells and their surroundings. This can be especially difficult for animal cells as, unlike plant cells, they do not have a strong supporting cell wall, only a cell membrane.

This means that if a blood cell, for example, is introduced into a hypertonic solution i.e. one with a higher concentration of solutes than that found within the cell cytoplasm, it will lose water by osmosis, and shrink. This can occur in the case of diabetes, where the sugar concentration in the blood becomes too high.

Burst

On the other hand, if the cell is in a hypotonic solution i.e. a solution with a lower concentration of solutes, then it will swell up and even burst under the osmotic pressure.

In either case there is a problem, so animal cells must always be bathed in an isotonic solution i.e. a solution having the same osmotic strength as their cytoplasm. The maintenance of such an isotonic solution is biologically very complex, being controlled by the kidneys under the influence of mechanisms in the brain which control the feeling of thirst, for example.

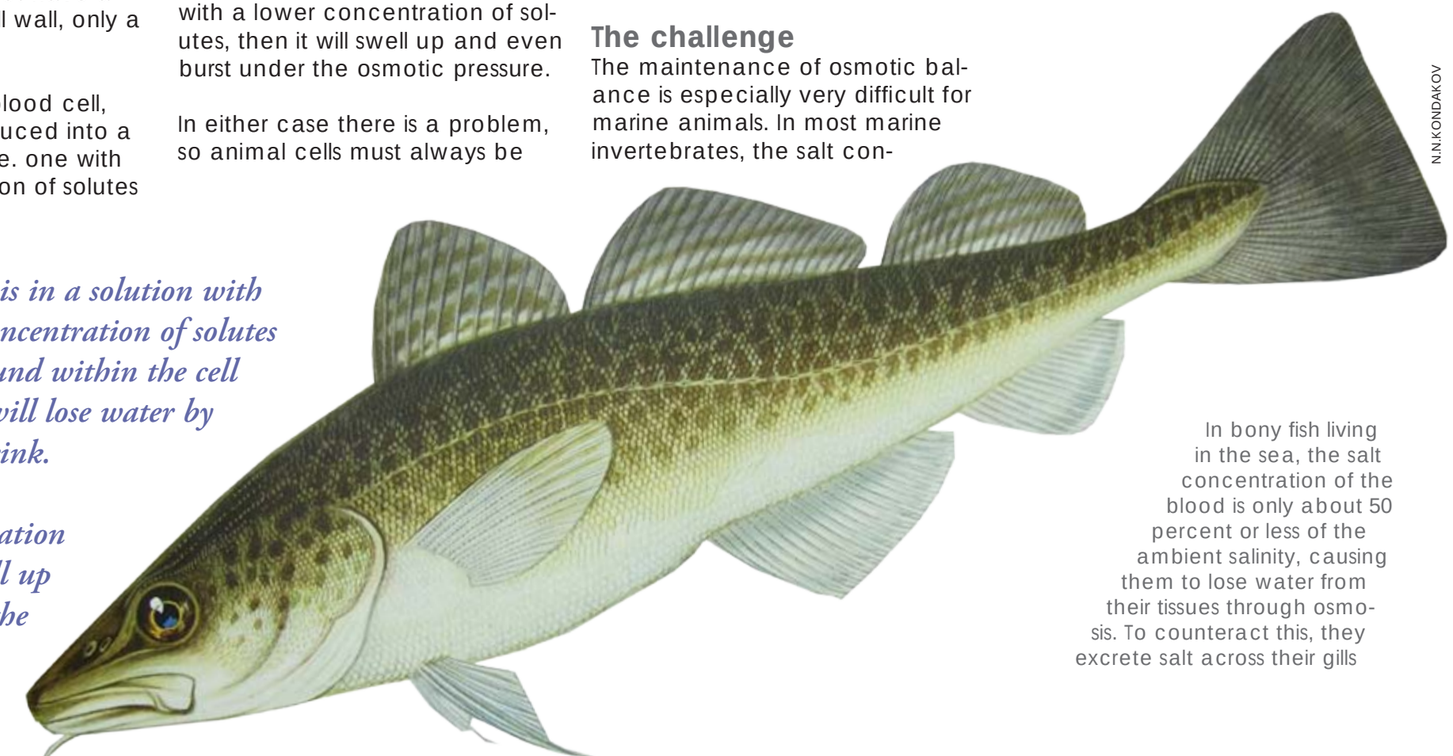
The challenge

The maintenance of osmotic balance is especially very difficult for marine animals. In most marine invertebrates, the salt content of the blood and body fluids is about the same as in seawater of average salinity. In the teleosts i.e. the bony fish, the salt concentration of the blood is only about 50% or less of the ambient salinity. This has physiological consequences, especially for aquatic animals migrating between seawater and freshwater.

The anadromous fish (from the Greek *anadromos*, running upwards) like the salmon, sturgeon, and sea lampreys migrate up rivers to breed in freshwater and their young then migrate to the sea. On the other hand, there are the catadromous fish (from the Greek *katadromos*, running down) which migrate down to the seas to breed but spend most of their adult life in freshwater, for example, the American and the European eels. It is also a problem for aquatic animals inhabiting estuaries where the salinity can change rapidly.

If the cell is in a solution with a higher concentration of solutes than that found within the cell cytoplasm, it will lose water by osmosis, and shrink.

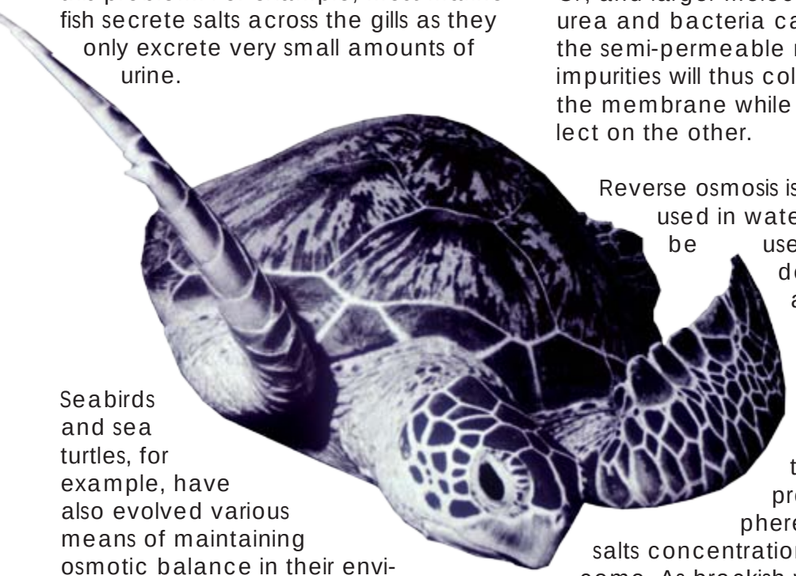
In a lower concentration of solutes, it will swell up and even burst under the osmotic pressure



N.N.KONDAKOV

In bony fish living in the sea, the salt concentration of the blood is only about 50 percent or less of the ambient salinity, causing them to lose water from their tissues through osmosis. To counteract this, they excrete salt across their gills

Because of the difference in salt concentration between blood and the ambient water, osmosis will cause teleost fish to lose water. Their internal salt concentration will therefore increase so that several mechanisms have evolved to counteract this problem. For example, most marine fish secrete salts across the gills as they only excrete very small amounts of urine.



Seabirds and sea turtles, for example, have also evolved various means of maintaining osmotic balance in their environments. Marine birds drink sea water to obtain water, but their kidneys are unable to produce concentrated urine. They therefore have special salt glands situated above the orbit of the eye, which can secrete salt. Marine mammals, on the other hand, do not have specialised glands for excreting salts. They avoid drinking seawater and get their water from the metabolism of food, depending on their kidneys for osmotic balance.

Reverse osmosis

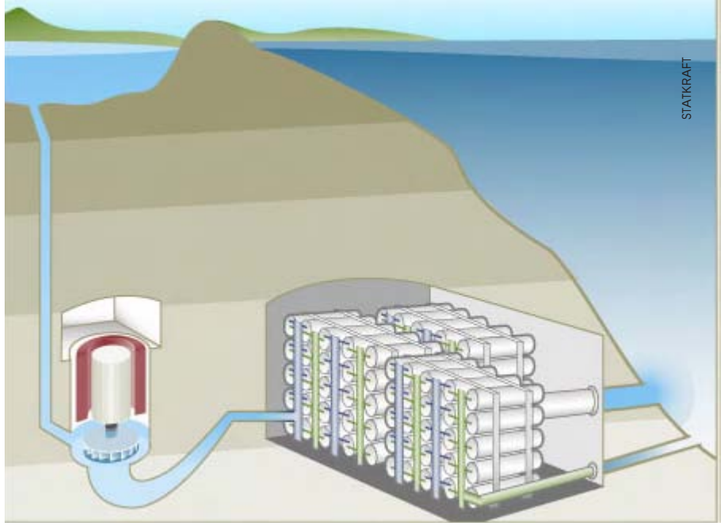
Osmosis can be slowed, stopped and even reversed if sufficient pressure is applied to the concentrated side of the membrane. Reverse osmosis thus occurs when the water is forced through the membrane against the concentration gradient, from the lower concentration to the higher. Ions such as Na^+, Ca^{++}, and Cl^-, and larger molecules such as sugars, urea and bacteria cannot pass through the semi-permeable membrane. The impurities will thus collect on one side of the membrane while clean water will collect on the other.

Reverse osmosis is therefore often used in water purification. It can be used, for example, to desalinate seawater, although it requires large amounts of energy. Pressures of up to 40 to 70 atmospheres are required because the natural osmotic pressure of 24 atmospheres arising from the salts concentration has to be overcome. As brackish water contains a much lower concentration of salts, the purification of fresh and brackish water requires much lower pressures of about 10 atmospheres.

It can also be used to remove water as an impurity from other liquids, for example from ethanol, or for removing medical and industrial contaminants from fresh water.

Dialysis

This is a very important application of osmosis, which is used for purifying blood with loss of kidney function. In a dialysis machine, the patent's blood is passed through tubes made of a semi-permeable material. The tubes are flushed externally with a sterile solution of sugars and other components. The corpuscular cells of the blood, such as the red and white blood cells, are too big to pass through the membrane of the tubes. However, urea and salt can pass though into the sterile solution and are thereby removed from the blood.



Salt power plant as envisioned by Norwegian energy company Statkraft

Electricity from osmosis

An interesting project is being carried out in Norway to enable electricity to be produced from sea water by using osmotic pressure. When salt water and fresh water, from a stream or a river, are separated by a semi-permeable membrane, an osmotic pressure will occur. As stated above for reverse osmosis, this pressure can be up to 24 atmospheres. A column of water can thus be produced, which theoretically can be 240 m high. The potential energy of this water column, like that from a dam, can be used to drive a turbine, which can then be used to drive a generator. The production of electricity by this method has no apparent ecological consequences, with the fresh water and salt water being mixed in the water column in the same way as would occur anyway at the mouth of the stream.

The potential for this form of ecologically-friendly energy is large, as such generators can be built anywhere that fresh water meets salt water, for example at the outflows from existing hydro-electric generators. ■

Reverse osmosis is often used in water purification

Pearls of the Mediterranean

PETER SUTTER

Text by Harald Apelt
Photos by Harald Apelt, Christoph Gerigk, Wolfgang Pölzer and Peter Sutter

Perhaps you think you know most of the amazing dive sites in the world from the Carribean to the Maldives, from Asia to Micronesia. Are you looking for something new? We've discovered some hidden pearls in the Mediterranean Sea that you probably have never heard of before. Starting in the next issue of *X-RAY MAG*, we will present our insider tips to you and take a closer look at some of the Mediterranean's most beautiful little picturesque villages and their stunning dive sites. Be prepared to be inspired.

What qualities makes a diving holiday great? Is it the variety of dive sites? The accommodation? Or is it the location? In our opinion, it is the total sum of these three parts and how the mixture comes together. There are so many good reasons to combine a trip to Europe with a visit to one of our "hidden pearls" at the Mediterranean Sea. Why? Because you will fall in love with these locations, their special mélange of historical charm, international atmosphere, mild climate and good diving. The multicultural nations at the Mediterranean shoreline offer a colourful mixture of culinary delights—a sea-oriented cuisine with roots in the kitchens of Africa, Asia and Europe.

The Mediterranean Sea is enclosed by the landmasses of no less than three continents: by Europe to the north, in the east by Asia and in the south by Africa. There are 22 countries in all connected by this sea, which historically, has had a big influence in the development of cultural exchange and trade.

Although the Mediterranean Sea covers about 2.5 million square kilometers, it does not belong to the seven seas. Officially, it is a part of the Atlantic Ocean to which it is connected with the Strait of Gibraltar, a 14-kilometer wide strait between Africa and Europe. There are 107 islands in the Mediterranean bigger than one square kilometer, and thousands of little islands and rocks that are worthwhile diving.

FRANCK GODDIO / HILTI FOUNDATION, PHOTO: CHRISTOPH GERIGK

TOP: Calella de Palafrugell at Spanish Costa Brava is one of the Mediterranean's "pearls"
RIGHT: The Mediterranean presents exiting moments like the discovery of the artefacts of old Alexandria Harbour at Egypt coast by Franck Goddio

pearls of the mediterranean


NASA

Rare moments at the Mediterranean: clouds over southern Italy. On the left side of the map, you see the narrow entry from North Atlantic to the Mediterranean—the Strait of Gibraltar

The Swimming Pool

In the high season from mid June to the beginning of September, the Mediterranean is the "swimmingpool" of the Europeans. Scandinavians, Germans, Dutch—and since the fall of the iron curtain more and more tourists from eastern Europe—journey down in droves by car on the packed highways to the shores of the Mediterranean. But you should not share this experience of being just one of a million at the beach resorts, hotels, camping grounds and overcrowded beaches during the intense weeks of midsummer vacation.


WOLFGANG PÖLZER

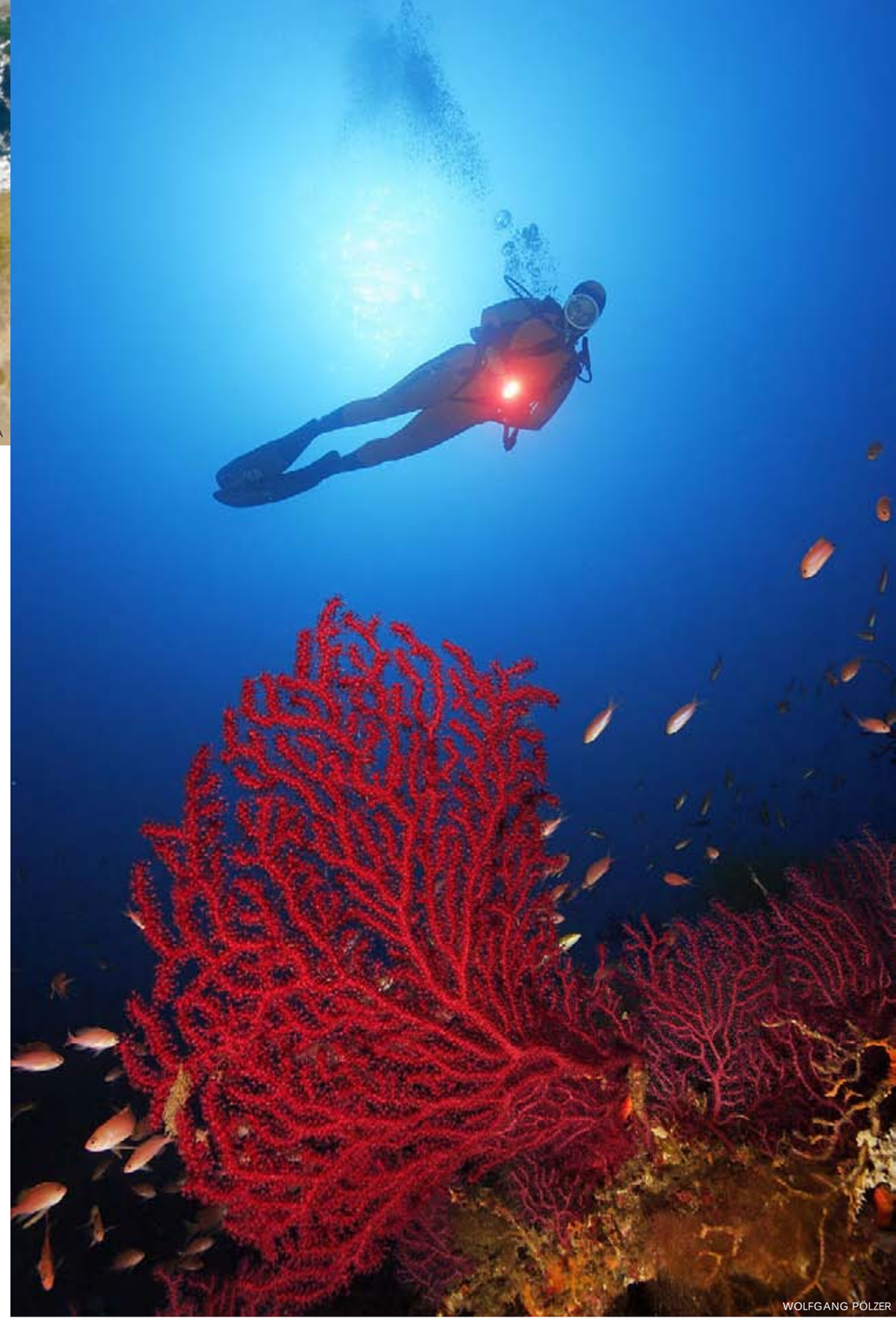
You should visit the lovely shores of Turkey, enter one of the numerous Greek islands or discover the western Mediterranean coastline, from Italy's Liguria via France's Cote d'Azur to the Spanish Costa Brava in late spring or in early September. You will meet hospitable, relaxed and friendly people. Outside the hectic main season, everybody slows down. This is exactly the right time to spend your holiday down there.

Diving

Divers will find good diving conditions throughout the season, which runs from April until the end of October. But the Mediterranean is a sea of very special conditions. It can be quite cold up to the end of April, and sometimes it can have quickly changing weather conditions and visibility.

It has diverse marine flora and wildlife. The western part of the Mediterranean Sea around northern Spain, south of France and the Italian coast can be quite colourful. The awesome reefs, covered with colour changing sea fans and sponges are an unforgettable spectacle even for divers who prefer the tropics.

Big fish are not very often seen, however. The big groupers have been hunted for many years by a huge number of harpoon-divers. Sharks are quite rare because of the high salinity of this sea. Despite this fact, the biggest Great White ever caught by a sport fisher was


WOLFGANG PÖLZER

ABOVE AND LEFT: Colourful impressions are awaiting divers, especially in the western part of the "Med"

pearls of the mediterranean


WOLFGANG PÖLZER

COUNTER-CLOCKWISE FROM LEFT: Vis Harbour at the Croatian island of Vis is a lovely place to spend summer time; Conger eel patrols WW II wreck; Divers meet these species on nearly every dive—Scorpionfish and cup corals (inset)

caught in the Mediterranean Sea.

Since opening of the Suez Canal in 1869, which connects the Red Sea with the Mediterranean Sea, a continuous migration of plants and animals from the Red Sea has colonized the eastern part of the Mediterranean Sea. Thus, step by step, invasive species from the Red Sea entered the eastern Mediterranean region. They are now endangering more and more endemic Mediterranean species.

What makes diving really unique in the Mediterranean Sea are the leftovers of thousands of years of human activity, which are still hidden under the surface of the sea. Historical ruins and amphora fields are mute witnesses of forgotten civilisations. One of the most spectacular discoveries was made by Frank Goddio and his team at the northern Egyptian coastline right in front of Alexandria. At the bottom of the bay of Abukir, he discovered remnants of ancient Alexandria. And further to the east, in front of the Turkish coastline, many historical sites have been found by divers. Finally, numerous WWII wrecks are located all over the Mediterranean and guarantee some exciting dives. ■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