

Contrary to popular belief rebreathers are actually a much older scuba diving technology than open circuit regulators

focus

Scrubbers & Sensors

The Long (his)Story About

From Fleuss to Evolution

There is more and more talk of rebreathers, stated as being the future of diving. However, not many people have tried them. So what is all the fuss about?

The greatest majority of the readers of this magazine will have learned to dive with a regulator originating from the Aqualung, which the renowned Jacques Cousteau and Emile Gagnan invented in 1940. The regulator was the first

commercial, generally available dive-system, and this promoted the later great expansion of sports diving everywhere. And it must be said that the regulator is a fine

piece of equipment. It is reliable, more or less foolproof, and its simple construction is very robust. These are good properties to have when one's underwater breathing depends on them. However, as we will see, there are also a number of disadvantages. And it is these that make re-breathers an interesting alternative system.

When diving with a regulator, it is said that one is diving with an *open*

circuit, because the exhaled air passes straight out into the surrounding water, and is thereby lost. As only about a quarter of the available oxygen has been taken up by the body, and the rest expelled, it is a rather ineffective utilisation of a scanty resource. (See table next page.)

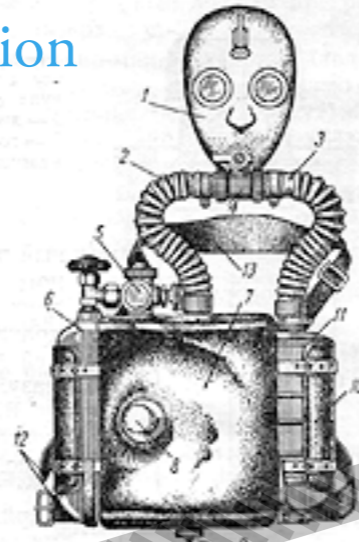
In addition, as the amount of air used increases proportionally with depth, open systems become more and more inefficient, and there are therefore major limitations to how long a diver can remain underwater. It seems obvious, then, to try

to re-use the air that has been exhaled, by using a closed system.

Closed circuit systems

Closed circuit systems are a far from new idea. It was Giovanni Borelli in the 1700's who first thought of re-using the exhaled air. His idea was to recirculate the air through a copper tube which was cooled by the sea water, and thereby "cleaned" the air before re-use. Luckily, it was never made. The mining industry and its problems with gas in the mine shafts also stimulated the relevant technical developments during the 1700's.

Henry Fleuss, an English naval officer from Germany, worked out the principles for a re-breathing apparatus, and produced a prototype at the end of the 1870's. He stayed down in a water tank for nearly an hour, and later went down to 5 meters in a lake using his system. Fleuss was the first "diver" in history with a re-breathing apparatus. At the beginning of the 1900's the military were quick to take up this idea. Oxygen-rebreathing equipment consisted of an oxygen tank together with a bag of potassium hydroxide and a breathing loop, and was used to rescue submarine crews and attack divers (there were no revealing bubbles on the surface). The German manufacturer Dräger released several models for military use in connection with World Wars I and II.



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Ambient Pressure Diving's Closed Circuit Rebreather *Evolution* is the latest step in CCR ...erh... evolution.

Respiration

In a modern medical textbook on physiology, one of the several chapters on aspects of respiration is entitled "Physical principles of gaseous exchange; diffusion of oxygen and carbon dioxide through the respiratory membrane". And it is these very important principles that are of great interest to divers. How we take in and utilise oxygen, and how we get rid of the carbon dioxide produced by metabolism.

Cellular metabolism is independent of pressure

The amount of air which is needed to take a normal breath at a depth of 20 meters is three times greater than at the surface, and therefore the consumption of air with open systems increases with depth. **However, more importantly, cellular metabolism does not depend on the pressure.**

Oxygen is required to make adenosin trifostat, ATP, the fuel of the human cell. And a molecule of oxygen is a molecule of oxygen, wherever it is to be found, at the beach, or 100 meters deep, with the

corresponding increase in pressure. Therefore, when using a closed circuit there is the same consumption of air, whatever the depth. At rest, 0.3 to 0.5 liters of oxygen are used per minute (l/min), and with maximum work up to 3.0 l/min are used. Of course, there are differences between individuals, depending on the size of the diver and his or her physical condition.

The carbon dioxide problem

As we have seen, cellular metabolism depends on oxygen, which is inhaled from the atmosphere. The following table gives the composition, in volume percent, of inhaled atmospheric air (on an average cool, clear day), and also the corresponding composition of exhaled air. (There is also a minor content of the non-reactive noble gases such as argon, helium, etc., but this has been ignored here.) It will be seen that the uptake of oxygen in the lungs has caused the oxygen content of the inhaled air to be reduced from its original 20.84% to 15.7% in the exhaled air. It will also be seen that the concentration of carbon dioxide, a biproduct of metabolism, has gone up by about ninety times, to 3.6%.

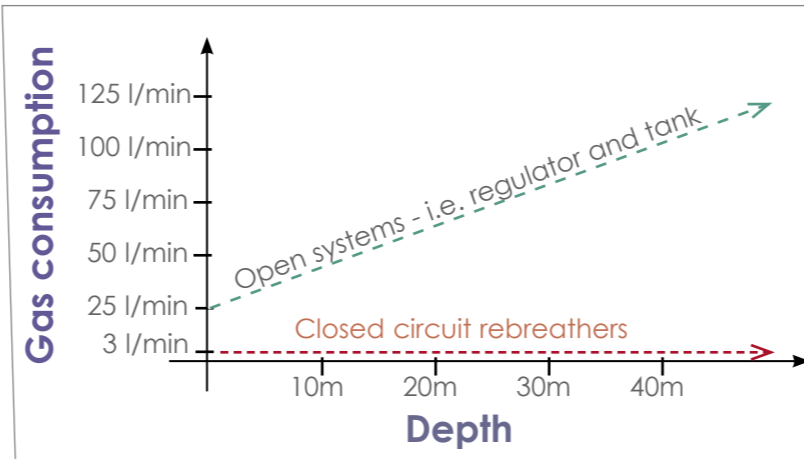
COMPONENT	INHALED AIR %	EXHALED AIR %
N ₂	78.62	74.5
O ₂	20.84	15.7
CO ₂	0.04	3.6
H ₂ O	0.50	6.2
Total	100.0	100.0

So, it is not so much the reduction in amount of oxygen that is the problem, for there is still some 16% available in each expelled breath, which should be available for re-use. It is the increase in carbon dioxide, CO₂, that is the real problem. A

diver can tolerate a build up to a CO₂ concentration of about 10%, increasing respiratory volume to compensate for the increased CO₂. However, beyond the 10% level the respiratory center in the brain stem begins to be depressed rather than stimulated, and the diver's respiration then actually begins to fall rather than to compensate. As a result of this, varying degrees of lethargy, narcosis, and, finally, anesthesia will occur. The CO₂ in the exhaled air must therefore be removed before the remaining oxygen can be re-used. Luckily, this is quite easy to do, using calcium hydroxide, Ca(OH)₂, which reacts with, and therefore fixes, the carbon dioxide. It is called CO₂-scrubbing and the filtering material, in this case calcium hydroxide, which comes as a granulate, is referred to as the scrubber.

In a rebreather, CO₂-scrubbing therefore takes place by circulating the breathing gas through a canister with the scrubber granulate in it.

Scrubber, in this case Sofnolime, comes in small granules,



Comparison of gas consumption in open and closed systems. In closed circuit rebreathers the gas consumption doesn't vary with depth.



A REBREATHER TIMELINE

1500's In England and France, full diving suits made of leather with metal helmets. The diving helmets were already some sort of rebreather, but needed surface supply and were without scrubber

1680 Giovanni Borelli designed a closed breathing circuit. The idea was to recirculate air through a copper tube which was cooled by sea water. The assumption was that all the impurities would then condense out of the air inside the tube.

1726 Stephen Hale designed the first scrubber: a flannel liner, soaked in salt and tarter, used in a helmet for mine disasters.

1772-4 Oxygen independently discovered by Swedish chemist, Carl Wilhelm Scheele, in 1772, and the English chemist Joseph Priestly, in 1774. Soon followed the first known ideas to use Oxygen for diving and first functional ideas to build autonomous rebreathers.

1876 Henry Fleuss began to develop an oxygen rebreather. He used a rubber face mask and a breathing bag connected to a copper oxygen tank. The carbon dioxide, scrubber was a rope yarn soaked in a solution of caustic potash. Enabling Fleuss to walk along a river, this was the first SCUBA Dive.

1879 Fleuss builds a Mining-Rescue Rebreather for Siebe/Gorman

1881 A special rebreather scrubber using a barium hydroxide is patented by Khotinsky and Lake.

1904 Siebe and Gorman patent Oxylite, a potassium- and sodium-peroxide mixture that produces oxygen on contact with water.

1907 A Dräger rebreather is used as submarine rescue equipment

1912 Dräger helmet-diving-rebreathers are available

1913 Dräger performs a successful simulated 40 minute dive to 80m in chamber.

1914 Dräger introduce a selfmixing Nitrox-Rebreather for max. 40m.

1926 Dräger presents the first early recreational rebreather, the 'Bade-taucherter'.

1941 Dräger "Kleintauchgerät 138"

1953 Dräger Leutnant Lund II and Barakuda Delphin I

1967 Russians experiments with predecessor to AKA-60



No, rebreathers are not new. In this 1912-footage we see Dräger's helmet diving rebreather in use. Photo: Dräger's archive.

Expression: Breathing loop

The whole volume of circulating gas in a rebreather, mainly the hoses, one or two counterlungs and also the diver's lungs.



PETER SYMES

Lt.Lund rebreather, 1953

Scrubbers

Although easy to do in principle, getting a CO₂-scrubber to function in a safe and reliable way is not completely without its complications - which many divers have found out to their cost. As with walking or running, it takes work to breath underwater. If the resistance to breathing is too high, there will be physiological problems which will limit the use of this system.

Also, *hypercapnea*, the condition where there is too much CO₂ in the body can become an issue. The material used to remove the carbon dioxide in the system, the scrubber, has a limited life, and can only fix a certain maximum amount of carbon dioxide.

As these filters cost money, people are disinclined to change them often enough. The maximum limit for how long these filters should be used is thus some times transgressed, which increases the risk of accidents.

The matter with oxygen

And while we are at it, why not increase the oxygen level in the inhaled air, even perhaps right up to 100% pure oxygen? This way we could also avoid breathing in nitrogen, which is the cause behind depth narcosis and decompression illness and give away with all concerns about decompression limits. If it only was so easy! The apparently paradoxical answer is that pure oxygen quickly becomes poisonous under pressure.

Partial pressure of oxygen

Assume that we have a mixture of gases. Then the total pressure of the mixture is equal to the sum of the pressures exerted separately by each of the individual components in the mixture. So, if the mixture we are considering is atmospheric air, we have:

$$P_{atmos} = P_N + P_O + P_{CO_2}$$

Where

P_{atmos} is the atmospheric pressure
 P_N is the partial pressure of nitrogen
 P_{CO_2} is the partial pressure of carbon dioxide
 P_O is the partial pressure of oxygen

Now, according to the ideal gas laws, as the components are all at the same temperature, the partial pressures must be proportional to the volumes of each gas present in the mixture. In the table given above, oxygen has an volume % of approximately 21 of atmospheric air. This means that its partial pressure is 0.21 of an atmosphere, or 0.21 bar. This is oxygen's contribution to the total atmospheric pressure.

So, at the beach, oxygen in the air has a partial pressure of ca 0.21 bar. And if the diver is using compressed air at a depth of 10 meters, then the corresponding oxygen partial pressure is 0.42 bar (0.21 x 2 bar), at 20 meters it is 0.63 bar, at 30m its 0.84 and so forth. In the literature the partial pressure of oxygen is written as ppO₂.

The importance of ppO₂

When discussing respiration this is probably the most important parameter to be considered. Not only must the excess carbon dioxide be removed from the air, but the partial pressure of the oxygen must also be maintained at a reasonably constant level to ensure correct cellular metabolism.

Gaseous diffusion from the alveoli of the lungs to the pulmonary blood is determined by the partial pressure of the oxygen. The partial pressure determines the force exerted in diffusion through the pulmonary membrane.

In other and more plain words, it is the ppO₂ and not the O₂ % that determines whether we live or die.

Consequently, ppO₂ should be maintained within a certain range to sustain life.

Normal ppO₂ (at sealevel) is, obviously, 0.21 as air contains 21% oxygen. If the partial pressure falls below 0.12 (12% oxygen at sealevel) most individuals will lose their ability to function. Below 0.10 bar ppO₂ they will lose conciousness and below that die from asphyxiation.

On the other hand, a prologued exposure to high ppO₂ leads to oxygen toxicity and the condition hyperoxia which manifests itself in sudden convulsions, which under water inevitably will lead to drowning. Therefore a ppO₂ of 1.6bar is usually considered the upper limit in recreational diving, and only for a limited time. And 1.3 bar the level not to exceed in general.

For these reasons it should be clear that maintaining the ppO₂ of the breathing gas within specific bounds is of utmost importance. It becomes, quite litterally, a matter of life and death.

Diving conventionally with compressed air on open systems, as most regular holiday makers do, controlling ppO₂ is usually not an issue as normal air only reaches a ppO₂ of 1.3 bar at a depth of 54m - far beyond where they should venture.

But as soon as we start tinkering and raising the O₂-content of our breathing gas, these matters change, as we are taught already at entry level Nitrox courses —such as PADI's Enriched Air Specialty, or the various Basic Nitrox courses offered elsewhere.

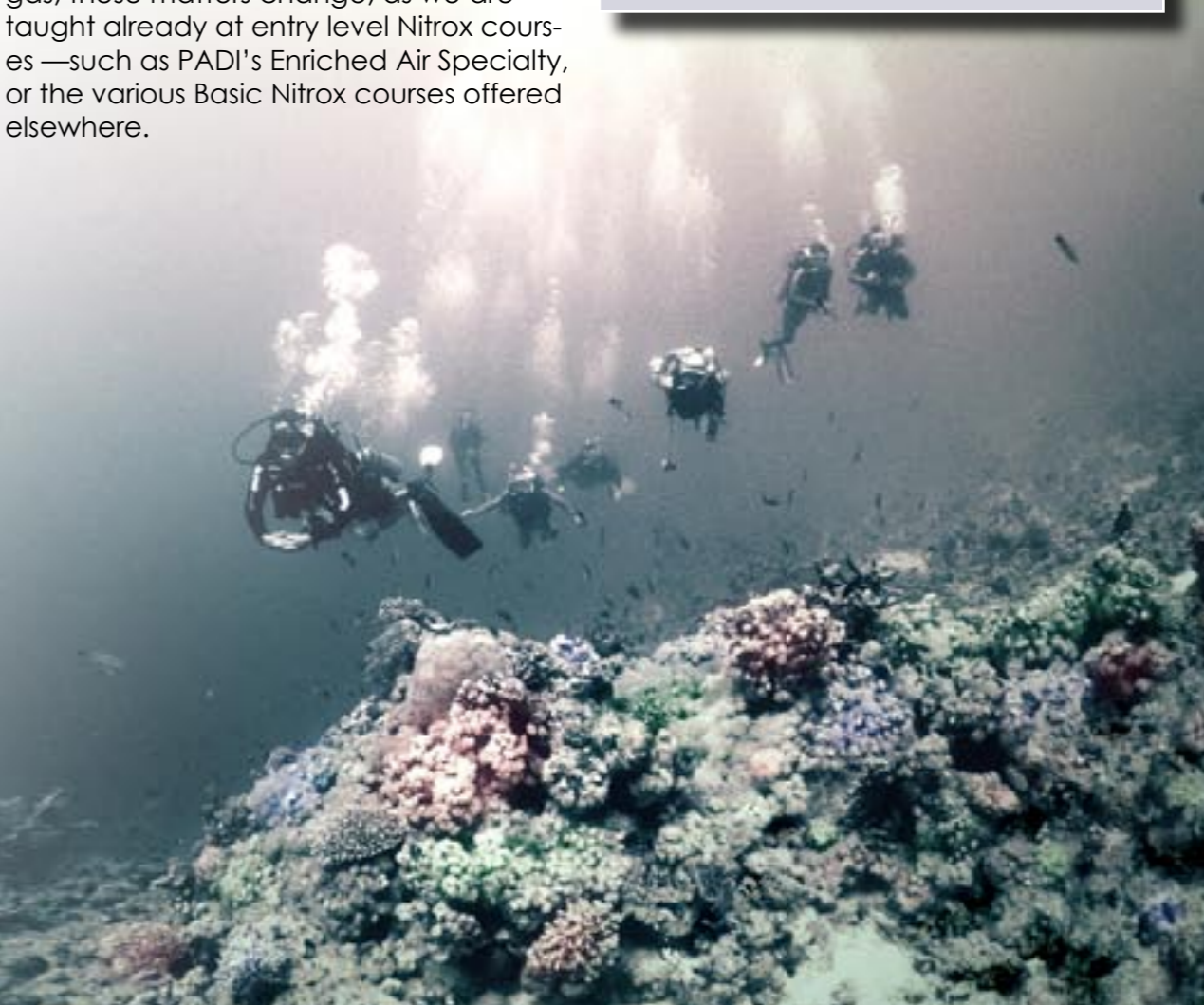
1968	First electronically controlled rebreather, the Electrolung, is marketed
1970	BioMarine CCR-1000
1972	BioMarine Mark 15
1975	Dräger LAR V
1977	BioMarine NM-6
1978	Interspiro ACSC
1982	Interspiro Oxydive
1984	Dräger Tieftauchsystem CCBS for operating depths of max. 600m
1985	AKA-60 (Russian)
1991	Dräger Newtsuit
1992	Interspiro DCSC
1995	Dräger SCR Atlantis (1998 renamed in Dräger-Dolphin)
1998	Buddy Inspiration
1999	Dräger-Ray
2001	Halcyon RB80, Cochran CCR and Mares SCR Azimuth
2004	Ambient Pressure Diving's Evolution

PETER SYMES



Oxygen rebreathers

In water pure oxygen rebreathers are restricted to use in shallow water of less than 6 meters - to keep ppO₂ below the 1.6 bar limit. For this reason the pure oxygen rebreathers are of limited and mainly military use. Oxygen rebreathers however also have a use on land with firefighters, rescue crew and miners.



Whether we dive on open systems or semi-closed rebreathers (see explanation below) we chose, prior to the dive, our breathing gas with a predetermined oxygen-content. This may be air or we may opt for another specific gas suitable for the depths we are aiming at. In most cases this will be Nitrox—which is now becoming quite a household word among divers.

Nitrox with 32 or 36% oxygen is now quite routinely being offered at divecentres, resorts and liveboards worldwide as these two “standard-blends” will cover most needs in the typical recreational range with near optimum benefits.

However, choosing the right oxygen-% will always be a compromise between longer no-decompression times versus maximum depth. For example, diving on Nitrox with 36% oxygen gives a generous no-deco time of 50 mins at 26m - rather than the usual 20 min when diving on air. That is nice, but Nitrox 36 can't take you any deeper, as ppO₂ is already 1.3 bar around that depth.

And if you dive any shallower you don't get the full benefits of Nitrox at that particular oxygen content. So, for each depth there seem to be an optimum oxygen % in the breathing gas. With the

current general limits, this optimum oxygen content corresponds to a constant oxygen partial pressure of 1.3 bar oxygen regardless of depth.

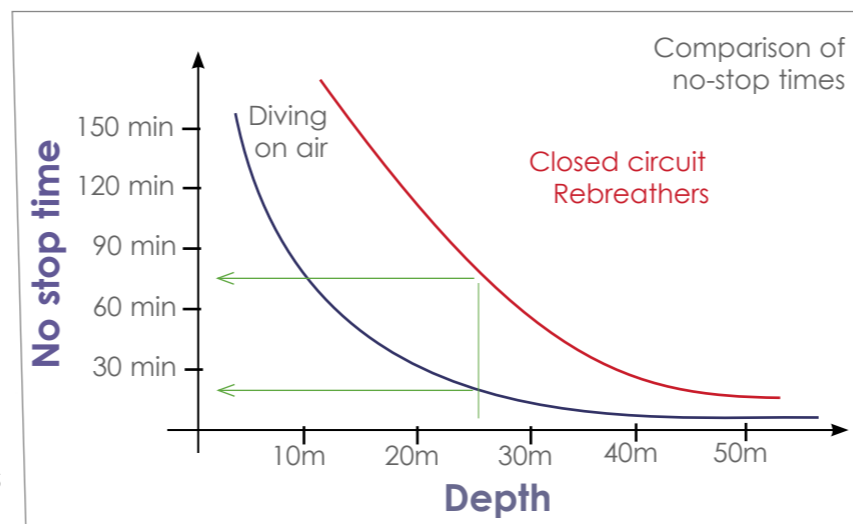
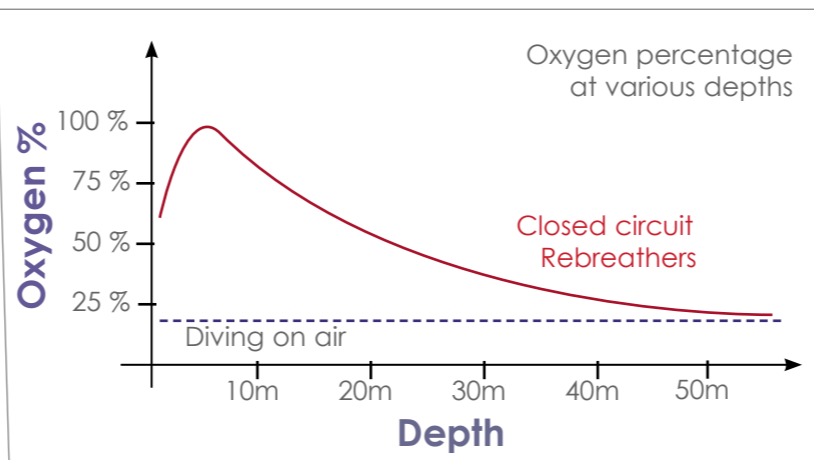
Controlling the ppO₂

To ensure that the correct oxygen level is obtained, i.e. its partial pressure, it is necessary to measure its concentration. For this purpose a special transducer is needed, an oxygen sensor. (see box below)

Modern closed breathing systems

With the advent of oxygen sensors and microprocessors, it is now possible to reduce the amount of gas taken down by a diver to a mere bagfull of atmospheric air and a few liters of compressed oxygen. These closed circuit rebreathers, CCR, use oxygen sensors to control the partial pressure of oxygen in the inhaled gas. This means that the diver can continually control and maintain oxygen partial pressure at certain levels during a dive. And this is where the fully closed rebreathers excel.

Say, for example, that a fully closed breathing system has been set to maintain a given oxygen partial pressure at depth, typically 1.3 bar. If the diver then descends to another depth, the ambient pressure increases, and with it the oxygen partial pressure in the breathing



loop. The rebreather then compensates to keep the oxygen partial pressure constant. Likewise, if the diver ascends, the pressure decreases, and the oxygen partial pressure will decrease. The apparatus

will then compensate in a controlled way by injecting some more oxygen into the loop.

As the graphs above clearly demonstrate, the potential extension of no-deco times are huge.

Open, semi-closed and fully closed circuits

By *Open Circuit* one usually refers to the omni-present regulator - a second and a first stage connected to on a tank of compressed air. The expression is partially misleading because the air doesn't go in a circuit. It travels from the tank and via the regulator, through the diver before getting exhaled into the water in a one-way process.

A *semi-closed circuit* is a type of rebreather in which (most commonly) the breathing gas is being continuously injected from the tank into the breathing loop where it circulates a number of times. On average the gas is re-circulated 4-5 times before being vented to the outside through an over-pressure valve. It is because gas is continuously being vented that these circuits are referred to as being semi-closed (or rather semi-open). The breathing gases used in these semi-closed (circuit) rebreathers or 'SCR' are various pre-set Nitrox-blends. The popular Dräger rebreathers (Dolphin, Ray...) are SCRs.

In a *fully closed (circuit) rebreather* or 'CCR' all the gas is continuously being recirculated and no gas is vented. The CCR is generally being considered the thoroughbred of rebreathers. In CCR's the only gas being consumed is the oxygen metabolised by the diver (not considering gas used for inflating suits, wings etc and gas lost during ascent and decent).

Another important distinction between the popular Dräger SCRs and a CCR such as the Inspiration, is that the SCRs have a present oxygen-% and a variable ppO₂, whereas in the Inspiration it is the ppO₂ that is fixed and the oxygen-% which varies with depth.



Dräger Dolphin SCR



APD Inspiration CCR



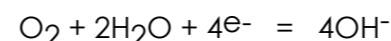
Oxygen sensors

An oxygen sensor can be considered as a small fuel-cell in which the chemical energy of oxygen is transformed into electrical energy.

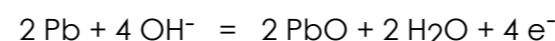
A very thin, plastic membrane, placed over the top of the sensor, operates as a solid barrier in which the oxygen molecules must dis-

solve in order to reach the sensing electrode. The flux of oxygen to the working anode is dependent on the partial pressure gradient of oxygen across the barrier. This means that the output signal from the cell is proportional to the partial pressure of the oxygen in the gas mixture.

When oxygen reaches the working electrode, it is immediately catalytically reduced to hydroxyl ions.



These hydroxyl ions migrate through a conductive electrolyte (typically potassium hydroxide) to the metallic lead anode, where they are involved in the oxidation of the lead to its oxide.



So, as the two processes take place, a current is generated (represented here by the four electrons 4e⁻). This current can be measured externally by passing it through a known resistance and measuring the potential drop across it. Since the current produced is proportional to the rate at which these reactions occur, its measurement allows accurate determination of the oxygen concentra-

tion. The current produced can then be used, via a computer, to control an oxygen inlet valve.

As the electrochemical reaction results in the oxidation of the lead anode, these sensors have a limited life. Once all the available lead has been oxidised they no longer work. Typically, oxygen sensors have 1 - 2 year life times.

Taking it further

Nitrogen is the usual diluent for oxygen in our normal atmosphere. However, as all divers know, nitrogen dissolves in the blood under high pressure, and can cause narcosis or decompression sickness. To reduce or eliminate this problem divers would like to use as little nitrogen as possible in the inhaled air.

Remove the biologically inactive nitrogen from the inhaled air and the risk of being hit by rapture of the deep disappears. And rebreathers can solve this problem, too, with the non-narcotic gas helium replacing nitrogen in the inhaled air being used at greater depths.

In CCRs like the Inspiration there are two tanks (see picture on previous page). One contains the oxygen which is being injected into to breathing loop to maintain the correct ppO_2 .

The other tank contains the *diluent gas*, which usually is just air, but it can be anything breathable such as trimix. This gas is, basi-

cally, the 'base substance' of what you breathe and what the oxygen gets injected into, it is what inflates the breathing loop and what is used for buoyancy in the wing or drysuit. So with an octopus attached this tank also can double as a normal open circuit and as backup system should there be a problem with the rebreather. (Switching to open system by closing the rebreather's mouthpiece and breathing from the octopus instead is referred to as *bail-out*).

The diluent gas is normally not consumed except for what is used to inflate the breathing loop and maybe the suit and wing (some carry separate tanks for this, i.e. when argon is used for suit inflation).

For trimix divers this is very good news as Helium is a very expensive gas so using a rebreather also come a significant economic incentive. Also it means a significant reduction in weight and the

number of tanks a diver who need to explore some extreme environments like deep wrecks and caves need to carry and for this reason the rebreather has become a preferred tool among many underwater explorers and scientists alike.

Next issue:

Diving the thing - what is it like and what the difference in skills?

US/Canada Distributor of Inpiration and Evolution Rebreathers



"Now, where did that contact lens go?"



Disclaimer:

Diving with rebreathers requires special training.

Diving with a fully closed system is, in many ways, significantly different from diving with an open system. Several things have to be re-learned, and re-learning is much more difficult if one has long been used to diving with an open system. Many experienced divers think that they are quite competent at diving, and often find it difficult to accept that they are beginners again when diving with a completely closed

breathing system.

For example, they may not realise that the oxygen partial pressure can vary considerably. Also, there is a risk that a very experienced diver will make serious elementary mistakes, due to a false feel-

ing of safety. This can lead to a failure to carry out the vital control checks of the equipment before and after each dive. Oxygen sensors degrade (oxidise) and must be changed every year, or more often, according to how much the system has been used. The reliability of the sensors and their output is also a matter of some controversy. It happens that

technical divers use fully closed systems at depths of more than 100 meters, in spite of the fact that neither the equipment nor the sensors are approved for these depths because of the doubts regarding the reduced reliability of their performance. (see, for example, the story about David Shaws fatal dive to 271m in X-RAY #3)

But, today, it is technically possible to dive to a depth of 100 meters with a couple

of 3-liter tanks containing 200 bars of compressed oxygen. However, the technique is so advanced that the necessary knowledge, training and maintenance of this equipment is not yet fully integrated into the training courses offered today.

To dive safely with fully closed systems requires a thorough theoretical and practical knowledge plus frequent use in order to maintain the routines and reflexes learned during training.

Sarawak - Malaysian Borneo

Miri Reef Map

Sarawak's ecological heritage is among the most distinctive in the world. Being part of the Indo-Australian Archipelago, the epicentre of marine biodiversity, the region comprises nearly 1000,000 square kilometer of coral reefs or 34 percent of the world's total, housing 600-800 reef-building coral species in the world. It is home to more than 3,000 species of fishes and the richest concentration of invertebrate species.

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The Uniqueness of Water

Water, obviously, is essential to our very existence, without it we rapidly die. In spite of this, everybody perceives water to be a rather ordinary sort of stuff, as it is transparent, odourless, and tasteless.

Many divers feel almost just at home in water as they do in air, and rarely, if ever, think about its more unusual physical properties. Water appears to be a very simple molecule, consisting of just two hydrogen atoms attached to an oxygen atom. There are, in fact, very few molecules that are smaller or lighter. In spite of this, it is a most remarkable substance, with many anomalous properties.

For a start, water is unique in that it is the only natural substance that is found in all three states – liquid, solid (ice) and vapour – at the temperatures normally found on Earth. And the fact that ice and liquid water can coexist at the not abnormal temperature of 0°C, is extremely important for all life on Earth.

Water has an unusually high density, and this density is further anomalous in that, unlike other liquids, it increases on cooling down to 3.984°C and then decreases until the freezing point temperature of 0°C is reached. The density of water is thus a maximum at about 4°C, meaning that it expands both on heating and cooling from this temperature. This density maximum, together with the low ice

density, ensures that all of a body of water (not just its surface) must be close to 0°C before any freezing can occur. The freezing of rivers, lakes and oceans is therefore from the top down, so insulating the water from further freezing. The oceans do not, therefore, freeze from the bottom upwards until they result in just a thin layer of liquid water on solid ice. If they did then life as we know it today could not have been possible.

The unusually high density of water is mainly due to the cohesive nature of the hydrogen-bonded network. This reduces the free volume and ensures a relatively high-density, compensating for the partial open nature of the hydrogen-bonded network. Why the density of water actually has a maximum at 4°C requires a much more detailed thermodynamic explanation than can be given here. ■

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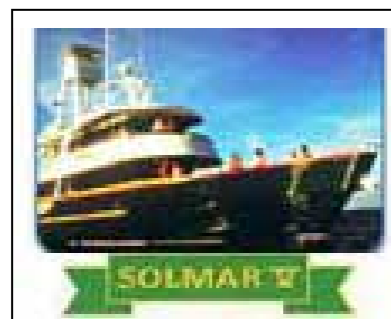
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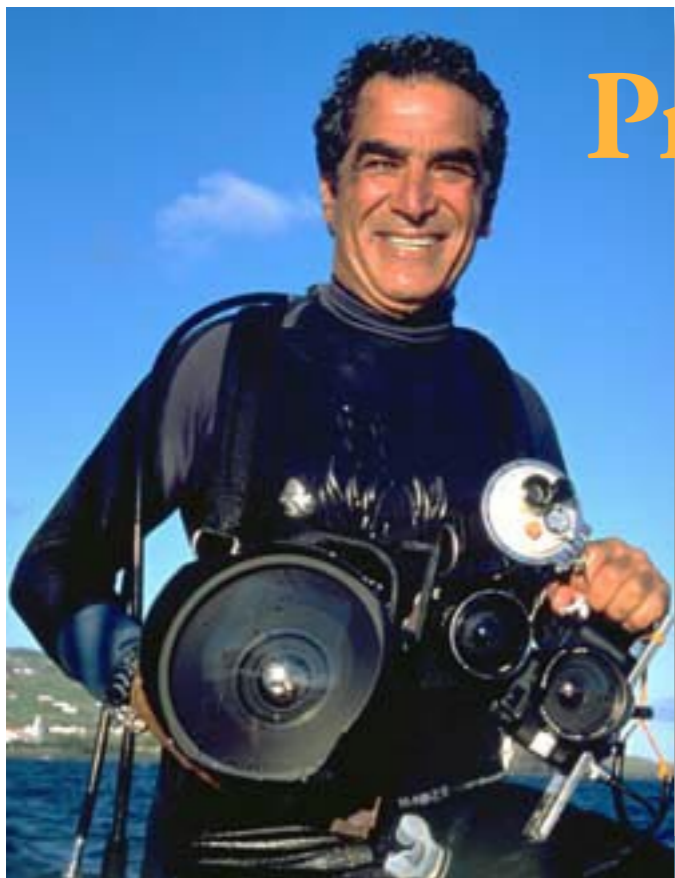
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Amos Nachoum

Interview by Edwin Marcow
Photographs by Amos Nachoum

Amos Nachoum, world acclaimed wildlife photographer is the recipient of numerous photographic awards and acknowledgements for his ground breaking work in free diving with Great White Sharks and Orcas in the open ocean, speaks to underwater photographer, Edwin Marcow, about his life, work and vision.

Amos was born in Israel in 1954. Today, he is based in San Francisco, California, USA.

EM: Amos how did you get started in photography?

AN: I was aged 12 and I knew that is what I wanted to do. For me, it was more evolutionary — I did not know what format of photography I wanted to do, but my desire and love for this art form started here.

EM: When you were a youngster growing up, were there any particular photographers that you admired or tried to emulate?

AN: For me it was not a question of any particular photographer. It was the concept of holding the camera adjusting and 'pushing' the camera's f-stop's shutter speed, and so on, to create the desired image that I had in my mind. This was a tool to communicate with others. I could not communicate very well when it came to writing and speaking in order to get across what I was trying to say.

While I was growing up, I had a difficult time within the family, and there were times when I did not always see eye to eye with my father. My mom would inadvertently take his side, so the medium and art form of photography became my escape — a way to express my self.

EM: Amos when did you get your first break in photography?

AN: As a youngster, I was fascinated by photography. I ran around the streets in Israel, camera in hand, photographing the people that I came across. My pictures were being sold and published by newspapers in Israel.

EM: When was your first break in marine and wildlife photography?

AN: I settled in the States in 1990-91. At that time, I was exchanging advertising

for stories, so naturally the magazines would use my images for the story. But this was a business arrangement to raise awareness for my Adventure Travel Company Big Animals. When I became a full time photographer, and not just a tour operator, I had to rethink everything that I had done previously.

So, I took a loan from the bank of \$4000 dollars, and I gave myself assignments to complete. I imagined that I had received a commission to shoot for National Geographic and to do a story.

I went to the island of Serbine in the Netherland Antilles, because I was very familiar with the Island and it's geography. I had good connections there. I shot the Island from the air, land and water.

This project took three weeks to complete. I chose only 15 images to portray the Island with the supporting article. I made several photocopies, and then sent this package to 55 different magazines around the US.

I sent this package to diverse and broad magazines in the travel and leisure market and to National Geographic.

The Condor Naste Traveller magazine gave me my first break. At this time, I was driving a taxi in New York to cover my costs. Then, I received a request from them to cover a story on Bonaire,



▲ TOP: Amos Nachoum
▲ Tail of a Humpback whale, Niue, South Pacific

Profiles



army often working whilst under fire. The discipline that I acquired from being under fire, having to cope with being put into strange situations, and understanding how to prepare for it, makes me feel a lot more comfortable underwater with any subject. Of course, no encounter is the same as another.

This has helped me when it comes to shooting underwater with large predators such as Great White

sharks. which included both topside images and marine life, though only from the perspective of snorkelling. This was 1991. From then on, things just took off.

EM: Amos, What would you say is your greatest achievement to date?

AN: Well, for me that would have to be that I am still doing what I love to do — rather than one individual experience or achievement.

EM: What is the scariest or most dangerous situation you have been in?

AN: In general, I have had a good grounding [in risky situations] from the many years I worked as a war correspondent and photographer in the Israeli



the boat manoeuvred between myself and the polar bear to allow me safe passage onto the boat.

Other than the incident with the polar bear, all encounters with wildlife have been peaceful, as long as my mindset is on the right plane and the circumstances fall into

place. my fins to fend off her attack. About to get bitten or gored, I turned to my side, and then she sank her tusks into my dry suit where she tore two large holes into the side of the suit, thankfully missing my groin. I got quite wet from that but no real injury.

She could have done a lot more damage. [He laughs]. She just wanted to push me out of the way.

sharks.

Underwater, I have had only one scary moment — when I encountered a polar bear. This was the most memorable moment of my life. Indeed, it was scary. In fact, I had to move the camera out of a shooting position and concentrate on saving myself.

I dived as deep as I could, to keep myself out of the reach of the polar bear. This took place about three years ago. But it is still on my agenda. I want to get a picture of a polar bear underwater in the wild—fully body in frame—precisely because all polar bear pictures have been taken in zoos where the bears are in captivity. The feet have been cut off or you only have an image with part of the

bear's body in the frame.

There have been only three photographers in the world who have been in the water with polar bears. One was an Italian filmmaker, now in his late 70's, whom I interviewed prior to my trip to the High Arctic. He advised me that a polar bear cannot dive deeper than 9 meters, or 30 feet. Armed with this information, I thought that I could dive to 40 feet and still achieve what I was looking for while working with the right lens. Well! No one told the polar bear this! For low and behold, the polar bear surprised me, defied all the rules and followed me down to about 24 meters (80 feet). But as I am usually ready for surprises and the unexpected, I took the necessary steps to prevent getting hurt. Upon my ascent,

place.

EM: Amos have you ever been bitten?

AN: [laughs] Well, these Great White sharks are very large fish! I have been bitten by a Clown fish. [He laughs]. At the time of the polar bear shoot, I was nearly bitten by a walrus, but due to a malfunction on the boat, the boat could not come to my aid. And there I was—in the water with this walrus mid-channel between the boat and the flow ice—without cover from the boat, as this large female closed the ground between us. I kicked out with

Amos Nachoum

- ◀ LEFT: An underwater photographer takes photos of a Humpback whale and its calf, Niue, South Pacific
- ◀ CENTER: A diver swims with the infant Humpback whale, Niue, South Pacific
- ▼ Spectacular shot of a killer whale diving to deeper depths, Norway



EM: How do you plan to push the envelope further, and how do you plan to cap your already amazing achievements?

AN: Pushing the envelope is a mindset that I apply even in everyday life. It is not something that I plan to do in advance.

When I am in the field, I weigh up the situation from what is going on around me, and then knowing what other people have done, what pictures have already been taken, bearing all this in mind and blessed with a quick memory, and based on emulating not copying what other people have achieved – I bring this with me to the field, with camera in hand. I see what I want to shoot but with the knowledge of what has been done before. I

see what can I do differently without endangering myself or others around me.

For me, it does not make a difference if I am taking a picture, of a Clown fish or a crocodile, or if I am on location in the North Pole. I do not push the envelope for the sake of “pushing the envelope”. It is a total understanding of personal and group safety, what has been done before and what I can do. While knowing what is going on in the field at the

time, I take new pictures with new results.

EM: What cameras and lenses do you use?

AN: I shoot with two Nikon RS,



and now I am shooting with a Hasselblad X Pan—an old concept brought back into fashion.

For the first time, a dedicated housing has been made for this camera by Aquatica in Canada, especially for me, and I am testing it here in Gansbaai on the Great White, and next, in the Cayman Islands to do some reef diving with this set up and test it further.

I am one of the first in the world to take this camera underwater,

and to shoot with it. Although, what is more important to me is to bring new images to the world.

EM: What is your favourite lens?

AN: There is only one, and that is

the fish eye, because water is 800 times denser than air, and anything we photograph, from more than one metre, loses its impact, power, and beauty, which Mother Nature provided, other than calibration, textures and shape.

The fish eye does the job. It is so sharp, it allows you to get closer to the subject. It can bring you very close to your subject and still fit everything in the frame.

EM: What is your preferred film

choice and speed?

AN: Kodachrome 64. It's a hard film to use. You have to be absolutely spot on with it. What is also very difficult is that it is almost impossible to have it developed anywhere in the world today. It's an excellent film, especially underwater, because it is so neutral, and with all that filtration of colours underwater already happening, you do not want to be “pushing” it further with a film that is already pushing the RGB spectrum through its chemical make up.

E6 processed films are already filtered, with blues, reds, and yellows, and Kodachrome brings that all alive when used underwater.

EM: Film versus Digital?

AN: Digital is here. It is the future. It will be better than film one day—no question. I still prefer to use film, because I know it so well. I enjoy working with it. In my opinion, film still has a higher quality. There is more depth in film. It has more texture than digital.

Sooner or later, digital will be able to achieve these results as well, which film gives you now.

I know that Fuji has come up with new chips. I think they are 11 or 12 MB files—6 MB are for highlights and 6 MB are for shadows or low light. I have not tested this myself. I have just heard about it.

So, in a year or so, digital will be as good or better than film. Personally, I will be waiting for the



◀ INSET: Napping polar bear, High Arctic, Canada

▲ TOP: A hunting wild dolphin breaches the surface, Sardine Run, South Africa

▲ BOTTOM: A leaping wild dolphin is captured on film in mid-air, Sardine Run, South Africa



◀ A dramatic moment when a leaping shark nabs its fleeing prey, a seal, for dinner, South Africa

mother and calf Humpback whale vertical in the water. I called it, *The Renaissances*.

Then, there was the Nikon 1993 award for a Great White lunging out of the water.

Nature's Best, the most prestigious wildlife and photography magazine in the world, gave my work an award in 2003.

I also got recognized by The Editorial Communication Arts magazine, which is the leading magazine in the US for general photography, and a cover for Rodale's Scuba Diving magazine, which was a half in-half out picture taken in the water of a diver with his fins in the air and his body in water, head facing towards the sea floor.

I felt that this image was my best work, because I was shooting with a fish eye lens that cannot use any filters. I balanced the exposure between the diver in and out of the water. This image really was for me, 'thinking out of the box'. I like this image the most due to the fact of how hard it was to balance the different exposures—from being underwater to topside and having to think out of the box to get it right.

On a last note about my photography and my continued pursuit in this field... It is not only a love for shooting in the water with large marine subjects, it is mostly my love and appreciation of photography, and what I can say with an image that I cannot with words. What I think most

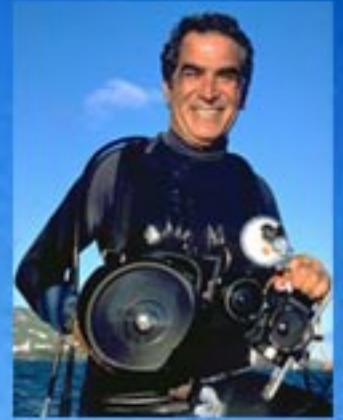
Amos Nachoum

underwater photographers miss, and what we are missing, is that people are not realising that they need to bring all the understanding and discipline of topside photography, which is so evolved, to the underwater realm.

Many of us have too narrow a point of view when it comes to underwater photography. One should have an understanding and love of all the great artists and emulate them, such as Monet, Rembrandt and Van Gogh. Look at paintings that have come out of these spectacular minds. Understand the rules of leading lines, beauty, light, drama, fear, power, and bring this into your work.

Painters and photographers are very similar, even though painters work with a blank canvas and have to add colours, shape and texture. Whereas, we go underwater, and we have the help of the greatest artist of them all, Mother Nature, who has painted everything for us. The only problem is that nature hides this element and colour from us, because number one, there is a lot happening down there (e.g. predation), and two, there is loss of light. We only need to learn how to understand white light and ambient light and how to read it.

In summary, I do not believe that marine photography is a genre in its own right. Marine photography is just another form of photography, and if one learns more from what has been done before—on land or by the great artists—one can bring this with oneself underwater and create better images. ■



AMOS NACHOUM'S
BIG ANIMALS
PHOTOGRAPHY EXPEDITIONS



Jon Gross

Text by Gunild Pak Symes

Jon Gross specializes in underwater and marine related photography from the west coast of North America, primarily Washington State, USA, and British Columbia, Canada. According to Jon, the marine life found in this part of the Pacific rivals anything found in the hottest tropical destinations in almost all aspects. He said that the challenges of this region, however, are cooler water temperatures and fickle water visibility. The diversity and abundance of marine life in these cold dark waters is relatively unexplored, and one of Jon's goals is to make this marine life more widely recognized.

► The Market, or Opalescent squid, is common in Puget Sound, and can be seen catching fish during night dives. Three Tree Point (north side), Washington State, USA.





▲ Egg Yolk Jellys often have crabs living on them that drift with them. They are usually found in the mantle, but this one was sitting on top of the bell, and is probably a Graceful Crab (*Cancer gracilis*) in the final larval stage. That identification is tentative though.

► This China Rockfish is defending its territory against me. Note the flared pectoral fins, and the upright dorsal fin. Waadah Island Fingers, Washington State, USA



▲ Very common on sandy or muddy bottoms in Puget Sound, the C-O sole buries itself on the bottom, and ambushes its prey. Mukilteo T-dock, Washington State, USA

◀ This Bering Hermit crab brought to mind (depressing as it may be) a suicidal person getting ready to jump from a bridge. I've seen Hermit Crabs jumping from their perches if you get too close, and falling up to 50 feet down a wall to land somewhere else. It's a handy escape response, but boy, climbing back up the wall must take awhile.

▲ PREVIOUS PAGE: Basket stars are ubiquitous with high current waters. They capture food from the water rushing by in their uplifted tentacles. Seven Tree Island, British Columbia, Canada





◀ Some of the largest anemones in the world are the Fish Eating Urticinas. The mouth on this particular specimen is almost 2 inches wide, and the oral disc can measure up to 18 inches. Waadah Island Fingers (Blades), Washington State, USA

▼ This octopus was sitting quietly on the top of an old engine block, which provided a beautiful rusty red backdrop. He (I think it was male) was living in one of the cylinders.

▼ NEXT PAGE: As I've mentioned in other images, these anemones grow to enormous size. This particular specimen is at least 18 inches in diameter.



▶ The Red Irish Lord is one of the most photographed fish in this area because of its arresting color patterns, and reluctance to move when approached with a camera. Browning Wall, British Columbia, Canada

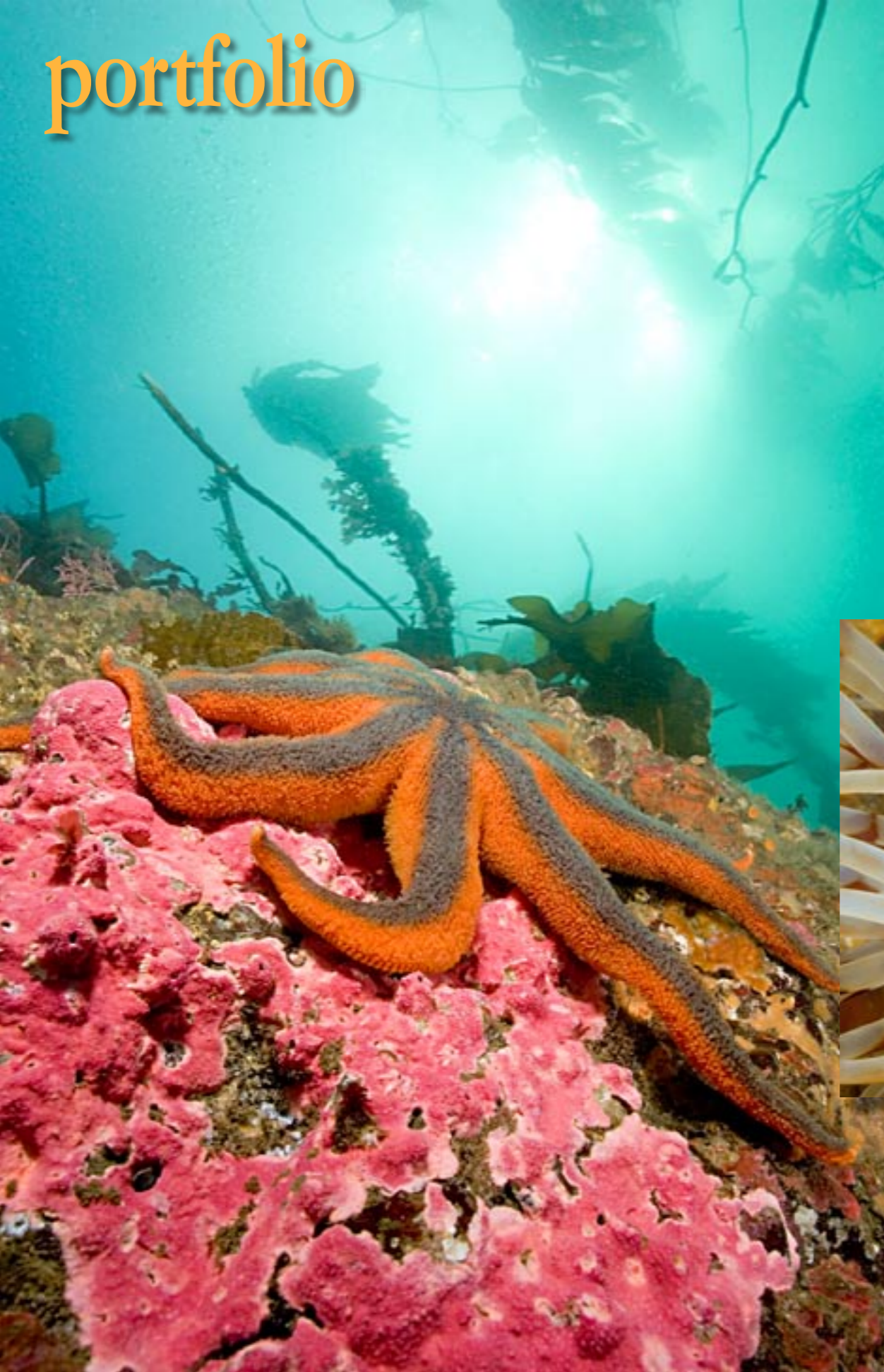




Jon Gross

◀ Stimpson's Sun Stars are a common sight on the Strait of Juan de Fuca, and the outer coast, underwater boulder fields covered with a kelp canopy make for beautiful diving. Sekiu Bay, Washington State, USA

▶ Nudibranch on Coralline Algae. These summer peak aeolids are very common nudibranchs both in Puget Sound in points north. They can be found on muddy bottoms, this rocky coralline algae substrate, broadleaf kelps, and other types of bottoms. Seven Tree Island, British Columbia, Canada



▲ This anemone lives in a tube, usually buried in the substrate. It is most famous for being eaten in a dramatic fast moving attack by various Dendronotid nudibranchs.





▲ These Surf Anemones can be found growing in cracks in the rocks in Port Hardy, and in enormous carpets down near Nanaimo, BC. They are gorgeous in the shallows, where the natural sunlight can reach them and set off their bright colors. The green in their bodies is from zooxanthella that live in the anemones tissue.

These zooxanthella, as a byproduct of photosynthesis, produce oxygen, which the anemone can metabolize. The anemone, in turn, produces molecules that the zooxanthella can metabolize. The green algae in the foreground is *Ulva fenestrata*, or Sea Lettuce, a common mid-shallow water green algae.

To order images directly from Jon Gross, visit his web sites at:
www.seaotter.com
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