POINT & CLICK ON BOLD LINKS

Equipment

Let it roll

Watershot Video Lights

The latest in the STRYKER series of underwater lights is the addition of a video light to its round up. The lights can be set up in tandem for use with video set ups or configured as a single dive light. The light head can be set to high lumen output or adjusted to three different levels, or strobe mode. **www.sitech.se**

Atomic Aquatics Cobalt

The engineers of Atomic Aquatics have created an OLED (organic light emitting diode) faced dive computer that sets the stage for the next generation of dive computers. Aside from its beautiful display (think iPhone), the computer packs advanced features that will appeal to recreational divers and technical divers alike. Running algorithms from the RGBM (reduced gradient bubble model), the computer can handle three gas mixes (up to 99 percent O_2), and user configurable conservationism. Topped out with digital compass, air integration, rechargeable battery (AC or USB from a laptop), and 40 to 60 hours of dive time. The test unit we were able to dive with this summer performed flawlessly, and the user interface and menu design were quickly and easily mastered without a manual. **www.atomicaquatics.com**

Icaro Tech

A BCD designed with needs of a tech diver, but equally useful for the recreational diver or underwater photographer. The Icaro Tech offers complete independence from the harness to the air-cell. Extremely light weight 3,050 grams (less than seven pounds), easily adjustable, and fully accessorized with six 55mm D rings. The outer material is polyurethane coated 1000 denier Cordura and finished with three convenient dump valves. **www.seacsub.com**

Titan

Into its third generation and boasting ten years of experience is the newly designed Titan regulator. This balanced diaphragm T-shaped design is made from stamped brass with multi-plated chrome finish. With the option to use either the right or left hand, the second stage has a quick disconnect and does not need tools. With its single hp port and four mp ports and a second model for cold water (the Titan Supreme) this regulator should fit the need for most divers. Complete specifications at: **www.aqualung.com**

ABC Safari bag

The iQ-ABC-Bag comes with two shoulder straps, so that it can be carried as a back-pack. With netting, so that the bag is well ventilated. Made from100% Polyester, robust 600 Denier fabric
IQ-Company

equipment

The Equipment News is brought to you in part by Gear Check, *compiled by Robert Sterner of Sterner Editorial Services. Suggest products to review and read earlier* Gear Check *items by product categories at* ***www.sternereditorial.com***

Nautilus Lifeline

This new radio and GPS for divers is designed to work with any marine radio and comes with Digital Selective Calling (DSC) capability to transmit GPS position or distress calls. DSC radio is the latest in marine radio technology. Digital Selective Calling is part of a global upgrade in maritime distress communications. Intuitive and easy to use. Use the button on the right to talk to every boat around you on CH16—the worldwide marine hailing frequency. Use the button on the left to chat with your dive boat or other divers. Advanced software prevents you from accidentally jamming the frequency and even automatically adjusts your squelch. Press the DSC button, and your GPS position will be transmitted to every boat and marine VHF DSC radio within 6km. Their radios will switch to CH16, alarms will sound, red lights will flash and your position will be shown on each radio display. **nautiluslifeline.com**

Scuba Pro Black Tech Regulators

Paired with either exclusive high flow piston MK25 or high-performing diaphragm MK17 first stage, the A700 systems are phenomenal in beauty and in breathing performance. The Black Tech incorporates a PVD (Physical Vapor Deposition) finishing process, which increases ruggedness, scratch resistance and surface hardness. PVD finishes are already found on military equipment, watches and tools. It is applied using titanium nitride and boasts a hardness of 2500 HV (chrome is 900 HV; stainless steel is 190 HV). The second stage has precision handcrafted all metal construction for a lifetime of diving. The regulator has unparalleled breathing performance regardless of depth, temperature or breathing position—now with a newly aligned co-axial VIVA (Venturi Initiated Vacuum Assist) system for more precise breathing assistance, control and comfort. Finished with two HP ports, five LP ports and swiveling turret. Available is chrome or Black Tech, and DIN or yoke. **www.scubapro.com**

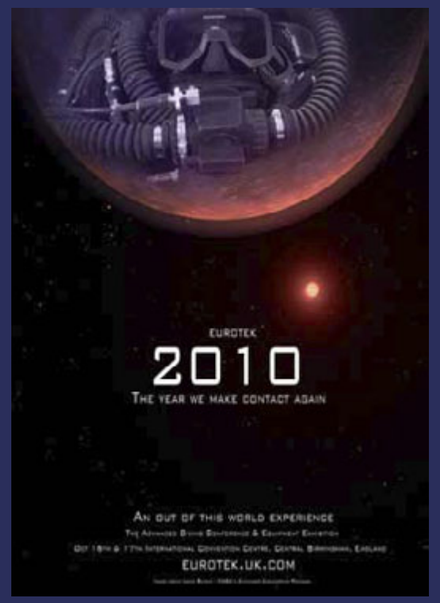
Kata handy dive gear tote

Kata bags weren't designed for divers but they should have been. The sturdy but very lightweight bags are found in photo stores with some designed to snuggle specific brands and models of cameras and others as general gadget bags. Bags are made with water-resistant fabric and zippers. Some even have cushions that can be inflated after gear is inserted, providing the ultimate in protection from jarring and making the bag buoyant should it fall overboard. Bags typically have dividers that are handy for organizing gear and a pillow to protect lenses from jostling. Toblerones are built into the bottom and edges to absorb shocks and to keep the bag above standing water. Click handles provide an ergonomic grip at different angles and dual-purpose buckles optimize carrying in various angles. The multi-sided shoulder strap fits left or right shoulders, slung either straight down or across the chest, and it's slotted to let air circulate under the strap. The optional trolley eases lugging the heavier bags and is sturdy enough to pile on another bag or two of luggage, too. **www.kata-bags.com**

October 16/17

EUROTEK 2010

ADVANCED DIVING CONFERENCE



"A phenomenal weekend and the best conference of the year"

EUROTEK.2010 - the bi-annual Advanced and Technical Diving Event - will be held on Saturday 16th and Sunday 17th October in Halls 9, 10 and 11 of the International Convention Centre, Broad Street, Birmingham, England, B1.

Declared "a phenomenal Weekend" and "the best Conference of the year" by many .08 Delegates, EUROTEK is a "must attend" event for any diver wanting to get more out of their diving. You don't need to be a techie, just curious and hungry for more information. Tickets will be available when doors open at 08.00 Saturday morning priced £43 and £75 respectively for a Day/ Weekend Pass.

During the weekend in addition to the 40 different exciting talks and useful workshops over two days, there's a display of historic rebreathers and diving equipment being brought over especially from the Netherlands, and a storming Expo with over 40 UK and overseas specialist companies exhibiting. This makes EUROTEK.2010 the perfect opportunity for you to spend time and talk directly to the manufacturers and training agencies and get your questions answered.

Just about every name that's anything to do with technical diving will be attending to listen to a mouth-watering list of 29 speakers. "We're delighted that we have secured such luminaries as the record breaking Cave Explorer Rick Stanton, underwater Cinematographer Carl Douglas, Algorithm Author Bruce Wienke (sponsored by Suunto) and tech legend Tom Mount (sponsored by IANTD)", stated Rosemary E Lunn, EUROTEK Co-organiser. "In addition and back by popular demand is the ever charming Professor Dr Simon Mitchell.

At 2008 it was standing room only in his presentations and not everyone got to hear him speak, hence his return to EUROTEK.2010. Simon has the knack of being able to explain quite complex physiological information to divers in quite simple terms whilst keeping the medics engaged. Divers tend to leave his talks with a key piece of information that has suddenly become crystal clear whilst pondering "now why didn't I see that before"? No wonder the room is always packed when Simon is on". So come to EUROTEK.2010, catch up with some old friends, meet new people and learn more about advanced and technical diving.

Speakers and Topics

Antti Apunen & Janne Suhonen
- The Molnar Janos Cave System beneath the City of Budapest
- Diving Finnish Mines


Leigh Bishop
- Britannic 2009; When deep wreck diving goes fatally wrong

Mark Caney
- Closed Circuit Rebreathers; Tec or Rec

Craig Challen
- Cocklebiddy; Extreme Cave Diving in the Australian Desert

Carl Douglas
- Shipwreck Discoveries in the Baltic Sea
- Filming Deep Wrecks in the Baltic

Note: the awesome photography that complements these talks is by Jonas Dahm

Martyn Farr
- Classic Dark Site Diving; Cave Diving around Europe
- Cave Diving in the UK; a look at traditional British Cave Diving

Kevin Gurr
- Rebreathers; Fact, Fiction or Voodoo

Jill Heinerth
- Extreme Cave Diving in Bahamian Blue Holes complimented by the Wes Skiles beautiful photography
- Digital Photography Still Imaging Clinic
- Diving the Ice Caves of the Antarctic

Evan Kovacs
- 3D Deep Ocean Imaging; A look at producing 3D films underwater
- Awesome 3D films from the Woods Hole Team

John Lamb
- Abuse of Oxygen Sensors with the expert from Vandagraph

José Santaria Marques & Armando Riberio
- Deep Portuguese Wreck Diving; a look at some stunning wrecks off the coast of Portugal

Gareth Lock
- Risk Management In Diving

José Santaria Marques & Armando Riberio
- 'Erich Glese'; Deep Wreck Diving on a Nazi Destroyer off Narvik

Barry McGill & Ian Lawler
- Deep Wrecks of Ireland – a look at the Carinthia, HMS Curaco and others


Agnes Milowka
- Cave Diving Down Under
- Caves of Florida; new discoveries and classic dives. (The stunning images are by the late Wes Skiles)

Dr Simon Mitchell
- Physiology of Divers
- Inwater decompression; current issues that have been topics of several forum debates
- CO^2 Issues with Rebreather Diving

Tom Mount
- The Evolution of Technical Diving; how technical diving came about
- Survival Dynamics; A look into the philosophy of diver survival

Martin Parker
- Staying In The Loop; Accident Analysis

Eduardo Pavia
- The Viminali – Deep Italian Wreck diving on this awesome Ocean Liner lying off Sicily

Mark Powell
- Decompression Planning; Translating decompression theory practically with PC Planning Tools
- Deep Stops and Bubble Models in Deco Theory

Daniel Rice
- Freebreathe Technology

Phill Short
- Cave Diving Adventures; one man's worldwide cave diving exploits
- Technical CCR Workshop focusing on Rebreather Safety

Arne Sieber
- The future technology of Sensors

Tomaz Stachura
- Graff Zeppelin; Deep Wreck Divers explore Hitler's Aircraft Carrier

Rick Stanton
- Doux de Coley and other European Cave Projects

Rick Stanton & Leigh Bishop
- DPV's for Wreck and Cave Diving

Rich Stevenson
- Getting started in CCR Diving

Rich Stevenson & Leigh Bishop
- The Development of British Wreck Diving over the last two decades

Bruce Wienke
- Decompression Algorithms; The Good, The Bad and The Ugly
- Valuable Technical Diving Resources

Please note that these talks and speakers are subject to change without notice.

Exhibitor list

Ambient Pressure Diving
Amphilogic
Bonex Scooters
Cathx Ocean
Custom Divers
Deep Ideas
Dive-In Cyprus
Dive-Tech
Fourth Element
Greenforce
Hollis
Hugyfot
Hydrogom
Jetsam Technologies
Kent Tooling Diving Products
Liquivision
Midlands & London Diving Chambers
Meridian Chartware
Miflex
MR Diving
Narked @ 90
Oceanic
OMS UK
O'Three
Otter
Papua Diving
Phil Grigg Technical Diving
Red Sea Diving College
rEvo Rebreathers
Santi
Scuba Industries Trade Association
Shearwater Research
Silent Planet
Stansted Fluid Power
Submerge Productions
Suex Scooters
Suunto Diving UK
Tech Thailand
The Rebreather Site
TillyTec
VR Technology
Waterproof
Wreck Diving Magazine
XRay Magazine

Agencies
GUE UK
IANTD UK
PADI TecRec
TDI

Edited by Kelly LaClaire
Gunild & Peter Symes

ALL PHOTOS COURTESY OF THE MANUFACTURERS OR VENDORS

POINT & CLICK ON BOLD LINKS

Dive Watches

Time, Technology & Style

When trying to determine if a particular watch is suitable for diving, first of all, look for a water-resistance rating of at least 200 meters, or 20 atm. The apparent overkill on the depth rating means that the watch should hold up fine underwater for most normal diving conditions. But a watch claiming to be water-resistant to 100 meters (330 feet) should be sufficient for recreational scuba diving, especially since those safe diving limits are set at 40m (130 feet).

So what's the deal?

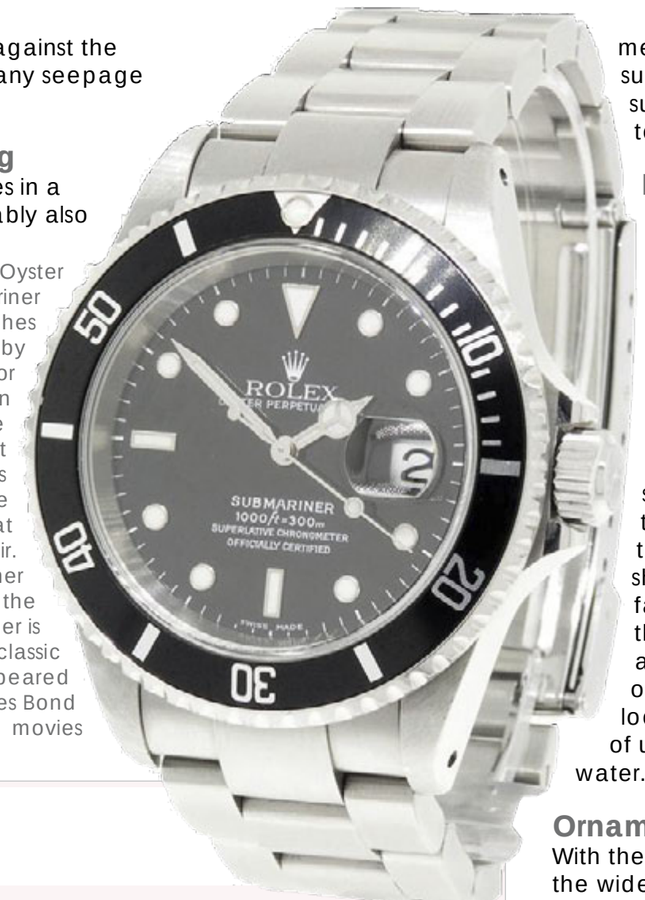
It is a matter of conventions that are, if not outright misleading, then certainly grounds for a great deal of confusion. However, the table (below) should provide some guidelines for buyers. First of all, the water-resistance ratings provided by manufacturers result from testing done under controlled circumstances. Basically, they indicate resistance to water penetration, assuming there is no movement by either the watch or the water, at a particular depth. The ratings do not take into account what happens if the watch is bumped or jarred.

In reality, several factors are at work simultaneously on a watch while underwater. Pressure is the most significant, but as a diver moves through the water, additional pressure is exerted. The watch cases of diving watches must be adequately water (pressure) resistant and be able to endure the galvanic corrosiveness of seawater. So, the cases are generally made out of materials like stainless steel, titanium, ceramics and synthetic resins or plastics. Gold may be a problem just because it's softer.

Seals must be used at each point where the case can be opened, and at other joints. This is primarily the case-back and crown (covering the stem). They may also be placed between the crystal and case unless a sealant is used. These seals, or gaskets are usually o-rings made of rubber or some other synthetic. Every watch made for diving should also feature screw-down case-backs and crowns. A case-back that screws down tight against a seal works much better than any type of back that is pressed in. The same goes for the crown; it needs to screw in so it seals tight against the o-ring to prevent any seepage around the stem.

Pressure testing

Changing batteries in a dive watch invariably also means it must go in for a renewed pressure test in hyberbaric chamber, so make sure you return your precious time piece to an authorized dealer.



The Rolex Oyster Perpetual Submariner is a line of watches manufactured by Rolex, designed for diving and known for their resistance to water. The first Submariner was introduced to the public in 1954 at the Swiss Watch Fair. Copied by other watch makers, the Rolex Submariner is recognised as a classic which has has appeared in eleven James Bond movies

Bezel

Analog diving watches will often feature a rotating bezel, which allows for an easier reading of elapsed time of under one hour from a specific point. This is also used to compute the length of a dive. The bezel is 'unidirectional', i.e. it contains a ratchet, so it can only be turned counter-clockwise to increase the apparent elapsed time. This is an important 'fail safe' feature. If the bezel could be turned clockwise, this could suggest to a diver that the elapsed time was shorter than it was, thus indicating a falsely short elapsed time reading, and therefore, falsely low air consumption assumptions, which are highly dangerous. Some dive watch models feature a lockable bezel to minimize the chance of unintentional bezel operation under water.

Ornamental feature of the past

With the advent of digital dive watches and the widespread use of dive computers, the exclusive use of a rotating bezel is now considered a rudimentary diving technique. Most contemporary dive watches with conspicuous 15 or 20 minute markings on their bezels are the result of copying a Rolex bezel design of the 1950s. Back then divers typically planned a dive to a certain maximum depth based on now obsolete U.S. Navy dive tables, and dove according to the planned dive profile. ■

Classification of diving watches

Watches are classified by their degree of water resistance.

Water resistance rating	Suitability	Notes
Water Resistant to 50 m	Swimming (no snorkeling related activity) and fishing.	***NOT*** suitable for diving
Water Resistant to 100 m	Recreational surfing, swimming, snorkeling, sailing and water sports	***NOT*** suitable for diving
Water Resistant to 200 m	Suitable for professional marine activity and serious surface water sports	***NOT*** suitable for diving.
Diver's 100 m	Minimum ISO standard (ISO 6425) for recreational scuba diving.	100 m and 150 m ratings are mostly seen on older watches.
Diver's 200 m or 300 m	Suitable for recreational scuba diving.	The most common ratings for modern dive watches.
Diver's 300+ m for mixed-gas diving	Suitable for saturation and advanced technical diving	Watches designed for mixed-gas diving will have an additional marking *DIVER'S WATCH L M FOR MIXED-GAS DIVING.* ■

Dive Watches

Standards for dive watches

The standards and features for dive watches are regulated by the International Organization for Standardization in the ISO 6425 standard. Besides water resistance standards to a minimum of 100-meter depth rating, ISO 6425 also provides minimum requirements for mechanical dive watches—quartz and digital watches have slightly differing readability requirements. ■

Oris

Swiss manufacturer Oris has joined forces with the Australian Marine Conservation Society (AMCS) by launching the Great Barrier Reef Limited Edition dive watch. Fifty Swiss francs from each piece sold will be donated to AMCS to help protect and preserve the world's largest and most stunning reef system. Water resistant to a staggering 100 bar (1000m, 3281ft) the Oris boasts a host of impressive design elements: multi-piece stainless steel casing with super scratch resistant sapphire face; automatic mechanical movement; easy to read centralized hour and minute displays with dark orange luminescent hands and face markings; helium buildup release button for divers who use pressure chambers; neoprene carrying case with logo and key fob. Also comes with a customized AMCS diver's log book.
www.oris.ch

IWC

Swiss watchmaker IWC Schaffhausen, partner and sponsor of the Jacques-Yves Cousteau Society, has dedicated a fifth special edition to "Le Commandant" in honor of his 100th birthday: the Aquatimer Chronograph Galapagos Islands Edition. This finely crafted timepiece begins with a stainless-steel casing coated with matte black rubber making the watch pressure resistant to 12 bar (120m, 393ft) and comes with a barrage of special features. The sapphire glass dial makes the face nearly scratch proof (you can mar the surface with a diamond but nothing else will affect it) and the mechanical chronograph movement is self-winding and has a 44-hour power reserve. Each watch has an external rotating bezel, date and day display and a patented quick-change bracelet system for use with business or formal attire. IWC makes a sizable contribution generated by proceeds from the sale of the Aquatimer to the Galapagos-based Charles Darwin Foundation. For 50 years, the foundation has been making visitors aware of the archipelago's uniqueness and providing them with guidelines to ecologically sound behavior and acting as sentries to ensure that the waters are not plundered and that the animals do not fall victim to poachers or predators imported from other seas.
www.iwc.com

Poseidon

Poseidon takes a more traditional approach to dive watches by offering the Chrono. Each watch has a large, easy to read rotating bezel, ultra accurate chronograph movement, super luminescent face index and hands as well as three separate timing dials for seconds, minutes and hours. Chrono's casing is made of stainless steel and is water resistant up to 20 bar (200m, 660ft) and comes in a plethora of face colors making this a fine timepiece for any serious diver. **www.poseidonwatches.se**

TAGHeuer

THE AQUARACER 500M CALIBRE 5 is as nice a dive watch as you will find anywhere and gives the wearer all the high-end options needed. The brushed stainless steel casing houses an ultra fine chronograph movement with automatic date surrounded by a unidirectional, soft-touch rubber bezel and is water resistant up to 30 bar (300m, 984ft). The crystal face is made of sapphire glass making scratches a virtual impossibility and the antireflective coating lets the luminescent hands and face indexes stand out in any light. For serious sport and technical divers, the 500M has a fine-brushed automatic helium valve which allows gas buildup in the watch to release due to time spent in pressure chambers or diving stations. The black rubber strap has a solid titanium clasp with safety push buttons for easy release and changes. **www.tagheuer.com**

Timeline

Early dive watches were often developed in response to military and professional needs. Later, they were designed for commercial diving, which started to appear in the 1960s. As a result, professional dive organisations came into being, touting needs for "tool" watches to help conduct dives safely at great depth.

1927 Rolex is credited with creating the first waterproof watch.

1932 Omega introduced the Marine, considered to be the first dive watch.

1930s Panerai produced a number of dive watches for the Italian Navy, waterproof to 650 feet.

1953 Blancpain produced the Fifty Fathoms dive watch worn by Jacques Cousteau in the film, *Le Monde du Silence*.

1954 Rolex introduced the Submariner—the watch of choice for James Bond in the first ten films.

1957 Omega Seamaster was introduced.

1967 Rolex Sea-Dweller introduced,first "ultra water resistant" dive watch, capable of depth to 610m.

1970 Omega Seamaster Professional introduced, capable of depth to 600m. ■

Dive Watches

Audemars Piguet

The high-class Royal Oak Offshore diver watch by Audemars Piguet can withstand pressures of 30 bar due to fine quality gaskets and the unique hexagon screw design mounting the case and face as secure as a sub hatch. With a new twist, the classic click bevel has been replaced with an internal rotating ring with diving scale that is controlled by a rubber coated crown mounted at 10 o'clock on the case. This keeps a diver from inadvertently moving the bezel while diving, always assuring any headings are taken and kept accurately. The finer points of the timepiece are just as impressive: self-winding, Calibre 3120 movement; stainless steel casing; luminescent coatings on watch dial and hands; hours and minute dive time measurements. We especially liked the rugged, octagonal face shape that dominates the face.

www.audemarspiguet.com

RedSea Holystone

RedSea, a new company started just this year by two avid watch enthusiasts, offers the Holystone, a professional dive timepiece with all the rugged extras you need when diving. Water resistant to 30 bar (300m, 984ft), this beautiful dive watch comes in your choice of stainless steel or black PVD (a long lasting protective coating used on high friction cutting tools). Each watch crystal is made of sapphire glass and the arms and face markings are layered eight times with special Lume-Tech coating for ultimate brilliance in dark areas. Both colors of the Holystone come with three separate bands—a five link steel bracelet for dressing up, Black nylon for more casual wear or a dark rubber dive strap for saltwater use. The large clicking bezel is easy to grab, even with gloves, and best of all, this new watch is priced below US$600. All watches will be available this winter, and if you place a pre-order, you will be automatically entered to win a free RedSea timepiece of your choice.

Redseawatches.com

Halios BlueRing

The Halios BlueRing is an aesthetic and beautifully crafted dive watch from a great independent brand in Vancouver, British Columbia, Canada. With only 100 models of each dial color, it offers exclusivity in ownership that extends beyond the distinct design and excellent packaging. If you missed your chance on earlier models, such as the Holotype, the BlueRing should be secured quickly since previous editions sold out in months, and the BlueRing is setting a pretty fast pace as well (as of late summer only the silver dial with brushed silver case is still in stock). Features include: water resistant up to 30 bar (300m, 984ft); highly calibrated ETA 2824-2 movement; silver dial with black bezel; domed sapphire crystal for outstanding scratch resistance. Now is the time to order a highly exclusive dive watch from a trusted and well known brand.

www.halioswatches.com/bluering

Luminox

Luminox has been the watch of choice for professionals like Navy SEALs, SCUBA legend Stan Waterman, the U.S. Coast Guard, law enforcement divers and many more. After 20 years of making 200 meter water resistant watches, Luminox has announced its 50 bar (500m, 1500ft) Deep Dive series. Specifically designed and constructed for use by professional divers, these watches can be taken to the deepest depths by technical divers doing their jobs, with all the attributes a true diving watch needs, including: stainless steel, PVD coated casing; screwed on crown with guard cover; sapphire glass face with anti-reflective coating; highly durable rubber strap; automatic helium release valve. The night vision tubes covering the dial, hands and bezel are ultra bright and are rated to last twenty-five years. This is serious gear for serious divers.

www.luminox.com

Watch strap

The choices you have for a strap are typically Rubber, Stainless Steel or Titanium.

Rubber: If its genuine—make sure to check—rubber is strong, comfortable and flexible. It will last for quite some time but will eventually deteriorate, and become brittle and susceptible to tearing.

Stainless Steel: Is fine for dive watches; the only thing to watch out for is checking that it is genuine stainless steel since other metal straps will rust or corrode.

Titanium: The best choice, if you can afford it, since it is stronger by a third over stainless steel and significantly lighter too, making it feel more comfortable as well. It's also more durable and more corrosion resistant than stainless steel, and hypoallergenic, too, which may be another consideration.

Further consideration: wetsuit clasp. This is a special clasp that makes the strap extendable so it's easy to adjust and wear over a wetsuit. ■

Dive Watches

Reactor

"Our new Poseidon has a number of firsts for us in terms of technology. In addition to the extreme 1,000m depth rating, the watch features an internal rotating bezel that can actually be adjusted underwater," stated Jimmy Olmes, president of Reactor, on their website. Their most seaworthy model to date, Reactor's Poseidon is built from stainless steel and has a substantially thickened case back and crystal face. The watch is available with a black and red dial with rubber strap, a yellow and black dial with two-tone black stainless bracelet, or a limited edition black and orange combination that will include both bands. The stainless bracelets include a wetsuit expander, another first for Reactor.
www.reactorwatch.com

Porsche Design

The first dive watch by Porsche Design since 1983, the P'6780 is not only uber-cool to look at but meets every high performance demand that can be placed on it. Capable of withstanding pressures at up to100 bar (1000m, 3281ft), the stainless steel case houses an ultra fine automatic movement and bright luminescent dial that is easy to read even in the darkness at its furthest depth range. The strap has a special extension that allows a diver to easily slip it on a wetsuit covered wrist without the hassle of popping the clasp open. But perhaps the most unique and functional design element is a special hinge that allows the watch case to swing upwards out of the titanium bracket. This allows the wearer to quickly move the crown without interference and blocks accidental movement while diving. Warning, if you're ADD like some of us folks with fins, you'll be flipping it up and down endlessly.
www.porsche-design.com

Victorinox Swiss Army

Precision timing meets extreme diving in the new Dive Master 500 Black Ice Chrono, now equipped with precision, self-winding movement in the same ultra-rugged and highly functional 43 mm sport watch from Victorinox Swiss Army. The 50 bar (500m, 1650ft) water resistance, which gives its name to the Dive Master 500 line, is maintained in this Chrono version which boasts a screw-in case back and crown, sapphire crystal with anti-reflective treatment. Of course, you'll find a unidirectional bezel and luminescent hands, hour markers, logo and bezel markers for super bright readings in deep or dark waters. This dive watch features enhanced legibility of its separate twelve-hour counter at 10 o'clock, date window and small second counter at 6 o'clock. The strap is genuine rubber and comes in several colors to match the dial you choose (black, red and orange). For a more stylish, sophisticated look, a stainless steel bracelet with gunmetal coated PVD is also available.
www.victorinox.com

Breitling

Breitling has revived the design of the legendary diver's instrument it launched in 1957. While the technical qualities that have forged the Superocean's reputation have been always been respected, the timepiece has been given a thoroughly updated look. The rubber-molded unidirectional bezel features sloping numerals that look and feel like a dive compass, and the notched edges make it easy to manipulate underwater even with heavy gloves for cold water diving. The strikingly distinctive dial is a continuation of the same vigorous design with oversized numerals and hour markers standing out nicely against the matte black face. This sleek and classy watch is water resistant up to depth of 1,500 meters and has all the attributes of a professional instrument, like the safety valve that automatically releases the accumulated helium when the internal over-pressure reaches around three bar, the self-winding chronometer certified movement and the extremely scratch resistant sapphire crystal that is anti-glare coated on both sides. For deep and dark dives, the hands and hour markers are brilliantly lit making timed calculations a breeze. Several bracelet designs (rubber or steel) and inner dial color combinations (yellow, red, blue, silver and black) are available. **www.breitling.com**

Dive Watches

Just for Kids

Speedo Junior UV analog watch —Kids will love this fun and entertaining watch as the strap changes color when outside in the sun while simultaneously offering UV protection to the skin underneath. Features include: fashion forward design and fun graphics; water resistant to 100 meters; unique comfort strap with pinless buckle; lightweight and waterproof case. Available in other sporty colors. Retails for US$40.00.

www.speedousa.com

Caretaking

Subjecting your watch to quick hot and cold temperature changes makes it much more likely to leak due to rapid expansion and contraction of the metal. In addition, chemicals like chlorine are hard on seals.

Take time following any saltwater diving, or swimming in a chlorinated pool to rinse off your watch with fresh water. Rotate the bezel also to flush out any salt and sand. Taking an extra couple seconds for rinsing will make a big difference in terms of longevity, same as it does for the rest of your dive gear. ■

The Hammerhead Chrono XL by Freestyle

Freestyle Speaks

Freestyle dive watches stand out from the pack. *X-RAY MAG*'s Gunild Symes interviewed Freestyle's marketing manager, Chad LaBass, to find out just what makes them tick.

GS: What makes your dive watches different from the others on the market?

CL: Affordability and durability add up to an overall value that separates us from our competitors. We understand that investing in dive equipment can be very expensive; we are proud to make dependable dive watches that don't have to be expensive to be effective.

GS: What makes your company different from others on the market?

CL: The Freestyle difference is in our product standards. Every watch we make is water resistant to minimum 100 meters, all dive specific watches to 200 meters, and we back all of them with a limited lifetime warranty.

GS: There are different types of divers out there. Which watch do you recommend for each type of diver and why?

CL: Freestyle offers entry level dive watches. We aren't in the business of competing with dive computers or expensive dive watches. We offer quality and value-packed dive watches from US$100-$175 for the price-conscious diver. Our recommendations:

Warm water diver

—dives in the tropics, lodging in luxury resorts and liveaboards: **The Hammerhead Chrono XL**. Why? For a stylish and bold look in and out of the water.

Cold water diver

—technical diver, wreck diver, diving in the temperate zones: **The Precision**. Why? It's a proven performer with analog and digital readout with a nightvision backlight.

Arctic diver

—technical diver, diving the extremes in the polar regions: **The Hammerhead**. Why? It's the staple of our dive line, no-nonsense style and durability.

Researchers

—conservationists and eco-conscious divers: **The Submersion**. Why? Choice between metal or polyurethane band and comes with a nightvision backlight.

Economy-minded

—middle class divers and university students: **The Hammerhead**. Why? We challenge anybody to find a better dive watch for under $100.

Weekend warrior

—occasional diver who wants to impress peers with a great dive watch: **The Hammerhead Chrono XL**. Why? For a stylish and bold look in and out of the water.

GS: Which models of your men's and women's dive watches are the most popular and why?

CL: The Hammerhead is our most popular model and has been for years. It's just one of those things, whether from word of mouth or just its classic dive style, the Hammerhead is always on top of our best seller list.

GS: Are there differences in preferences of features and styling in dive watches between men and women? If so, what are they?

CL: Not necessarily for the Freestyle consumer, they are generally looking to us for a dependable dive watch at a fair price.

GS: What is the future of dive watches? New technologies on the horizon? New fashion and style attitudes? New philosophies in watches in general?

CL: For now we don't have any plans on investing in new technologies, as most of the time new technology will drive the price of watch up. We like our position in the market catering to the entry level diver, and we want to concentrate on offering the most durable and dependable dive watches we can make in the US$100-175 range. If anything, we will find ways to make them even more stylish and comfortable.

GS: Tell us about your sponsorships in the field of diving.

CL: Currently, we don't have any sponsorship agreements with divers, however we do plan on adding that category later in the year. In fact, we have recently opened up a sponsorship application for aspiring divers: **www.freestyleusa.com/sponsorship**

GS: Anything else you would to tell our readers about your dive watches and your company?

CL: We are working on a new women's specific dive watch due out Holiday 2010. Stay Tuned! ■

Cephalopods use color change to interact with their own species, with other species, and with their environments.

Cephalopods

Jet-powered Masters of Disguise

Text based on Dr James Wood and Kelsie Jackson's *Cephalopod Lesson Plan*. Adaption edited by Peter Symes

Most cephalopods—the group in which scientists classify octopuses, squid, cuttlefish and nautiluses—can change color faster than a chameleon. They can also change texture and body shape, and if those camouflage techniques don't work, they can still "disappear" in a cloud of ink, which they use as a smoke-screen or decoy.

Cephalopods are also fascinating because they have three hearts that pump blue blood; they're jet powered; and they're found in all the oceans of the world—from the tropics to the poles, from the intertidal to the abyss.

Cephalopods have inspired legends and stories throughout history and are thought to be the most intelligent of the invertebrates. Some can squeeze through the tiniest of cracks. They have eyes and other senses that rival those of humans.

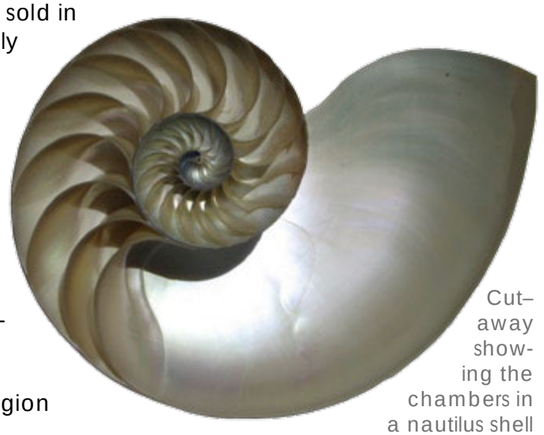
Brainy

The class *Cephalopoda*, which means "head foot", are mollusks and therefore related to bivalves (scallops, oysters, clams), gastropods (snails and slugs), scaphopoda (tusk shells), and polyplacophorans (chitons). Some mollusks, such as bivalves, don't even have a head, much less something large enough to be called a brain! Yet, cephalopods have well-developed senses and large brains. Most mollusks are protected by a hard external shell and many of them are not very mobile. Although the nautilus has an external shell, the trend in cephalopods is to internalize and reduce the shell. The shell in cuttlefish, when present, is internal and is called the cuttlebone, which is sold in many pet shops to supply calcium to birds. Squid also have a reduced internal shell called a pen. Octopuses lack a shell altogether.

Cephalopods are found in all of the world's oceans, from the warm water of the tropics to the near freezing water at the poles. They are found from the wave swept intertidal region to the dark, cold abyss. All species are marine, and with a few exceptions, they do not tolerate even brackish water.

Ancient

Cephalopods are an ancient group that appeared some time in the late Cambrian period several million years before the first primitive fish began swimming in the ocean. Scientists believe that



Cut–away showing the chambers in a nautilus shell

the ancestors of modern cephalopods (Subclass *Coleoidea*: octopus, squid, and cuttlefish) diverged from the primitive externally-shelled *Nautiloidea* (Nautilus) very early—perhaps in the Ordovician, some 438 million years ago.

How long ago was this? To put this into perspective, this is before the first mammals appeared, before vertebrates invaded land and even before there were fish in the ocean and upright plants on land! Thus, nautilus is very different from modern cephalopods in terms of morphology and life history.

Cephalopods were once one of the dominant life forms in the world's oceans. Today, there are only about 800 living species of cephalopods. By comparison, there is 30,000 living species of bony fish. However, in terms of productivity, some scientists believe that cephalopods are still giving fish a run for their money.

Many species of cephalopods to grow very fast, reproduce over a short period of time, and then die. With overfishing and climate change, there may be more biomass of cephalopods now than anytime in recent history.

Color change

Cephalopods use their awesome abilities to change their color and appearance primarily for two things: camouflage and communication. The ability of the cephalopods to change color is a trait that has evolved over time due to a greater need to avoid predators and become competitive in an environment shared with vertebrates.

These abilities, and the behaviors associated with them, have become a major contributing factor to the success of the cephalopod family and are great examples of adaptation—physically, through natural selection, and behaviorally.

JON GROSS

The nautilus is similar in general form to other cephalopods, with a prominent head and tentacles. Nautiluses typically have more tentacles than other cephalopods, up to ninety. These tentacles are arranged into two circles and, unlike the tentacles of other cephalopods, they have no suckers, are undifferentiated and retractable.

Camouflage

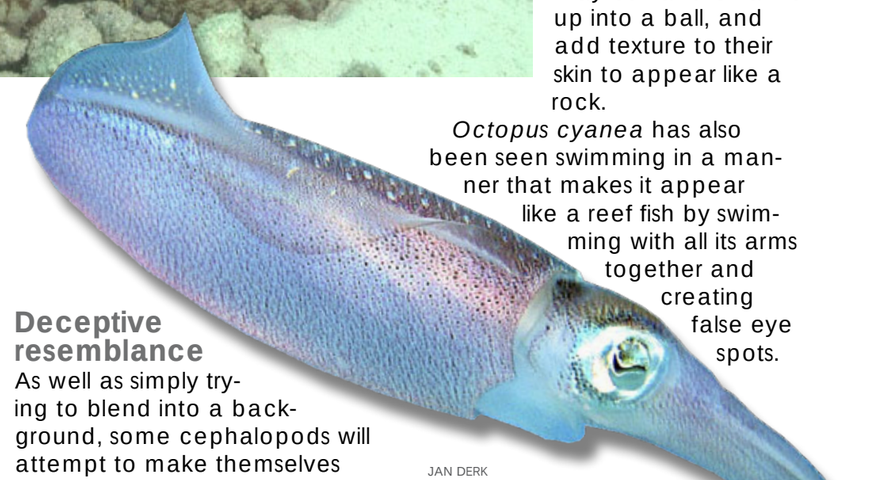
Camouflage is usually a cephalopod's primary defense against predators. As cephalopods don't have the protection of hard shells like many of their mollusk relatives, they make an easy to digest meal for a hungry predator. Therefore, most cephalopods try to avoid being seen to avoid being eaten. As well as predator avoidance, camouflage can also be used when lying in wait for unsuspecting prey to pass. Interestingly, cephalopods have more than one strategy for camouflage, and these will be discussed here.

JAMES WOOD

Resembling the background

Background resemblance is the most well known form of camouflage. This is when the animal changes its color and texture to match as closely as possible that of its background.

Cephalopods use their ***chromatophores*** to change color to match the brightness of the environment they are attempting to blend into, and some can also change texture using muscles in their skin. Many also use different body postures to help with this. They may hold their arms in certain ways or flatten them on the substrate to become what appears to be simply part of the scenery.



JAN DERK

Deceptive resemblance

As well as simply trying to blend into a background, some cephalopods will attempt to make themselves appear like a specific object in their environments. This is termed ***deceptive resemblance***.

The Caribbean reef squid, *Sepioteuthis sepioidea*, is often seen floating vertically at the surface of the water with its arms pointing downward to resemble floating sargassum weed. Some octopus may curl all their arms up into a ball, and add texture to their skin to appear like a rock.

Octopus cyanea has also been seen swimming in a manner that makes it appear like a reef fish by swimming with all its arms together and creating false eye spots.

JAMES WOOD

Deceptive resemblance

JAMES WOOD

Disruptive patterning being displayed by the cuttlefish, *Sepia pharaonis*. The large white band helps to break up the outline of the cuttlefish, making it harder to distinguish it from a complex environment when viewed from above by predators

Disruptive patterning

Disruptive patterning is seen in many creatures as well as cephalopods and serves to break up the outline of the animal to confuse predators. It involves the chromatophores, which are used to create sharply contrasting patterns on the body, often wide stripes or spots. This is best seen in cuttlefish, which employ this technique more readily than other cephalopods.

Countershading

Countershading is used to help a cephalopod blend in when there is no substrate against which to match itself. For instance, squid that spend much of their time in midwater rather than on or near the bottom can be seen easily by predators from below. Photophores and reflector cells on their underside match the light coming in through the water column, to make the squid almost invisible to animals below it. Countershading also makes rounded surfaces appear flat. So, a squid with a darker top surface and shades gradually decreasing to a pale under-surface will be harder to spot when viewed laterally.

Deimatic behavior

Deimatic behavior is often used when camouflage fails, and the cephalopod is still threatened. It involves changing rapidly from the color it was using to blend into its environment, to bold contrasting colors such as white and black. Some species of octopus will change instantly from their mottled appearance to bright white with black around their eyes. Deimatic behavior usually also involves body postures that make the animal appear bigger than it is. If this doesn't work and the animal is still threatened, cephalopods will then usually ink and jet away.

Communication

Cephalopods use color change as well as body postures to communicate, both with members of their own species as well as with members of other species. Many cephalopods have courtship displays in which males attempt to attract females by using chromatic displays (displays using color changes) to show that they are suitable mates. This is well developed in squid and cuttlefish but is less common in octopus in which complex courtship rituals have not yet been seen. Often during courtship, males will not only have to attempt to attract females, but also to fend off other males. As chromatophores are neurally controlled, the animal may be able to produce a pattern on one side of its body to attract a female while producing another pattern on the other side, which it directs at other males.

One side of the body produces a pattern to attract a female while producing another pattern on the other side, which is directed at other males

JAMES WOOD

Fighting between males also exhibits a lot of communication. With squid, time spent in acts of aggression involve mostly displays and very little physical contact. Squid will often show chromatic displays and body postures with increasing intensity until one backs down.

In midwater, light organs and photophores are thought to be used for communication. In the same way as color is used in shallow water, bioluminescence can be used where there is less light to attract a mate, lure prey and dissuade predators.

Predator avoidance may also involve some forms of communication to the predator. As with deimat-

It is hard to know for sure the first benefit that the adaptation of changing appearance had for cephalopods. The fossil record is spotty and does not provide many clues as to behavioral adaptations.

However, most scientists believe the initial benefit of the adaptation of changing appearance was ***crypsis***, the ability to blend in with the environment. This allowed cephalopods to be camouflaged so they could more easily catch their prey. Perhaps even more importantly, camouflage was the first line of defense against predators.

Much of cephalopod evolution is thought to be driven by predator avoidance. The earliest of cephalopods are thought to have used the ability to leave the bottom and swim up into the water column as a way to escape predators.

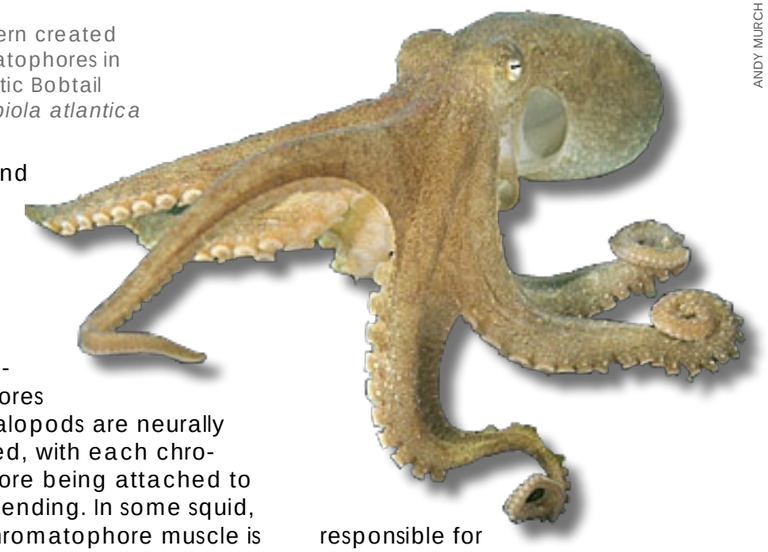
As both predators and their prey evolved, two major groups of cephalopods—the ammonites and nautilus—became some of the most common marine animals. These two groups relied on their external shell to protect them from predators. The ammonites are extinct, and there are now only six species of nautilus in existence. All the rest of the modern cephalopods, the coleoid cephalopods, have reduced and internalized shells and have the ability to change color, texture and shape to camouflage and avoid detection from predators. ■

JAMES WOOD

A California two-spot octopus, *Octopus bimaculatus*, displays its abilities to camouflage in different environments. This type of camouflage is known as background resemblance, as both octopuses have adopted colors, textures and postures to attempt to blend into the background

JAMES WOOD

Octopuses are, of course, not the only cephalopods to display background resemblance. A cuttlefish, *Sepia pharaonis*, is attempting to match the color and texture of the sand in its laboratory tank. Notice the white tipped papillae closest to the sand that give the appearance of small pebbles that can be seen in other areas of the tank. This ability not only protects the animal from predators, it also assists with hunting as prey can come quite close without realizing there is a hungry cephalopod nearby



Skin pattern created by cromatophores in this Atlantic Bobtail squid *Sepiola atlantica*

ic behaviors, showing a predator that it has been spotted and attempting to make itself larger and more frightful than it is will at least often make a predator stop and think, giving vital seconds for escape. On the other hand, if the bluff is successful, the predator may back away, thinking that it is not as easy a target as anticipated.

Cephalopods have often been referred to as the chameleons of the sea. However, their ability to change color is more impressive than that of the chameleon. Unlike the chameleon, many of the cephalopod's color producing cells are controlled neurally, which allows them to change colors very rapidly.

The patterns and colors seen in cephalopods are produced by different layers of cells stacked together, and it is the combination of certain cells operating at once that allows cephalopods to possess such a large array of patterns and colors.

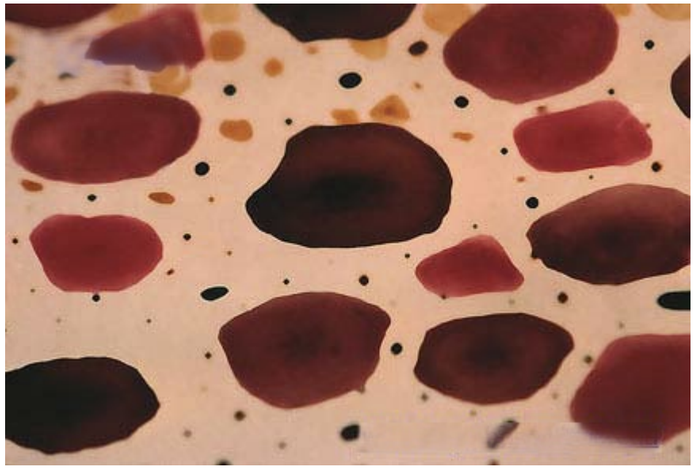
Chromatophores

The most well known of these cells is the chromatophore. Chromatophores are groups of cells that include an elastic saccule that holds a pigment, as well as 15-25 muscles attached to this saccule. These cells are located directly under the skin of cephalopods. When the muscles contract, they stretch the saccule allowing the pigment inside to cover a larger surface area. When the muscles relax, the saccule shrinks and hides the pigment.

Unlike in other animals, the chromatophores in cephalopods are neurally controlled, with each chromatophore being attached to a nerve ending. In some squid, each chromatophore muscle is innervated by two to six nerves that directly link to the animal's brain.

In this way, the animal can increase the size of one saccule while decreasing the size of another one right next to it. This allows the cephalopods to produce complex patterns, such as the zebra stripes seen in aggressive displays by male cuttlefish.

The speed at which this can be controlled allows the animal to manipulate these patterns in a way that makes them appear to move across the body. In some species of cuttlefish, it has been noted that while hunting, the cuttlefish may produce a series of stripes that move down their bodies and arms. Some scientists have suggested that this could be used to mesmerize prey before striking, but the purpose of this behavior has yet to be proven.



Closeup of cromatophores

The pigments in chromatophores can be black, brown, red, orange or yellow. They are not responsible for producing the blue and green colors seen in some species. Interestingly, many deep water forms possess fewer chromatophores as they are less useful in an environment in little or no light.

Iridophores

Iridophores are found in the next layer under the chromatopphores. Iridophores are layered stacks of platelets that are chitinous in some species and protein based in others. They are responsible for producing the metallic looking greens, blues and golds seen in some species, as well as the silver color around the eyes and ink sac of others. Iridophores work by reflecting light and can be used to conceal organs, as is often the case with the silver coloration around the eyes and ink sacs. Additonally, they assist in concealment and communication.

Previously, it was thought that these colors were permanent and unchanging unlike the colors produced by chromatophores. New studies on some species of squid suggest that the colors may change in response to changing levels of certain hormones. However, these changes are obviously slower than neural-

Chromatophores are located directly under the skin of cephalopods. When the muscles contract, they stretch the saccule allowing the pigment inside to cover a larger surface area. When the muscles relax, the saccule shrinks and hides the pigment.

ly controlled chromatophore changes. Iridophores can be found in cuttlefish, some squid and some species of octopus.

Leucophores

Leucophores are the last layer of cells. These cells are responsible for the white spots occurring on some species of cuttlefish, squid and octopus. Leucophores are flattened, branched cells that are thought to scatter and reflect incoming light. In this way, the color of the leucophores will reflect the predominant wavelength of light in the environment. In white light, they will be white, while in blue light, they will be blue. It is thought that this adds to the animal's ability to blend into its environment.

Photophores

Cephalopods have one final ability to change color and pattern, the photophores. These produce light by bioluminescence. Photophores are found in most midwater and deep sea cephalopods and are often absent in shallow water species.

Bioluminescence is produced by a chemical reaction similar to that of a chemical light stick. Photophores may produce light constantly or flash light intermittently. The mechanism for this is not yet known, but one theory is that the photophores can be covered up by pigments in the chromatophores when the animal does not wish for them to show.

Some species also have sacs containing resident bacteria that produce bioluminescence such as the tiny squid Euprymna. Midwater squid use photophores to match downwelling light or to attract prey.

It is the use of these cells in combination that allow cephalopods to produce amazing colors and patterns not seen in any other family of animal. However, not all species of cephalopod possess all the cells described above. For instance, photophores may be necessary for animals in deep water environments but are often absent in shallow water forms. Deep sea species may possess few or even no chromatophores as their color changes would not be visible in an environment with no light.

Recent research has suggested that there may be some correlation between the amount of chromatophores (and hence the complexity of patterns available) and the type and complexity of a cephalopod's environment. For instance, midwater species may possess fewer chromatophores. While species living in reef type environments may possess more. However, further research still needs to be conducted in this area.

JON GROSS

JAMES WOOD

Octopus burryi showing white spots due to leucophores

Cephalopod vision

Cephalopods are known to have excellent senses, and of these senses, their vision is perhaps the best studied. At first glance, cephalopod eyes look very similar to those of humans, whales and fishes. With the exception of the externally shelled and primitive nautilus, all cephalopods can perceive focused images, just like we can.

Cephalopods are invertebrates and other than being multicellular animals, they are not even closely related to vertebrates such as whales, humans and fish. Cephalopods, and their eyes, evolved independently. Why would animals so distantly related as a fish and a cephalopod have developed an eye that is so similar?

Colorblind

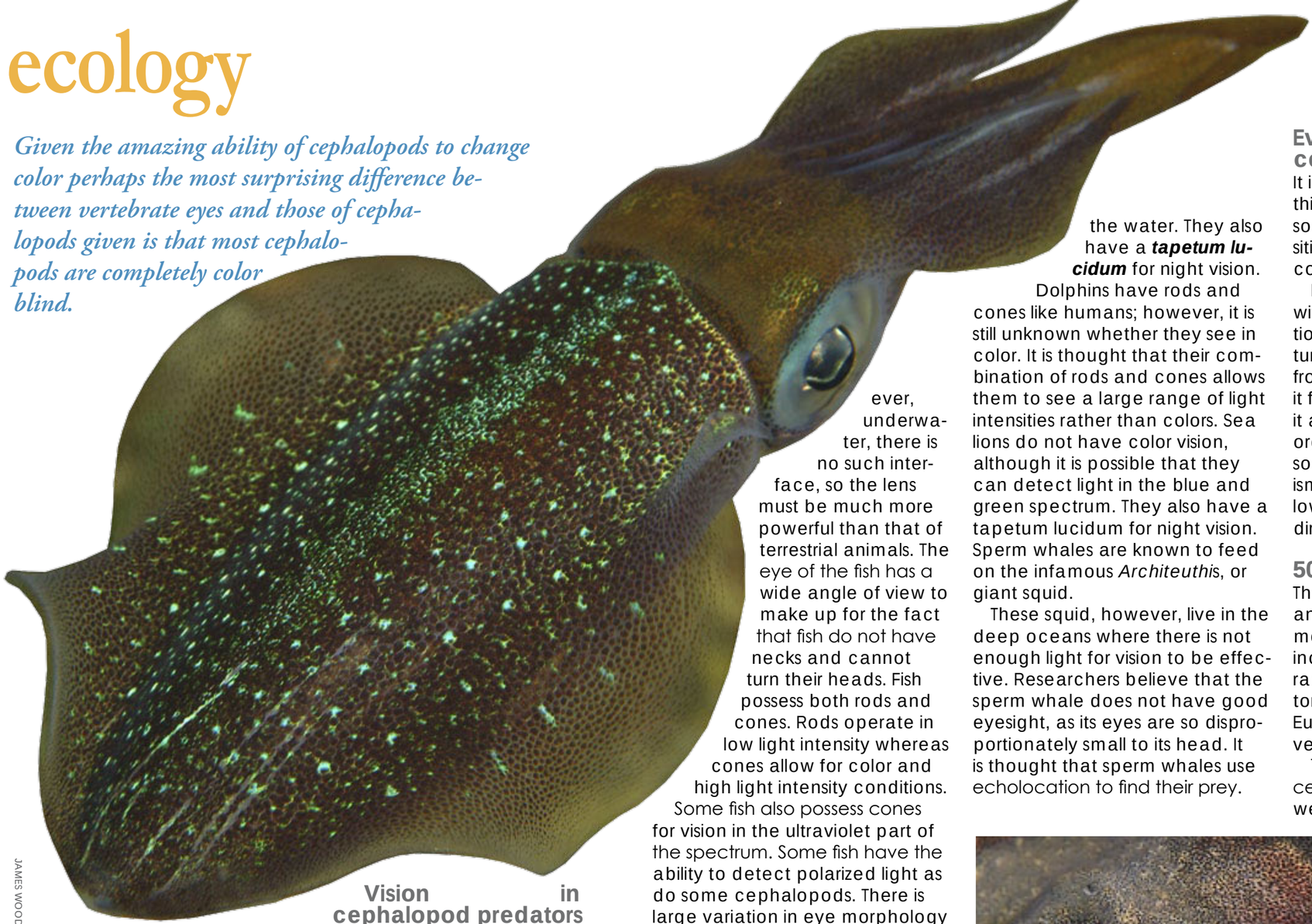
Given the amazing ability of cephalopods to change color perhaps the most surprising difference between vertebrate eyes and those of cephalopods is that most cephalopods are completely color blind. How do we know? We can train octopuses to pick black objects over white objects, white objects over black objects, light grey objects over dark grey objects and vice versa, but we can not train them to differentiate between colorful objects that look the same in grayscale. Also, most cephalopods only have one visual pigment. We have three.

Although many species have not yet been tested, the only cephalopod known so far to have color vision is the firefly squid, *Watasenia scintillans*. This species of midwater squid is bioluminescent and has three visual pigments. All other species tested so far only have one visual pigment.

Polarized light

Although most cephalopods can not see in color, it has been demonstrated that octopuses and cuttlefish can detect differences in polarized light—without wear-

Given the amazing ability of cephalopods to change color perhaps the most surprising difference between vertebrate eyes and those of cephalopods given is that most cephalopods are completely color blind.



JAMES WOOD

ing polarized sunglasses. Shashar and Hanlon showed that squids (*Loligo pealei*) and Sepiolids (*Euprymna scolopes*) can exhibit polarized light patterns on their skin. Therefore, cephalopods can not only see differences in polarized light, they can also create patterns using these differences on their bodies. (*See fact file on next page.*)

Vision in cephalopod predators

The predators of cephalopods include fish—such as sharks—birds, marine mammals and other cephalopods. All of these predators have single lens eyes, although often there is some variation between them to make their eyes more suitable to their environment and behavior.

Fish On land, it is the air-cornea interface of vertebrates that gives most of the ability to focus. However, underwater, there is no such interface, so the lens must be much more powerful than that of terrestrial animals. The eye of the fish has a wide angle of view to make up for the fact that fish do not have necks and cannot turn their heads. Fish possess both rods and cones. Rods operate in low light intensity whereas cones allow for color and high light intensity conditions.

Some fish also possess cones for vision in the ultraviolet part of the spectrum. Some fish have the ability to detect polarized light as do some cephalopods. There is large variation in eye morphology within fish as they inhabit a large number of habitats with varying light regimes, from complex coral reefs to the pitch black of the deep sea.

Marine mammals that feed on cephalopods include dolphins, sea lions, and whales. Dolphins have a few adaptations to their eyes to assist them. For instance, they have muscles that can bend their lenses, so they can focus above the water. They also have a ***tapetum lucidum*** for night vision.

Dolphins have rods and cones like humans; however, it is still unknown whether they see in color. It is thought that their combination of rods and cones allows them to see a large range of light intensities rather than colors. Sea lions do not have color vision, although it is possible that they can detect light in the blue and green spectrum. They also have a tapetum lucidum for night vision. Sperm whales are known to feed on the infamous *Architeuthis*, or giant squid.

These squid, however, live in the deep oceans where there is not enough light for vision to be effective. Researchers believe that the sperm whale does not have good eyesight, as its eyes are so disproportionately small to its head. It is thought that sperm whales use echolocation to find their prey.

JAMES WOOD

Evolution of cephalopod vision

It is known that nearly all living things including plants show some form of photosensitivity. How did this come to be?

Firstly, most life, with the exception of some deep sea vent creatures, is affected by light emitted from the sun, whether they require it for survival or are sensitive to it and must hide from it. All such organisms need to possess some sort of organ that allows an organism to know whether it is in high or low light, and possibly from which direction the light is coming.

500 million years

The ability to detect light with and eye has been developing for more than 500 million years and includes a variety of possible forms ranging from simple photoreceptors in single celled organisms like Euglena to the highly complex vertebrate eye.

The first "eye" seen in single-celled organisms and flatworms were simple photoreceptors that

PETER SYMES

Glossary:
The *tapetum lucidum* (Latin for "bright tapestry"; plural tapeta lucida) is a layer of tissue in the eye of many vertebrate animals, that lies immediately behind or sometimes within the retina. It reflects visible light back through the retina, increasing the light available to the photoreceptors. This improves vision in low-light conditions, but can cause the perceived image to be blurry from the interference of the reflected light. The tapetum lucidum contributes to the superior night vision of some animals. Many of these animals are nocturnal, especially carnivores that hunt their prey at night, while others are deep sea animals. Although strepsirrhine primates have a tapetum lucidum, humans and other haplorhine primates do not. ■

Seeing Polarized Light

It has been shown through scientific experiments that squid, octopus and cuttlefish are able to detect polarized light as well as create signals using polarized light on their skin.

What the difference?

What is polarized light and how is it different from unpolarized light? Light is a form of electromagnetic radiation that travels as a wave. The wave doesn't just vibrate on one plane; instead, it vibrates on many planes and in many directions at once while still traveling in the same general direction. Looking head on at a light wave, the assumption is that the wave is a straight vertical line as it moves toward the viewer. But, in actual fact, the wave moves vertically, horizontally, and diagonally all at the same time. This is how unpolarized light from the sun behaves, it is disorganized. Polarized light, on the other hand, only vibrates on one plane. The wave of polarized light, traveling toward the viewer appears as only one vertical or horizontal line

JAMES WOOD

How does it happen?

Polarization can happen in a number of ways. Firstly, when light hits an object, it can become polarized if it is reflected, refracted or scattered of off certain surfaces. Light may reflect off a non-metallic object or substance (like water) and become polarized. Polarized light that has experienced reflection will travel parallel to the surface of the object, which in the case of bodies of water, creates glare.

The amount of polarization will depend on the angle of the incoming light. When light undergoes refraction (i.e. when it passes from air to water and gets bent), it may become polarized, although this time the polarized wave will usually travel perpendicular to the surface of the substance it has passed through. Light may also become partially polarized by scattering, as light waves bounce off particles while passing through a substance.

They can but we cannot

So why can cephalopods, and the majority of mobile marine animals, see polarized light and humans cannot? Cephalopods have different photoreceptor cells from humans. Cephalopods have photoreceptor cells that contain microvilli. The microvilli of each receptor cell are lined up parallel to each other. Microvilli contain the visual pigment rhodopsin, which is also orientated parallel in the microvilli. Receptor cells are aligned at right angles to each other, and hence the microvilli of one receptor cell will be at right angles to that of the next receptor cell. The rhodopsin assist in seeing the polarized light. Because the microvilli are arranged at right angles to one another, the animal is able to distinguish between different planes that the light is traveling on.

Reflections

Cephalopods can use their ability to see polarized light in many ways. Firstly, it is thought that they can see though the reflection created by silvery fish scales to better identify prey and predators Often this reflection is polarized. Just as humans put on polarized sunglasses to see through the glare created by polarized reflection off the surface of the ocean, the cephalopod can cut out the glare of polarized light produced by reflection off fish scales to better distinguish prey. Translucent prey may also be more visible for the same reason, as light reflecting off the tissues of the prey may be polarized, and while it may not produce glare, it would make the prey animal more visible to animals that can see this reflection such as cephalopods.

Manipulating polarisations

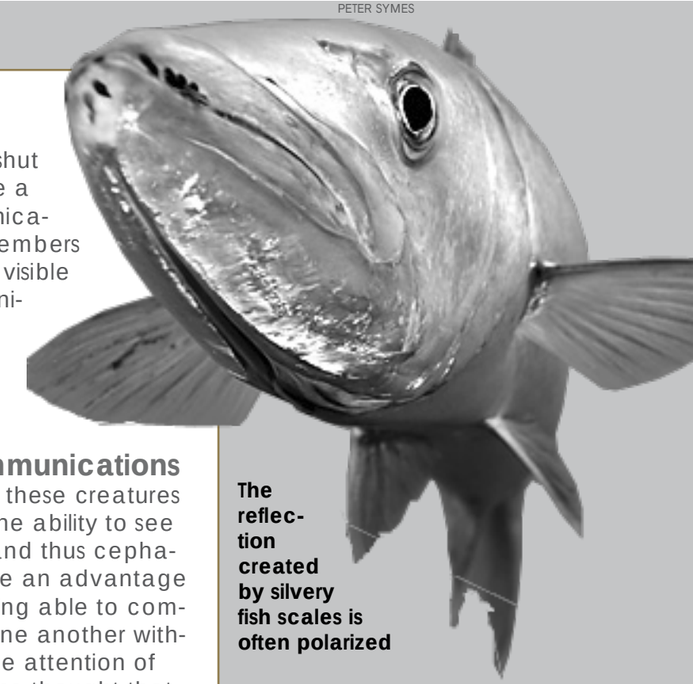
It has been shown that the iridophores on cuttlefish reflect polarized light in a way that they can intensify or shut off. This could be a form of communication between members of a species not visible to some other animals, especially predators such as sharks, seals and cetaceans.

Invisible communications

It is thought that these creatures do not possess the ability to see polarized light, and thus cephalopods may have an advantage over them in being able to communicate with one another without attracting the attention of predators. It is also thought that cephalopods and other marine animals that can detect differences in polarized light may use their abilities to detect polarization to assist them in navigation. ■

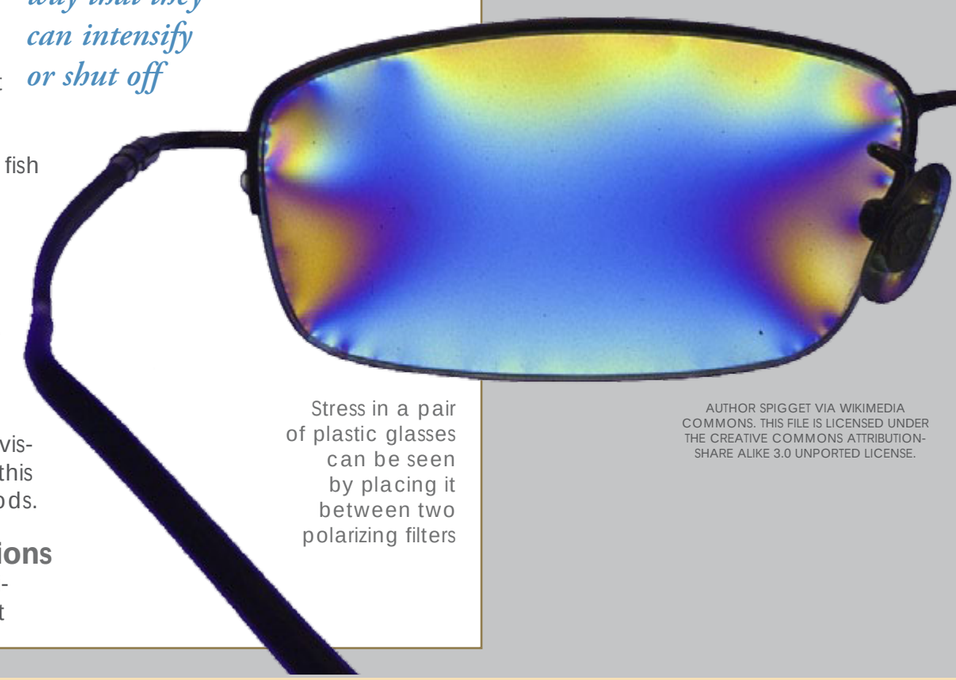
Cuttlefish reflect polarized light in a way that they can intensify or shut off

PETER SYMES



The reflection created by silvery fish scales is often polarized

Unpolarized light is disorganized. Polarized light, on the other hand, only vibrates on one plane.



Stress in a pair of plastic glasses can be seen by placing it between two polarizing filters

ANDY MURCH

The ability to detect light with and eye has been developing for more than 500 million years and includes a variety of possible forms ranging from simple photoreceptors in single celled organisms to the highly complex vertebrate eye.

could ascertain only the amount of light in the environment. The more advanced form of this was cup-shaped, which allowed the animal to discern from which direction the light was coming. However, this sort of eye did not allow the organisms to see as we think of it. Thus, the pinhole eye developed.

Pinhole eye

The pinhole eye is found in the Nautilus and consists of a small opening into a chamber, which allows a very small amount of light through. Light will pass through the pinhole after bouncing off different points of an object, and in this way basic shapes can be interpreted, not in any detail however. The hole is so tiny only a small amount of light can get in which makes the image faint. If the hole were larger, the image would be distorted. This type of eye is incapable of focusing on objects at different distances. Instead, the size of the image produced will change in relation to the distance away from the object.

The compound eye was the first true image-forming eye, which was thought to have formed some time during the Cambrian period, about 500 million years ago. The compound eye is common in insects and arthropods and consists of many ommatidia. Each ommatidia consists of a lens, crystalline cells, pigment cells and visual cells. The number of ommatidia will vary between species but may be up to 1000 per eye. Each ommatidia passes information on to the brain. This forms an image that is made of up dots, as if looking very close at a digital photo. A higher number of ommatidia mean more dots which make the image clearer. This type of eye is only useful over short distances. However, it is excellent for movement detection.

For an animal to be able to focus on objects at different distances or even to produce a clear image of its surroundings at all, its eyes needed to develop lenses. It is thought that early cup-shaped eyes, like those of flatworms, contained a substance that protected them from seawater. If this substance were to bulge, it would form a pseudo lens that would help to make an image form more precisely, and this may be favored by the process of natural selection. Although the compound eye is full of lenses, the only way to make the image sharper with this design was to add more ommatidia. Of course, this means the eye would have to increase in size and can only do this to a point before it is too large for the animal. Thus, more complex lens eyes formed in both vertebrates and in cephalopods. Although both of these designs have many differences, there are also many similarities.

JAMES WOOD

The pinhole eye of a Nautilus is incapable of focusing on objects at different distances. Instead, the size of the image produced will change in relation to the distance away from the object.

Cephalopod vs. Vertebrate Vision

As already stated, both cephalopods and vertebrates have very complex image-forming eyes with lenses. Both cephalopods and vertebrates have single lens eyes. They work by allowing light to enter through the pupil and be focused by the lens onto the photoreceptor cells of the retina. However, between the two groups of animals, there are differences in the shape of the pupil, the way the lens changes focus for distance, the type of receptor cells that receive the light as well as some more subtle differences.

JAMES WOOD

In vertebrates the pupil is round, and it changes in diameter depending on the amount of light in the environment. This is important because too much light will distort the image, and too little light will be interpreted as a very faint image. The cephalopod pupil is square and adjusts for the level of light by changing from a square to a narrow rectangle.

The way in which the two groups use the lens to focus differs. Vertebrates use muscles around the eye to change the shape of the lens, while cephalopods are able to manipulate their lens in or out to focus at different distances.

The receptor cells of vertebrate eyes are rods and cones. The cones are used for vision in high light environments, while the rods are used in low light. The time of day the animal needs its vision to be most effective will dictate the ratio of rods to cones. Cephalopods, however, have receptor cells called rhabdomeres similar to those of other mollusks. These contain microvilli, which allow the animal to see polarized and unpolarized light (see page on polarization vision).

Lastly, the way in which light is directed at the retina differs between the two groups. Cephalopod retinas receive incoming light directly, while vertebrate retinas receive light that is bounced back from the back of the eye.

Evolution

The evolution of cephalopods is thought to be due to an evolutionary "arms race". Over the course of cephalopod history, they have moved from the sea floor, lost their shells, developed abilities to change color, shape and texture as well as the ability to communicate in complex ways. It was their capacity to adapt to changing pressures that ensured their survival as a family. Those that did not adapt mostly became extinct.

The first cephalopods appeared 500 mya, before bony fish existed. These first cephalopods had a hard external shell like many other mollusks but were able to leave the ocean bottom and swim to escape predators.

Squid fossil hundreds of millions years old

When a predator came along, all the cephalopod had to do was let go of the bottom and float away like a hot air balloon. One of the first advances may have been the creation of multiple chambers connected by a ***siphuncle***; this allowed these early cephalopods to slowly change their buoyancy.

Other early advances were likely to have been the ability to swim slowly to control direction. Two groups of cephalopods, the Nautiloids and Ammonids (570 mya), depended on their external shell and ability to swim to protect them from predators. Both of these sub-classes of cephalopods do not have many of the traits of their modern relatives, such as the ability to change color, to produce sharp images with a lens-based eye, or the ability to swim fast.

JAMES WOOD

Ammonoids first appeared in the Late Silurian to Early Devonian (circa 400 million years ago)

USER HANS HILLEWAERT ON WIKIMEDIA BOMMONS. IMAGE REPRODUCED ACCORDING TO THE CREATIVE COMMONS ATTRIBUTION-SHARE 3.0 UNPORTED LICENSE

It is hard to say why the Ammonites and all but six species of Nautilus have become extinct. These cephalopods had a wide variety of external shells, some coiled, some long and straight, some with spines. These shells provided good protection from predators but inhibited the animals' mobility. Predation pressure has long been thought to be one of the major forces driving cephalopod evolution. Perhaps as species of bony fish, many of which swim much faster than an externally shelled cephalopod, appeared in the early oceans, armor just wasn't enough, and of those species that depended on armor, almost all have become extinct.

Differently strategy

Modern cephalopods have evolved a different strategy. Instead of a heavy protective external shell, they have reduced and internalized this armor. The loss of the heavy armor frees them from the weight of carrying it around and the energy needed to produce it. Most modern cephalopods are active predators. Instead of heavy armor, they rely on speed and visual tricks to avoid being eaten. Some scientists have suggested that these adaptations were in response to pressure from predators. Indeed, many of the tricks such as the ability to change color, shape and texture as well as the ability to produce a visual ink decoy seem to be aimed directly at their predators. ■

Glossary:
The siphuncle is a strand of tissue passing longitudinally through the shell of a cephalopod mollusk. Only cephalopods with chambered shells have siphuncles, such as the extinct ammonites and belemnites, and the living nautiluses, cuttlefish, and Spirula. In the case of the cuttlefish, the siphuncle is indistinct and connects all the small chambers of that animal's highly modified shell; in the other cephalopods it is thread-like and passes through small openings in the walls dividing the chambers. ■