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diving medicine

the facts°

VISION UNDERWATER - VISION AND OUR ABILITY TO SEE ARE SO INTEGRAL TO OUR LIVES THAT WE USUALLY TAKE THEM FOR GRANTED. IN DIVING, GOOD VISION IS NOT ONLY VITALLY IMPORTANT FOR SAFETY BUT IT IS ALSO A MAJOR SOURCE OF ENJOYMENT DURING THE DIVE!

Anatomy and Physiology

The eye is really just a complex, living camera. The main parts of the eye are the cornea, the iris, the lens, and the retina. The cornea is clear and has no blood supply. It protects the eye but its main function is to focus the light that enters the eye on the retina. A diopter is a measure of the power of a lens and the power of the cornea is equivalent to a +43 diopter lens. It is composed of five layers but for simplicity can be thought of as having a thin layer on the surface (epithelium) and a body composed of flat stromal cells. The epithelium has many nerve endings and therefore, when we get a hair or some other foreign body in the eye and scratch the cornea, it hurts a great deal!

After passing through the cornea, light crosses the anterior chamber and then goes through the opening in the iris called the pupil. The iris is a muscle and forms the coloured part of the eye so that when we say someone has blue eyes or brown eyes, we are really saying that their iris is blue or brown. The iris functions the same as the aperture in a camera; it leaves a large opening when the light is dim and a small opening when the light is bright. This controls the amount of light that enters the posterior part of the eye.

When we are excited or frightened the pupil dilates, allowing more light into the eye and allowing us to see more clearly. Men consider women more beautiful if they have larger pupils (they assume the woman is excited to see them!). Women in ancient Egypt used to rub juice from the belladonna plant (contains the drug atropine) in their eyes to dilate the pupils to make themselves appear more beautiful!

Light has to be 'bent' just the right amount so that it is focused on the retina for us to see clearly. Light from objects that are far away has to be 'bent' less than light from near objects. The purpose of the lens is to change the refractive power of the eye to accommodate for objects at different distances. As the ciliary muscles contract, they release the tension on the suspensory ligament of the lens and the natural elasticity of the lens capsule causes it to assume a more rounded shape. In a normal eye light from distant objects is focused on the retina with the ciliary muscles relaxed. To focus the light from near objects, the ciliary muscles contract and the lens becomes rounder, increasing the focusing power of the eye.

When light hits the retina, a series of chemical changes occur which generate an electrical signal that is transmitted to the brain and through a very complex process translated into the images we see. Now that we have a basic understanding of how the eye works, what happens when we try and see underwater?

WE RETURNED TO THE DIVE SITE TWO DAYS LATER. THE SILT WAS SO FINE (GLACIAL FLOUR) THAT EVEN THOUGH THE WATER WAS ABSOLUTELY STILL, THE VISIBILITY HAD ONLY IMPROVED TO 30 CM (12 INCHES).

Vision Underwater

The amount light is focused when it passes through the cornea is due to the difference in density between air and the cornea. The cornea has a density almost the same as water and therefore the difference in density between water and the cornea is very small. When light passes from water to the cornea, very little focusing occurs and the light will not be in focus until it is behind the retina. Therefore, when we open our eyes underwater everything appears blurry!

The solution is to wear a dive mask. The dive mask creates an airspace in front of the cornea, allowing the normal amount of focusing to occur when light passes from the air to the cornea, giving us the same vision as on the surface. Now that we can see clearly, we notice that everything appears larger underwater than it does on land. What is going on?


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The glass in the dive mask has almost the same optical properties as water and therefore very little focusing occurs as light passes from the water into the mask lens. However, the density of the mask lens is much greater than the density of the air in the mask. As light passes from the mask lens into the airspace in the mask, it diverges (the opposite of focusing)! This results in objects appearing larger than they would out of the water. The magnification is about 25%, so that a 40 cm long fish will appear to be 50 cm in length. Exactly the same mechanism occurs when we look down into very clear water from above the surface (light coming from the fish diverges as it passes from the water into the air) so that fish we see in the water appear 25% larger than they really are.


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We have several mechanisms for helping us determine how far away an object is. One is the apparent size of the object. We know how large our dive buddy is on the surface at various distances (they appear smaller when they are farther away). When we look at our buddy underwater, we notice how large they appear to be and use our experience on land to determine how far away they are. The problem is that underwater they appear 25% larger than they do in the air and thus we think that they are 25% closer than they actually are. If we reach out to touch them (or anything else) we may find that our arm is too short!

The bottom line is that underwater things generally appear to be 25% larger and 25% closer than they really are. Therefore, divers have a much better excuse for telling stories about how large the fish was than their above water friends!

Colour

The next major change in our vision when we are diving is that the colours often seem drab. This is because water absorbs light. Colours are simply light of different wavelengths and water absorbs them at different rates so that after light has passed through about 5 metres (16 feet) of water, most of the reds are absorbed. After 10 msw (33 fsw), the oranges are also absorbed. The yellows disappear next followed by the greens and blues so that by the time we are deeper than about 20 msw (66 fsw), everything appears blue / grey. Using artificial lights restores the colours but the light from an underwater light is not exactly the same as the light from the sun and the colours will not be quite the same as if the object was out of the water.

Turbidity

The ability of light to pass through water (and our ability to see clearly) is also influenced by its turbidity. Turbidity is influenced by many factors but they can be grouped into two large classes, things suspended in the water and things dissolved in the water. Suspended things include silt, plankton, etc. while dissolved things include salt and chemicals. When a diver is swimming along near the bottom, the water movement caused by their fins often stirs up the silt and for a while the water behind them has high turbidity. This often results in death when open water divers enter caves. The water is crystal clear in front of them and they do not realize until they turn around that they have been kicking up the silt and they can no longer see the way out of the cave.

If the water is still, the silt will eventually settle back down to the

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DAVID SAWATZKY, S.C., C.D., B.Med.Sc., M.D., M.Sc., is a diving medical specialist on contract at Defence Research and Development Toronto from 1998 to 2005. Previously he was the Canadian Forces Staff Officer in Hyperbaric Medicine at DCIEM (1986-1993) and later the Senior Medical Officer at Garrison Support Unit Toronto (1993-1998). He's written a monthly column on diving medicine in Canada's *Diver* Magazine since 1993, has been on the Board of Advisors for the International Association of Nitrox and Technical Divers (IANTD) since 2000, and is an active cave, trimix and closed circuit rebreather diver/instructor/instructor trainer. David's first love is cave diving exploration and he's been exploring and surveying underwater passages in Canada since 1985. David was responsible for the exploration and mapping of almost 11 kilometres of underwater passages in the Ottawa River Cave System. In 1995, he executed the first successful rescue of a missing trained cave diver. David received the Canadian Star of Courage for this rescue which took place in the chilly Canadian waters of Tobermory, Ontario. He still dives as much as possible, but admits his three year old son Lukas, two year old daughter Emeline and wife (Dr Debbie Pestell) are currently higher priorities than diving!

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bottom and the water will become clear once again. The time this process takes depends upon the size of the silt particles. Grains of sand will settle in a minute or two while the ultra fine grains of rock flour produced by a glacier will take several

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weeks to completely settle out. During a cave diving trip under the Columbia Icefields in 1987 the water was 'air clear' when we arrived at the dive site. After we had made the area safe and several hundred (or thousand) kilograms (pounds) of mud and rocks had been dropped into the water, the visibility was less than 2.5 cm (1 inch)! We went back to the surface and returned to the dive site two days later. The silt was so fine (glacial flour) that even though the water was absolutely still, the visibility had only improved to 30 cm (12 inches).

Salt water has large quantities of salt and other chemicals dissolved in it and for this reason, can never be as clear as fresh water. The best clarity to be found in the ocean would be around 60 metres (200 feet) while in some fresh water caves the water is so clear it can not be seen, visibility is over 300 metres (1,000 feet). These ideal conditions are rarely encountered and we usually have much less visibility. For example, the Ottawa River contains water with many dissolved chemicals (from soil, trees, etc.) and visibility is seldom more than 6 metres (20 feet). The St. Lawrence River used to be similar but the infestation of billions of zebra mussels has changed this situation drastically. Zebra mussels are filter feeders and each mussel filters the silt and chemicals out of a large amount of water every day. The result is that places where 6 metres (20 feet) visibility used to be considered good now frequently have 30 metres (100 feet) visibility or more. The problem is, now that the water is clear enough for divers to see well, the wrecks still can't be seen because they are now covered in many layers of zebra mussels! ■

SHARKWATER
THE TRUTH WILL SURFACE

For filmmaker Rob Stewart, exploring sharks began as an underwater adventure. What it turned into was a beautiful and dangerous life journey into the balance of life on earth. Driven by passion fed from a life-long fascination with sharks, Stewart debunks historical stereotypes and media depictions of sharks as bloodthirsty, man-eating monsters and reveals the reality of sharks as pillars in the evolution of the seas. Filmed in visually stunning, high definition video, Sharkwater takes you into the most shark rich waters of the world, exposing the exploitation and corruption surrounding the world's shark populations in the marine reserves of Cocos Island, Costa Rica and the Galapagos Islands, Ecuador. Stewart's remarkable journey of courage and determination changes from a mission to save the world's sharks, into a fight for his life, and that of humankind. www.sharkwater.com

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