BRISBANE SOUTH MARINE STUDIES PROJECT

MARINE STUDIES SERIES

UNIT 9

DIVING SCIENCE

GOLD COAST UNDERWATER CLUB

written by

GOEFF BROOMHEAD

GOLD COAST UNDERWATER CLUB

DEDICATION

The members, past, present and future, of the Gold Coast Underwater Club would like to express their whole-hearted appreciation to Jeff Broomhead for his untiring efforts in teaching and the research which has resulted in this book. Without his drive and enthusiasm it would never have been possible.

---o0Oo---

THE SCIENCE OF DIVING

GOLD COAST UNDERWATER CLUB

T.A.F.E. COLLEGE : EDUCATION DEPARTMENT

SNORKEL COURSE

LIST OF CONTENTS

THE SCIENCE OF DIVING

THE SNORKEL AND SCUBA COURSES

OF

THE GOLD COAST UNDERWATER CLUB

AND

THE TECHNICAL AND FURTHER ECUCATION COLLEGE

SURFERS PARADISE

THE GOLD COAST

AUSTRALIA

ACKNOWLEDGEMENTS

To the many good people who gave so freely of their thought, time, and energy in the building of these texts - Our Grateful Thanks.

The course was developed in the crucible of the learning process of many groups of students, and in the teaching processes assembled by the instructors with the same joy and pain found in the making of any worthwhile thing.

It was not born in a day, or a month, or a year, but in thousands of hours over years; and in the cross fertilization of ideas in discussions - earnest, searching, heated and coldly clinical. Pictures and films are also associated with the courses.

The wonderful world of practical teaching of diving in the ocean is not touched on here, except for some parts that can be put on paper. You have to be there to learn of that through the joy of taking part. Out there Sally Worrall and Rex Neale are superb.

Any text book can only deal with one part of any science. The aim here has been to give a basic introduction to the science of diving, to show the main risks involved, how to stay healthy, what to do in emergencies.

The text is for use in classes for training students for examination within the framework set by the Federation Of Australian Underwater Instructors.

More excellent divers contributed, and more text books from around the world were consulted, than we could possibly mention.

But some names stand out and need especial thanks.

Chris Boyle gave freely of his own course papers and examination questions, and this booklet was built around those. His insistence on a high standard set the tone and pace from the beginning.

Inspiration, enthusiasm, and a great amount of work was given by Dr Rex Neale, Sally Worrall, Peter Scott, Dr Terry McGrath, Noel and John Kogler, Tony Smith, Phil McKee, Rob Wall, Paula Schmierer, Graeme Bond and many others.

Beautiful art work was freely given by Trish and Glen Smith and Robert Ross.

To my sons:- Malcolm and his beautiful wife Jillian of the British Sub Aqua Club in the Persian Gulf were those who started and inspired the Editor on his voyage, and Richard with the Madang Divers kept the wheels spinning. Ken and the lovely Annette by their fine approach to their own professions inspired the quest for perfection.

Dudley Sinclair the Head of School, Business and General Studies of the T.A.F.E. College, Surfers Paradise, lifted our efforts with his own dedication, and by the provision of the wonderful teaching facilities at the college. Russ Gunner with his beautifying skills, his printing workmanship and art; and his insistence that only the best is good enough often made us resolve to do better.

So we tried for perfection, but now realize that it comes to very few.

But, lacking perfection - very much so - we present these notes with the modest hope that, at the level for which they are designed, our courses of instruction, in the class room and ocean, may be considered to make a worthwhile contribution to the great sport and art of diving.

Jeff Broomhead
Editor and Contributor

INTRODUCTION

GOLD COAST UNDERWATER CLUB

SCIENCE OF DIVING

In building the text for these courses much information has been obtained from Instructors of the G.C.U.C. who have worked in previous years, and much advice has come from club members. Textbooks on diving have been searched for the best information from Australia and overseas.

The depth, to which the student should be taken in the study of the science has been given a great deal of consideration. We certainly do not need to study for a Ph. D. degree, but we need to know enough to dive with confidence and in safety. A balance has been struck which it is expected will allow the student to prepare to enter the diving world with enough knowledge to know what he is doing and why. Thus he should be able to enjoy the sea, not be a danger to himself and others, and be equipped to learn more.

Diving is a sport where we are our brother's and sister's keeper. It is a team sport where our continual care is to help and assist each other, especially the weaker members. It is not a competitive sport.

The evolution of diving in both practice and theory has taken many thousands of years, as far back as Alexander the Great, and even further. The acquisition of this knowledge has been paid for in many instances by loss of life. Remember what you learn well. It may save your and your friends' lives.

The instructors adopt a professional approach and give instruction freely and without fee. Reward them by giving performance to your very best. Then it is possible that you may be accepted as an equal, in a proud and happy club.

GOLD COAST UNDERWATER CLUB TRAINING RULES

1. Acceptance Of Students:
   - 1.1 To qualify for acceptance and continuity of acceptance to undergo training, intending students must:-
     - 1.1.1 Become members of the GCUC and pay class fees
     - 1.1.2 Pass medical test
     - 1.1.3 Pass swimming test
     - 1.1.4 Continue to satisfy all instructors that they are keen on course, and are sincerely trying to improve themselves in diving theory and practice as provided in the course.

2. Students Are Expected To:
   - 2.1 Regularly attend training sessions in the water
   - 2.2 Regularly attend theory lectures in the classroom
   - 2.3 Complete all home assignments between classes
   - 2.4 Become physically fit and keep themselves physically fit. It is expected that students will steadily progress from the start of the course to a state of fitness to swim thirty lengths of an Olympic Pool continously, using the Freestyle stroke, after 12 weeks from the start of the course.

   Recommended text books on physical fitness are:
   "The New Aerobics" by Kenneth H. Cooper, MD. MPH.
   "Total Fitness" by Laurence E. Moorhouse Ph.D & Leonard Gross.

3. The students will continually be assessed by all instructors for mental attitude. Students are informed that at any stage of the course, they may be told to leave the course if in the opinion of an instructor they should not continue, and they won't get their fees back!

4. It is confidently expected by the instructors that all students who start the course will complete it, with satisfaction to themselves and honour to the Club. We will freely give instruction, but the joy of learning, the performance and the tenacity of purpose must come from each student's inner self.

FOR MAKING DIVING A REAL PLEASURE

1. FITNESS
2. ATTITUDE
3. JUDGEMENT
4. DISCIPLINE
5. KNOW YOUR CAPABILITIES and LIMITATIONS
6. FOUR GOLDEN RULES

---

1. FITNESS

A diver should always endeavour to maintain himself in the best physical condition that he can possibly attain.

Sport diving does not demand great strength, but in an emergency the diver's endurance, his ability to withstand heavy exertion, may be tested.

Emotional stability and mental attitude are also of prime importance if a diver is called upon to handle an emergency situation.

Learning to dive can be easy and may give a sense of security and complacency to someone who is out of condition.

Before one can undertake a Scuba Course, it is essential to have a medical examination according to Australian Standard 2299-1979. A number of Doctors in Australia are familiar with the form which will be shown to you.

2. ATTITUDE

If you are really interested in safe diving, you will work hard and make a sincere effort to learn. If you do this it will help the instructor to help you. There will be times during your course when you will say, "Why do I have to learn this? I can't see the importance of it." You will not be the first student to have thought that, and naturally you will not be the last.

So give credit to your instructor, and pay attention. It may well be that he knows more about the subject than you do.

3. JUDGEMENT

If you add commonsense and experience together, you usually wind up with good judgement.

The learner naturally does not have the experience but should in all instances exhibit commonsense during the course. If you do foolish things, no one will particularly want to dive with you and you may at some stage place yourself or your buddy in a dangerous situation.

At some stage in your diving career, you will get yourself into a spot. Stay calm and think, then act. The opposite of 'PANIC' is 'COOL'.

In a dangerous situation the urge to panic is strong.

Even the best, most experienced divers still face the urge to panic in different situations. If it were not for their coolness and their judgement they would not be around today. You can do it too if you apply yourself right from the start.

4. DISCIPLINE

Discipline basically means doing the right thing. Obey the safety rules. Do not be tempted into doing something dangerous, whatever your motives or reasons may be.

The choice may be, on occasion, a difficult one. For example, you may have dropped your very expensive underwater camera into a crevasse or hole and you know that your air is low - very low, and that you should return to the surface, and not stay there and try to get it out. Only you can make the right decision.

If the G.C.U.C. had control over students as in the Fighting Services, we could very quickly teach discipline. That is, we could teach discipline from without.

We must and do, however, ask you to develop, if you do not already have it, a much more difficult form of discipline. We ask for self-discipline, with all that entails. We ask for discipline from within.

5. KNOW YOUR CAPABILITIES AND LIMITATIONS

You will find most of these out while training. Learn them well and keep within them. Resist the tendency to show off as the sea is mightier than we are, and will let us die with indifference. Use your 'Grey Cells'.

6. FOUR GOLDEN RULES

To become a highly competant and experienced diver there is much technical knowledge to be learned, practical experience to be gained, and many safety rules to be remembered. However, for the beginner, there are FOUR all important golden rules to be remembered and observed at ALL TIMES.

1. NEVER DIVE ALONE.

This is the basic and fundamental rule of diving and it applies no matter how experienced you become. The Majority of fatal accidents have been due to drowning and all these have occured when the diver had no other diver at hand to help him.

2. AVOID PANIC.

When a person panics he loses all rational control and endangers himself to a much greater extent than the original cause of the panic. To overcome panic a large amount of will-power has to be used and this control will come only from confidence and experience. OBSERVE - ASSESS - DECIDE - ACT.

3. DON'T HOLD YOUR BREATH WHILST ASCENDING ON SCUBA.

This can cause the air inside your lungs to expand and the lung tissues to rupture. A good rule is to BREATH NORMALLY AT ALL TIMES. There is a tendency for beginner divers to hold their breath inadvertantly, particularly if nervous or slightly panicky. It is important to try and overcome this tendency.

Remember......BREATH NORMALLY AT ALL TIMES.

4. MAINTAIN A GOOD PHYSICAL CONDITION

Diving is generally not a highly strenuous sport, but a times will call considerably on reserves of effort and stamina. For this reason, you should not go diving whilst in a poor state of health, whilst overtired, with a hangover, or suffering from any other temporary physical disability.

BASIC EQUIPMENT

Mask. When you purchase a diving mask the following features are important.

1. A comfortable and water-tight fit. This may be checked by placing the mask on your face without the strap over your head and inhale slightly through your nose, the mask should cling to your face for several seconds due to the slight vacuum created.
2. Made of good quality neoprene with safety glass and compensating depressions in the bottom. A purge valve is also sometimes fitted but not strictly necessary and can sometimes be the cause of a leaking mask.
3. A double seal mask is preferable.

Snorkel. A snorkel should not have too great a volume i.e. not too long or too large a diameter so that the first part of your inhaled breath is not stale air. It should have a comfortable rubber mouthpiece firmly attached to the tube. Avoid snorkels with valve devices on the top - they are dangerous.

Fins. Any comfortable fins are acceptable. It is best to have a slightly larger fit so as not to cause cramp. Some divers prefer to wear soft or hard sole boots inside the fin. Smaller fins for novice divers or jet fins for more experienced divers preferred.

Wet Suits. Possible one of the most important purchases you will make, the wet suit not only keeps you warm, but is a natural life preserver as well because it provides positive buoyancy. The reason for this buoyancy can be explained by the theory as laid down by a gentleman named Archimedes. This will be taught on the scuba course.

Because the wet suit has millions of air cells, it can give you a positive buoyance. If you are in trouble, just release your weight belt and it will be virtually impossible for you to drown - unless the head is face down in the water. A wet suit allows you to stay under water longer, comfortably, more relaxed, and it nullifies the danger of cramps, cuts, abrasions, jelly fish stings, etc. As the name implies, a wet suit is not intended to keep a diver dry. The diver is kept warm due to the insulating properties of the foam neoprene - millions of inbuilt air cells reduce conduction to a minimum - thus preventing the body heat from being lost to the water. A thin film of water between the wet suit and the divers body quickly becomes warm, so that the diver fins about in a little bath of warm water. To work efficiently a wet suit should be a close, neat fit, but should not be so tight as to cause chafing or discomfort. A poor fitting suit is an inneff-icient one. Each one of us is different in some physical form and it is virtually impossible to buy a successful suit in 4 or 5 standard sizes. The ideal solution then is to insist on having the suit custom tailored to provide maximum warmth, comfort and efficiency.

There are three main advantages of wearing a wet suit.

1. Buoyancy.
2. Protection.
3. Warmth.

There are many different styles, thicknesses and surfaces to choose from in a wet suit. Jackets can be made with zipps in a coat form, or can be pulled on like a pullover. The hood can be attached or separate. The trousers can be built up to the waist or can be extended to fit like overalls up to the shoulders (Alaskan or Farmer John trousers). The boots can have soft or heavy duty soles and can be zippered for easy entry.

Some features to look for in a wet suit.

1. Flexibility and softness of neoprene whether in shark-skin (dimpled finish) or smooth. Suggest 4mm thickness.
2. Nylon lining - colours too - strengthens the suit and is much easier to get in and out of.
3. Zipps in arms and legs - again for quick pulling on and off.
4. Seams should be sewn for extra long life and rough handling.
5. Detailed tailoring in the knee and shoulders area to eliminate chafing and allow freedom of movement.
6. Jacket flaps must have positive toggles which won't snap open when swimming.
7. Tapes protect seams and provide easy identification and smart appearance.

Gloves. Can be cumbersome if you wish to take photos or need the full dexterity of your hands. But they are ideal for protection against rocks, shell or fish life. The most suitable type of glove is the jersey lined PVC type used for gardening or electrical work. These are strong, robust and offer good protection. It is a good idea for gloves to have long cuffs.

Knives. A very useful and essential part of your equipment. You may never use it on a shark but it will be often handy to clear yourself from kelp or entangled rope. It is also handy to collect shellfish and clean or kill fish. Stainless steel knives have a stainless or synthetic handle which controls corrosion. It is hard to keep an edge on stainless steel and it must be regularly sharpened. A knife should have sufficient weight to get thrust through the water, and be carried in a strong sheath strapped to your leg. A knife is a tool rather than a weapon.

Weight belts and weights.
A most important and necessary aid. Because of the buoyancy of the wet suit we may need up to 18lbs of lead to compensate. This needs to be carried comfortable - contouring the back of the weight helps considerably - and the belt should have a quick release buckle to allow instant removal. Terylene or plastic is most suitable and white or colours set off for identification.

Remember: Always put your lead belt on last - It is the first thing you ditch when in trouble.

Adjustable Buoyancy Life Jackets. ABLJs

1. Reference:- BSAC Diving Manual.
2. Advice from:- Mr William Hunt. 07-2685816,
   18 Phelan Street, Clayfield, QLD 4011.

   2.1 Disinfect with approved disinfectant (Milton or Hibitane - both available at chemists).
   2.2 Try to dry out vest. You will not get the inside dry but get out all the water and disinfectant you can.
   2.3 Inflate the jacket loosely, but enough to keep the jacket material from touching other parts of the vest.
   2.4 Hang the vest in a place where air is fresh and dry.
   2.5 Take the bottle off the jacket and if the aperture looks as if it could collect dust, tape it over.
   2.6 Have the bottle inspected and part filled with air. Store in a dry place.
   2.7 It is also a good idea to purchase some Armorall from a motor car supply shop. Wipe this over the vest with a cloth. It is a rubber preserving compound.
   2.8 There does not seem much point in using french chalks.

2.9 Inspect from time to time.

This information applies only to safety vests which feature compressed air bottles. Care of a CO2 vest differs only slightly in that they should be disinfected periodically, washed and hung to dry after each dive but not treated with any rubber preservers as they are mostly made of a terylene fibre. Always ensure that the CO2 cylinder is in good condition and not corroded as a damaged cylinder could interfere with the function of the vest if called for in an emergency.

Perhaps best of all are the vests which draw the air supply from the Scuba Cylinder.

Spearguns or Hand Spears.

Remember that it is illegal to spear fish when using scuba, so only use your spears on snorkel. Scuba divers say they use eyes more than spears against dangerous marine animals - more of that later.

Other Accessories.

These are so many it is impossible to list them all. From carry bags to submersibles - from torches to high powered boats - all these can be admired and procured as the bank balance permits.

Care & Maintenance Of Your Diving Equipment.

With the fun of the dive over, now the maintenance work begins. All equipment should be carefully washed in fresh water and dried out of the sun. This is very important after salt water immersion, as the salt particles adhere to your equipment and allow corrosion and deterioration to take place. Also, sunlight can quickly perish rubber goods if exposed too long.

Rubber Goods - Most equipment is made of rubber or synthetics, and it must receive your consideration if it is to survive the onslaught of the sun and salt water. Synthetics like neoprene are relatively immune to both of these strong forces, but they should receive care in order to serve you with maximum efficiency. Since the suit is one of the largest of the divers investments, he will want to protect it so that it may protect him. After a days diving completely wash both sides of your suit in fresh water and dry thoroughly, usually the best way to do this is to turn the suit inside out and dry first the inside, perhaps spreading it out over night. Then reverse the suit and dry the outside.

The best way to protect your suit in storage is to hang it on a coat hanger to avoid creasing. This also protects the cellular materials from being flattened by folds. Other rubber goods or synthetics, which need protection are your mask, fins and snorkel. Most swim fins wear well as long as they are washed with fresh water and kept away from heat. This holds true for a good snorkel. The mask should, however, be well talcked, especially the strap. A good simple maintenance practice is to keep a lightweight box liberally filled with talc, for storage of your mask, fins, and snorkel. It is an easy matter after drying these parts to load them in the box, seal and shake. Later when you need them, just blow off the talc and rinse in water before use.

LOG BOOK

The national qualification system in Australia issues a "DIVING LOG BOOK".

Two copies of this log book are issued to each student diver in the Gold Coast Underwater Club.

It is the responsibility of each diver, and student diver, to have proper entries made in his/her log book, to keep it up to date, to have it in a place where a rescuer can find it, and to memorize the editorial included. These matters are dealt with more fully later, Students, while it looks easy to remember what is there, try it and prove to yourself that you can learn it all. The examiner will have very cold eyes when he/she asks you about it, or marks the examination papers.

But there may well be a much more important test, that may come upon you without warning, perhaps in many years, when a life, maybe your own, will depend on what you now learn from your log book.

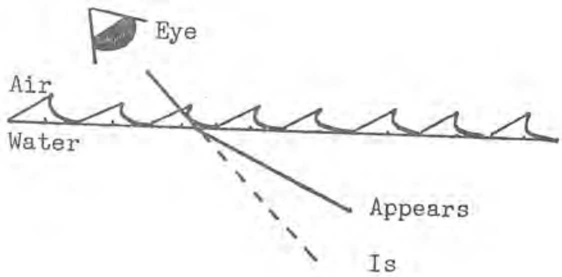
READ, LEARN AND INWARDLY DIGEST,

AND COME BACK OFTEN TO REMEMBER.

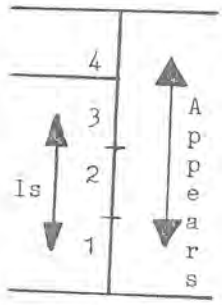
UNDERWATER PHYSICS

1) Light: Light travels slower.

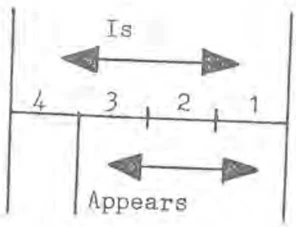
1.1 Angles appear distorted.



1.2 Size: Size appears larger.



Say to the shark "You are not as big as you look and not as close either!" Famous last words!!



Distance appears closer

1.3 Colours:

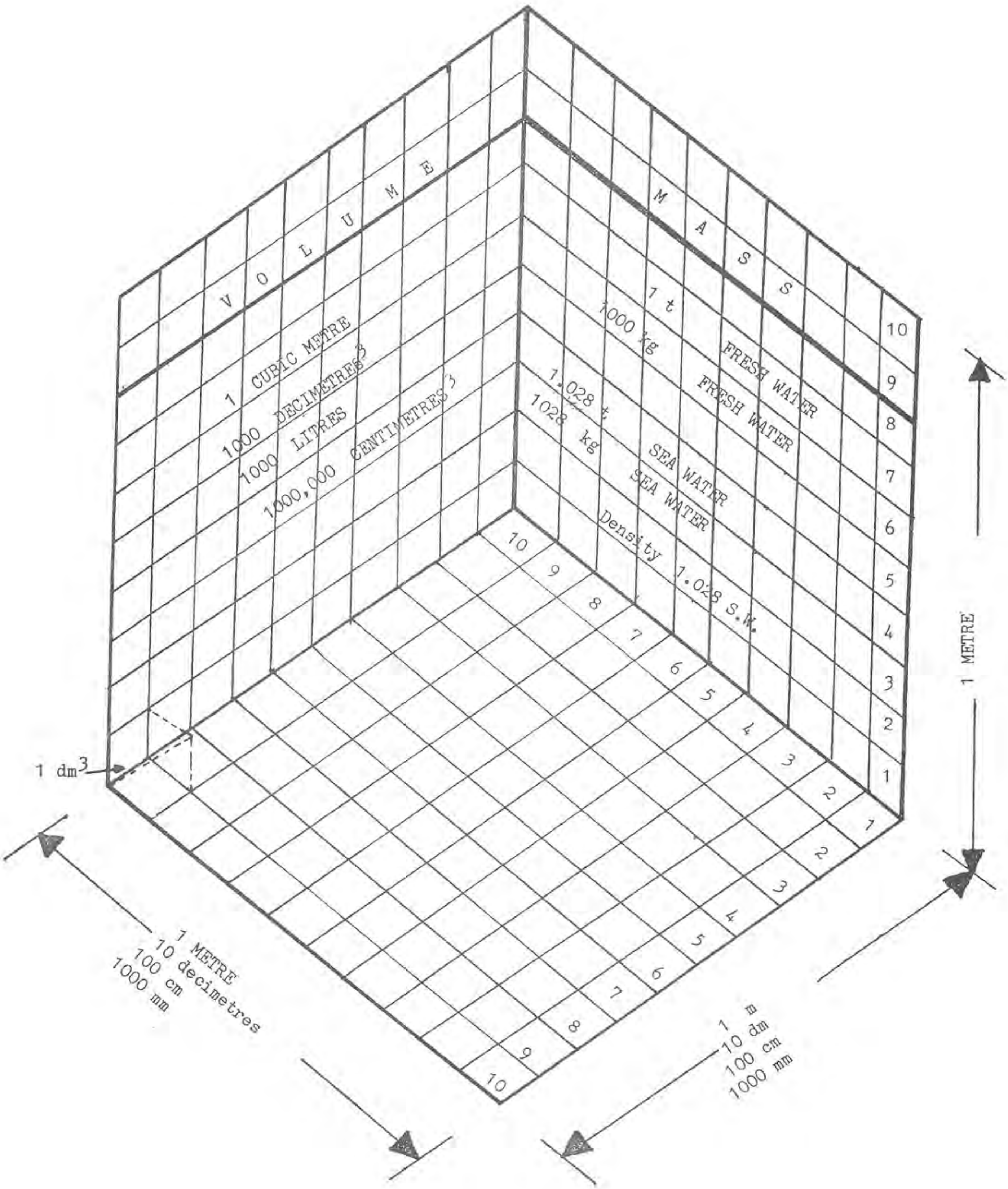
Red, Orange		Absorbed Most
Yellow		Absorbed less.
Green, Blue Violet, Indigo		Absorbed Least

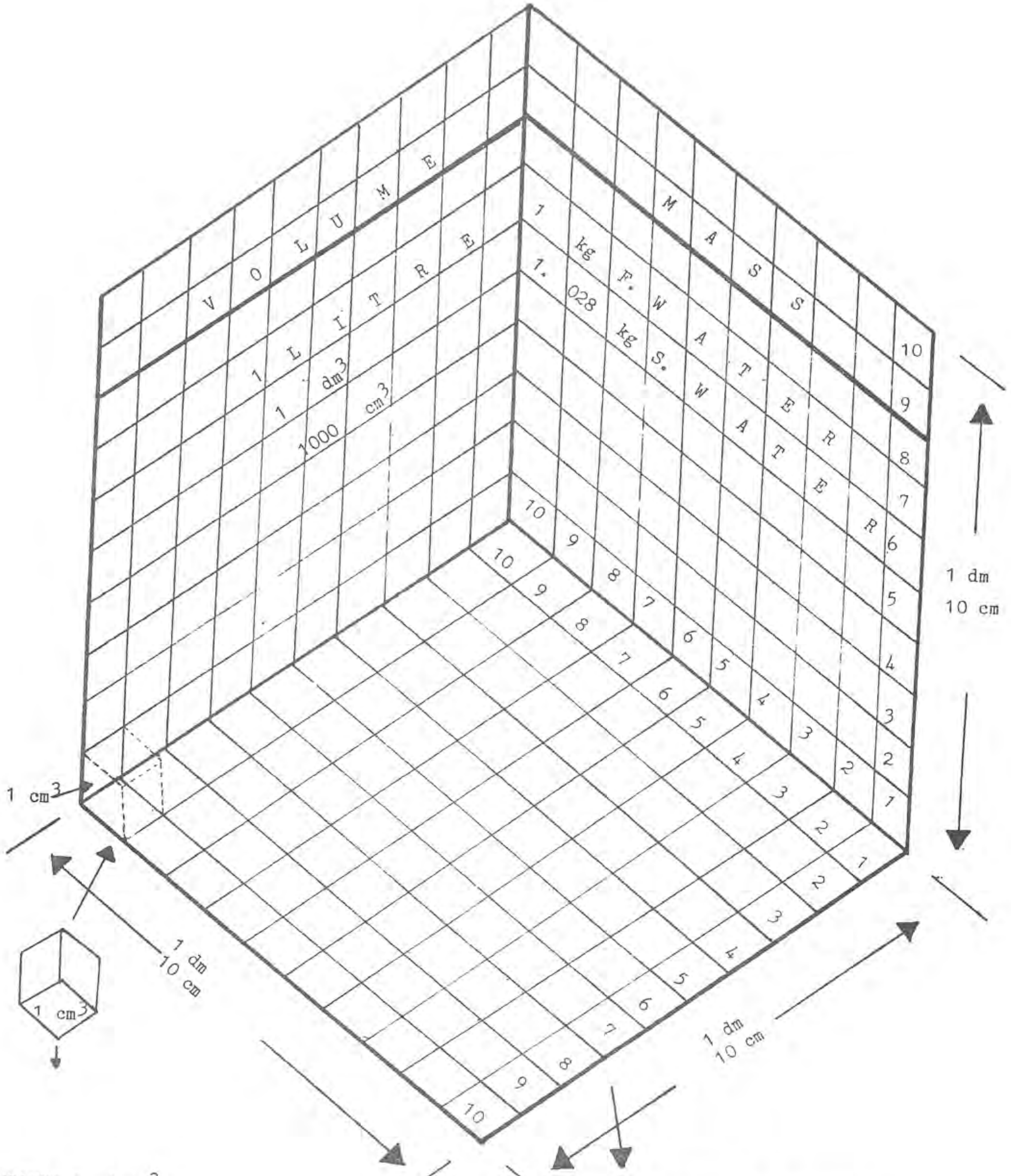
2) Sound: Sound Travels Faster.

Speed of Sound - Air- 332.2m/s - You can judge direction.
" "Underwater 1400 m/s - You <u>cannot</u> judge direction.

METRIC: VOLUME. MASS. DENSITY.

Diagram not to scale





VOLUME : 1 cm^3
CAPACITY: 1 millilitre (ml)
MASS: 1g Fresh Water
1.028g Sea Water
WEIGHT: 1g Fresh Water
1.028g Sea Water

WEIGHT PART WAY TO MOON
Where Gravity Earth = G/Moon
0 kg Fresh Water
0 kg Sea Water

VOLUME ANYWHERE IN UNIVERSE
1dm^3
10^3 cm^3 (1000 cm^3)
CAPACITY: 1 Litre (L)
MASS: ANYWHERE IN UNIVERSE
1 Kg Fresh Water
1.028 kg Sea Water
SG F.W. = 1 SG S.W. = 1.028
(But varies

WEIGHT AT SURFACE PLANET EARTH
UNDER STANDARD CONDITIONS
1 kg Fresh Water
1.028 kg Sea Water

SNORKEL COURSE

MNE MONICS : LEARN UNTIL MEMORY AUTOMATIC

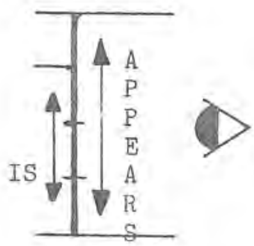
$1\ cm^3$ { 1 gm Mass F.W. / 1.028 gm Mass S.W.

$10\ cm^3$ { 1 kg Mass F.W. / 1.028 gm Mass S.W.

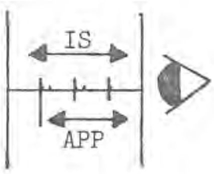
$1\ m^3$ { 1 tonne Mass F.W. / 1.028 t Mass S.W.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

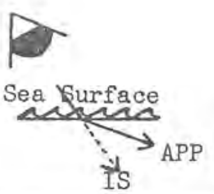
LIGHT SLOWER



Size Appears Larger



Distance Appears Closer



Angles Distorted

SOUND FASTER

Water : 1400 ms
Air : 332.2 ms

1 ATA. 1 ATG. 1 ATM

101.3	KPa
1.013	Bars
14.696	lbs/in^3
1.033	Kg/cm^3
760	mm Hg
760	Torr

$$1\ Pa = \frac{1\ N}{m^2}$$

$$100\ KPa = \frac{100\ KN}{m^2}$$

100 KPa = 1 Bar

1 ATS Pressure

100 Say	Km Air
10.33	m F.W.
10.045	m S.W.

ABC	Airways Breathing Circulation
EAR	Expired Air Resusitation
ECM	External Cardiac Massage
ECP	External Cardiac Pressure

COMPOSITION AIR
ATMOSPHERE AIR

N_2	78%
O_2	21%
CO_2	.03%
OTHER	.97%

EXPIRED AIR

N_2	78%
O_2	16.3%
CO_2	4.04%
OTHER	1.66%

Mental Aritmatic

$lbs/in^2 \times 7 = KPa$ Approx

G L O S S A R Y

UNDERWATER SCIENCE

A B C	Airways Breathing Circulation
ACCELERATION DUE TO GRAVITY	Under standard conditions the temperature is that of melting ice (0^{o}C) and the acceleration due to gravity is 9.80665 m/s^2. Manual of Meteorology Part 1. Dept. of science: Bureau of Meteorology.
AIR EMBOLISM	Embolism - blockage of blood vessel by foreign body. Therefore Air embolism is blockage of blood vessel by a bubble of air.
ALVEOLI SACS	Air Sacs/Air Cells in lungs.
AMBIENT	When used to describe pressure means surrounding pressures. Some text books use it to mean absolute pressure and others to mean gauge pressure. Therefore you are advised to use the words 'absolute pressure' and 'guage pressure' to describe your meaning. If you read 'ambient' in a text book, get the meaning from the text. If you are asked a question which includes the words 'ambient pressure', state in your answer which meaning you apply. Often it is inferred in the question, but still state your meaning in your answer.
AMNESIA	Loss of memory.
ANAESTHESIA	No sensation.
ANOREXIA	Absence of appetite.
ANOXIA	Total lack of oxygen.
ANTITOXIN	Serum or principle serving to neutralize a toxin.
ASPHYXIA	Lack of oxygen (in the body).
ATA	Atmospheres absolute (of pressure).
ATMOSPHERIC PRESSURE	The pressure extended by the atmosphere at the surface of the earth is due to the weight of the air, or pressure of the air. Variations in the atmospheric pressure are measured by means of a barometer.
ATS	Atmospheres of pressure.
BAR	Unit of barometric pressure equivalent to a pressure of 100 kPa.

BALANCE	In relation to scuba regulators means that the moving parts of those equipments, such as pistons, are so designed that the movement of those parts is not materially influenced by H.P. air from tank pressing on one side only.
BARO-TRAUMA	Any damage to tissue due to pressure.
CELL	Unit of structure of living matter; mass of protoplasm bounded by a membrane (cell wall) and containing a nucleus.
COMPENSATE	Blowing: The act of compensating pressures in air spaces, as in ears, by holding nose and blowing air up eustachian tubes to middle ears. SEE: Valsalva Manoeuvre. It can also be done by swallowing.
CUTANEOUS	Of the skin.
DENSITY	The amount of matter in a body. The proportion of Mass to Volume: $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$
EAR	Expired Air Resuscitation
E C M	External Cardiac Massage
EMBOLISM (n)	Blockage of blood vessel by blood clot, air bubble, fat globule or other foreign body.
EMPHYSEMA (swelling)	Abnormal swelling in tissue caused by pressure of air or gas.
EQUALIZE	Waiting: The act of equalizing the pressure of air in the spaces, as in the lungs, ears, sinuses, by waiting at the levels in diving. In general usage, 'equalize' is often used in the meaning shown here for 'compensate'.
EXHAUSTION	Inability to function due to overstimulation of muscles and nerves.
HAEMOGLOBIN	The O2 carrying pigment contained in the red blood cells of vertebrates.
HYPERCAPNIA	Excess Carbon-Dioxide in the blood, causing over-stimulation of the respiratory centre. A result of breath-holding or under-breathing in an attempt to conserve air consumption. Also a result of exertion.
HYPER	Increased. Excess of.

HYPERTENSION	Raised blood pressure.
HYPERTONIC	Having a higher osmotic pressure than a standard, e.g. that of blood, or of the sap of cells which are being tested for their osmotic properties.
HYPO	Decreased.
HYPOTENSION	Lowered blood pressure.
HYPOXIA	Partial lack of oxygen.
INTEGUMENT	Skin, husk, rind or similar.
ISCHAEMIA	Blanching. Local diminution in blood supply due to obstruction of inflow of arterial blood. (Not getting enough O_2 through the blood supply).
LANCINATION PAIN	Acute shooting pain.
LATENT HYPOXIA	Non obvious at depth, but the potential exists for hypoxia to occur on ascent.
LESION (ZHN) n	Damage; injury; especially morbid change in functioning or texture of organs.
MASS	'Quantity of matter in a body' Websters Dictionary. i.e. number of molucules/atoms in a body of matter. Mass, being a material substance, is attracted by gravity to the planet earth. This attraction is measured as weight. Weight and mass are measured in the same unit, i.e. grams, kilograms, pounds etc.
METABOLISM	Means change, change which takes place from the time nutrients enter the body, as air, food and liquids until the final moment of discharge of waste. Includes all reactions where nutrients, oxygen and so on are converted to the use of the body. It includes anabolism and catabolism which does not concern us. The passing of air gases across the alveoli walls to the blood in solution, the carrying of oxygen to the cells, the use by the cells of the O_2, the giving off by the cells of the exhaust gas CO_2, the carrying by the blood of CO_2 where it changes back from solution to gas, and the expiration of CO_2 gas from lungs through the nasal passages - is part of the process of metabolism, in relation to air.
MEDIASTINAL EMPHYSEMA	Result of air having been forced into the tissues about the heart, major blood vessels, and the trachea in the middle of the chest.

NARCOSIS	Operation or effects of narcotics; state of insensibility.
NARCOTIC	Inducing drowsiness, sleep, stupor, or insensibility. Also n. - Narcotic drug used in medicine; any of several such drugs taken habitually by addicts.
NECROSIS	Death of circumscribed piece of tissue, espeically mortification of bones.
NEMATOCYSTS	Cell in Jellyfish, Sea-Anemones etc. Containing coiled thread that can be projected as a sting.
NEURO-MUSCULAR	Pertaining jointly to nerves and muscles as neuro-muscular junction.
NEWTON	Symbol N. The unit of force in the SI system, being the force required to impart, to a mass of one kilogram, acceleration of one metre per second. 1 Newton = 0.2248 pounds force.
OEDEMA	Abnormal accumulatuon of fluid in tissue.
OSMOSIS	Diffusion of a solvent trhough a skin permeable membrane tending to equalize the concentrations on both sides of the membrane. Chambers.
OSTEO	Bones: Skeleton.
PARAESTHESIAE (paraesthezia)	Abnormal sensations.
PARTIAL PRESSURE	Is the pressure exerted by one gas only in a mixture of gases.
PASCAL	Unit of pressure or stress, one Newton per square metre. Named after Pascal, a famous scientist/
PLASMA	Colourless liquid forming chief part of blood, Coagulable solution of salts and proteins in which blood cells (Corpuscles) are suspended.
PNEUMOTHORAX	Result of air having been forced into the area between the lung and the chest wall causing partial callapse of the lung in that region.
PRESSURE	Force on a unit of area. See also Force and Weight.
FORCE	We speak of the force of gravity by which we mean the effect of gravity attracting a mass in a general sense.

FORCE (continued)

When we measure the effect of the attraction of gravity on a unit mass as a block of lead we call it weight.

When we measure the effect of the attraction of gravity on a unit mass of gas or fluid, like free air or water, we are really measuring the weight of the air or water. However as the air or water is free to move about, and can wrap itself around things, we call this effect of the force of gravity "Pressure".

Scientists make a distinction between force and pressure. They say pressure is force on a unit of area, when speaking of gases and fluids.

When we pump or compress air into a container like a motor car tyre, or a scuba tank, we certainly increase the weight, as anyone who lifts an empty and then an air filled scuba tank knows. But we have another force and pressure there. The molecules of air do not like being crushed together any more than people like being crushed together say in a lift. (Except the boys and girls). When the lift doors open the crushed people force or press their way out and apart. The air molecules in the tyre or scuba tank do the same, and it is this pressing apart of the crushed air molecules which we measure on guages and speak of a pressure of so many pounds per square inch, or kilopascals, or bars, or atmospheres of pressure, etc.

RESPIRATORY TRACT

Nasal Cavities
Mouth
Pharynx (pipe) Back of throat: food and air passages
Larynx (pipe) Throat: air passage only: vocal cords
Trachea (pipe) "Deep Throat": Continuation of air passage.
Bronchi (pipes) Two of: From trachea
Bronchioles (pipes) Divisions of bronchi connection to air sacs

SERUM — Watery fluid remaining from the fluids of the body especially blood, after coagulation.

SEPTA — Partitions

SIGNS — What you show

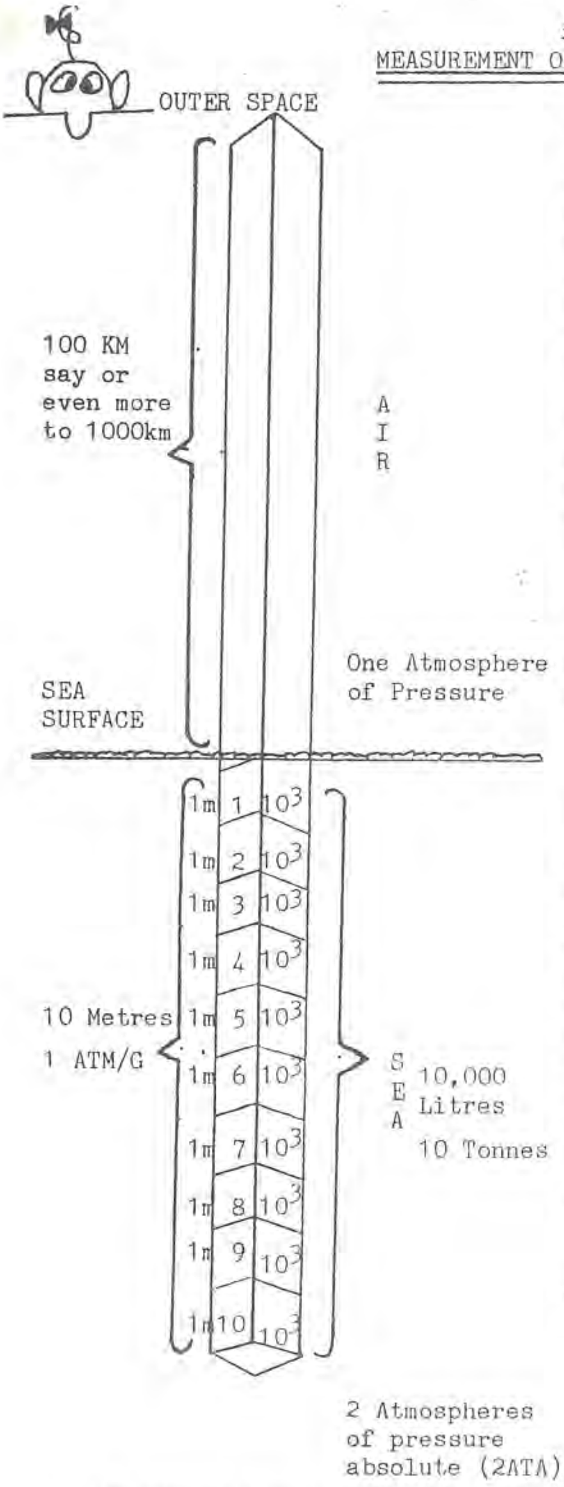
SINUSES — Hallow spaces within the skull bones, lined with mucus membrane, continuous with nasal passages. See text for names of sinuses.

SQUEEZE — The term squeeze, or Barotrauma, of descent or ascent refers to any injury that occurs as a result of the diver's inability to equalise pressure between a closed air space and the outside water pressure.

STASIS	Slowing of circulation of any body fluids. In general usage we speak of stasis, or slowing of the blood in circulation.
SURGICAL EMPHYSEMA	Presence of gas in tissues. Results from entry of gas into the tissues where the integument, skin or mucosa is broken and in contact with a gas space. It may also be called Mediastinal or subcutaneous emphysema, etc, depending on where the gas has tracked. The air/gas can come from the alveoli, sinuses, or air passages generally.
SUBCUTANEOUS EMPHYSEMA	The presence of air in the tissues under the skin.
SYMPTOMS	What you feel inside.
TACHYCARDIA (ki) n	Abnormal rapid action of the heart
TISSUE	Substance of animal or plant body, especially of a particular part; organised mass of cells of similar kind, as muscular tissue, nervous tissue, etc.
TORR	Unit of pressure = 1 mm Mercury. Named after Torricelli, the scientist who discovered how to measure the weight of air - (called pressure).
TOXIN	Poison
TYMPANIC MEMBRANE	Ear drum
WEIGHT	The measure of Gravity attracting a mass. See also pressure and force.
VALSALVA MANOEUVRE	Pinching nostrils and trying to exhale through nose.
SPECIFIC GRAVITY	Ratio of weight of any substance to weight of an equal volume, at same temperature, of another substance. Usually fresh water for solids and liquids.

ATMOSPHERIC PRESSURE

MEASUREMENT OF PRESSURE OF AIR AND WATER



AIR

The air that surrounds the planet Earth extends from the surface of the planet upwards for, say, 100 km, through out there it is as rare or thin as a vacuum is on earth. This envelope of air around the Earth is called the atmosphere.

This air has weight and presses down towards the centre of the earth, like all other substances, because of gravity.

If we think of column of air one metre square, and extneding to the top of the atmosphere, we will find that the air in that column presses down on that square metre on the surface of the earth. We call this pressure on that square metre one atmosphere of pressure. For minor measure, see hereunder.
In thinking of pressure on a diver, always imagine yourself to be in a spacecraft 100 km altitude, looking down through the two oceans of Air and Water.

WATER

A column of water one metre square and ten metres high presses down with approximately the same pressure - that is, one atmosphere. (In feet, 33ft approx) For minor variations, see hereunder.
The measure or tool by which divers calculate air and water pressure is one atmosphere, and multiples of one atmosphere. We speak of pressures of so many atmospheres (x number of ATs)
Other measure of pressures are in use, but for calculations, always convert back to the pressures as shown hereunder.

$$1 \frac{N}{m^2} = 1 \text{ Pa}$$

$$\frac{100 \text{ KN}}{m^2} = 100 \text{ KPa} = 1 \text{ BAR}$$

ATMOSPHERIC PRESSURES : BASICS

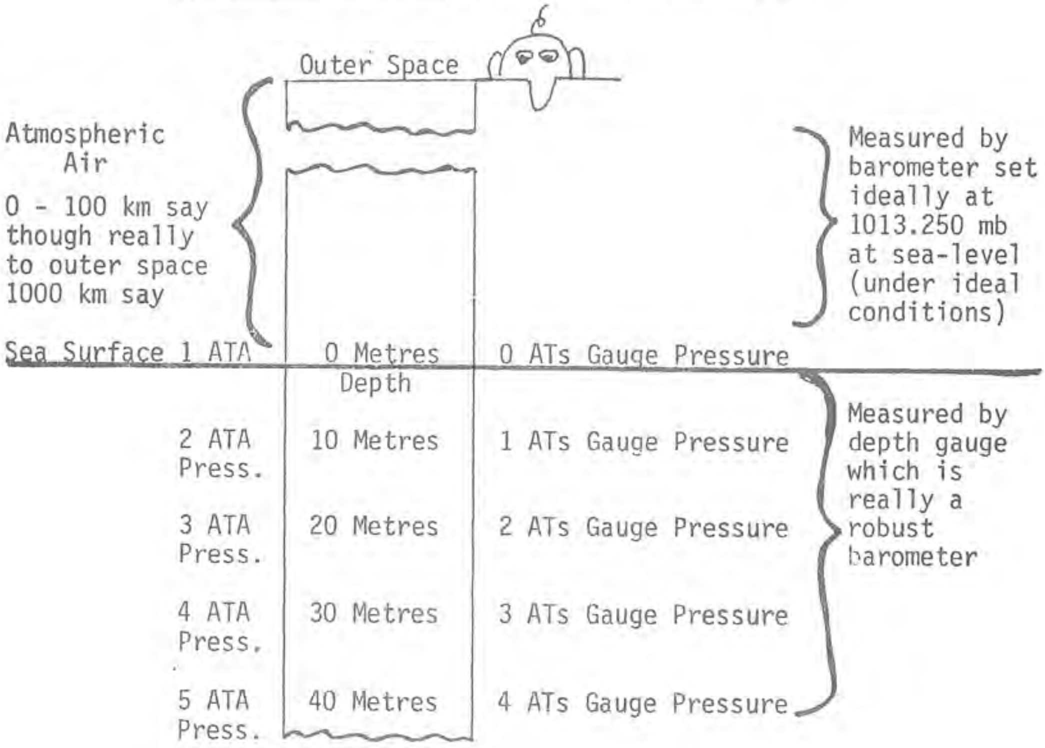
There are two great oceans surrounding the planet earth. The outer ocean if air - we humans and land animals live on the bottom of this ocean. The air has weight, because of the pull of gravity. Theweight of air varies a little depending on how much air is above the place of measurement. A standard weight of air is assumed. As air is a gas or fluid, we call the " weight" of air a force or pressure. Its standard weight is 14.696 lbs per sq. inch, 1 ATS., 1.033 kgm cm^2, 101.3 KPa or $\frac{100 \text{ K Newtons}}{m^2}$, 1 Bar, 760 mm Hg. 1 Torr.

Divers mostly use the measure of one atmosphere, 101.3 KPa

The second ocean below the ocean of air is the sea. The water in the sea is also acted upon by gravity, forcing it towards the centre of the earth. We measure the pressure of this water in the same units we use to measure air pressure (see above). We are used to the pressure of the air from birth, but when we dive down into the sea and increase this pressure on our bodies, sometimes several times over, all sorts of things can happen, and we can quickly and easily get ourselves killed. How to live, work, and play in these pressures is known, and we will look into these methods. Basically we can go into areas of greater pressure if we take air into our lungs at a pressure equal to the pressure of the water around us.

MEASURING PRESSURES ON A DIVER

DIAGRAM SHOWING ABSOLUTE AND GAUGE PRESSURES



ATA = Absolute Pressure

As the pressure acts in all directions, the diver's body is pressed in from all directions as he descends. Thus his body is compressed a little and his wet suit certainly is compressed, and he and his suit occupy a smaller volume, increasingly smaller as he descends. He does not have to lift up the weight of the water like Atlas bearing the weight of the sky.

TABLES SHOWING DIFFERENT DEPTHS AND PRESSURES

RANGE OF DEPTHS AND PRESSURES

DEPTHS IN METRES			ATMO-SPHERES PRESSURE ABSOLUTE	MEASURES OF PRESSURE			
SEA WATER	FRESH WATER	ROUND FIGURES		kPa	Kg wt cm^2	mm Hg	lbs in^2
Metres	Metres	Metres	ATA				
0	0	0	1	101.3	1.033	760	14.696
10.045	10.33	10	2	202.6	2.066	1520	29.392
20.090	20.66	20	3	303.9	3.099	2280	44.088
30.135	30.99	30	4	405.2	4.132	3040	58.784
40.180	41.32	40	5	506.5	5.165	3800	73.480

It is necessary to learn and commit to memory the first line of figures for use in your diving career and for examination purposes.
As a suggestion, try the folded paper mnemonic.
If you remember the first line, you can convert from one measure of pressure to another by going back to 1 ATs. e.g. suppose you were asked what is the equivalent in kPa of 2280 mm Hg - Solve the problem thus:

2280 mmHg ÷ 760 = 3 ATs
101.3 kPa = 1 AT
101.3 x 3 = 303.9 = 3 ATs

∴ 2280 mm Hg = 303.9 kPa

ATMOSPHERE OF PRESSURE AND BARS OF PRESSURE

1 ATM = 101.3 KPa

1 BAR = 100 KPa

For Approximations and mental working Use Bars then 1 ATM = 1 BAR (approx)

OUTER SPACE

100 km (approx)

Remember that a spaceman looks down through two oceans. Air & Water. Hence absolute pressure.

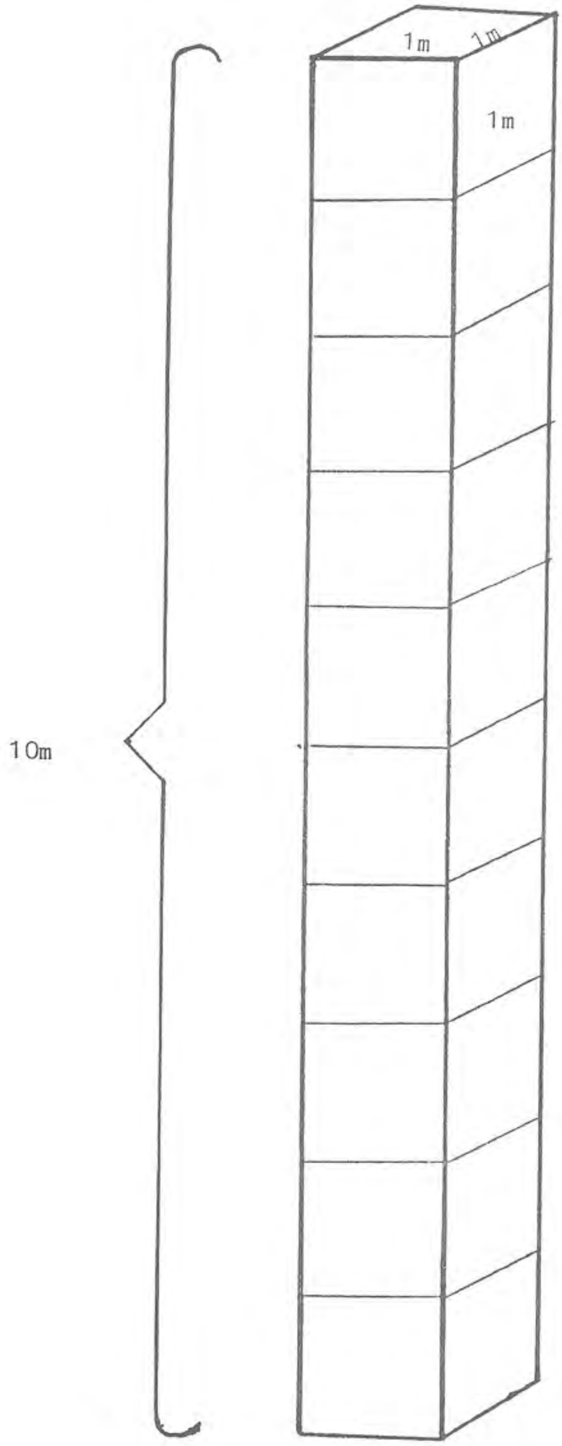
			ATS		BARS		
		Absolute	Gauge	Gauge	Gauge	Guage	Absolute
0 ft	0m	1 ATA	0 ATG	0 KPa	0 KPa	0 Bars^G	1 BAR ^{A}
33 ft	10m	2 ATA	1 ATG	101.3 KPa	100 KPa	1 BARS^G	1 BARS ^{A}
66ft	20m	3 ATA	2 ATG	202.6 KPa	200 KPa	2 BARS^G	3 BARS^A
99 ft	30m	4 ATA	3 ATG	303.9 KPa	300 KPa	3 BARS^G	4 BARS^G
132 ft	40m	4 ATA	4 ATG	405.2 KPa	400 KPa	4 BARS^G	5 BARS^G

SPORT DIVING

For all practical sport diving purposes we approximate and say:

10m of Fresh Water = 1 ATS = 1 BAR

10m of Sea Water = 1 ATS = 1 BAR



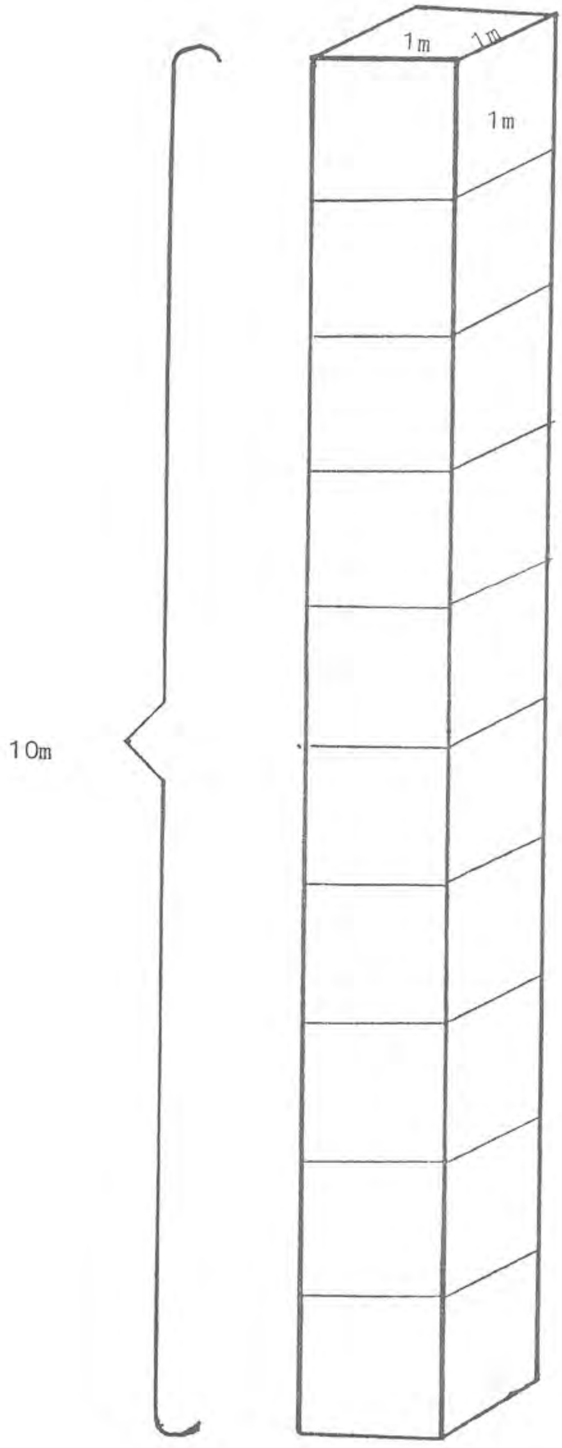
1 ATS
1 BAR PRACTICAL SPORT DIVING

SPORT DIVING

For all practical sport diving purposes we approximate and say:

10m of Fresh Water = 1 ATS = 1 BAR

10m of Sea Water = 1 ATS = 1 BAR



1 ATS
1 BAR PRACTICAL SPORT DIVING

TABLE OF ATMOSPHERIC PRESSURES

Approx Feet	Approx m	ATG	ATA	$\frac{KN}{m^2}$	Approx Bars	$\frac{kg\ wt}{cm^2}$	TORRS or m mHg	$\frac{lbs\ wt}{inch^2}$	Sea Water	Fresh Water
				ABSOLUTE PRESSURES					m	m
0	0	0	1	101.3	Bars kPa 1 = 100	1.033	760	14.696	0	0
33 66 99	10 20 30	1 2 3	2 3 4	202.6 303.9 405.2	2 = 200 3 = 300 4 = 400	2.066 3.099 4.132	1 520 2 280 3 040	29.392 44.088 58.784	10.045 20.090 30.135	10.33 20.66 30.99
132 165 198	40 50 60	4 5 6	5 6 7	506.5 607.8 709.1	5 = 500 6 = 600 7 = 700	5.165 6.198 7.231	3 800 4 560 5 320	73.480 88.176 102.872	40.180 50.225 60.270	41.32 51.65 61.98
					FOR MANUAL CALCULATIONS. APPROX.					
				STEEL TANKS: GUAGE PRESSURES WP						
4,950	1,500	150	151	15,195	150 Bars 15,000 kPa	154	114,000	2,204		
5,049	1,530	153	154	15,489	153 15,300	158	116,280	2,248 (2 250)		
			ALUMINIUM ALLOY TANKS GUAGE PRESSURES WP							
6,600	2,000	200	201	20,260	200 20,000	206	152,000	2,939		
6,732	2,040	204	205	20,665	204 20,400	210	155,040	2,997 (3 000)		

GREATER ACCURACY
1.013 Bars = 1 ATM

MEMO: Kilo ponds kP are much the same value as kg (wt)/cm^2 in large numbers.

TYPES OF PRESSURE

1. ATMOSPHERIC PRESSURES: Imagine a column of air one metre square, extending to the edge of space. If this column could be weighed at sea level, it would weigh just 1 ATS or 101.3 Kpa. This weight is known as atmospheric pressure or the pressure of one atmosphere.

2. WATER PRESSURE: (Hydrostatic Pressure)

   Water is practically incompressible, so its density remains virtually the same regardless of the depth of pressure, applied to it. The Hydrostatic Pressure at a given depth will be the same and act equally in all directions at that depth. Also the pressure exerted by water is directly proportional to its depth e.g. The guage pressure exerted at a depth of 20 metres, is twice the gauge pressure of that at 10 metres.

3. GAUGE PRESSURE: Gauge pressure is the difference in pressure between the pressure being measured and the surrounding atmospheric pressure. When we say that the gauge pressure in a cylinder is 150 ATS, we mean that the pressure is 150 ATS above atmospheric pressure. Thus when the cylinder is empty, the gauge reads Zero. There is, however, still actually the atmospheric pressure (1 ATS) in the cylinder. Think of the spaceman 100 km up. If this were not so, there would be a vacuum inside the cylinder.

   NOTE: Cylinder pressures appear in different international units depending on the country of manufacture. e.g.
   U.S.A = p.si. (approximately 2,250p.s.s.)
   EUROPE = ATS (approximately 150 ATS) or Mpa (approximately 15-20 Mpa)
   AUSTRALIA = Kg. Wt/cm^2 or Mpa.
   U.K. = BAR or ATS

4. ABSOLUTE PRESSURE: This is the true or total pressure being exerted. It is the gauge pressure plus 1 atmosphere. In dealing with any calculations or problems concerning pressure, it is essential that we talk in terms of absolute pressure.

5. PARTIAL PRESSURE: The law governing partial pressure is Dalton's law which states..."When total pressure exerted by a mixture of gases is the sum of the pressures that would be exerted by each of the gases if it alone were present and occupied the total volume."

   If a container is filled with pure (100%) oxygen at normal atmospheric pressure, then the partial pressure in that container would be 1 ATS. Then partial pressure of oxygen in this case would be equal to the total pressure because no other gas molecules were present. If an equal number of nitrogen molecules were then introduced into the container without letting any oxygen excape, and without changing the temperature, the total (absolute) pressure would become two atmospheres. The number of oxygen molecules in the container is still the same so the partial pressure of oxygen is the same... one atmosphere. This pressure now would only be half the total, because the partial pressure of nitrogen would also be at one atmosphere.

6. AMBIENT PRESSURE: ATA pressure of surrounding water but see glossary.

BOYLE'S LAW

DEFINITION: If the temperature is kept constant, the volume of the gas will vary inversely as the absolute pressure, while the density will vary directly as the absolute pressure.

FORMULA: P1 x V1 = P2 x V2
P = pressure in atmospheres absolute
V = volume

We use air and water. Carefully consider that air is compressible and water is not. On this fact is based the Gas Laws of diving.

With Boyle's Law we consider the smaller volumes to which a given quantity of air is compressed as pressure is increased around that air.

For example let us assume that you are in a boat, you have a toy balloon and that you blow air into it until it is of six litres volume, surrounding air pressure is 1 ATA. Then suppose you take that balloon on a dive to 10 m (33 feet) where the surrounding pressure is 2 ATA. You will find that because the surrounding pressure doubles, your balloon compresses to half volume, three litres, even though no air escapes. The volume decreases and the density of the air increases, all Re. Boyle's Law.

With Boyle's Law we also consider the larger volumes to which a given quantity of air expands as the surrounding pressure is decreased.

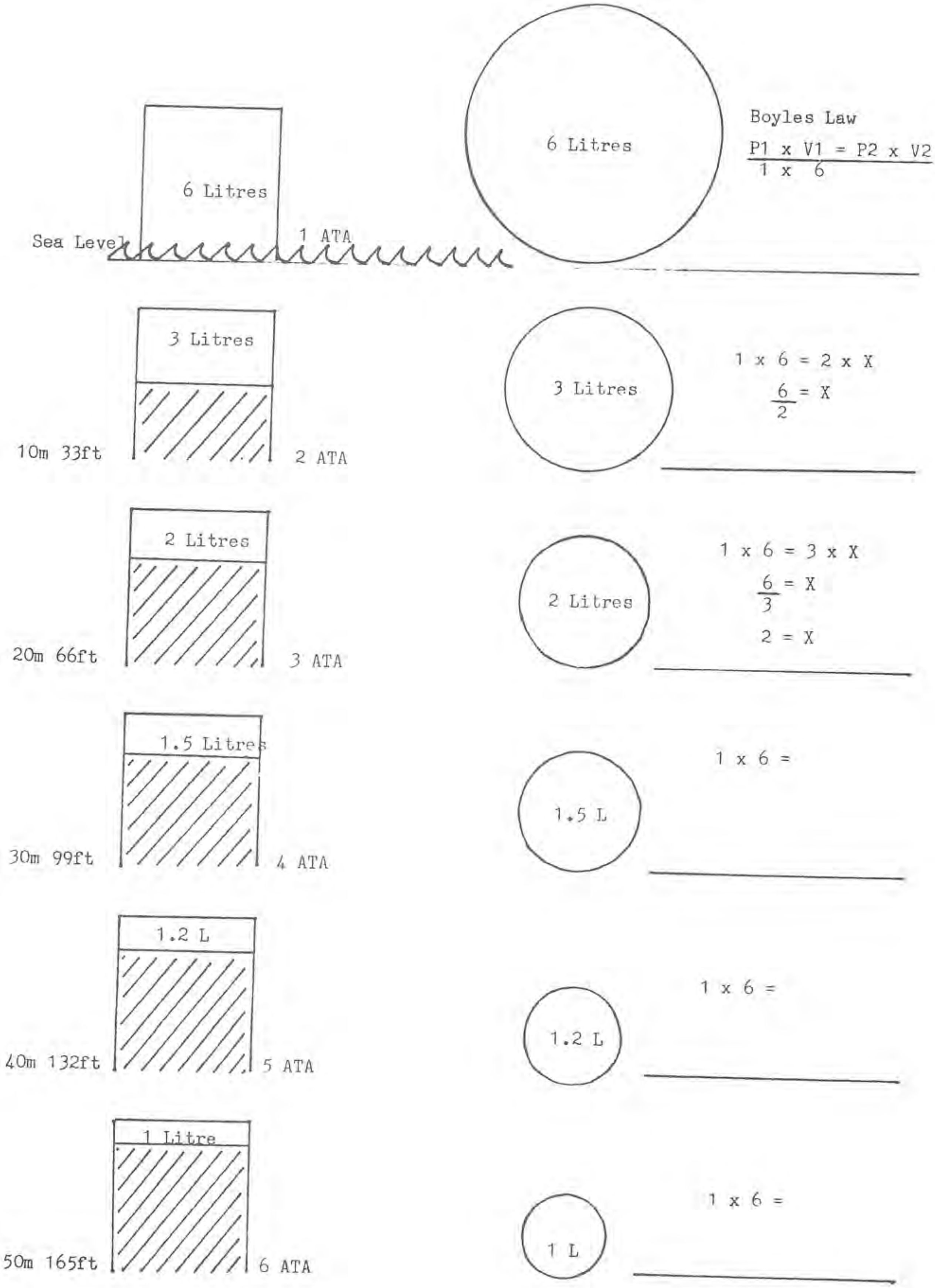
For example when, in the dive we considered, you rise to the surface of the sea. Your balloon expands as the pressure decreases, until at the surface, 1 ATA, the balloon would again assume the volume of six litres. Your lungs do this in a breath-hold dive.

With Boyle's Law we also consider the amounts of air, shall we say the volumes or masses of air, we can pump into a container, for example we can pump a lot of air into a motor car tyre, and a lot more into a scuba cylinder, because air is compressible.

We also consider how much air we can get out of the scuba cylinder to breath at various depths. A few examples will clarify these matters.

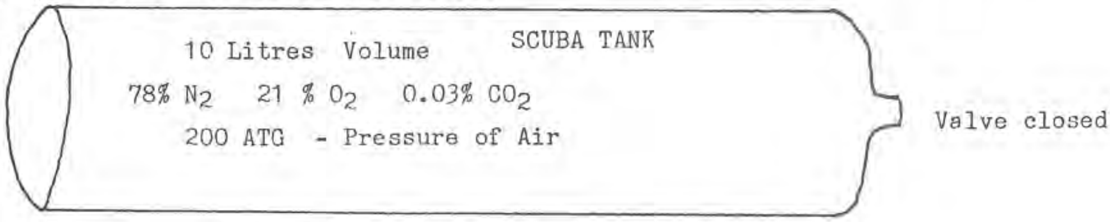
BOYLES LAW

These diagrams show how volume of snorkel divers lungs compress and expand at various depths.



BOYLES LAW   P1 x V1 = P2 x V2

The below is suitable to show the principle and is also suitable for Sprt Divers aritmatic. To be precise we should work in ATA and account for the 10 litres of air left in the cylinder . More about that later.



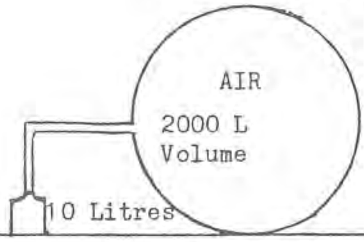
Q1; If the air is released into a balloon at the surface
What will be the volume of the balloon?

P1 x V1 = P2 x V2

200 x 10 L = 1 x X

ANSWER: 2000L = X

(30) 2000
66 min



0 m 0 ft 1 ATA SEA LEVEL

Q2: As above At 10 Metres?

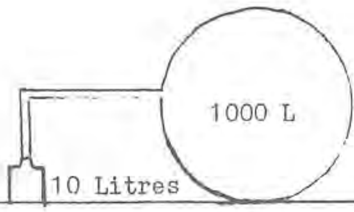
P1 x V1 = P2 x V2

200 x 10L = 2 x X

2000 ÷ 2 = X

ANSWER: 1000 L" = X

(30) 1000
33 min



10m 33ft 2 ATA

Q3 : As above At 20 metres?

P1 x V1 = P2 x V2

200 x 10L = 3 x X

2000 ÷ 3 = X

ANSWER : 666L = X

(30) 666
22 min

20m 66ft 3ATA

Q4: As above At 30 metres?

P1 x V1 = P2 x V2

200 x 10L = 4 x X

2000 ÷ 4 = X

ANSWER: 500 L = X

(30) 500
16 min

30m 99ft 4 ATA

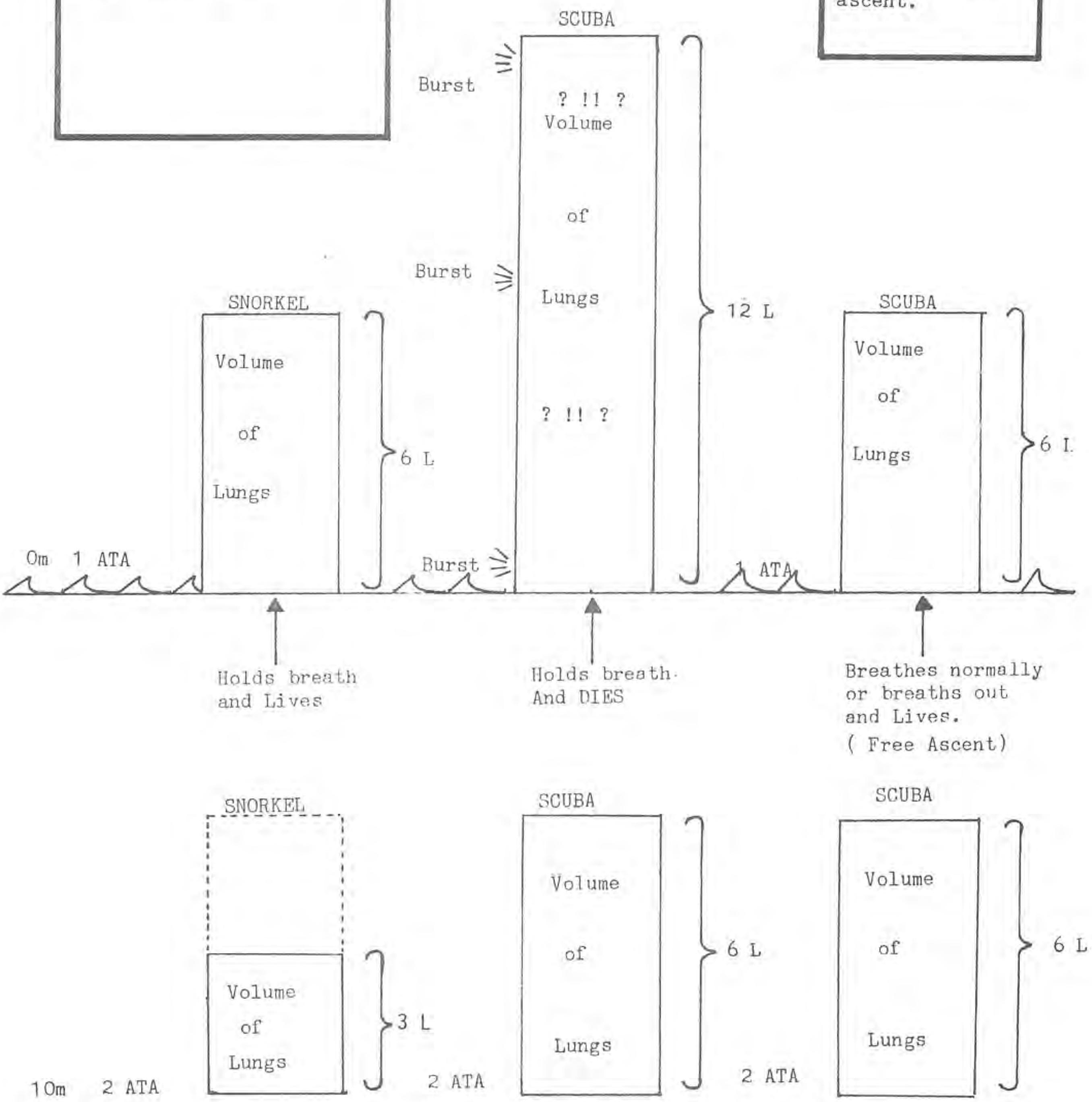
BOYLES LAW P1 x V1 = P2 x V2

HOW TO KILL YOURSELF ON SCUBA:: Hold breath on way up.

On way Up :			
Snorkel	: No need to breathe out.		
Scuba	: Air in tank	: Breathe normally	: And Live
		: Hold breath	: And DIE
	: Empty tank	: Breathe out	: And Live
		: Hold Breath	: And DIE

In swimming pool on scuba.
Breathe out on way up
if leave scuba
below. And Live.
Hold breath : AND DIE

You would be a
fool to empty
your tank below
and do the
dangerous free
ascent.



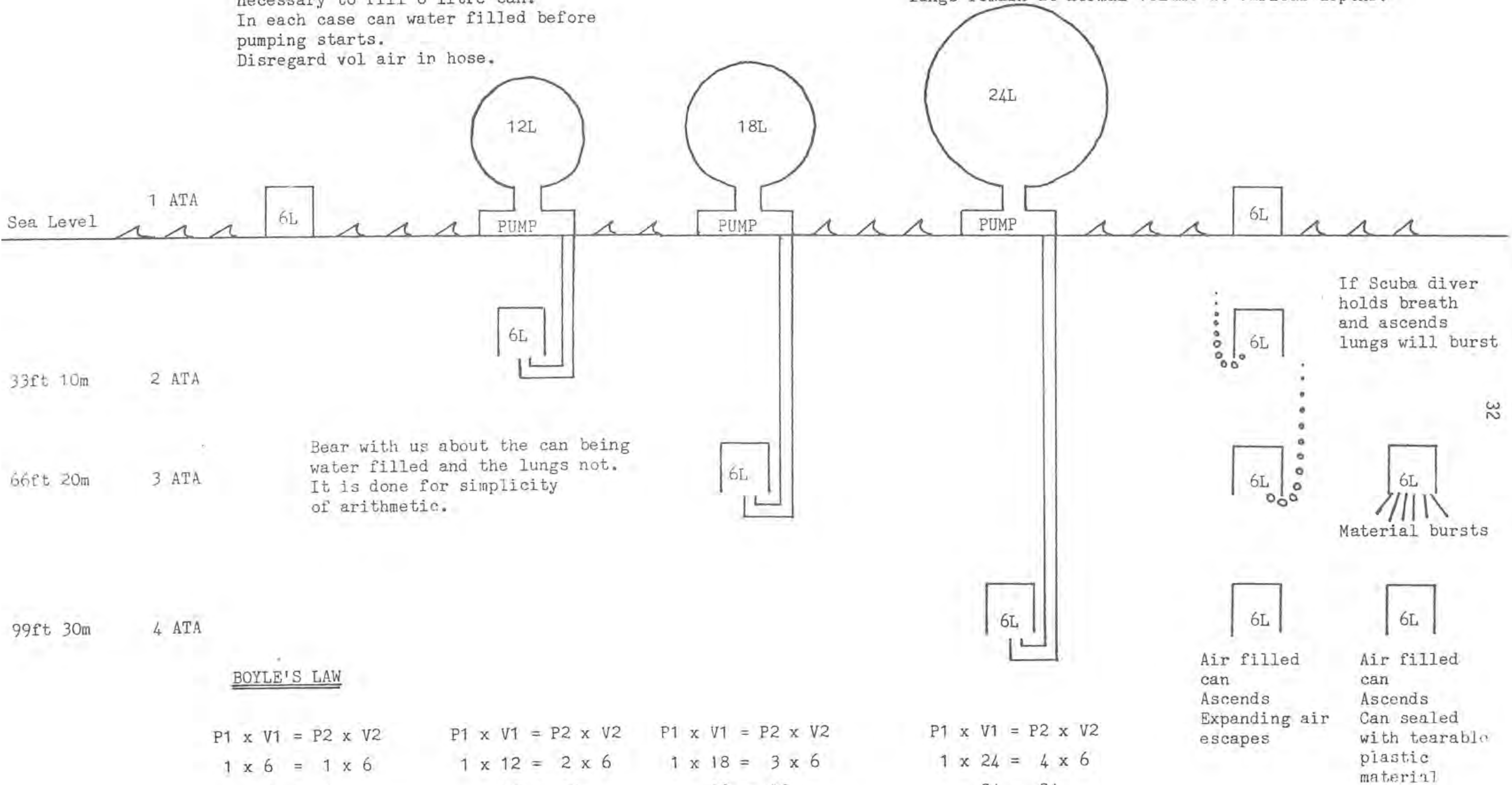
BOYLES LAW

P1 x V1 = P2 x V2	P1 x V1 = P2 x V2
2 x 3 = 1 x 6	2 x 6 = 1 x 12
6 = 6	12 = 12

BOYLE'S LAW

Diagrams showing volume of surface air necessary to fill 6 litre can.
In each case can water filled before pumping starts.
Disregard vol air in hose.

These diagrams show how volume of Scuba Divers lungs remain at normal volume at various depths.



Bear with us about the can being water filled and the lungs not. It is done for simplicity of arithmetic.

BOYLE'S LAW

$P1 \times V1 = P2 \times V2$
$1 \times 6 = 1 \times 6$
$6 = 6$

$P1 \times V1 = P2 \times V2$
$1 \times 12 = 2 \times 6$
$12 = 12$

$P1 \times V1 = P2 \times V2$
$1 \times 18 = 3 \times 6$
$18 = 18$

$P1 \times V1 = P2 \times V2$
$1 \times 24 = 4 \times 6$
$24 = 24$

BOYLES LAW

TO SUM UP THE USES OF BOYLE'S LAW IN DIVING

1. ON A BREATH-HOLD, SNORKEL, DIVE our lungs and the air in them decrease in volume, and increase in density as we descent in the water and vice versa as we ascend.

   This has three effects one "Good" and two "Bad" for the Snorkel Diver:

   1.1 Good: The air in the lungs is compressed in descent so that the pressure of it pressing outwards equals the pressure of the surrounding water pressing inwards on the body. Thus the body is not harmed by the varying pressures bearing in from the surrounding ocean.

   1.2 Bad: When the air is compressed in the lungs on a snorkel dive we can use up so much oxygen that there is not enough oxygen left to enable us to get back to the surface if we have hyperventilated. More about that in Dalton's law of partial pressure, and later in the course.

   1.3 Bad: If the diver goes deeply enough to compress the lungs beyond the residual volume the lungs will be crushed and the diver will die. You will learn about residual volume of the lungs in the Anatomy Section of the course.

   Do not be concerned about crushed lungs, you will not be able to dive that deep on a breath-hold, or snorkel, dive at least for a long time to come. It does not apply on a scuba dive as then the lungs are pumped up to the normal surface volume by the scuba.

2. ON A SCUBA DIVE:

   2.1 On a scuba dive where your lungs are pumped up to normal surface volume by the scuba at any depth. The lungs contain a much greater amount or mass of air than at the surface. This air is compressed and its outward pressure equals the inward pressure of the surrounding sea. Thus again the body can withstand the great pressures cancelling each other.

   However there is a real danger here. If the diver ascends holding the breath, the air in the lungs expands and bursts the lungs-Baro Trauma of ascent. The answer is to keep breathing from the scuba, or to whistle and let the expanding air out, (Free Ascent). Do not practise free ascent, it can be dangerous.

   2.2 With Boyle's law we can also ascertain how much air, shall we say what surface volume or mass of air, we pump or compress into a scuba cylinder and what air we can get out of the cylinder again to breathe at various depths. We can calculate the time we can breathe from a cylinder.

3. Boyle's law leads to another of the diving laws, remember from the definition of Boyle's law, "If The Temperature Remains Constant". However in practice temperature varies.

This variation is taken into account in:

THE GENERAL GAS LAW

$$\frac{P1 \times V1}{T1} = \frac{P2 \times V2}{T2}$$

The temperatures are of absolute value.

The general gas law is included here so that students may know of it, but it is of concern to the sport diver.

There is another law "Charle's Law" where variations of temperature are shown to affect scuba and are taken into account as part of this course.

More of that later under "Charle's Law".

DALTON'S LAW

Definition:- The Total Pressure exerted by a mixture of gases, is the sum of the pressures that would be exerted by each gas if it alone were present and occupied the total volume.

Formula:- PP = TP x %

As far as we sport divers are concerned, Dalton's Law is used to explain the partial pressures of the gas we call air.

The Partial Pressures of the various components of air in the lungs at the following depths are:-

			Nitrogen N2 ATA	Oxygen O2 ATA	Carbon Dioxide CO2 ATA	Other ATA
0ft	0m	1 ATA	0.78	0.21	0.0003	0.0097
33ft	10m	2 ATA	1.56	0.42	0.0006	0.0194
66ft	20m	3 ATA	2.34	0.63	0.0009	0.0291
99ft	30m	4 ATA	3.12	0.84	0.0012	0.0388
132ft	40m	5 ATA	3.90	1.05	0.0015	0.0485
165ft	50m	6 ATA	4.68	1.26	0.0018	0.0582

For those students not used to working in decimals, do not be concerned too much. The table is just included for interest. But try to understand the columns for Nitrogen and Oxygen.

Most folk know that say - 78% = $\frac{78}{100}$ = 0.78

The Table gets interesting when we consider the various parts separately:-

Nitrogen N2:- We know from practice that at a depth of, more or less than, 30m (99ft) we can expect to start to get intoxicated on Nitrogen (Nitrogen Narcosis, "Nit Narcs", Rapture of the Deeps), thus "Nit Narcs" begins at A PP of N2 of approx. 4 ATA

Oxygen O2:- 0m = 1 ATA = PP O2 = 21% or say 1/5 of one ATA.
Dealing in pounds weight per square inch.

1 ATA = 14.696 lbs/in^2 or 14.7 lbs/in^2 of air

For mental arithmetic let us say

1 ATA = 15lbs/in^2 = of air

Then partial pressure O2 = 15 ÷ 5 = 3lbs/in^2 O2 at the surface (approx).

Thus at the surface the PP O2 across the alveoli wall in lungs is 3lbs/in^2 approximately (less of course any remaining O2 in the blood stream).

More precisely $\frac{14.696}{1} \times \frac{21}{100} = 3.086 lbs/in^2$ (21.27 kPa)

Students now redo this in kPa.

And show your workings to your instructor.

Navy divers have a custom of not diving below 8m on pure O_2, this is partial pressure of 1.8 ATA of O_2, because beyond that, they expect oxygen poisoning. On our table re Air, we do not approach a PP O_2 of 1.8 ATA, but we would find it at 9 ATA = 80m = 264ft. Sport divers do not go that deep, so we do not face oxygen poisoning in sport diving on air. Sport divers should never use pure O_2, or never enrich the air in their cylinders with O_2!!! Don't be mad!!! You may die if you do!!!

We do use pure O_2 when treating "bends", of which more later. But we do not then descend below 9m.

There is one danger about PP O_2. However, that is very real, for the snorkel diver, and we will consider that after the next paragraph on Carbon Dioxide CO_2.

Carbon Dioxide CO_2

This is such a tiny component of air that at first glance it does not seem to matter. It can be a life saver or a killer for the sport diver when on a breath-hold (snorkel dive).

We know that CO_2 is 0.03% of free air at the surface. We also know from our section on anatomy that CO_2 is the exhaust gas from the cells of the body and in expired air it builds up to over 4% of the expired air. If something goes wrong in say a rebreathing apparatus and a diver keeps on rebreathing expired air, the body will go unconscious. WHEN the PP CO_2 = 10% approximately. Girls try swapping breaths with the boys and vice versa. But be prudent - don't let them send you unconscious! This effect is called "CO_2 Build-Up" of which more later.

It is the CO_2 which wills us to re-breath - not the lack of O_2. Try holding your breath until at break point you find you breathe out, because the CO_2 has activated the body to expel the CO_2, not to get more O_2 in.

Hyperventilation

Now, re that paragraph under Oxygen above, concerning a real danger for the snorkel diver. Suppose before a breath-hold (snorkel) dive we take a lot of deep breathes to try to charge the body with O_2 - so we could stay down longer (hyperventilate).

We might get some more O_2 into the bloodstream and cells, but risk the danger of suicide because we breathe off a lot of CO_2, the alarm giving gas.

Down we go on our breath-hold or snorkel dive. How good it is. We seem to be able to stop down forever. The body gives no sensation of wanting to re-breathe because the alarm gas (CO_2) has not built up enough partial pressure to give warning. The body uses up the oxygen O_2.

Then one of three things can happen. The first two fatal and the third lifesaving.

1. We get caught up in a sense of Euphoria, and stay down until the PP O_2 drops to 10% when we go unconscious without warning, breathe in water and drown. (Note that 10% again - remember what happened when CO_2 built up to 10% - makes it easy to remember).

2. Our natural caution asserts itself and we think it must be time to ascend, but suppose we are at 10m (33ft) 2 ATA. The density of the air in the lungs is twice that at the surface (Boyle's Law). At the start the PP 02 would have been 21% ATA x 2 = 42% ATA., and suppose that during the dive the body used up that 02 until its PP at 10m dropped to PP 15% ATA. No real problem at that depth, but there is a latent problem (Latent hypoxia) waiting to occur as it were.

   Remember from Boyle's Law at 10m (2 ATA) the lungs of the snorkel diver compress to half the volume at the surface. When the diver ascends to the surface the volume of the lungs expands to normal size and the density of the air in them drops to normal or half of that at 10m.

   Thus the PP 02 at 10m in our example was PP 15% ATA, at the surface it would drop to PP 7½% ATA. But the diver would go unconscious when the PP 02 = 10% ATA. He would then inspire water and drown. This often occurs at approximately 3m (say 9ft) and is called "shallow water black-out".

   Rule: Do not hyperventilate at all before a dive.

3. At the start of this section we promised a lifesaver. It is this. Suppose you forgot what you had been taught, hyperventilated, and then dived. On the way down you remembered, ascended, breathed - and lived.

4. Scuba Tanks

Dalton's Law can also be used to ascertain the PP of gases in scuba tanks. For example if your tank contained air at a pressure of 100 ATA, the PP 02 = $100 \times \frac{21}{100}$ = 21 ATA.

Let us now consider some examples of Dalton's Law.

DALTONS LAW PP -= TP x %

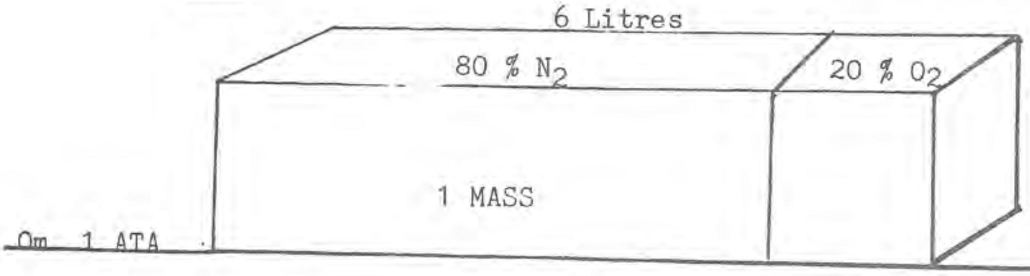
100 Km

The total pressure exerted by a mixture of gases, is the sum of the pressures, that would be exerted by each of the gases, if it alone occupied the total volume.

DEPTH				PP N_2 ATA	PP O_2 ATA
0 ft 0m	100 KPa = 1 Bar A 101.3 KPa - 1 ATA	1 ATA	1 BAR A	0.8	0.2
33 ft 10m	1 ATG	2 ATA	2 BAR A	1.6	0.4
66ft 20m	2 ATG	3 ATA	3 BAR A	2.4	0.6
99 ft 30m	3 ATG	4 ATA	4 BARS A	3.2	0.8
132ft 40m	4 ATG	5 ATA	5 BARS A	4.0	1.0
165ft 50m	5 ATG	6 ATA	6 BARS A	4.8	1.2
198ft 60m	6 ATG	7 ATA	7 BARS A	5.6	1.4
231ft 70m	7 ATG	8 ATA	8 BARS A	6.4	1.6
264ft 80m	8 ATG	9 ATA	9 BARS A	7.2	1.8
297ft 90m	9 ATG	10 ATA	10 BARS A	8.0	2.0
330ft 100m	10 ATG	11 ATA	11 BARS A	8.8	2.2

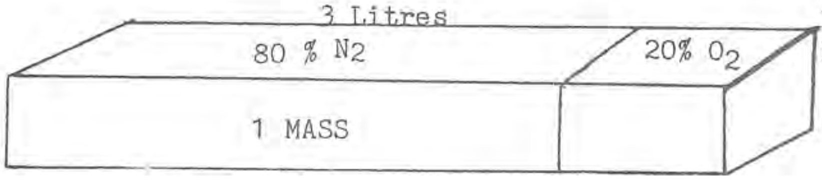
DALTONS LAW PP = TP x %

PP in SNORKEL DIVERS LUNGS



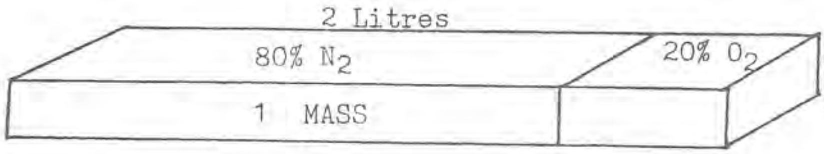
PP = TP x %
PP O_2 = ATA x 20%
= 1 x 20%
= 20% of 1 ATA
= 0.2 ATA

10m 2 ATA



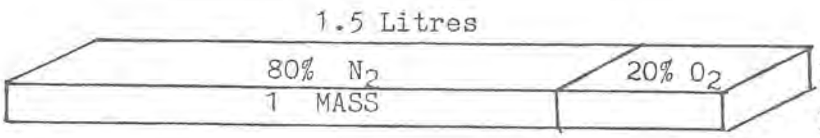
PP = TP x %
PP O_2 = TP x %
= 2 ATA x 20%
$= \frac{2}{1} \times \frac{20}{100}$
= 0.4 ATA

20m 3 ATA



PP = TP x %
PP O_2 = 3 ATA x 20%
= 0.6 ATA

30m 4ATA



PP = TP x %
PP O_2 = 4 ATA x 20%
= 0.8 ATA

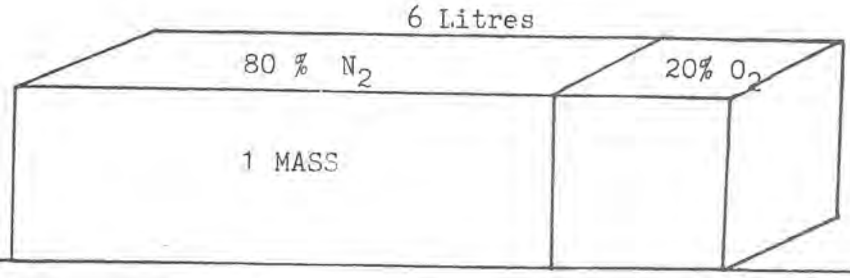
MASS:

In each case the mass of air is the same . Air is compressible and the same mass of air is compressed into smaller volumes as depth is increased. Of course the O_2 is slowly used up by the metabolism of the body and more N_2 passes in solution into the body.

Round figures are used for simplicity. Of course the closer composition of air is: N_2 78% O_2 21% CO_2 0.03 % Other 0.97%

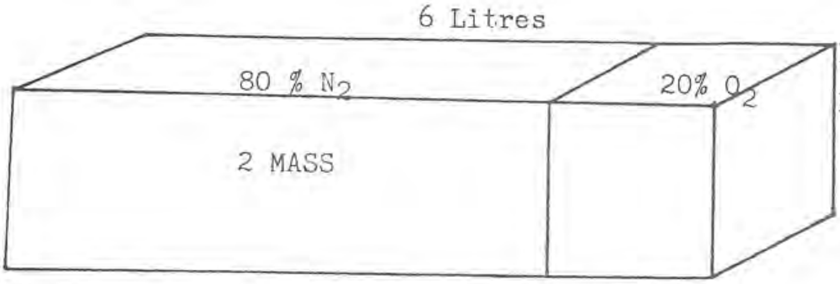
DALTONS LAW PP = TP x %

PP in SCUBA Divers lungs



0m 1 ATA

PP = TP x %
PP O_2 = 1ATA x 20% of 1 ATA
= 20% of 1ATA



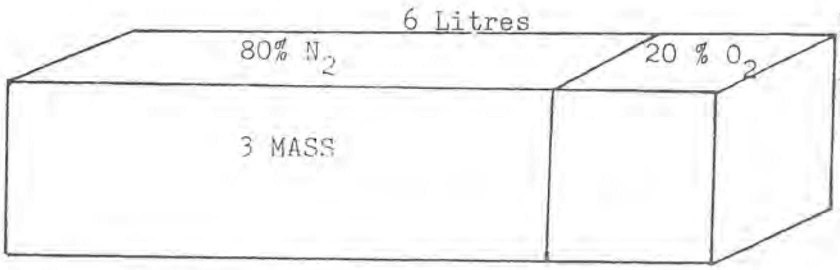
10m 2 ATA

PP = TP x %
PP O_2 = 2ATA x 20%

$= \frac{2}{1} \times \frac{20}{100}$

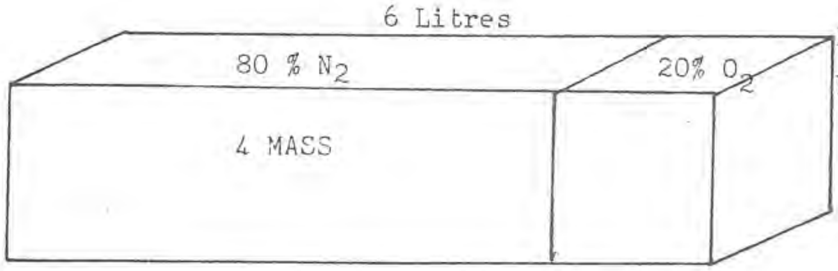
$= \frac{40}{100}$

= 0.4 ATA



20m 3 ATA

PP = TP x %
PP O_2 = 3ATA x 20%
= 3 x 20%
= .06 ATA



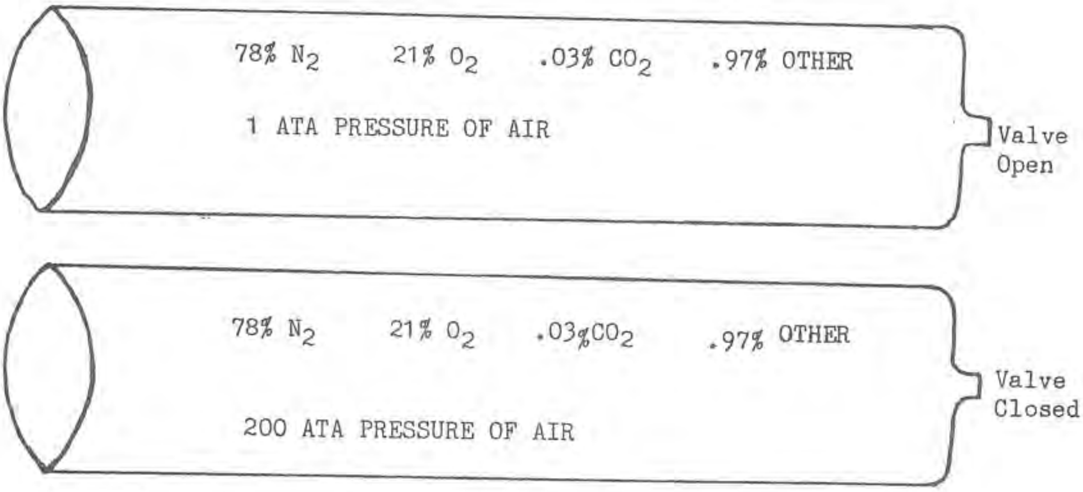
30m 4 ATA

PP = TP x %
PP O_2= 4 ATA x 20%
= 4 x 20%
= 0.8 ATA

The volume remains the same because the lungs are pumped up to original size by more air from the scuba cylinder. Thus the lungs at 30m contain four times as much air as they did at the surface, but still in the same volume, 6 litres.
The Partial Pressures are the same as for the snorkel diver.

DALTONS LAW $PP = TP \times \%$

SCUBA CYLINDERS



Q. What is the Partial Pressure of oxygen in the filled cylinder?

A. $PP = TP \times \%$

$PP\ O_2 = 200\ ATA \times 21\%$

$= \frac{200}{1} \times \frac{21}{100}$

$= 42$ ATA

ANSWER: $PP\ O_2 = 42$ ATA

Mental Check

$\frac{1}{5} \times \frac{200}{1} = 40$

Q. What is the Partial Pressure of nitrogen in the filled cylinder?

A. $PP = TP \times \%$

$PP\ N_2 = 200 \times 78\%$

$= \frac{200}{1} \times \frac{78}{100}$

$= 156$ ATA

ANSWER: $PPN_2 = 156$ ATA

Mental Check

$\frac{200}{1} \times \frac{80}{100} = 160$

HENRY'S LAW

HENRY'S LAW States that "At a constant temperature the amount of a gas that will dissolve in a liquid is proportional to the partial pressure of the gas over the liquid". This law implies an equilibrium in which equal amounts of each gas are passing into and out of any solution in contact with it. At sea level (1ATA), a man's body tissues contain about 1L of gaseous nitrogen in solution. If he dived to 10 metres and thus breathed air at 2 ATA, he would eventually reach equilibrium again and have twice as much nitrogen in solution in his body. The time taken to reach a new equilibrium depends on the solubility of the gas, in the tissues and cells and the rate of gas supplied to each cell.

When the total pressure or the partial pressure of a particular gas is reduced, gas must pass out of the solution. A rapid total pressure drop occurs, a tissue may contain more gas than it can hold in solution. In this situation bubbles may form and may cause decompression sickness (Caissons Disease). (Bends).

The physiological effects of the solubility of gases are also relevent to oxygen toxicity and nitrogen narcoses.

The gases take time to get into the tissues and cells and time to get out again.

A bottle of lemonade, or champagne, does not go flat at once when opened. It takes a considerable time for all of the CO2 in solution in the liquid to come out. Likewise the various gases in the cells and tissues.

The basic idea of solubility must be distinguished from Henry's Law, which simply expresses the effect of partial pressure on the amount of gas that will dissolve in a liquid. i.e. the solubility of nitrogen in oil or fat is about five times its solubility in water at the same Partial Pressure. This Law should be fully understood as its practical use will be referred to in the section on Decompression Sickness and Narcosis.

THE FORMULA:

Henry's Law = $\frac{VG}{VL} = \propto P_1$

VG = VOLUME OF GAS DISSOLVED (THERE IS A STANDARD USED)

VL = VOLUME OF LIQUID

$\propto$ = SOLUBILITY/COEFFICIENT

p1 = PARTIAL PRESSURE OF THE GAS IN ATMOSPHERES PRESSING ON THE LIQUID.

CHARLE'S LAW

CHARLE'S LAW Definitions for the purpose of this course:-

Charle's Law states that the volume of a gas varies directly as its absolute temperature, if the pressure remains constant.

There is a longer and more complete definition which is available, but the definition given is sufficient for our purpose.

Learn it off by heart.

Note that the gas varies directly as the Absolute temperature. That starts some two or three hundred degrees below zero where molecular action ceases. Thus if the temperature of a scuba tank varies from say 15°C to 30°C the volume of the gas does not double, but varies in proportion the absolute temperature, which proportion is relatively slight, but large enough to do damage.

Of course the volume cannot vary in a scuba tank, so the pressure rises. If you are foolish enough to leave a fully charged scuba tank on a hot beach or in the boot of your car on a hot day, the heat could cause enough rise in pressure inside the tank to rupture the disc in the safety plug of the cylinder valve. (Please refer to your diagram of cylinder valve.)

The air than escapes rapidly through the safety plug opening. The cylinder is 'vented'.

This stops your dive, but worse happens.

During the venting the sudden large drop in pressure causes a large drop in temperature. Ice forms from the water vapour in the escaping air, especially inside the cylinder. When the ice goes back to water, you have water in the tank. Result - a rusty cylinder if you have a steel tank, and with any type of cylinder, water from the cylinder can get into your lungs and spoil the functioning there too.

Another application of Charle's Law occurs when tanks are being filled. You will notice that your friendly dive shop manager will put your tank in a vat of water and splash water over any part of the tank not under the water as the air is being compressed into your tank. This is to keep the temperature down.

The pressure causes heat in the same way that the temperature rises in the cylinder of your car when the gas is compressed on the compression stroke. Remember that in a diesel engine this rise in temperature is used to fire the diesel gas. Thus no spark plug is used in a diesel engine. Again Charle's Law applies on the compression stroke.

By the way, a rapidly venting tank can cause injury to you or your companions. The outrushing air could blind you, for example if you had your face near the tank valve, when the safety disc 'blew'. It could damage your car in a sealed boot.

Keep a charged scuba tank in a cool place.

ANATOMY OF BODY

STUDENTS: Your Instructor will show you pictures of:

Body in outline

Skeleton

Muscles and Sinews

Head

Thorax

Abdomen

Brain, Ears, Sinuses, Teeth, Eyes

Respiratory Tract

Alveoli

Lung Capacities

The Heart

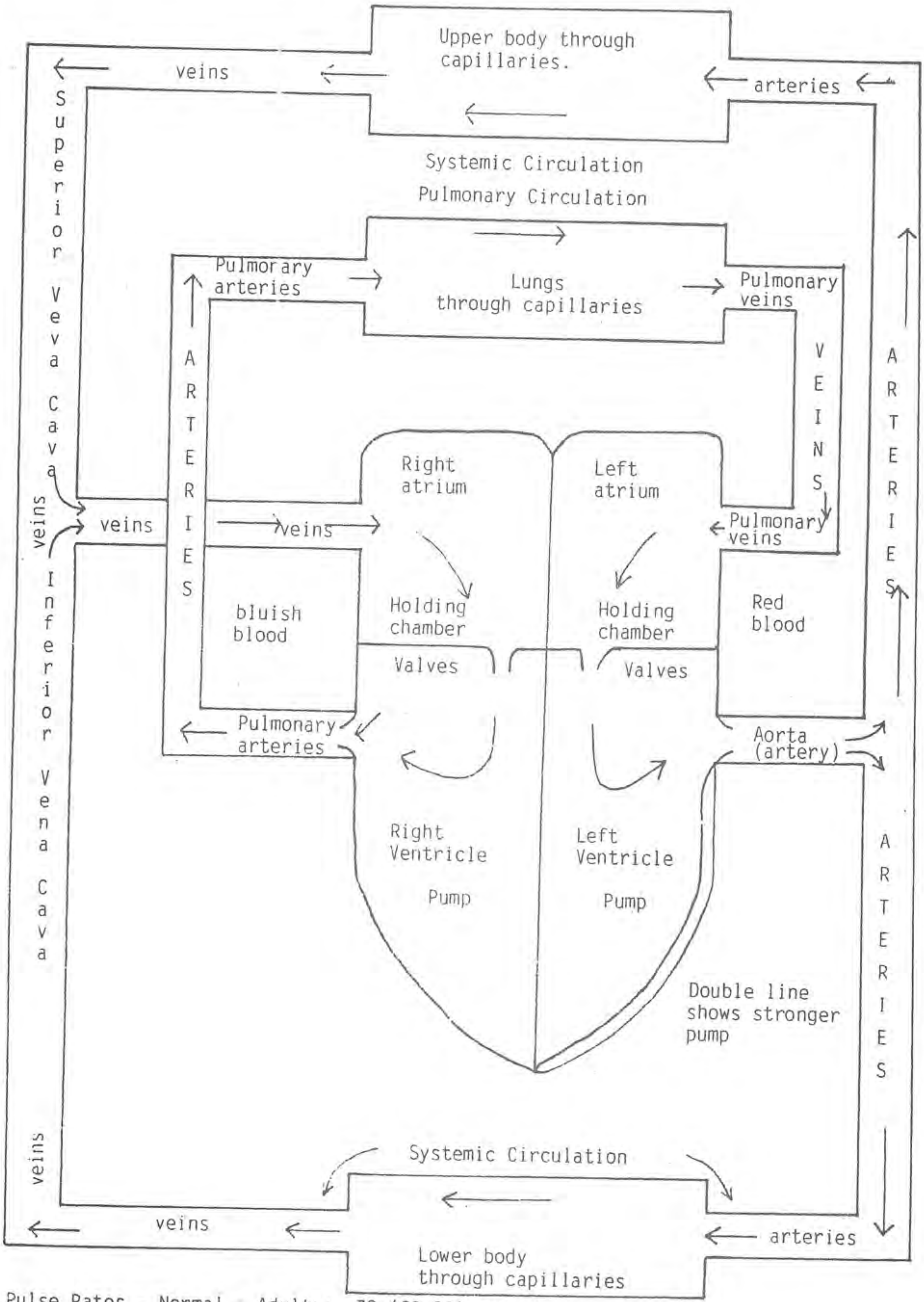
Bloodstream and Cells

Lymph Vessels and Lymph Glands

The Skin

HEART DIAGRAM

Schematic.



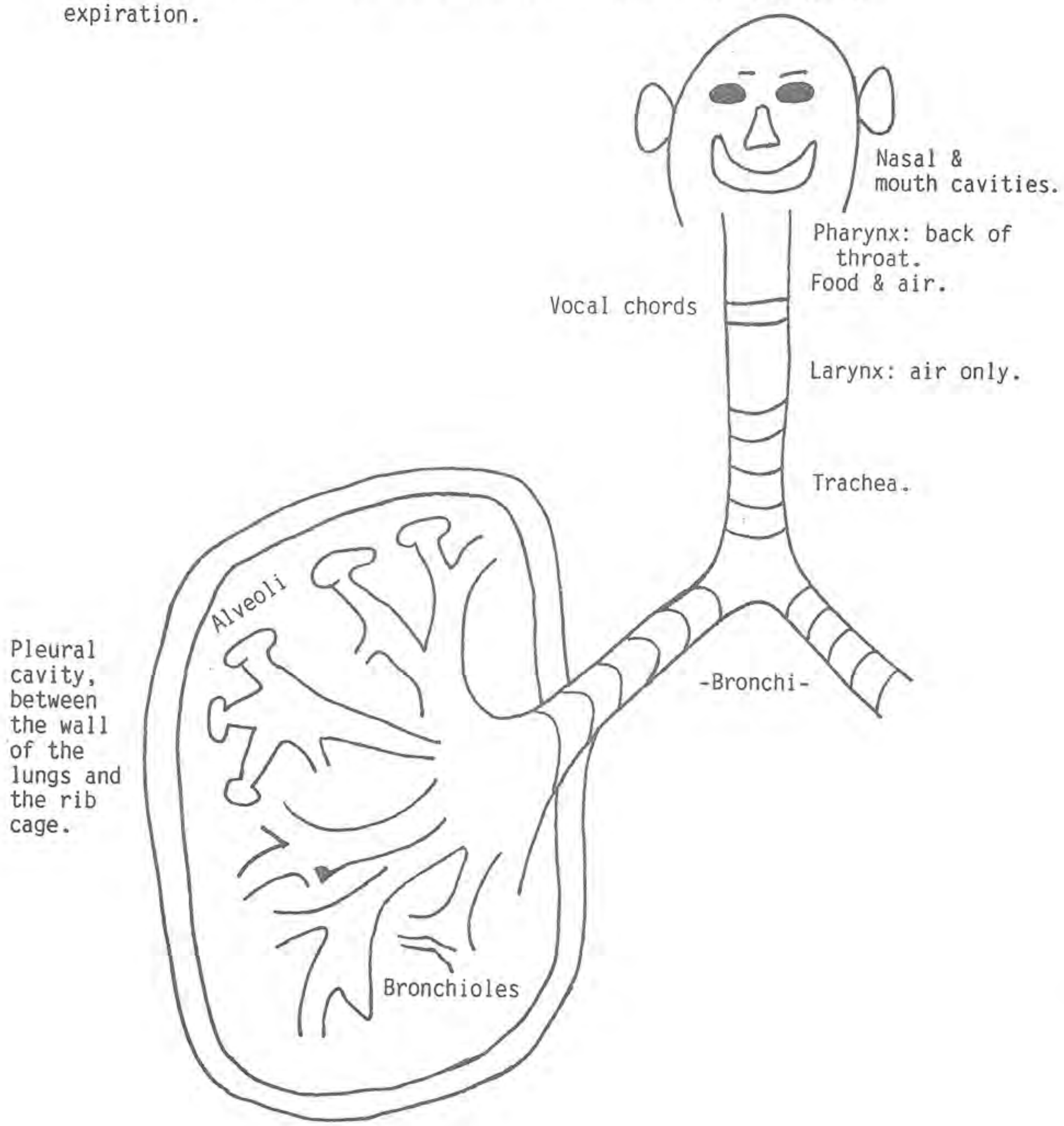
Pulse Rates - Normal - Adults: 72 (60-80) per minute
Children: Up to 100 per minute
Infants: Up to 140 per minute

RESPIRATORY TRACT

Nasal and Mouth Cavities
Pharynx
Larynx
Trachea
Bronchi
Bronchioles
Alveoli (air sacs)

EXCHANGE OF GASES IN THE LUNGS -

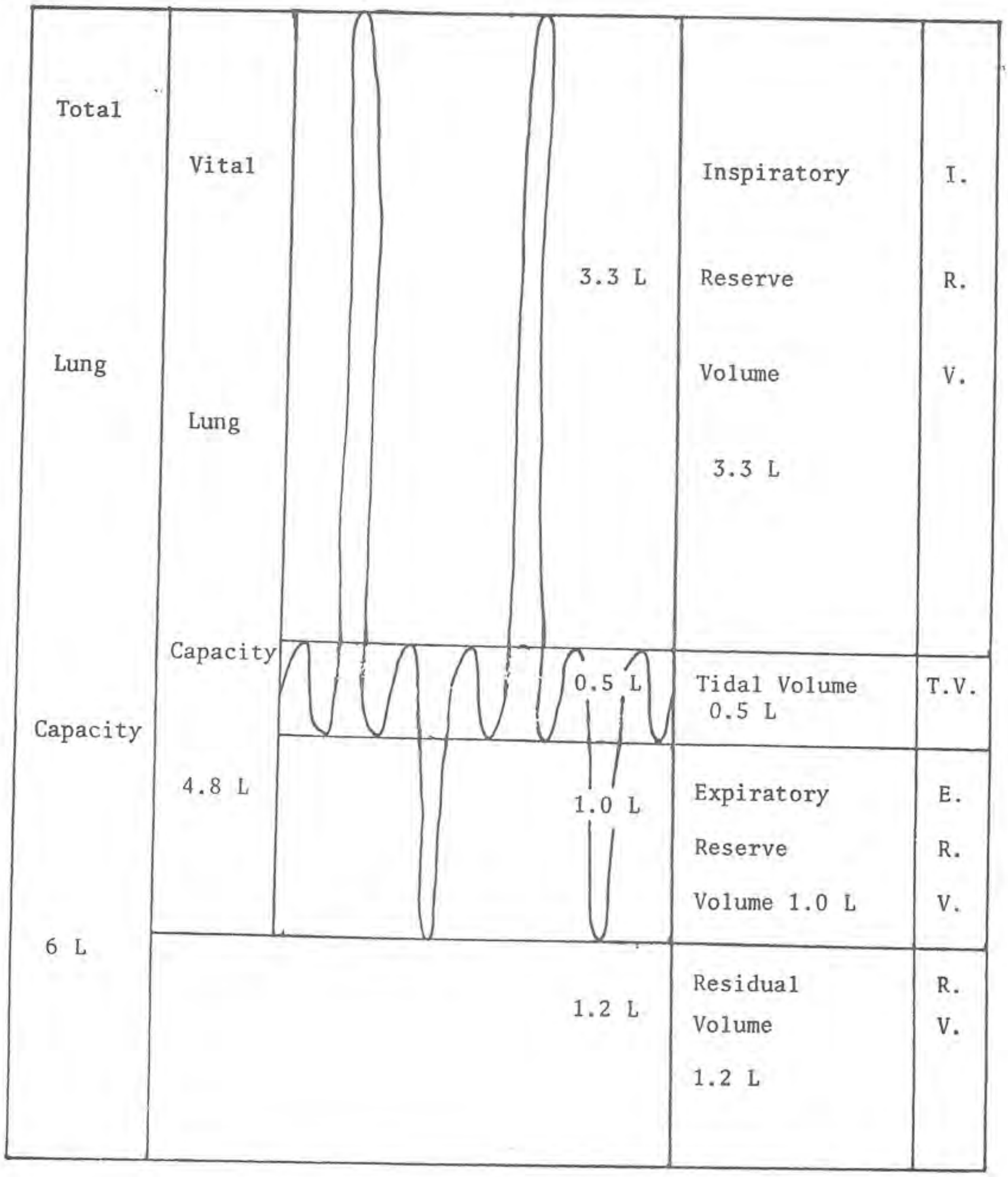
- occurs between the air in the Alveoli and blood in the capillaries for distribution throughout the body to the cells.
Oxygen (02) to the blook from the air in the Alveoli,
Carbon Dioxide (C02) from the blood to the air in the Alveoli for expiration.



LUNG CAPACITIES AND VOLUMES.

Total Lung Capacities: Male 6 Litres.
Female 4.2 Litres.

All capacities and volumes vary considerably.



Diving Breathing Rate for SCUBA 30 L/min. average.

Free Air Breathing at Rest on Surface from Above Diagram:-

16 to 20 Breaths per Minute:- 20 x 0.5 L = 10 L/min.

16 x 0.5 L = 8 L/min.

EFFECTS OF PRESSURE DURING DESCENT

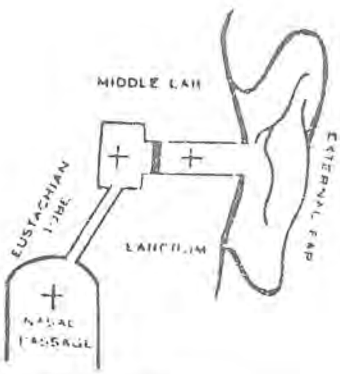
Squeeze:

The term Squeeze or (barotrauma) refers to any injury that occurs as a result of the diver's inability to equalise pressure between a closed air space and the outside water pressure. If an air space within the body (or attached to it) has rigid or semi-rigid walls, it must be equalised by free entry of air. (Non-rigid air spaces equalise simply by compression.)

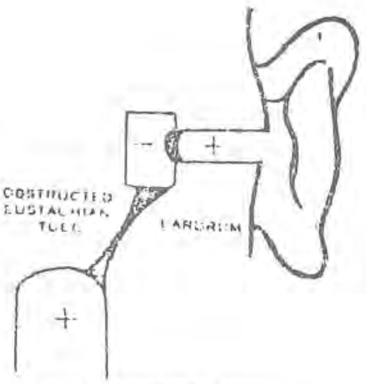
Ears, Sinuses and Teeth, cause the most problems with squeeze.

EARS: The ear is made up of three sections.

1. The Outer Ear: this consists of the external part of the ear and the canal leading to the ear drum which is a thin membrane.
2. The Middle Ear: this is the cavity the other side of the ear drum and contains the system of bone 'levers' which connect the drum to the inner ear.
3. The Inner Ear: this has the actual 'sound sensing' nerves in it which connect with the levers of the middle ear.



EQUILIBRATED EARDRUM



UNEQUILIBRATED EARDRUM

RESPIRATION OF AIR

1. The simple act of respiration is the breathing of air, per nose or mouth, into the lungs; and then breathing the used air out again.

2. A fuller description of respiration is that air is breathed in through the nose or mouth, and passing down the air passages at the back of the mouth, passes through the Trachea, Bronchi and Bronchiole Tubes to the Air Sacs or Alveoli in the lungs. The air gases then pass through the alveoli walls and go into solution in the blood. The blood carries the gases in solution around the body and to the cells. The oxygen is used by the cells. "EXHAUST" gases, in solution, especially Carbon Dioxide, are given off by the cells to the blood, whence they are carried back to the lungs and expelled into the air.

THE LUNGS

The lungs are composed of millions of tiny air sacs or 'alveoli'. Each alveoli has a network of microscopic blood vessels over its inner surface where the exchange of oxygen and carbon dioxide between the blood and the air in the lungs takes place. The membrane between the blood vessels and the air in the alveoli is so thin that its effect on the diffusion of gases in and out of the blood is negligible. The lungs are connected to the back of the throat by a large tube called the 'trachea', the trachea then branches into 2 smaller air passages called 'bronchi', which in turn branch into even smaller passages called 'bronchioles', each bronchiole has hundreds of alveoli attached to it. The whole system may be pictured as rather like a busy tree, the main trunk being the trachea, the leaves, the alveoli and the branches and twigs the bronchi and bronchioles. The nett air/blood surface area of the alveoli in one pair of human lungs is about half a tennis court.

1. The respiratory rate is between 16 and 20 breaths per minute.

2. Total lung capacity is the total volume of air that lungs can hold when filled to capacity and is normally between 5 and 6 litres. 5.5 L.

3. Vital capacity is the greatest volume of air that a man can expel from his lungs after a full inspiration and is between 4 and 5 litres. 4.5 L.

4. Tidal volume is the volume of air moved in and out of the lungs during a single normal respiratory cycle and is about half a litre. It increases considerable during physical exertion. 0.5 L.

5. Inspriatory reserve volume is the amount of air that can be brought in by forcible inspiration and is about three and a third litres. 3.3 L.

6. Expiratory reserve volume is the amount of air that can be expelled by forcible expiration at the end of a normal expiration and is about 1 L.

7. Residual volume is the amount of air that remains in the lungs even after the most forceful expiration and is between 1 and 1½ litres. 1.2 L.

Table of Gas Mixtures

Atmospheric Air

Oxygen	=	21.00%
Nitrogen	=	78.00%
Carbon Dioxide	=	0.03%
Trace gases and Water vapour	=	0.97%
		100.0%

Expired Air

Oxygen	=	16.30%
Nitrogen	=	78.00%
Carbon Dioxide		4.04%
Trace gases and Water Vapour	=	1.66%
		100.0%

STRESS ON THE SNORKEL DIVER (AND ALL DIVERS)

	PHYSICAL DAMAGE TO BODY			BODY PUSHED BEYOND LIMITATIONS	
THE ITEM	SQUEEZE/DESCENT	BURST/ASCENT	TORPEDOING BOATS ETC. ON ASCENT	COLD AND TIRED	
SHOWN AS	BAROTRAUMA INWARDS	BAROTRAUMA OUTWARDS	COLLISIONS	HYPOTHERMIA	OVEREXERTION - EXHAUSTION
DEFINITION	Barotrauma is damage to body tissue due to pressure. B/Inwards means that the pressure from outside the body is greater than the pressure from inside the body.	Barotrauma is damage to body tissue due to pressure. B/Outwards means that the pressure from inside the body is greater than the pressure outside the body.	On ascent diver colliding with boat, swimmer, shark, snake etc. with top of his head.	Fall of body temperature.	Overexertion: Exerting body beyond limits strength and endurance. Exhaustion: Inability to function owing to over-stimulation of muscles & nerves.
CAUSES	On descent, pressure from inside the body cavities not building up as quickly as that outside i.e. descent too fast. Cavities are: ears, sinuses, teeth lungs or thorax face in mask.	On ascent pressure from inside the body cavities not losing pressure as quickly as that outside; i.e. ascent too fast. Main damage is in scuba diving.	Not looking up during ascent.	Heat loss in water. Cold water. Long exposure. Physical activity. Insufficient clothing Drugs, alcohol.	Necessity for sheer hard work as in rescues. Working in cold dark water and/or strong currents. Shallow and skip breathing Snorkelling in choppy water
EFFECTS	Ears - burst eardrum. Sinuses: pain and bleeding. Teeth - pain. Lung & Thoracic squeeze - if lung compressed smaller than residual vol. crushes lung. Face - pain - damage only from gogles.	In snorkel, diver damage or even pain is uncommon. Pain comes from tubes to sinuses or ears (eustacian tubes) blocked by mucous during time below. Usually pressure inside blows blockage out.	Concussion or provoking attack.	Shivering. Distress. Inability to do fine work. Loss consciousness. Death.	Body finally refuses to function. Danger lies in not being able to main-tain breathing & extreme cold causes vital organs to cease work, than lose consciousness & death.
DIAGNOSIS S & S	Pain & distress Water in middle ear - disorientates diver. Crushed lung kills	DITTO	Diver concussed or subject of attack	Shivering, Blueness clumsiness, distress restlessness. Inability concentrate Unconscious.	Feeling of exhaustion. Laboured breathing. Body not able to cope. No matter what mental effort
ACTION BY DIVER	Do not dive with a cold because of mucous in tubes to sinuses & eustacian tube to ears, as well as in alveoli. Do not dive too deep to crush lungs in snorkel dive i.e. much over 30m. When pain comes, ascend or compensate.	DITTO When pain comes in tubes valsalva manoeuvre.	To Avoid Look up on ascent. Listen for motors. To escape Get back in boat or give distress signal	Wear adequate wet or dry suits. Go to surface of boat Seek wamth away from water & wind. Hot drinks. Hot shower or bath. No alcohol or pores open.	STOP REST VENTILATE. Know limitations & stay within them. Use line in strong current Training & experience. Keep fit.
FIRST AID RESCUER	GET PATIENT TO SURFACE A.B.C. GET PATIENT TO BOAT NORMAL FIRST AID	DITTO	GET PATIENT BACK IN BOAT A.B.C. & NORMAL FIRST AID.	A.B.C. if necessary. Warm Bath. Warm shower Warm drinks. Wet suit may be left on.	A.B.C. if necessary. Rescue diver from water. Recovery position. Keep warm. Rest.
MEDICAL AID	Radio or telephone for Ambulance or Helicopter. Telephone 000 or 013 to alert rescue organisations.				DITTO

SQUEEZE: BAROTRAUMA INWARDS

SQUEEZE

Ears:

The inner ear is filled with liquid and not affected by squeeze. The middle ear is an air-filled space and is affected by outside pressure differences via the ear drum. To equalise this space, there is a narrow tube called the Eustachian Tube joining the middle ear to the nasal passage. If this tube becomes blocked by mucus or an over-growth of tissue, the equalisation of pressure on both sides of the ear drum cannot take place and pain will result. If the pressure increases without equalisation, it will become more painful and the ear drum will bulge inwards with such a force as to tear blood vessels connected to the drum, to hemorrhage, and finally rupture.

The pain produced before the drum ruptures often becomes so intense that it prevents further descent by the diver. Returning to normal pressure brings about immediate relief. When an ear drum ruptures during a dive in which the diver's ears are exposed to the water (this includes diving with wet suit hood), the cold water entering the middle ear will cause a severe upset in the sense of balance, so much so, that vomiting may often occur.

This unpleasant feeling will pass as soon as the water in the ear warms to body temperature. A diver who has ruptured an ear drum should seek immediate medical attention if he wishes ever to dive again. This is most important as the middle ear is very easily infected and once infected it is doubtful if the drum will ever heal again. Between rupturing an ear drum and obtaining medical attention all foreign bodies must be kept out of the ear. This includes medical preparations, swabs, fingers etc. A small piece of clean cotton wool may be placed and left in the ear to prevent the access of germs. If these precautions are adhered to, the chances of the drum healing are extremely good and once it has healed (from four to six weeks) diving may be resumed.

It is possible though extremely rare, that an ear drum may rupture on ascent if a blockage occurs in the eustachian tube. Usually the tube allows the escape of air much more readily than it admits it on descent.

If a diver is wearing a suit with a hood, the hood may "seal" around the external ear and thus on descent there will be a relative "low pressure" space in the outer ear and on equalisation of the middle ear, the drum may rupture outwards. This will also occur if ear plugs are used - which should be NEVER. In wet suits this is prevented by having a small hole in the hood alongside each ear; in dry suits this is not possible and care must be taken to prevent a seal on the ear taking place.

As a diver descends he must ensure that his ears "clear" or equalise about every 3 metres of his descent. There are several ways to bring about this equalisation; the simplest being to "swallow" or yawn, or move about the jaw so that the eustachion tube is momentarily opened to allow air to enter the middle ear. If this process doesn't work, the other most usual method is to force air through the eustachian tube by pinching the nostrils closed with the fingers and blowing fairly hard against the closed nostrils. (Valsalva Manoeuvre).

Sinuses:

All sinuses are located within hollow spaces in the skull bones and are lined with mucus membrane continuous with that of the nasal cavities. Essentially the sinuses are small air pouches which connect with the nasal cavity through narrow passages. If pressure is applied to the body and passages to any of the sinuses are obstructed by mucus or tissue growths, pain will soon be experienced in the obstructed area. The pain will be relieved by ascent.

Signs:

a) Blood and mucus discharged from the nose upon surfacing if any damage has been done.

b) Tenderness over the sinus area.

Treatment:

a) avoid diving until cause subsides.

b) Use a nasal spray or drops; if the condition is not serious, this may enable a diver to continue the dive.

Teeth: A squeeze in the teeth due to small gas pockets in the pulp or behind a filling. Quite severe aching of the particular tooth is the only effect and this will be relieved upon ascent.

Gas in the Stomach and Intestine:

While a diver is under pressure, gas formation may take place within his intestines or air may be swallowed and trapped in his stomach. On ascent, this trapped gas expands and occasionally causes enough discomfort to require stopping until it can be expelled. Familiar manoeuvres will generally accomplish this without difficulty. Continuing ascent in spite of marked discomfort may result in actual harm.

Before diving, avoid fizzing drinks, alcohol or any foods likely to produce intestinal gas. Do not swallow air into the stomach.

Lung or Thoracic Squeeze:

Cause:

Squeeze occurs when gas in the lung is compressed to less than the residual volume (1.2 litres).

a) too deep a descent during a skin dive, usually more than 30 metres.

b) breath held during descent with diving equipment.

c) failure of self-contained gear or gas supply during descent.

Symptoms and Signs:

a) Sensation of chest compression during descent.

b) pain in chest (occasional symptom)

c) difficulty in breathing on return to the surface.

d) bloody frothy sputum.

Treatment:

a) bring diver to surface.

b) place in drainage position; try to clear blood from mouth.

c) give artificial respiration if not breathing.

d) any other normal first aid.

Face Squeeze:

This is brought about by using the old type goggles or failing to equalise the pressure in a face mask (by letting air into the mask through the nose) while descending. If the squeeze is allowed to develop too far it can result in blood vessels in the face breaking, or, if carried to extremes, the eyes would be forced into the mask. This last, rather drastic mishap is unlikely to happen as pain will usually warn the diver far in advance of its occurence.

THE EAR

AND

THE EUSTACHIAN TUBE

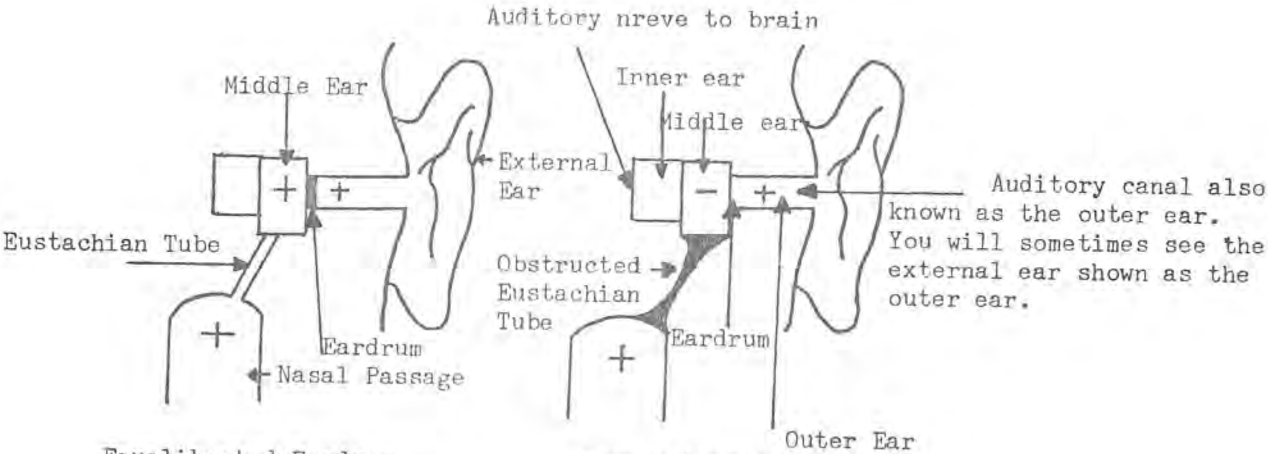
Ears:

The ear is made up of three sections .

1. The Outer Ear: This consists of the external part of the ear and the canal leading to the ear drum which is a thin membrane.

2. The Middle Ear: This is the cavity the other side of the ear drum and contains the system of bone " levers " which connect the drum to the inner ear.

3. The Inner Ear: This has the actual " sound sensing " nerves in it which connect with the levers of the middle ear.



Equalibrated Eardrum

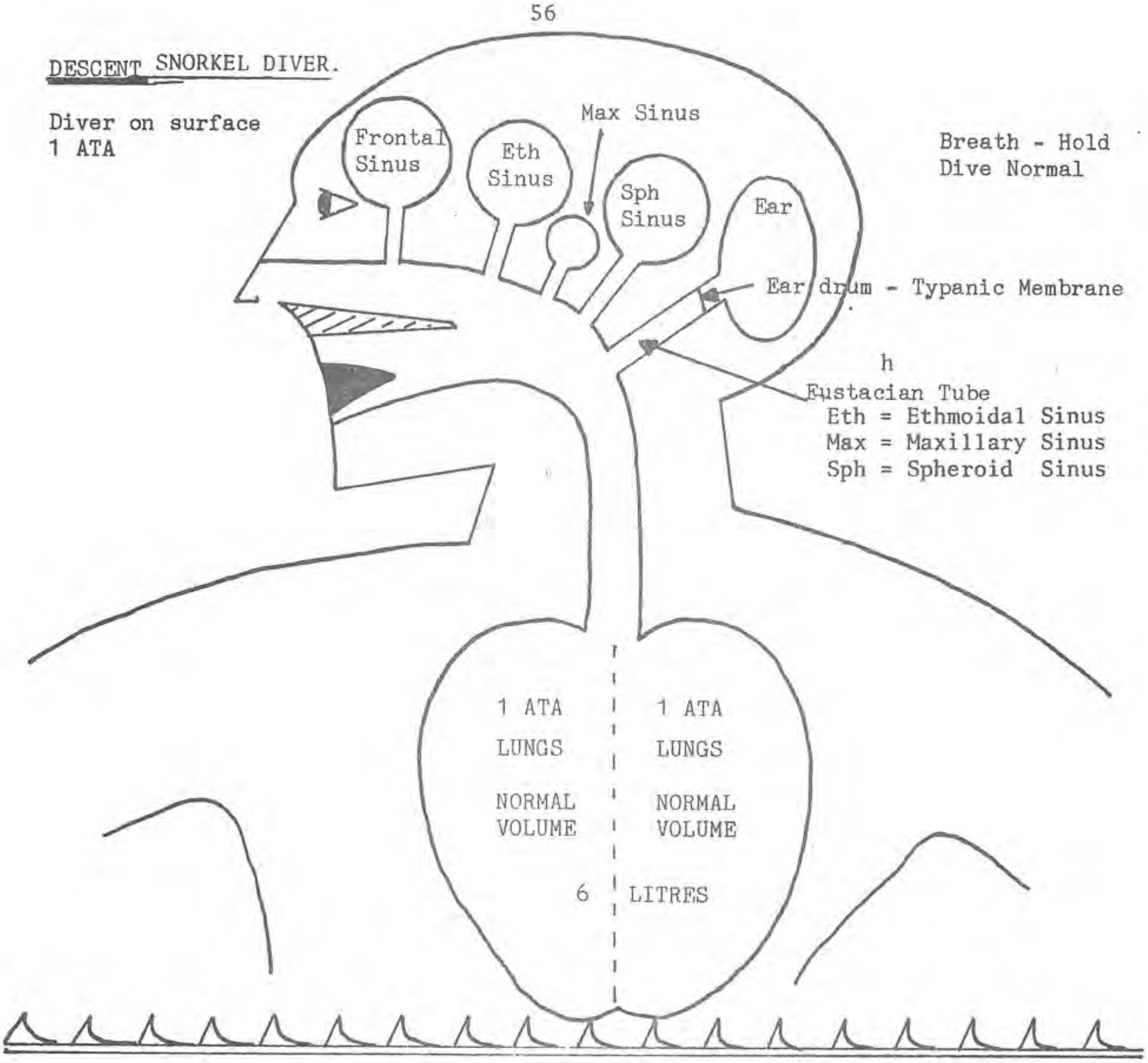
Unequilibrated Eardrum

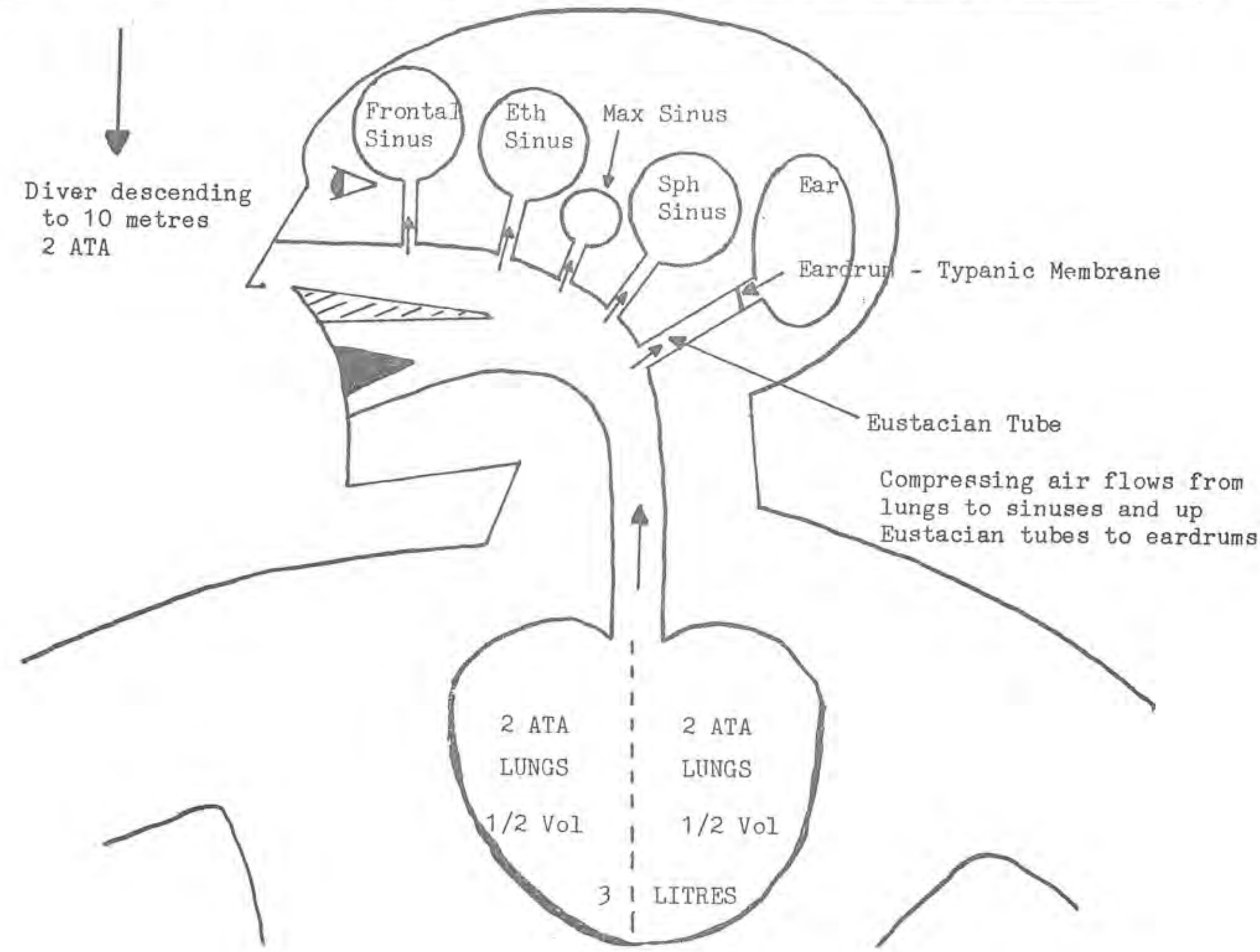
The eardrum is also called the Typanic Membrane.

If the eardrum bursts and water enters the middle ear, the water pressure on the inner ear may disorientate the diver.
The sense of balance is upset.

The Diver may do " Cartwheels "
Buddy to see patient keeps his regulator in use, get patient to surface, into boat and seek medical aid.

DESCENT SNORKEL DIVER.





STREES ON SNORKEL AND ALL DIVERS

Burst - Barotrauma Outwards

Barotrauma outwards occurs on ascent. This is when the Absolute Pressure pressing inwards on the diver is decreasing during ascent.

This is the reverse of the barotrauma inwards which occured increasingly during descent.

During ascent on a breath-hold dive, the compressed lungs expand and 'suck' the compressed air from the sinuses, Eustachian Tube and other places such as hollows in teeth. Read again the paper on Barotrauma inwards on descent and use your imagination to see how decreasing pressure on ascent applies.

It would be more scientific to say that the expanding lungs decrease the pressure in those lungs and air flows from the areas of higher pressure such as sinuses and Eustachian Tubes.

On ascent the gas pressures in the bloodstream and tissues also decreases. The blood and tissues do not compress or expand but the air gases in solution there, will come out of solution and form bubbles if pressure is taken off too quickly. Usually only on scuba dives.

Now if one of the passages from a sinus, Eustachian Tube, or even a group of Alveoli are blocked, say by mucous, or again, a part of the interstine has expanding gas from fizzie drinks, the high pressure air or gas cannot escape, but expands and presses on surrounding tissue causing pain and perhaps damage. The pressure might blow the blocking mucous off of the Eustachian or Sinus tube etc., thus righting itself.

The diver may descend to try to equalise the pressure and ascend slowly; or hold nose and ~~blow~~ suck, or wait suffering and resolving not to dive with a cold next time.

Revise the papers 'Descent' and 'Squeeze - Barotrauma Inwards'.

These same squeezes can occur on Scuba.

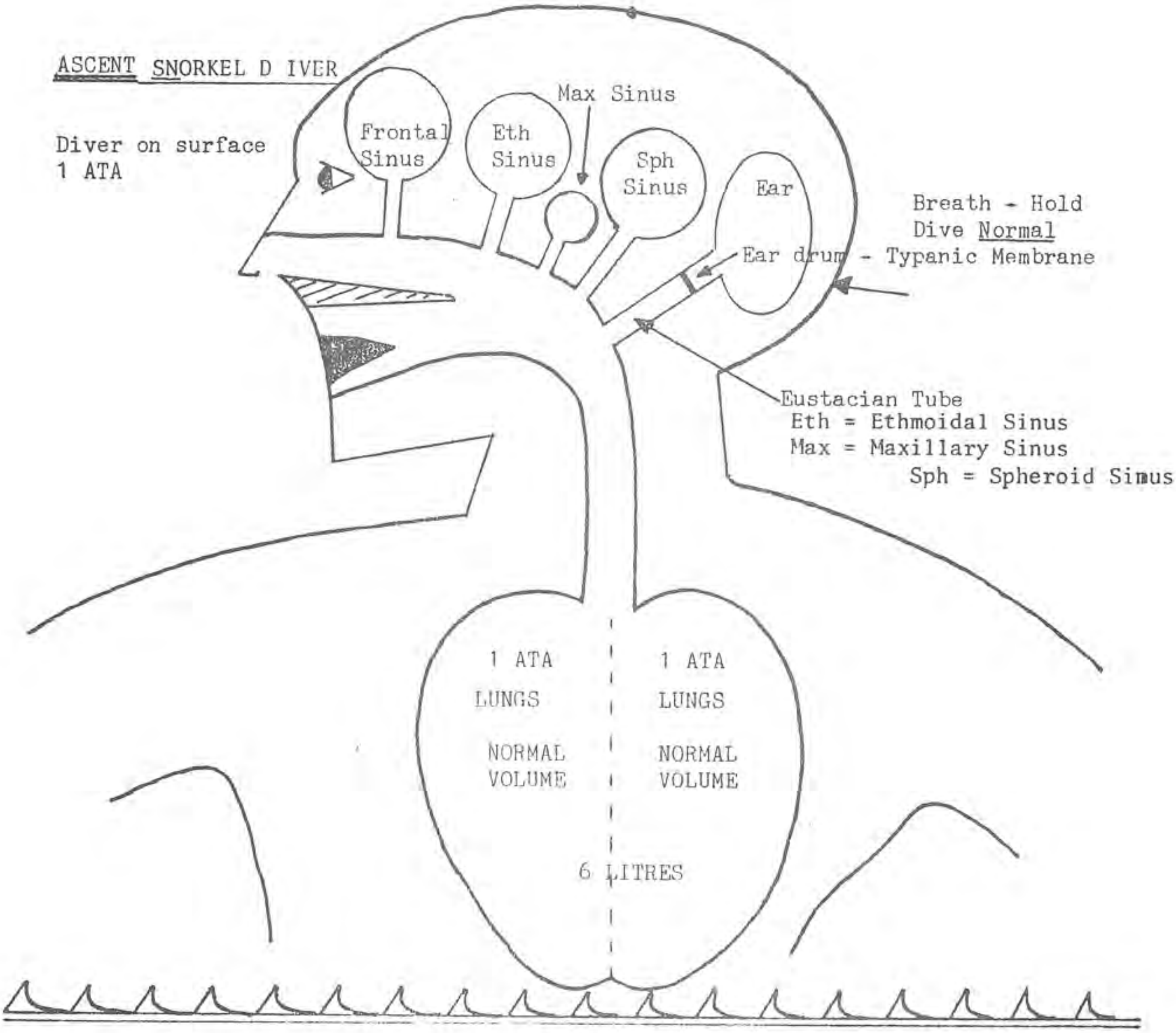
This is often overlooked because the scuba equipment is pumping pressurised air into the divers lungs and it seems easier to equalise the body to the surrounding ATA pressures. The lungs stay at normal size being pumped up with compressed air from the scuba at the same ATA pressure as the surrounding water.

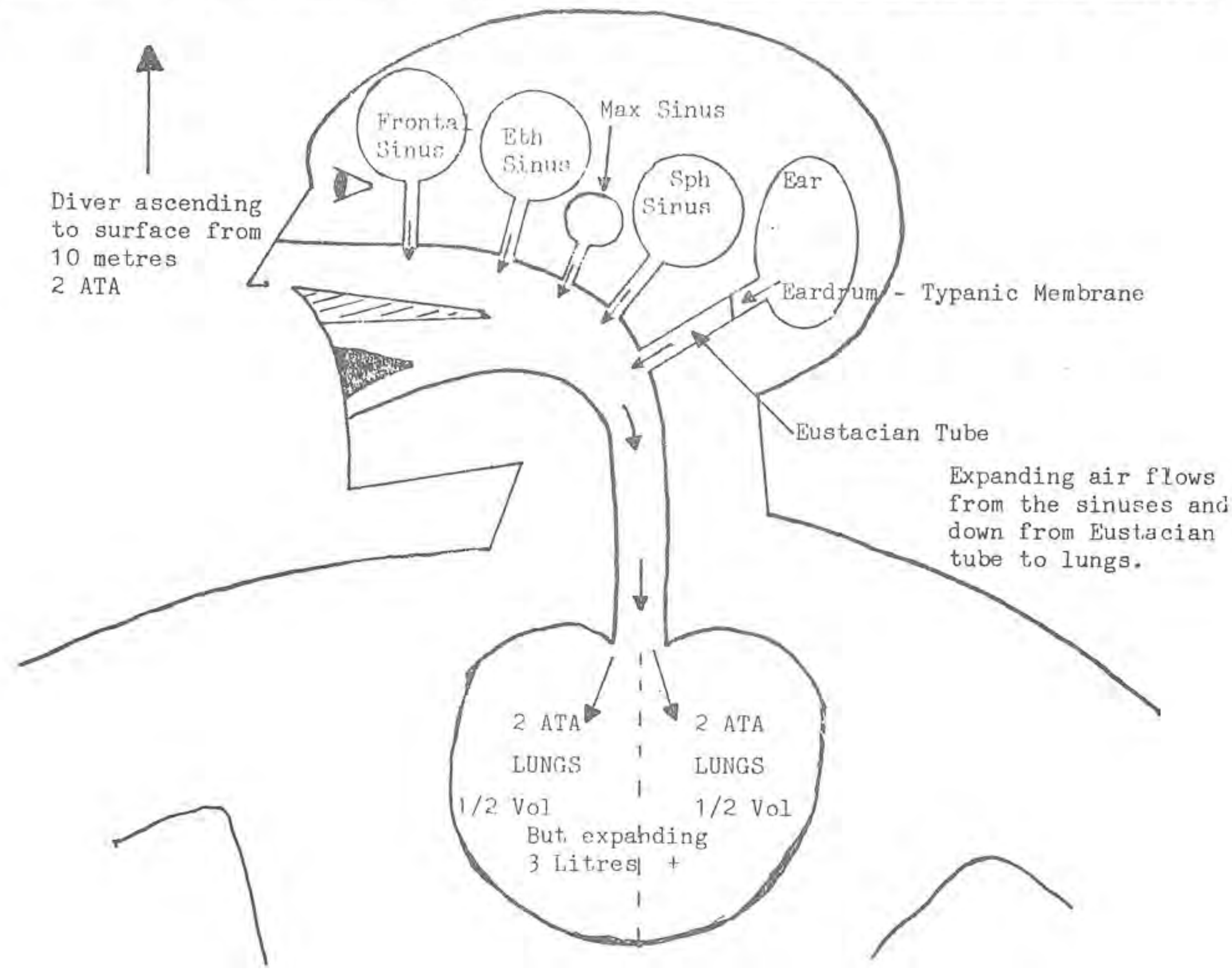
Students are reminded that the same stresses can occur with the same dangers of pain and injury, so that the same care should be used in scuba as in snorkel diving.

Some divers are so aware of the squeezes that they descend feet first and slowly to give the body time to adjust to the increasing pressure.

It seems unbelievable but there actually are some experienced divers who go down with the anchor holding on to it as it falls, to get a nice quick ride down. There are also people who jump out of aeroplanes without parachutes, but not many as pilots have the same saying as divers, "There are old divers and bold divers, but not many bold and old divers".

A slow swim downwards, perhaps along the anchor line, is reasonable and is the usual way. The speed of descent is certainly slowed by pain in the ears if it develops. If it does, ascend a little to have less pressure coming in the ear canal, wait to equalise, or blow to compensate by the Valsalva manoeuvre.


ASCENT SNORKEL D IVER
Diver on surface
1 ATA
Max Sinus
Frontal Sinus
Eth Sinus
Sph Sinus
Ear
Breath - Hold
Dive Normal
Ear drum - Typanic Membrane
Eustacian Tube
Eth = Ethmoidal Sinus
Max = Maxillary Sinus
Sph = Spheroid Simus
1 ATA
LUNGS
NORMAL VOLUME
1 ATA
LUNGS
NORMAL VOLUME
6 LITRES


Diver ascending
to surface from
10 metres
2 ATA
Max Sinus
Frontal Sinus
Eth Sinus
Sph Sinus
Ear
Eardrum - Typanic Membrane
Eustacian Tube
Expanding air flows
from the sinuses and
down from Eustacian
tube to lungs.
2 ATA
LUNGS
1/2 Vol
2 ATA
LUNGS
1/2 Vol
But expanding
3 Litres +

Torpedoinq Boats On Ascent

This means to hit a boat or any other obstruction, with the top of the head on ascent.

Of course a diver should look where he is going on ascent, the same as he would on descent, or walking along a street for that matter.

On ascent the diver should continually look up and slowly rotate.

Beware of sailing boats such as cats which make no noise worth mentioning and travel quickly.

It is suprising to notice how many divers look down, or sideways, and not up, on ascent.

The danger is that a knock on the top of the head could concuss the diver, causing unconsciousness and drowning.

Look Up And Live.

HYPOTHERMIA

1. The Fall Of Body Temperature, with diving, is Due To rapid Heat Loss into the surrounding water.
(25 x Air)

2. It is Made Worse By:

   2.1 A Low Water Temperature
   2.2 Long Exposure
   2.3 Inadequate Insulation in Clothing
   2.4 Increased Depth If Wet Suits are Worn
   2.5 Physical Activity
   2.6 The Taking of Drugs or Alcohol which Interfere with the Bodies Response to Cold

3. Adaption and Insulation Protection:

   3.1 A degree of adaption does occur with repeated exposures.
   3.2 Obesity does offer some protection
   3.3 Water conducts heat 25 times as rapidly as air. Therefore Insulation/Protection is required for survival during prolonged exposure below 32^{o}C. (See below: Wet/Dry Suits).

4. Signs and Symptoms:

   4.1 Initially the Diver:
   (a) Becomes Restless
   (b) Loses his ability to perform fine movements with the hands
   (c) May shiver

   4.2 Later the Diver:
   (a) Finds a reduction in his capability to perform physical work

   4.3 Finally the Diver:
   (a) Loses consciousness
   (b) May die

5. Treatment:

   5.1 Maintain Respiration and Circulation and
   5.2 Rapidly rewarm the diver by e.g.:

   (a) Warm Bath)
   (b) Hot Shower) May continue to wear wet suit
   (c) Hot Drinks)

6. Suits for Insulation and Protection:

   6.1 Wet Suits: (a) Foam Neoprene:
   (1) Has similar insulation properties to wool felt
   (2) But it's effectiveness is reduced by: loss of heat with water movement, and increasing pressure; which decreases it's insulation by reducing the size of air sacs in the foam.
   (Neoprene halves its thickness at 20 m)

   6.2 Dry Suits:
   (a) These are water tight suits with seals around the mask hood or helmet and hands openings.
   (b) They allow the diver to wear an insulating layer of warm clothes that are kept dry by the suit.
   (c) It must have a gas supply, and relief valve, to compensate for changes in suit volume with pressure.

OVER-EXERTION and EXHAUSTION

DEFINITIONS

Overexertion: is exerting oneself beyond the limits of strength and endurance of the body and thus bringing on exhaustion.

Eshaustion: is the inability to functiondue to overstimulation of muscles and nerves.

CAUSES

1. Everyones ability to do hard work has definite limits. Most of us do not know what those limits are, especiallv in water deeper than ones own heiaht.

2. When diver over depth in water the limits can come much faster than on land. may take the diver by surprise, and can cause him to drown.

3. On land the exhausted person can stop and rest, thus the human mind tends to be unaware of the danger in water where rest is more difficult to take, and the uninformed diver tends not to be on guard against exhaustion.

4. Exhaustion in water is usually accompanied by the body gasping for air, the body then tends to sink, more effort is required to surface for air, thus exhaustion quickly becomes worse.

5. Some situations that can cause a diver to exceed his limits of endurance and become exhausted are:

   a. Sheer necessity to get work done as in rescuing anohter person.

   b. Working against strong currents or on an unusually muddy bottom.

   c. Diving jobs requiring heavy exertion or unusually prolonged task.

   d. Wasting effort early in dive.

   e. Efforts to get free when fouled, especially if efforts badly planned, ineffectual.

   f. Panic.

   g. Excessive breathing resistance in SCUBA.

   h. Use of controlled or shallow breathing.

   i. Bad air, breathing mixture too low in 02 or CO poisoning

   j. Excessive cold or inadequate protection.

   h. Snorkelling with SCUBA in choppy water.

EFFECTS

1. When the body has been exerted beyond its limits of endurance, it may not respond sufficiently to enable the diver to save his life, usually from drowning.

2. Exhaustion is not a danger in itself, the danger lies in drowning as a result of that exhaustion.

SIGNS AND SYMPTOMS

1. Feeling of exhaustion which can occur suddenly.

2. Body not responding sufficiently no matter what the mental effort.

3. The appearance of being unable to cope.

4. Exhaustion its physical form is usually characterised by laboured breathing.

ACTION BY DIVER

1. To rest: as rest enables the body to recover at least enough to perhaps save his life by:

   a. If has vest to inflate vest and float.

   b. If no vest, float on back, or alternatively float on stomach lifting head to breath, or if has snorkel breath through it.

   c. Overcome the desire to drift-downward into blessed oblivion. Think "NOT YET".

2. Prevention of exhaustion by the diver:

   a. Knowing own limits and staying within them.

   b. Discontinue dive if it exceeds his powers.

   c. Using good gear in good condition.

   d. Concentrate on training and experience to help eliminate panic.

   e. Instead of panicing: observe, evaluate, decide, act.

   f. Employ weights and line when working in strong currents.

   g. Stop to rest and ventilate when becoming over fatigued.

   h. Wear adequate cold water protection.

   i. Always keep in good physical condition.

TREATMENT

1. Rescue the exhausted diver, ABC, EAR if necessary.

2. Take patient from water, ABC, EAR if necessary. ECM if no pulse

3. If breathing put in coma position, keep warm, give warm nourishing drinks when conscious.

4. Rest brings complete recovery from exhaustion.

STRESS ON THE SNORKEL DIVER (AND ALL DIVERS)

	LUNGS — RESPIRATORY STRESS				HEART — CIRCULATORY STRESS	
THE ITEM	O_2 LACK LIFE GAS	CO_2 EXCESS. EXHAUST GAS	CO_2 LACK ALARM GAS	WATER IN LUNGS	BLOOD NOT TRANS- PORTING O_2	THE PUMP STOPS
KNOWN AS	ANOXIA HYPOXIA	CO_2 BUILD UP HYPER CAPNIA	HYPERVENTILATION HYPOCAPNIA	NEAR DROWNINGS	SHOCK	HEART FAILURE
DEFINITION	ANOXIA Total lack of O_2 HYPOXIA Partial lack of O_2	HYPERCAPNIA Too much CO_2 in blood and cells.	HYPOCAPNIA Not enough CO_2 in blood and cells. HYPERVENTILATION Deep breathing for several minutes continuosly.	An air breathing animal aspiring water into lungs instead of air, and resulting O_2 lack.	A form of Hypoxia blood not trans-porting sufficient O_2 to brain and other cells. Usual cause fluid loss, or nervous reaction.	Heart ceasing or partly ceasing pumping, thus circulation of blood ceases or slows.
CAUSES	LACK OF AIR TO BREATHE LACK OF O_2 IN THAT AIR SEQUEL TO HYPERVENTILATION	CO_2 BUILD UP IN EQUIPT.REBREATHED OVER EXERTION CO_2 NOT EXPIRED AS IN SKIP BREATHING SHALL BREATHING BREATH HOLDING	CO_2 purged from blood and cells by hyperventilation Diver trying for more u/water time Nervousness - Anxiety	Through exhaustion panic, unconsciousness, or break point reached u/water diver aspires water into lungs	Blood & fluid loss from burns, internal and exter. bleeding emotional effects on heart & on pool-ing blood in dilated vessels.	Electrical Impulses cease stimulation. embolism of air, or nitrogen bubbles; or blood clot, blocks coronary circulation.
EFFECTS	DEATH OF BODY CELLS ESP. BRAIN. P.P. O_2 NORMAL 21% P.P. O_2 UNCONS. 10% DROWNING & DEATH.	GREAT TIREDNESS PANTING UNCONSCIOUSNESS. P.P. CO_2 0.03% OK. P.P. CO_2 10% UNCONS. DROWNING & DEATH.	Diver not trig-gered to breathe from lack CO_2 alarm gas. Uses up CO_2 under increased PP. on ascent RPO2 drop reaches PP O_2 (10%) uncons. death.	Lack of air in lungs blood & cells caus-ing uncons. & death Sea water: draws fluid from blood. Fresh water Leaves lungs & enters blood.	Prolonged fall in blood pressure, thus blood not circulating normally, & thus not enough O_2 to cells, esp. brain. Unconsc. & death.	Heart ceases pump-ing through lack of O_2 & build up of CO_2 thus circulation stop or slows througout body. O_2 lack & CO_2 exc. kills cells esp. brain.
DIAGNOSIS S&S	DIVER MAY GO UNCONSC WITHOUT WARNING. EMOTIONAL INSTAB. & EUPHORIA AS NIT. NARCS CONFUSION. CLUMS-SINESS FOOLISHNESS CYANOSIS(BLUENESS)	SOMETIMES NO WARNING AS IN ANOXIA LABOURED BREATHING. HEADACHE. WEAKNESS. UNABLE THINK CLEARLY UNCONSC. DEATH.	None until chemore-ceptor triggered by CO_2 as for anoxia/Hypoxia. In this Case effects be-come worse on ascent fall in PP O_2.	Patient floundering & real distress or face down in water, perhaps unconscious.	Pale cold clammy skin Weakness, anxiety. Anxiety. Rapid Breathing. Heart may beat fast or slow. Similar to Anoxia/Hypoxia.	Extreme pain over heart. Unconscious. No pulse. Death.

S&S	CESSATION BREATHING DEATH					
ACTION BY DIVER	BEFORE DIVE: CHECK & RECHECK EQUIPMENT & AIR DURING DIVE: CHECK GUAGES, RESERVE. FIRST SIGN SOME-WRONG. SIGNAL BUDDY AND SURFACE. THEN INFLATE VEST.	STOP. REST VENTILATE DITTO	Do not hyperventilate at all. Surface immediately urged to breathe. Fight back On surface inflate vest.	Know limitations and stay within them. Resist Panic. Float Breathe. On Surface inflate vest.	Stop arterial bleed-ing ligature poison bites. Lie down. legs up. Comfort self knowing help will come.	If feel attack com-ing on get out of water. Signal for help.
FIRST AID BY RESCUER	SEE DIVER HAS AIR HIS OR YOURS. BUDDY BREATHE IN NEC. GET TO SURFACE. FRESH AIR DIVER RECOVER IF NOT BREATHING ABC & RESCUE PROCEDURE. IF NEC. CALL MEDICAL AID.	DITTO (Breathing Usually continues)	DITTO Anoxia/Hypoxia	DITTO Anoxia/Hypoxia Encourage coughing to being up water/ lungs.	Stop arterial bleed-ing. Ligature poisonous bite. give C.C. & attention. Truth only. Recovery position, or If lacks blood put on back & legs up. Nothing by mouth. No alcohol.	DITTO Anoxia/Hypoxia
MEDICAL AID	RADIO OR TELEPHONE FOR AMBULANCE OR HELICOPTER TELEPHONE 000 OR 013 TO ALERT RESCUE ORGANIZATION	DITTO	DITTO	DITTO	DITTO	DITTO

&S	CESSATION BREATHING DEATH					
A TION BY DIVER	BEFORE DIVE: CHECK & RECHECK EQUIPMENT & AIR DURING DIVE: CHECK GUAGES, RESERVE. FIRST SIGN SOME-WRONG. SIGNAL BUDDY AND SURFACE. THEN INFLATE VEST.	STOP. REST VENTILATE DITTO	Do not hyperventilate at all. Surface immediately urged to breathe. Fight back On surface inflate vest.	Know limitations and stay within them. Resist Panic. Float Breathe. On Surface inflate vest.	Stop arterial bleed-ing ligature poison bites. Lie down. legs up. Comfort self knowing help will come.	If feel attack com-ing on get out of water. Signal for help.
B FIRST D RESCUER	SEE DIVER HAS AIR HIS OR YOURS. BUDDY BREATHE IN NEC. GET TO SURFACE. FRESH AIR DIVER RECOVER IF NOT BREATHING ABC & RESCUE PROCEDURE. IF NEC. CALL MEDICAL AID.	DITTO (Breathing Usually continues)	DITTO Anoxia/Hypoxia	DITTO Anoxia/Hypoxia Encourage coughing to being up water/ lungs.	Stop arterial bleed-ing. Ligature poisonous bite. give C.C. & attention. Truth only. Recovery position, or If lacks blood put on back & legs up. Nothing by mouth. No alcohol.	DITTO Anoxia/Hypoxia
MEDICAL AID	RADIO OR TELEPHONE FOR AMBULANCE OR HELICOPTER TELEPHONE 000 OR 013 TO ALERT RESCUE ORGANIZATION	DITTO	DITTO	DITTO	DITTO	DITTO

02.. ANOXIA (TOTAL LACK OF 02), HYPOXIA (PARTIAL LACK OF 02)

DEFINITION:- Anoxia is the term applying to any situation which causes the body cells to be starved of oxygen (02). This is really hypoxia but the word anoxia is in common use. Anoxia - total lack of 02.. Hypoxia - partial lack of 02.

Causes

1. Lack of air to breathe.
   1.1 Failure of air supply.
   1.2 Loss of mouthpiece and/or its attachments.
2. Lack of 02 in that air.
   2.1 As when scuba units filled with air from a room where 02 being used up from freshly painted walls, or deteriorating stores.
   2.2 Insufficient 02 being transported as in too long a snorkel.
3. Hyperventilation.
   Shallow water black-out. See Hyperventilation notes on separate page.

Effects

1. Death of body cells is the eventual result from anoxia/hypoxia.
2. Brain cells are by far the most susceptible. Brain cells die after 3 minutes of no oxygen.
3. Brain damage (permanent), occurs shortly after unconsciousness.
4. Death follows quickly.
5. Partial pressure of oxygen is the key.
   If there is PP21% 02 in the lungs that is normal.
   If there is PP10% 02 in the lungs the diver may go unconscious.

Diagnosis - Signs and Symptoms

1. Diver frequently notices nothing. May go unconscious without warning.
2. Emotional instability followed closely by a feeling of euphoria - unfounded feeling of extreme well being, also signs and symptoms of nitrogen narcosis.
3. Slowing of responses, confusion, clumsiness, foolish behaviour.
4. Cyanosis (blueness).
5. Unconsciousness.
6. Cessation of breathing, death close.

Action By Diver

Prevention.

Before dive - check equipment, read contents gauge, breathe from regulator, immerse and check for leaks.

During dive - every few minutes that reserve lever is up, check contents gauge, surface before reserve is needed.

Treatment

First Aid.

1. At first sign something is wrong signal buddy, quickly check gear, buddy breathe if necessary, surface.
2. If you feel unconsciousness coming on, fight back, surface for air.

Action By Rescuers - First Aid

1. If conscious and breathing, give support, fresh air will cause rapid recovery.
2. If unconscious and breathing, normal first aid, ABC, get patient out of water and lay in coma position.
3. If unconconscious and not breathing, be quick, ABC, EAR, get patient out of water, ABC, EAR, ECM if no pulse.
4. If been unconscious, medical aid, ambulance/doctor.

HYPERCAPNIA

CO2 CARBON DIOXIDE EXCESS

DEFINITION:- Hypercapnia is CO_2 excess in the blood and cells, causing overstimulation of the respiratory centre. CO_2 is produced by the metabolism process in the cells, and is normally carried away by the bloodstream to the lungs, and expired. If it is re-breathed, or produced too fast to be got rid of, CO_2 excess occurs. It is rarely found in the scuba tank over normal percentages.

Causes

1. CO_2 in the air the diver breathes and/or re-breathes.
   - 1.1 CO_2 in the air the diver breathes from a scuba tank. Presence of carbon-dioxide in areas where scuba units are being filled, near a fire or engine exhaust - in this situation however, either a lack of oxygen or the presence of carbon monoxide are likely to be a far greater hazard.
   - 1.2 CO_2 produced by divers body being re-breathed. Excessive 'dead space' in full face mask units. Carbon-dioxide, being heavier than air, can accumulate in the mask and thus be inhaled instead of fresh air.

     Over long exhaust tube or snorkels - exhaled air is just moved up and down the snorkel and insufficient fresh air is inhaled.
2. Insufficient ventilation of lungs. Shallow breathing, usually in endeavouring to conserve air, causing insufficient fresh air to be brought into the lungs to 'wash out' carbon-dioxide produced in the body.
3. CO_2 produced too fast to be got rid of. Over exertion - too much carbon-dioxide is produced for maximum flow of air from scuba unit to ventilate the lungs properly.

Effects - Tiredness, panting, unconsciousness

The partial pressure of CO_2 determines the degree of the effect. At the surface 2% (0.02 ATS), increased breathing rate: 5% will cause shortness of breath and panting; 10% may cause unconsciousness; 15% and above muscle spasms regidity. However, 2% at surface will become 10% (0.1 ATS) at 40 metres and will cause unconsciousness.

Diagnosis - Signs and Symptoms

1. Sometimes none, as in anoxia.
2. Usually notice laboured breathing, air hunger.
3. May have headache, dizziness, weakness, unusual perspiring.
4. May note mental changes - inability to think clearly, confusion.
5. Unconsciousness - breathing usually continues.

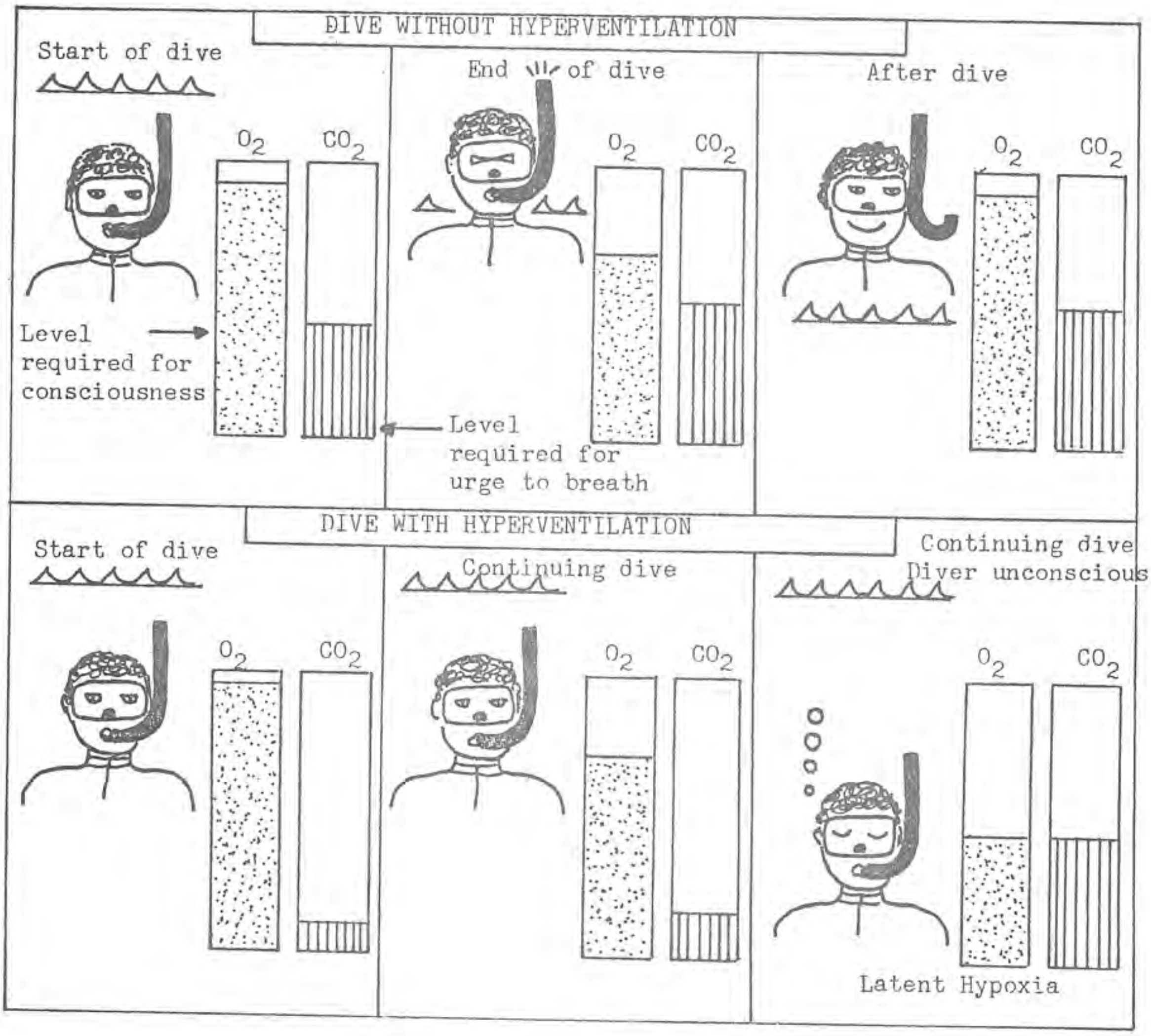
Action by the Diver

1. Diver should stop, rest, ventilate - surface if practical.
2. Discontinue dive if breathing continues to be excessive or mental changes are noted.

Action by the Rescuer

1. Get patient to the surface as fresh air will cause diver to regain consciousness.
2. If unconscious, normal first aid - ABC.

HYPERVENTILATION



Diagrammatic representation of the gas content of "arteroile" blood during two types of breath- hold dive.

LATENT HYPOXIA   Not obvious at depth but the potential exists for Hypoxia to occur near the surface

HYPERVENTILATION

DEFINITION:- The act of hyperventilation is to inhale and exhale deeply from ½ to 3 minutes. This action purges the lungs and the blood stream of CO_2 and saturates the lungs and the blood stream with O_2. Another definition is that if you are aware that you are breathing, you are hyperventilating.

Hyperventilation can occur with SCUBA, but from this body and reaching a state of hypocapnia - not enough CO_2.

Causes

1. Unintentional hyperventilation is mostly triggered by nervous tension, and can be experienced by normal individuals under stress, excitement, nervousness etc. or the distraction effect of sudden immersion in cold water. It can cause contraction of muscles. and on land is relieved by bag over mouth nose to re-breathe own breath and thus quickly build up again CO_2 in body.
2. Divers using SCUBA for the first few times are likely to hyperventilate largely from anxiety.
3. Uninformed snorkel divers may hyperventilate to extend underwater time.

Effects

1. With CO_2 blown off, and O_2 saturation of blood, diver begins under ideal conditions with maximum O_2.
2. Also as depth of dive increases partial pressure (Dalton's Law) increases, and by (Henry's Law) (solubility of gases) dissolves more O_2 from air in lungs to blood and thence to cell fluids and cells. So diver can stay down longer.
3. As O_2 is used up by the metabolism of the cells. CO_2 is being returned from cells to blood. (pp O_2 falls pp CO_2 rises).
4. CO_2 builds up in the blood. (and stimulates the Chemoreceptor in the carotid sinus which wills us to inspire.
5. So diver ascends to get air to breathe, but O_2 has dropped below safe level.
6. During the ascent the lung volume increases (Boyles Law) and the P. Pressure of O_2 in the lungs decreases.
7. Insufficient O_2 available to maintain consciousness. This is called shallow water BLACKOUT and usually occurs at approximately 3 metres where there is the greatest change ATA pressure.
8. Hence name Severest Hypoxic State.
9. Effects then become those of Anoxia/Hypoxia and Drownings.

Diagnosis - Signs and Symptoms

1. None until chemoreceptor triggered by CO_2 build up.
2. Then as for Anoxia Hypoxia.
3. In this case however assuming diver on snorkel the effects rapidly become worse on ascent as the lungs expand, the air in the lungs expands and the PP O_2 drops very quickly. When on SCUBA dense air is in lungs and though this is allowed to escape by respiration, the PP does not fall to dangerous limits as in case of snorkel diver - because there is more air in the lungs at start of ascent.

Action by Diver

Precautions

1. Do not practice hyperventilation, even if experienced.
2. Surface immediately urged to breathe.

First Aid Fight back.

Action by Rescuers

First Aid As for Anoxia Hypoxia.

NEAR DROWNINGS

DEFINITION:- Drowning can be defined as the death of an air breathing animal due to aspiration of fluid.

Near drowning is when recovery occurs.

Causes

1. Through exhaustion and/or panic, a patient breathes a fluid, usually water, into the lungs instead of air.
2. The water takes up the spaces in the lungs and alveoli normally filled by air so that O_2 cannot get to lungs and system.
3. Patient suffers and may die from lack of O_2 as in anoxia/hypoxia.

Effects

1. Sea Water Drownings
   Being hypertonic, inhalation of sea water causes plasma fluid to be drawn into the alveoli, thus the lungs increase in weight and widespread Peripheral haemorrhages occur.

   It is possible blood fluid may rise as fluid is drawn from the tissues into the blood.
2. Fresh Water Drownings
   Inhaled water is rapidly lost from the alveoli and a 50% rise in blood volume may occur in 2 to 3 minutes. This is the so called dry drowning. Fresh water near drownings sea water as the water is gone too far (into the blood) to get out again.

Diagnosis Signs and Symptoms

1. Near Drownings
   Patient floundering andin real distress though quickly becomes unconscious and is either floating face down on surface or is unconscious under water.
2. It may be hard to know, and perhaps is not really important to know at once what caused the unconsciousness though if no scuba it is probably drowning.
3. The importance lies in quickly going into rescue procedure.
4. Later if patient is coughing up water diagnose near drowning but there may be a contributing cause. CO_2 excess, hypervent. etc.

Action by Diver

Precautions When beyond depth, keep within own limitations.

First Aid Resist panic float, breathe.

Action by Rescuers

1. Prompt initial measures in support of the Respiratory and Circulatory Systems, greatly influences the eventual outcome.
2. Immediate first aid ABC EAR.
3. The normal fast rescue of unconscious, person from water.
4. Medical aid: Ambulance.
5. If patient coughs encourage this, as patient will start to cough matter from lungs.

NEAR DROWNINGS

DEFINITION:- Drowning can be defined as the death of an air breathing animal due to aspiration of fluid.

Near drowning is when recovery occurs.

Causes

1. Through exhaustion and/or panic, a patient breathes a fluid, usually water, into the lungs instead of air.
2. The water takes up the spaces in the lungs and alveoli normally filled by air so that O_2 cannot get to lungs and system.
3. Patient suffers and may die from lack of O_2 as in anoxia/ hypoxia.

Effects

1. Sea Water Drownings
   Being hypertonic, inhalation of sea water causes plasma fluid to be drawn into the alveoli, thus the lungs increase in weight and widespread Peripheral haemorrhages occur.

   It is possible blood fluid may rise as fluid is drawn from the tissues into the blood.
2. Fresh Water Drownings
   Inhaled water is rapidly lost from the alveoli and a 50% rise in blood volume may occur in 2 to 3 minutes. This is the so called dry drowning. Fresh water near drownings sea water as the water is gone too far (into the blood) to get out again.

Diagnosis Signs and Symptoms

1. Near Drownings
   Patient floundering andin real distress though quickly becomes unconscious and is either floating face down on surface or is unconscious under water.
2. It may be hard to know, and perhaps is not really important to know at once what caused the unconsciousness though if no scuba it is probably drowning.
3. The importance lies in quickly going into rescue procedure.
4. Later if patient is coughing up water diagnose near drowning but there may be a contributing cause. CO_2 excess, hypervent. etc.

Action by Diver

Precautions When beyond depth, keep within own limitations.

First Aid Resist panic float, breathe.

Action by Rescuers

1. Prompt initial measures in support of the Respiratory and Circulatory Systems, greatly influences the eventual outcome.
2. Immediate first aid ABC EAR.
3. The normal fast rescue of unconscious. person from water.
4. Medical aid: Ambulance.
5. If patient coughs encourage this, as patient will start to cough matter from lungs.

SHOCK

DEFINITION:- Shock is a form of hypoxia, lack of oxygen being caused by insufficient blood pressure and flow, to carry sufficient oxygen around the body, even when there is ample oxygen in the alveoli of the lungs. It is often associated with blood loss or nervous reaction.

Causes

There are many causes of the inadequate pressure and flow of blood. For divers the basics are:

1. Blood loss from haemorrhage, external and internal, so that there is not enough blood flowing and at too low a pressure.
2. Nervous and emotional factors:
   2.1 Effects on heart action.
   2.2 Blood pooled in dilated large blood vessels.

Effects

'A prolonged fall in blood pressure is termed Shock. If shock is not treated, death can follow due to inadequate supply of oxygen carrying blood to vital organs such as the brain'

'Diver's Medical companion' p19.

Diagnosis Signs and Symptoms

1. Pale, cold, clammy skin.
2. Weakness, anxiety and restlessness.
3. Rapid breathing.
4. Heart rate slow, then fast and weak, but not always.
5. Similar to anoxia/hypoxia.
6. Shock is usually present following a dramatic accident.

Actions by Diver Patient

1. Stop arterial bleeding.
2. Ligature for poisonous bites.
3. Lie down coma/recovery position, or on back legs up.
4. Tell Yourself:
   4.1 The mind distorts things under stress. Things will look better later. Defer despair.
   4.2 Help will come.

Actions by Rescuers

1. Send for medical aid.
2. ABC including attention to haemorrhage and poison bites.
3. Make use of what circulating blood remains, patient to lie down, head low, arms and legs high to drain blood to trunk. Do not bring blood away to skin by heating it
4. CCA (care, comfort and attention) reassure:
   4.1 Truth only.
5. Recovery position of enough blood, otherwise keep legs. arms up.
6. Nothing by mouth. No alcohol.

References

1. St John Ambulance Association.
   1.1 First Aid Manual.
   1.2 RLSSA.
   1.3 Manual of Water Safety and Life Saving.

HEART FAILURE

1. DEFINITION: Heart failure means that the heart stops pumping and so the circulation of the blood ceases.

2. CAUSES: There are many causes, the most usual being:

   2.1 The electrical impulses to the heart ceases and so the heart muscles are not stimulated.

   2.2 A foreign body in the blood vessels of the heart muscles stop the circulation of blood in those heart muscles which themselves are thus starved of oxygen and get sick and die. (Coronary Occlusion)

   Some such foreign bodies are:
   2.2.1 An air embolism, that is a bubble of air in the coronary circulation.

   2.2.2 Other such embolisms in the coronary circulation:
   2.2.2.1 Nitrogen bubbles

   2.2.2.2 Cholestrol Clots

   2.2.2.3 Blood clots

   2.3 The blood vessels in the coronary system gradually being choked with cholestrol like rusty water pipes.

3. EFFECT: Blood stops flowing throught the body and thus stops carrying oxygen to the cells and waste matter, CO_2, from the cells. Thus the cells die. The brain cells dying first after approximately 3 minutes.

4. DIAGNOSIS: 4.1 Unconsciousness

   4.2 No pulse

5. ACTION BY THE CASUALTY:

   5.1 If you feel the attack coming on, get out of the water and seek help.

   5.2 Once attack starts there's not much one can do: signal for help.

6. ACTION BY RESCUER:

   6.1 A.B.C.

   6.2 Medical Aid.

FIRST AID KIT LIST

FOR CAMPING DIVE TRIP

1. Books of Reference to Include in Kit

St John Ambulance First Aid Manual
Dr Straun Sutherland's C.S.L First Aid for Snake Bite in Australia
Dr Carl Edmond's Dangerous Underwater Animals of The S.W. Pacific Areas

2. For Injuries

Bandages: Several ½ inch, 1 inch and 1½ inch wide
For bleeding wounds and poisonous bites:
- Two of four inch wide crepe bandages
- One rubber bandage 7.5 cm hand crepe durelastic (also doubles as tourniquet.)
- Sticking plaster ½ inch and 1 inch wide rolls
- Pad for arterial bleeding
- triangular bandage

3. Scissors, Tweezers and Razor Blades of Stainless Steel

4. For Skin

Ultraviolet sunscreen such as blockout
Methylated spirits as antiseptic
Can of spray on plastic skin
1 bottle sunburn soothing lotion
1 tube anitbiotic cream (Neomycin)
100 ml Cetavion (or similar) for skin infections
1 tube Amolin (or similar) for dry chapped skin

5. For Stings

1 bottle vinegar (any kind, all have acetic acid)
Stingose: Several plastic Satchets
1 plastic bottle
1 bottle permanganate of potash

6. Anaesthetics and Pain Killers

Ointment as lignocaine
Spray in can. Ask chemist latest issued
Packet paracetamol tablets
Packet asprin

7. For Diarrhoea and Digestive Upsets

Lomotic or similar
Bottle milk magnesia
Sea sick pills (Kweels, Dramazine)

8. Poisonous Fish, Etc., Eaten Accidentally

Syrup of Ipecac for emetic
Activated charcoal to mix with water drink to absorb toxins
Maxolon, anti emetic, when you have thrown it all up no need to keep on.

A respirator (such as Oxy-viva) with an oxygen supply should also be carried (for use in near drowning, or a non breathing patient.

Each diver may have need of a different first aid kit. Some students may te relatively very young and still acquiring knowledge or experience. Others may be medical practitioners.

Remember your task in first aid is basically to keep patient alive by getting a regular oxygen supply to the brain, stopping haemorrage, treating for shock, preventing injuries from becoming worse; and getting patient to medical aid. (QATB officers and especially doctors).

This kit is recommended for extended trips to the Great Barrier Reef areas. It really goes beyond first aid...The items should be housed in a sturdy plastic or wooden box which will float and remain water proof.

MARINE STUDIES SERIES

OTHER UNITS :

There are two types of Classroom Note : Practical & Applied

(a) Practical Notes

Unit 1	Navigation	Features of the Coastline, Navigation Methods, Practical, Weather, Pilotage, Tides, Exam.
Unit 2	Snorkelling	Physiology, Techniques, First Aid, Dangerous Marine Animals, Safety, Certificate.
Unit 3	Radio	Components, Features, Discipline, Types, Practice Excercises, Certificate.
Unit 4	Boating	Buying a Boat, Safety, Seamanship skills, Handling, Maintenance, Licence.
Unit 5	Camping	Types of, Equipment for Camping with a boat, Campsites, Practical Conservation, Safety, Leadership Skills.

(b) Applied Notes

Unit 6	Fisheries Biology	Plankton, Nekton, Benthos, Fishing Methods, Protected Species, Fisheries Management
Unit 7	Estuarine Chemistry	Laboratory Methods, Pollution, Salinity, Temperature, Ph, and other parameters.
Unit 8	Coastal Physics	Waves, Tides, Beach Erosion, Beach Protection, Coastal Management, Local Coast Management
Unit 9	Diving Science	Boyles Law, Charles Law, Effects of Pressure on Diver, Marine Medicine.
Unit 10	Sampling Methods	Marine Technology in Scientific sampling apparatus, student project, collection methods.

SAFE BOATING = KNOWLEDGE + COMMON SENSE + COURTESY