

Fitness and Bubbles.

Helsingfors 29 – 30 januari 2011.

Finska sportdykarförbundet och Finska dykläkarförbundet tillsammans med DAN Europe arrangerade sista helgen i januari 2011 ett symposium med temat Fitness and Bubbles.

Programmet framgår nedan och på de följande sidorna finner ni bilderna från mitt föredrag ”The role of oxygen and carbon dioxide in the transport of inert gases.” Ett sammandrag av konferensen kommer att finnas i tidningen Sukeltaja eller <http://www.sukeltaja.fi/content/en/11501/83/83.html>

AGENDA

SATURDAY 29.1.2011

9.00 Registration and coffee

Morning session

Chairman Prof. Seppo Sipinen (SSLY)

10.00 Opening session (Prof. Seppo Sipinen SSly & Dr Matti Anttila, Finnish Divers' Federation)

10.30 Prevention of decompression sickness - issues beyond decompression algorithms (Prof. Simon Mitchell)

DAN Divers' Day

11.30 Diving accident statistics among domestic divers in Finland (Dr Jari Suvilehto)

12.15 Lunch

13.45 What is DAN? (Mr Steve Clark)

14.15 Recent advances in recreational diving medicine research (Prof. A. Marroni)

15.15 Coffee

15.45 Decompression safety aspects in technical diving (Dr O. Hyldegaard)

Afternoon session

Chairman Prof. Seppo Sipinen (SSLY)

16.45 Aerobic exercise for DCS prevention (Prof. Alf Brubakk)

17.15 Close

19.45 Dinner party (Restaurant Botta, Museokatu 10, Helsinki)

SUNDAY 30.1.2011

9.00 Registration and coffee

Morning session

Chairs Mr Mika Rautiainen (Finnish Divers' Federation) & Dr Timo Jama (SSLY)

10.00 The role of oxygen and carbon dioxide in the transport of inert gases (Prof. Hans Örnhammar)

10.45 Carbon dioxide: big, bad and hard to measure, relevant to any diver (Prof. Simon Mitchell)

12.00 Lunch

Afternoon session

Chairs Prof. Seppo Sipinen (SSLY) & Dr Matti Anttila (Finnish Divers' Federation)

13.15 Cold and DCS (Prof. Alf Brubakk)

14.15 Respiratory physiology at extreme depth (Prof. Simon Mitchell)

15.00 Panel discussion

16.00 Close

The role of oxygen and carbon dioxide in the transport of inert gases.

Hans Örnham, MD, PhD Director of Research (Ret)
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Consulting physician Swedish Sport diving Federation

For a better understanding of inert gas transport some basic knowledge is needed.

- Composition of air
- Diffusion, mass flow and perfusion
- The function of Hemoglobine and Carboxy anhydrase
- The concept supersaturation and bubble formation
- Partial pressure of a gas and fraction of a gas in gases
- Partial pressure of a gas and amount dissolved of the gas in liquids
- Physical solution of a gas in a liquid and total amount carried in blood



O₂ and CO₂ in inert gas transport
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There is no special carrier for inert gas in the blood but two chemical compounds that facilitate inert gas transport indirectly

these are

- **Hemoglobine** through transport of oxygen
- **Carboxy anhydrase** through conversion of CO₂ to bicarbonate and back to CO₂



O₂ and CO₂ in inert gas transport
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Partial pressures of gases (kPa) in dry air and in the lung

| | Dry air | In the lung |
|------------------|---------|-------------|
| N ₂ | 78 | 74,0 |
| O ₂ | 20,9 | 13,4 |
| Ar | 1 | 0,9 |
| CO ₂ | 0,004 | 5,4 |
| H ₂ O | 0,1 | 6,3 |
| Total pressure | 100 kPa | 100 kPa |

Humidification, addition of CO₂ and extraction of O₂ are responsible for the changes.



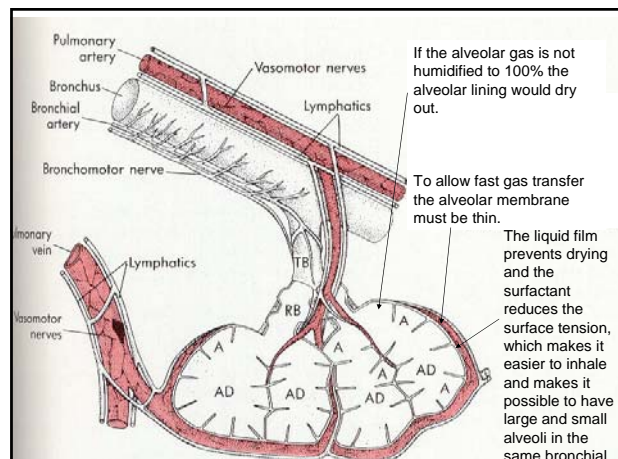
O₂ and CO₂ in inert gas transport
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In the lungs

- A large diffusion area (70 – 80 m²) and a short diffusion distance (2 μm) give the arterial blood the same partial pressures as the alveolar gas.
- The blood contains 0.01 ml N₂ per ml blod at a PN₂ of 75 kPa (air breathing)
- If we breathe 100 % oxygen the arterial blood will be nitrogen free



O₂ and CO₂ in inert gas transport
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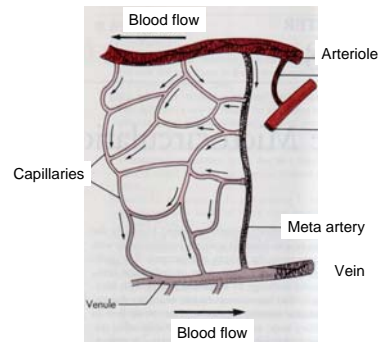


A cup of water on the floor

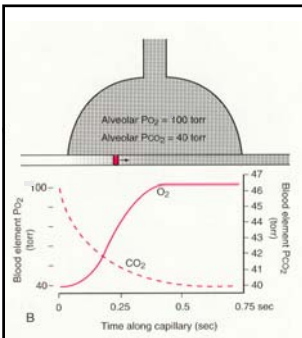
The pulmonary circulation contains approximately 200 ml or 0.2 liters
 Take this amount of water (a cup) and spread it on the floor of a room of 70 m.
 This shows how thin the air to blood layer is in the lungs.



O₂ and CO₂ in inert gas transport
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O₂ and CO₂ in inert gas transport
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A red blood cell spends about 0.75 seconds in a pulmonary capillary. As seen in the diagram the transport of CO₂ and O₂ is finished after 2/3 of this time. There is thus a spare capacity for an increase in cardiac out put, but after a 50 % increase more capillaries have to be opened to allow complete equilibration between alveolar gas and blood.

In a gas mix, diffusion is inversly proportional to the square root of the molecular weight
 In liquids, diffusion of a gas is directly proportional to the solubility of the gas in the liquid



O₂ and CO₂ in inert gas transport
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To get the optimum pH in our body 7.4 the dissociation of CO₂ in water has to be balanced at a PCO₂ of 5.5 kPa (40mmHg)

CO₂ + H₂O -> HCO₃ + H
 Carbon dioxide is transported in blood as bicarbonate.

Carboxy anhydrase in red blood cells facilitate this. **As important to life as hemoglobine**



O₂ and CO₂ in inert gas transport
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How much gas is there in the body liquids at normal pressure?

Oxygen

- Arterial blood (Hb bound) 200 mL
- Venous blood (Hb bound) 600 mL
- Muscles (Myoglobin bound) 250 mL
- 75 L water and fat (@ 7 kPa O₂) 75 mL
- Total 1125 mL

Carbon dioxide

- Bone (Calcium carbonate) 123 000 mL
- Muscles (Bicarbonate) 9 600 mL
- Blood (Bicarbonate) 7 000 mL
- Total 139 600 mL



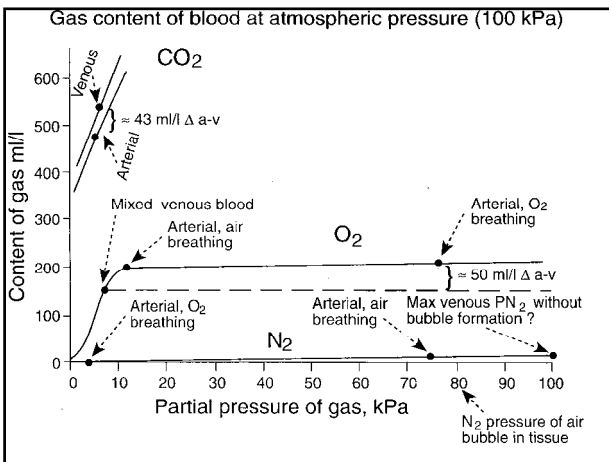
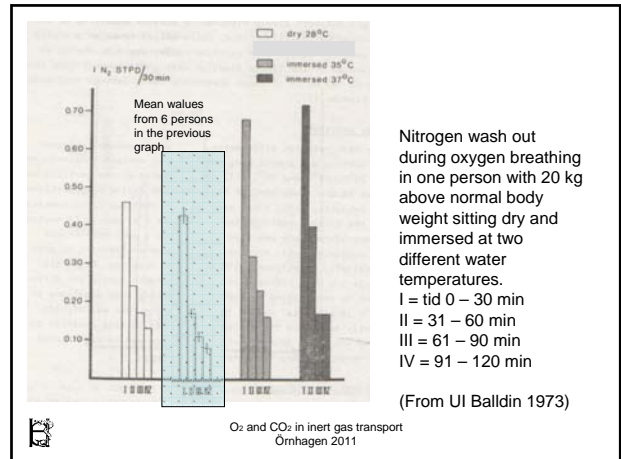
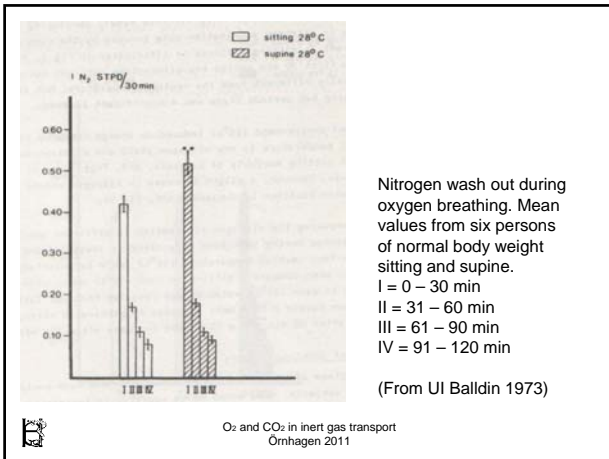
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The body contains nitrogen already at 1 atmosphere

- We are "saturation divers" at 100 kPa (1 atm). PN₂ in the lungs is 75 kPa
- The body contains:
 - in the water phase 65 kg (0.75x0.012x65) 580 ml N₂
 - in the fat phase 15 kg (0.75x0.062x15) 680 ml N₂
 - which means a total of appr 1.3 liter of N₂
- If we go to, and stay 12 h, at the double pressure 200 kPa the another 1.3 liter N₂ is dissolved in the body.

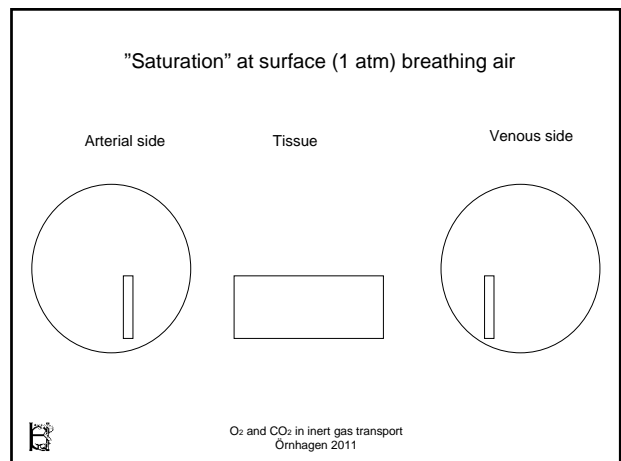
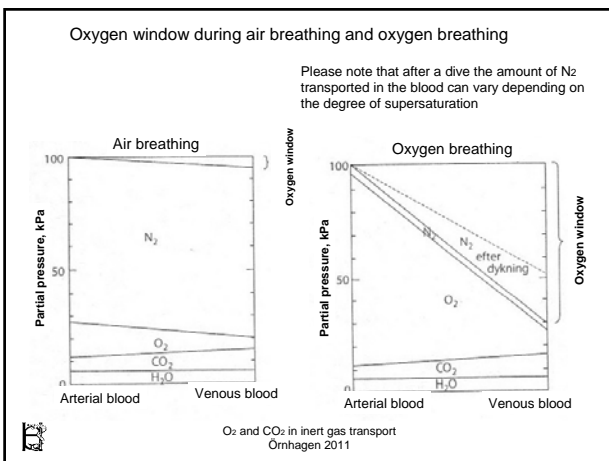


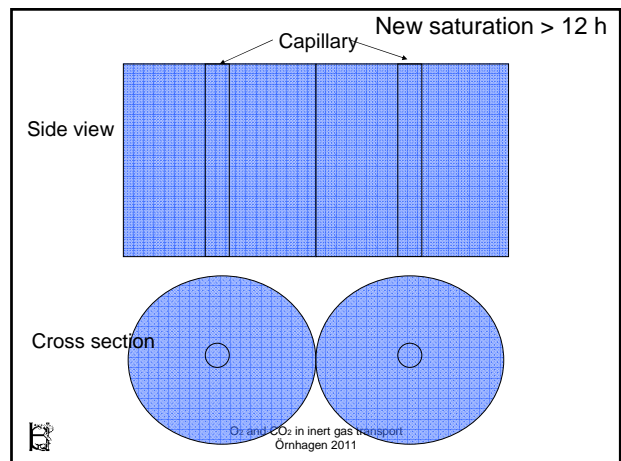
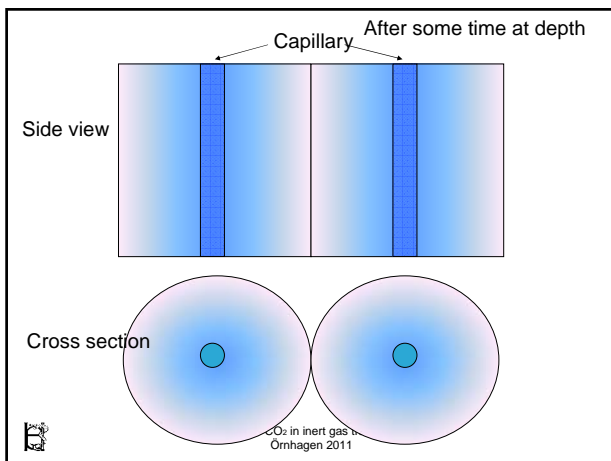
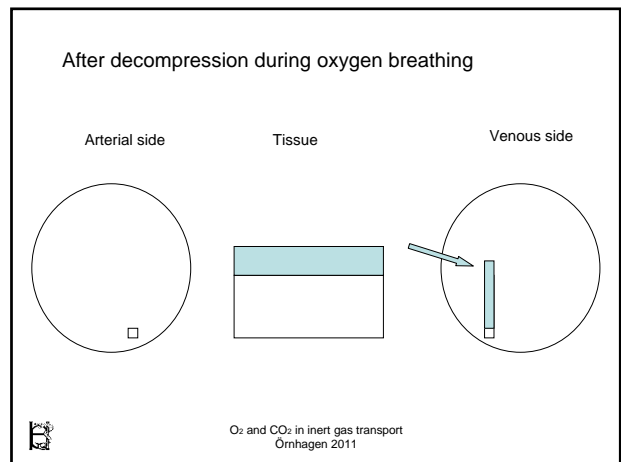
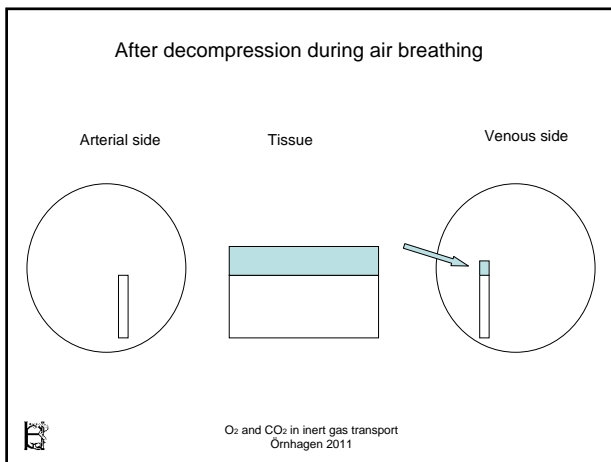
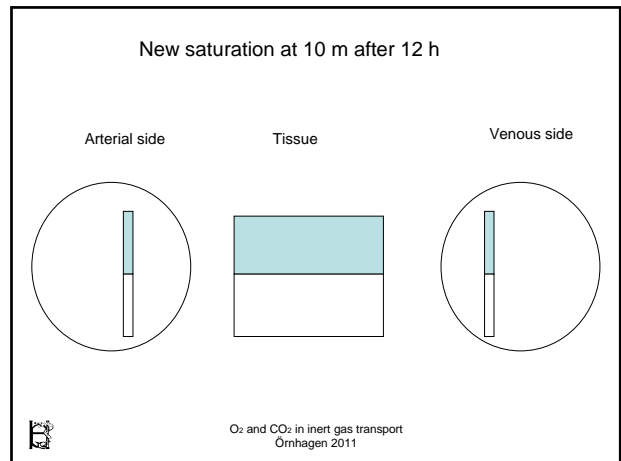
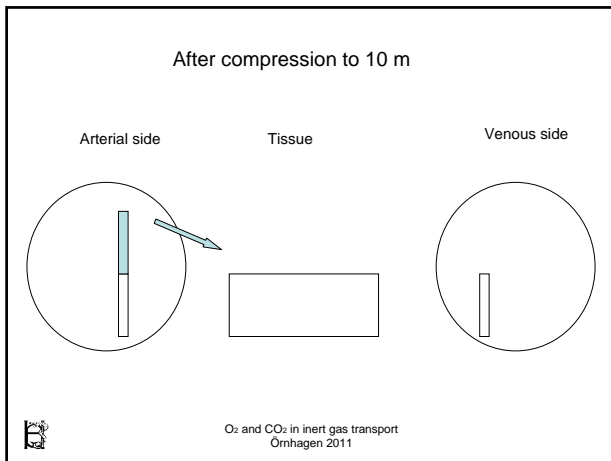
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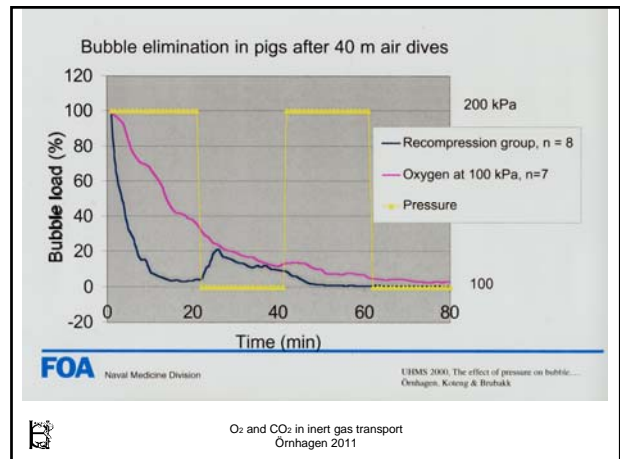
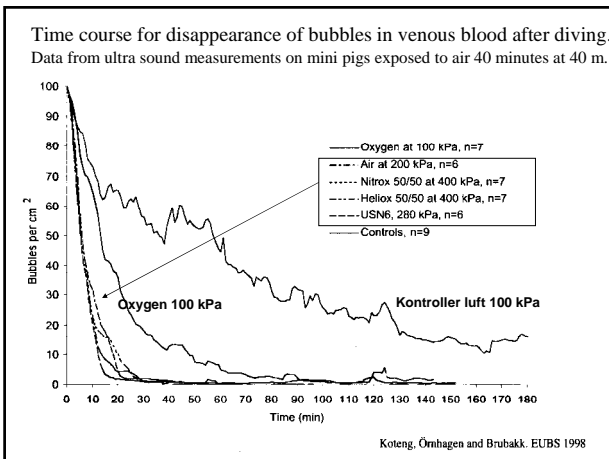
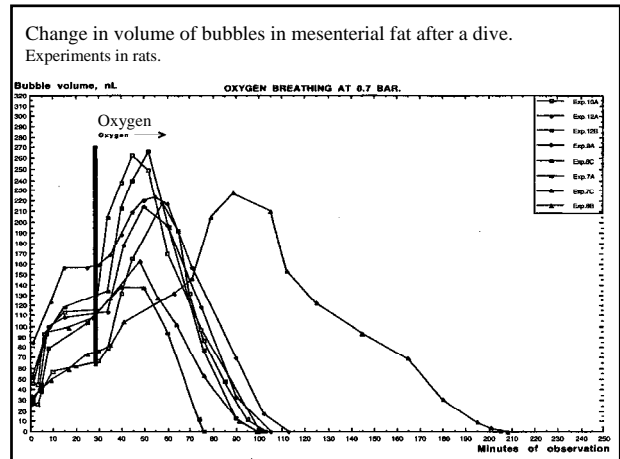
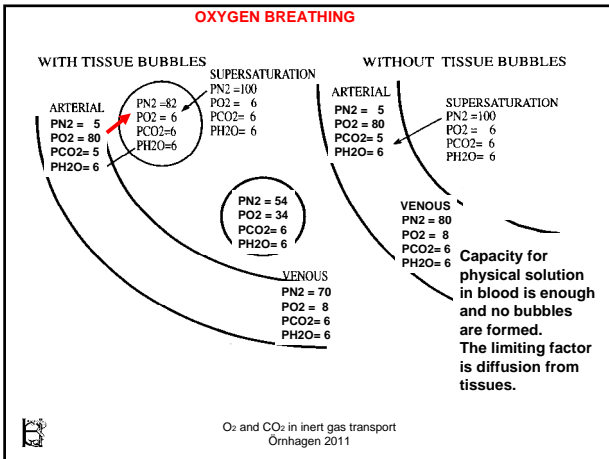
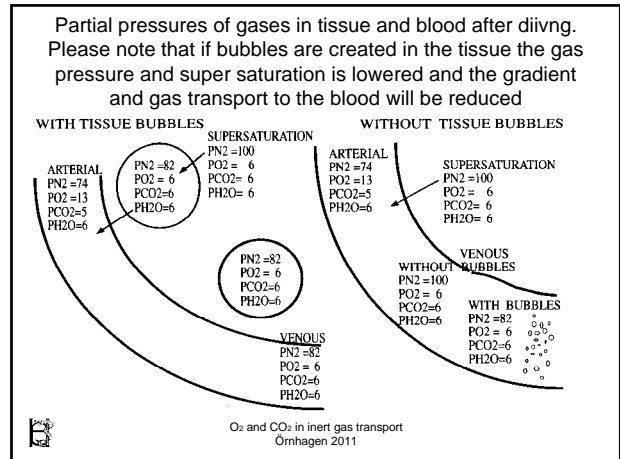
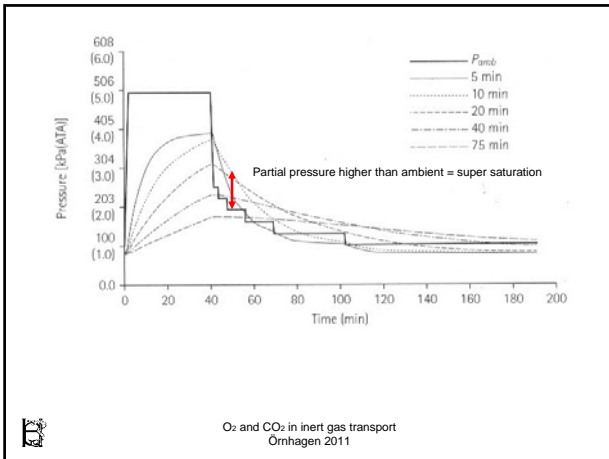


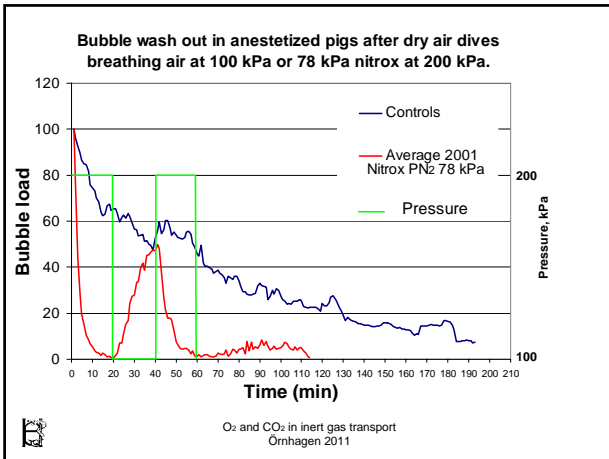
| Gas partial pressures (kPa) during air and oxygen breathing | | | | | | |
|---|-------------------|------------------|----------------|-----------------|-------|--------|
| Air | | H ₂ O | O ₂ | CO ₂ | Inert | = Tot |
| | Outside air | 2 | 21 | 0,004 | 77 | = 101 |
| | In lungs | 6,3 | 13,4 | 5,5 | 75,8 | = 101 |
| | In arterial blood | 6,3 | 13,2 | 5,5 | 76 | = 101 |
| | In venous blood | 6,3 | 7 | 6,5 | 76 | = 95,8 |
| | | | | Oxygen window | | 5,2 |
| Oxygen | | | | | | |
| | Dry oxygen | 0 | 101 | 0 | 0 | = 101 |
| | In lungs | 6,3 | 87,2 | 5,5 | 2 | = 101 |
| | In arterial blood | 6,3 | 87 | 5,5 | 2 | = 101 |
| | In venous blood | 6,3 | 8 | 6,5 | 5 | = 25,8 |
| | | | | Oxygen window | | 75,2 |

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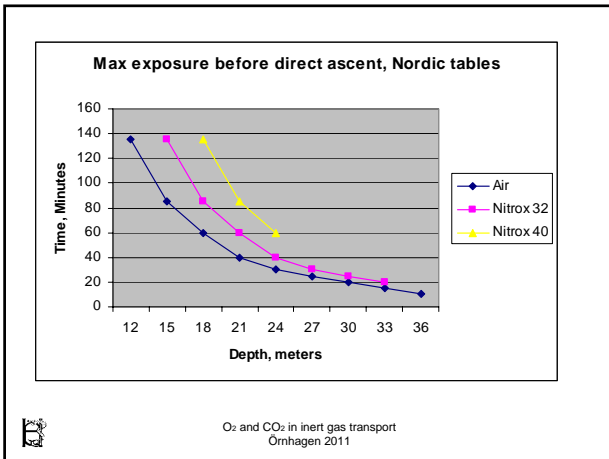
With this knowledge

- You can increase the rate of saturation decomposition
- You can shorten decompression time in bounce diving
- You can reduce bubble load and treat decompression illness

But you can also use oxygen prophylactically

- Nitrox or oxygen enriched air

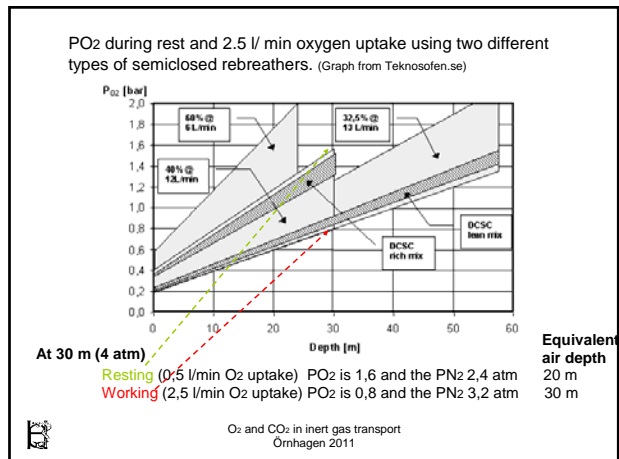
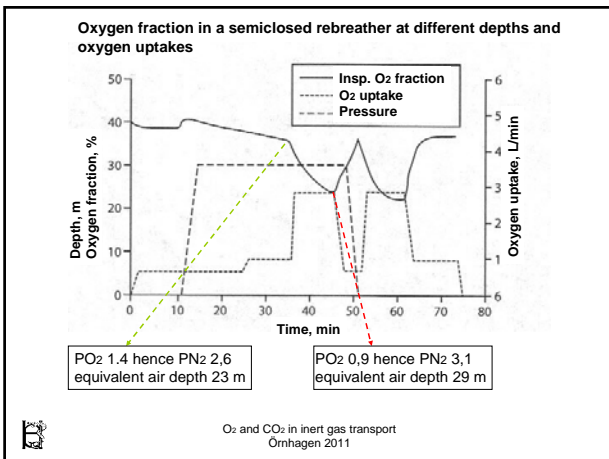
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Nitrox is easy and safe at shallow depth and open demand systems.

In rebreathers you need to know the exact oxygen fraction or partial pressure

O₂ and CO₂ in inert gas transport
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Please remember

- It is the carboxyanhydrase that does the trick through production of bicarbonate, which reduces the blood PCO_2 and the sum of partial pressures in the venous blood and makes it possible to transport inert gas without too high super saturation.



O₂ and CO₂ in inert gas transport
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O₂ and CO₂ in inert gas transport
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